BUSINESS PROCESS REENGINEERING

Business process reengineering (BPR) is popular because it promises to deliver corporations from the quagmire of inefficiency, high cost, and dissatisfied customers. Unlike incremental improvements offered by quality management programs, BPR holds out the hope of working with a clean slate (1–3). Such promise, backed by a handful of success stories, has vaulted BPR into the business mainstream. *Fortune* magazine featured BPR as the hot new managing tool in August 1993, and *Reengineering the Corporation* by Michael Hammer and James Champy (3) was on the *New York Times* best-seller list for months.

Yet such popularity has a price: BPR has become faddish. A typical sentiment was expressed in the *Fortune* article, "If you want to get something funded around here—anything, even a new chair for your office—call it reengineering." Thus the term BPR has become enigmatic, leaving business managers unsure of its definition and even less sure of its real benefits (1,3–6).

BUSINESS PROCESS REENGINEERING DEFINED

A widely used definition of BPR states: "[BPR is] The fundamental rethinking and radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed" (3, p. 32).

Despite the popularity of the copyrighted term "Reengineering," there is still widespread confusion among executives on what it really means. Bashein (7) sites a survey of 121 executives in the manufacturing, insurance, and utilities industries conducted by Gateway Information Services, where only 46% of the respondents agreed with the above definition of reengineering. The remaining defined it as technological change, product improvement, customer satisfaction or just didn't know (see Table 1) (3,5,8,9).

Considering that BPR is a new field, every practitioner and researcher has defined BPR differently and provided slightly

Table 1. Reengineering Is Not

	Downsizing / Restructuring
Reality:	Nothing could be further from the truth. Reinventing the enterprise through reengineering is about doing things differently and more effectively, with or without existing resource levels (5). As Hammer and Champy (3) stated: "These [downsizing/restructuring] are just fancy terms for reducing capacity to meet current, lower demand. When the market wants fewer GM cars, GM reduces its size to better match demand. But downsizing and restructuring only mean doing less with less. Reengineering, by contrast, means doing *more* with less."
	Reorganizing / Delayering / Flattening an Organization
Reality:	Above-mentioned projects take the vertical view or hierarchical view of the organization, and business processes are often left untouched. Job descriptions and reporting lines are modified to reflect the removal of one or more layers but the business processes do not undergo major modifications. Hammer and Champy (3) said: ". . . the problems facing companies do not result from their organizational structures but their process structures."
	Information Technology / Systems Integration / Applications Development / Software Engineering / Automation
Reality:	Reengineering recognizes that these above-mentioned technologies are the enabling agent of change and essential to any reengineering effort. However, in and by itself, reengineering is not simply about information technology. Monteleone (8) stated: "A poorly understood or supported technology can hinder the acceptance of the systems it is part of and hurt the overall process the system is designed to support."
	Quality Movement / Total Quality Management / Continuous Incremental Improvement
Reality:	These improvement techniques are based on the assumption that a business will improve simply by refocusing on the customer's needs and improving the same old business practices with slightly increased efficiency or effectiveness while reengineering means performing a work activity in a radically new way. Paul O'Neil, the chairman of Alcoa, summarized the change in attitude: "I believe we have made a major mistake in our advocacy of continuous improvement. Let me explain what I mean. Continuous improvement is exactly the right idea if you are the world leader in everything you do. It is a terrible idea if you are lagging in the world leadership benchmark. It is probably a disastrous idea if you are far behind the world standard . . . [W]e need rapid, quantum-leap improvement. We cannot be satisfied to lay out a plan that will move us toward the existing world standard over some protracted period time—say 1995 to 2000—because if we accept such a plan, we will never be the world leader" [Keen (9,10)].

varied formulations with different emphasis. In this chapter, the definition of BPR by Hammer and Champy (3) will be used as a guiding light to differentiate BPR projects from all other projects (see Table 2).

LOGIC OF BUSINESS PROCESS REENGINEERING

Reengineering, in contrast, promises no miracle cure. It offers no quick, simple, and painless fix. On the contrary, it entails difficult, strenuous work. It requires that people running companies and working in them change how they think as well as what they do. It requires that companies replace their old practices with entirely new ones. Doing so isn't easy (3).

Understanding the evolution of BPR explains the necessity for participating in such a high-risk endeavor, reasons for its failure, and the timeliness of this research.

Rigid Organizations

The literature on organizational change from the 1950s to the 1970s and into the 1980s stressed the difficulty of making more than incremental improvements in processes. Change was seen as an exception to the rule (9).

As Mische and Warren (5) state: "Straddled with rigid practices and procedures, stoic organizational structures, and a preoccupation with historical preservation of yesterday's management practices, the cultures and structures of these organizations simply do not allow them to be agile and adaptive in a real-time world."

The pattern of radical changes being forced on the pack by breakaway players is apparent in the auto industry. Detroit automakers had set their own manufacturing pace and priorities for more than fifty years, but these rules were drastically changed in the 1970s, when Toyota cut years from the seven it typically took American companies to design and launch new car models and set new standards for quality. The historically rigid US industry had to become more flexible, to bridge the production gap opened up by Toyota. Chrysler Corp., for example, cut its new-model cycle in the 1980s from fifty-nine months to thirty-nine months for its LH truck lines and thirty-one months for its successful Neon models in the 1990s (9).

Cruel Economy and the Changing Nature of Change

It is no secret that we live in an era of relentless competition, eroding margins, overcapacity, gradual but continuing global deregulation, increasing customer power and sophistication, and accelerating business cycles. Quality and service, once the hallmarks of market leaders, are now basic requirements.

Businesses today can no longer be content to find an edge; they must find and sustain the edge. No firm is safe today, no matter how successful or even dominant it has been in the past (9).

Who would have believed, in 1980, that the disaster cases of the early 1990s would include IBM, Sears Reobuck & Co., General Motors, Citibank, and Digital Equipment Corp.; that Bloomingdale's and Macy's would file for Chapter 11 bankruptcy; and that American Airlines would actively look to get out of the airline business? By 1985, thirty years after the Fortune 500 was first established, 238 of the firms on the initial list had disappeared as independent entities, an average of eight a year. Between 1985 and 1990, another 143 were gone, disappearing at a rate of almost 30 per year. Of the 43 companies identified by Tom Peters and Robert Waterman (59) as models for the new business age in their 1984 book, *In Search of Excellence,* only 12 remain in good shape; some have been disasters (9).

Change has become the norm, not the exception. The old principles of change management, which stressed incrementalism, are inadequate to respond to the waves of change that characterize almost every business environment. Transformation, not incrementalism, describes the new agenda for change (9).

Dynamic Capabilities

Economists think of dynamic capabilities as firm-specific assets, a distinctive competence defined as "a set of differentiated skills, complementary assets and organizational routines which together allow a firm to coordinate a particular set of activities in a way that provides the basis for competitive advantages in a particular market or markets" (10).

Developing this competence requires "investment in specialized information, education and training, physical assets and systems for coordination and integration, and incentives" (11). Pfeffer (12) notes that this is a source of success "that is difficult to duplicate and consequently is sustainable over time."

Table 2. Reengineering Is [Adapted from Hammer and Champy (3)]

Fundamental
In doing reengineering, business people must ask the most basic questions about their companies and how do they operate: Why do we do what we do? And why do we do it the way we do? Reengineering takes nothing for granted. It ignores what is and concentrates on what should be.
Radical
Radical redesign means getting to the root of things: not making superficial changes or fiddling with what is already in place, but throwing away the old.
Dramatic
Reengineering isn't about making marginal or incremental improvements but about achieving quantum leaps in performance (2× to 10×).
Processes
Reengineering is not focused on tasks, on jobs, on people, or on structures, but on business processes.

By creating new ways of overcoming the barriers of physical distance and dramatically reducing the number of process steps and personnel, information technology (IT) can radically lower coordination costs and provide opportunities to develop new, internal processes that are, in fact, firm-specific assets. Recent ongoing technological innovation and technology costs that drop at rates of up to 40% a year are opening up new opportunities for fundamental process improvement (9).

And business processes and their reengineering are at the heart of this source of competitive advantage. All these powerful factors make the kind of fundamental improvements promised by BPR both possible and obligatory (9).

In the 1980s, the idea of redesigning business processes was being advanced by large consulting units such as Peat Marwick and McKinsey. Index Group and Michael Hammer directed programs on cross-functional systems in which several firms were studied (13).

The fundamentals of BPR were published in two seminal articles published almost simultaneously (2,14), which appeared in journals with an audience that included both academics and practitioners. This was followed by books entitled *Reengineering the Corporation* (3) and *Process Innovation* (15). Both these books were tremendously popular and spurred significant reengineering activity in both practice and academia.

In the 1970s, an incremental efficiency improvement of 20% was considered a notable news item; two decades later, firms that instituted process reforms were experiencing ten- and twenty-fold increases, and occasionally more than that. Not surprisingly, the transformation of business processes has been big news in the 1990s (9).

BUSINESS PROCESS REENGINEERING FAILS

Not all the news about process transformation, however, has been good (9).

As Crowe, Rathi, and Rolfes (16) note: "The radical discontinuous nature of BPR is the heart of its innovative strength—but it also represents BPR's biggest challenge. In a March 1992 CSC Index Inc. survey 23.5% of corporate respondents reported that their BPR projects were less than successful (60) and likewise in a May 1993 *Industrial Engineering* survey 27% of respondents reported negative results from BPR efforts (61). Again, in 1996 Mandel (62) reports that two-thirds of BPR fail."

The phenomenon is described in an article (17, p. 119) that ought to alarm any firm that has initiated programs to transform business processes: "In all too many companies, reengineering has been not only a great success but also a great failure. After months, even years, of careful redesign, these companies achieve dramatic improvements in individual processes only to watch overall results decline. By now, paradoxical outcomes of this kind have become almost commonplace. A computer company reengineers its finance department, reducing process costs by 34%—yet operating income stalls. An insurer cuts claims processing time 44%—yet profits drop. Managers proclaim a 20% cost reduction, a 25% quality improvement—yet in the same period business-unit costs increase and profits decline."

Research on these failures produced a list of critical failure factors that include lack of management commitment and leadership, resistance to change, unclear specifications, inadequate resources, technocentricism, a lack of user/customer involvement, and failure to address the human aspect of planned change (4).

McPartlin (18) based on his research on reengineering failure comments "The primary impediments to reengineering are undirected expectations and the lack of focus on specific value-added business processes." The desire and the creativity are there, but the road map is missing.

While many of the reasons for failure of BPR efforts occur during BPR project implementation, two critical faults often doom a BPR project from its outset. These two "front-end" weaknesses involve (1) not having a consistent definition of the firm's strategic objectives, and (2) not selecting business processes to be reengineered that maximize the positive impact upon those strategic objectives (16)

Hammer and Champy (3, p. 203), while cataloging the most common errors that lead companies to fail at reengineering say, "A reengineering effort, as we have seen, triggers changes of many kinds. Job designs, organizational structures, management systems—everything associated with the process—must be refashioned in order to maintain a coherent business system diamond."

Peter Keen (9) suggests a process paradox that causes some businesses to decline even as some of their processes improve, caused by investing in the wrong processes, not any by inherent fallacy in process improvement.

E. M. Goldratt and J. Cox's (19) elaborate and readable examples of bottleneck chasing in a fictional manufacturing plant bring home the importance of fixing the right process and measuring success correctly.

Simply put, one of the most difficult decisions in any BPR project is deciding which business process or processes to reengineer, and even more difficult is selecting business processes for redesign based upon the processes' impact upon the firm's strategic objectives.

Research reported herein addresses this critical issue and helps to identify the business processes within a strategic business unit (SBU) that, through reengineering, can contribute the most to the SBU's strategic objectives (16,20). This exciting research area continues to be extended, most recently, through system dynamics principles as described later in this article.

HOW TO GET STARTED FOR REENGINEERING

Naming all the processes that go on within a firm is not a simple task: the sheer number is daunting. Business processes are much more numerous than many analysts realize (9).

Thomas Davenport (15), a thoughtful commentator on business processes, argues that "most companies, even large and complex ones, can be broken into fewer than twenty major processes." He says that IBM has eighteen major processes; Xerox Corp., fourteen; and Dow Chemical, nine.

Michael Hammer and James Champy (3) assert that "hardly any company contains more than ten or so principal processes." However, Anderson Consulting has published a database that identifies 170 important business processes.

As Keen (9, p. 41) explains, "The number you arrive at obviously depends on your definition of major or principal processes . . .. Davenport lists the 18 IBM processes he considers major, but I can immediately name 60 that might merit the term. In fact, I can list 300 IBM processes that have annual budgets of more than $200 million (one reasonable definition of major), and I can quickly add another 50 cultural and management processes that cost less but have a significant effect on the company."

As expected, various definitions for business processes exist but these definitions have lot more similarities than differences. For the purpose of this article the term business process is characterized by (16):

- Sequence of linked functional-level activities that takes inputs and produce outputs
- Description of what the process does, not how it does it

Again, difficulty derives from the fact that processes are almost infinitely divisible. The activities involved in taking and fulfilling a customer order, for example, can be viewed as one process or hundreds (15). A process can be as narrowly defined as a single activity in a single function or as broadly defined as the entire business system for the business unit.

If the process is defined narrowly, redesign cannot produce the kind of widespread results that the company is looking for, and results in reengineering failure. Still other reengineering efforts fail because of a too-broad process; the improvements are more likely to extend throughout the entire business unit, for which the company may not be prepared (17).

Keen (9) defines a major business process as one that has or might have an important impact on a firm's value and concomitant success.

Based on Michael Porter's Value Chain and Gluck and Buaron's Business System, Crowe, Rathi, and Rolfes (16,20), identified eight major business processes (see Table 3) within SIC-36 manufacturers.

Table 3. SIC-36 Business Processes Defined [Adapted from Crowe, Rathi, and Rolfes (16)]

1. *Knowledge of Market to Orders.* This is the process of taking preliminary knowledge of a product market, analyzing it to find the target audience, increasing the awareness of this audience through product promotion, for the purpose of winning orders.
2. *Customer Order to Processed Order.* This is the process in which a customer order is received and all of the necessary paperwork is processed so the order can be filled.
3. *Concept to Successful Design / Redesign.* This is the conversion of a product idea (or product improvement idea) into a complete set of verified product plans.
4. *Unpriced Product to Final Price.* This is the process of compiling factors used that add cost to a product to determine how much the product should sell for.
5. *Need for Resources to Payment.* This is the process of acquiring all goods and services into a finished product which is then packaged, stored, and then supplied to a customer.
6. *Raw Material to Shipped Product.* This is the conversion of raw material into a finished product which is then packaged, stored, and then shipped to a customer.
7. *Shipped Product to Payment Received.* This is the process of collecting payment for products that have been shipped to a customer.
8. *Customer Feedback to Serviced Customer.* This process provides support to a customer before or after a sale.

The taxonomy of business processes represents the main business processes for any firm within SIC-36 industry classification, although it is not true that every firm will have all the eight processes. Notice from Table 3 that activities like Human Resources and Research & Development have deliberately been not included in the taxonomy. The premise behind not including these activities as separate business processes is two-fold:

1. The nature of these activities is *all pervading.* It is believed that these activities contribute more or less to all the eight processes and are not intrinsically separate from them.
2. By themselves, these activities are not value-adding.

Michael Porter's work seems to support this notion (21). Porter labels such activities as secondary, in that they do not participate in the firm's primary value chain.

NEED FOR FORMAL MODELING

In spite of low success rates, less than expected results, and some spectacular failures, reports on business process reengineering work indicate that more companies than ever are involved in a BPR initiative (17,22,23). Sixty-nine percent of US and 75% of European firms were involved in a BPR initiative during 1994 and, of the remaining, 50% were planning to undertake BPR in 1995–1996 (24). Seemingly, the trend to reengineer has impetus from the highly publicized successes and our own corporate cultures (25), but the fact is that competitive pressures are forcing companies to change (26).

As Warren, Crosslin, and MacArthur (27) state, "BPR is regarded by some as a panacea, but change is expensive and risky—radical change, much more." The primary impediments to reengineering are undirected expectations and the lack of "focus on specific value-added business processes" (18). Traditionally, business decisions to redesign business processes are made from recommendations or gut feelings (27).

Some form of formal modeling is absolutely needed to make well-informed business decisions about redesigning, for justifying massive investment in BPR, and to help measure the impact of proposed changes before any damaging practices are implemented by a company as a part of reengineering work.

Harold Cypress, in his February 1994 *OR/MS Today* article (28), defines the reengineering that took place in the past 4 to 5 years as "first-generation" reengineering. He states that not much management science/operations research (MS/OR) thinking was used in first-generation reengineering and predicts that "second generation" reengineering will support a greater solution space with a broader use of proven MS/OR tools and solutions.

EXAMPLE OF OR/MS THINKING USED FOR REENGINEERING

Hammer and Champy (3, p. 66) define process teams as "a unit that naturally falls together to complete a whole piece of work—a process." The advantage of creating process teams is that the organizational structure becomes flat and less hierarchical. Due to this people become more integrated. The employees become empowered to make their own decisions, thereby increasing productivity. Process teams are traditionally created using flow charts and common sense.

Work by Jones, Noble, and Crowe (29) presents the use of cellular manufacturing techniques to form process teams. Speaking on the similarity between jobshop and office environment, Jones, Noble, and Crowe (29) state, "It is not difficult to see the similarities between the jobshop and the office environment. Jobshops are simply many sets of similar machines placed in close proximity so that a part travels from group to group visiting some machine in each group until all the manufacturing processes are performed. A typical business can be explained in a similar manner by replacing the word machine with department and part with business process. A department usually consists of a group of people with similar skills or focus. A business process requires skills from people in many different departments and transverses each required department before completion. Therefore, a business process can be viewed in a similar manner to a part in that it must travel between departments before its completion. By analyzing the business process from a process point of view, it becomes apparent that it is logical to create business process cells . . . . These business process cells are essentially process teams."

Binary ordering algorithm is one of the techniques used to create manufacturing cells. The authors Jones, Noble, and Crowe (29) discuss, with an example, how this algorithm can be used to create process teams. Besides making it easy to form effective process teams, another advantage of using binary ordering approach for team formation is that it is easy to see what skills need to be taught to the employees so that the most efficient process teams are formed (29).

BUSINESS PROCESS MODELING TOOLS

Most BPR practitioners follow stepwise recipe-like procedures which do not include the use of a formal modeling methodology (14,30–39). But over the past few years, several new software tools have been developed specifically for modeling business processes and workflows. Most of these tools define business processes using graphical symbols or objects, with individual process activities depicted as a series of boxes and arrows. Special characteristics of each process or activity may then be attached as attributes of the process. Many of these tools also allow for some type of analysis, depending on the sophistication of the underlying methodology of the tool.

Analysis and modeling tools can be broken into three categories (40):

1. *Flow Diagramming Tools.* At the most basic levels are flow diagramming and drawing tools that help define processes and work flows by linking text descriptions of processes to symbols. Typically, flowchart models provide little if any analysis capability.
2. *CASE Tools.* These tools provide a conceptual framework for modeling hierarchies and process definitions. They are typically built on relational databases and include functions that provide linear, static, and deterministic analysis capability.
3. *Simulation Modeling Tools.* Simulation tools provide continuous or discrete-event, dynamic, and stochastic

analysis capability. Furthermore, simulation tools typically provide animation capabilities that allow process designers to see how customers and/or work objects flow through the system.

Based on customer surveys conducted by Galdwin and Tumay (40), they found that in over 80% of reengineering projects, the modeling tools of choice have been flowcharting tools.

Although static modeling tools offer help in understanding the overall nature of an existing process, they lack the ability to accurately predict the outcome of proposed changes to that process. In general, static modeling tools are deterministic and independent of process sequence.

Simulation Modeling

Shannon (41) has defined simulation as "the process of designing a model of a real system and conducting experiments with this model for the purpose, of either understanding the behavior of the system or of evaluating various strategies (within the limits imposed by a criterion or set of criteria) for the operation of the system."

Simulation Over Operational Research Techniques. The very definition of simulation reveals its great potential as a tool for BPR. Indeed, simulation modeling of an organization's processes can help toward understanding the behavior of the existing system, identification of problematic tasks, and also makes experimentation with alternative processes easier, directly comparable and less risky.

The major advantages of simulation over other operational research techniques are described by Law and Kelton (42) as follows:

- Most complex, real-world systems with stochastic elements cannot be accurately described by a mathematical model that can be evaluated analytically. Thus, simulation is often the only type of investigation possible.
- Simulation allows for estimating the performance of an existing system under some projected set of operating conditions.
- Alternative proposed system designs (or alternative operating policies for a single system) can be compared via simulation, to see which meets a specified requirement.
- In a simulation one can maintain much better control over experimental conditions than would generally be possible when experimenting with the system itself.
- Simulation allows one to study a system with a long time frame (e.g., an economic system) in compressed time.
- Simulation, especially when combined with graphical animation and interaction capabilities, facilitates understanding of a system's behavior, of the impact of proposed changes, and allows for better communication of results.

Simulation: Ideal for Business Process Modeling. Some characteristics of simulation that make it ideal for business process modeling, include (43):

- Simulation modeling techniques are, by nature, process-oriented.
- Simulation allows for experimentation with any element of a business system.
- Simulation helps to define deficiencies early in the design process when correction is easily and inexpensively accomplished.
- Simulation models can be easily updated to follow changes in the actual system, thus enabling model maintenance and reusability.
- Simulation models can improve decision quality through their consistency and objectivity.
- Simulation models can help the decision makers generate and communicate ideas and interact with the model to immediately assess the impact of proposed changes.
- The stochastic nature of business processes (i.e., the "random" way in which they are triggered by external events) can be modeled in a simulation study.
- The analysis of results can be targeted to match the objectives of specific studies.
- Simulation allows the decision maker to obtain a "system-wide" view of the effects of local changes in a system and allows for the identification of implicit dependencies between parts of the system.
- Finally, simulation encourages a cultural shift in the way modeling is perceived in an organization, by means of continuous measurement and evaluation of business activities.

But Simulation Is Not Enough. Although useful for traditional incremental improvement efforts, most traditional simulation appears cumbersome for BPR projects because:

- The traditional simulation models require an enormous degree of detail to reflect the span of influence that BPR projects cover. For example, Nuño et al.'s 1993 BPR project's simulation model (44) included the representation of 1900 parts on 95 machines with 1775 setups, and required a supercomputer for timely execution.
- The traditional models are situationally unique.
- The traditional models result in performance measurements that are localized in nature—there are no ties to the firm's strategic objectives.

So What Is Required?

System dynamics models are a significant modeling innovation based on feedback theory. At a macro level the technique has been widely applied, while its potential for applications at a corporate level is yet to be fully exploited (45). As Jay Forrester puts it, ". . . activity is doubling about every three years. Indeed, corporate involvement with system dynamics goes much further than we can readily observe, because the best work is surrounded by a high degree of confidentiality" (46, p. 18).

System dynamics differ from other mathematical modeling techniques in as much as they use a systems concept which inquires into the components of a system and their interrelationships, with a view to answering a simple question: What affects what? The hypothesis underlying the system dynamics is that the causes of dynamic behavior as exhibited by various systems lie in their structure and policies (45). Forrester (47) suggested that causes underlying the dynamic behavior exhibited by all systems lie in the presence of causal loops of interdependence of various variables in a system.

The various applications of system dynamics can be grouped into three categories, namely, (1) macro-level applications, (2) industry-level applications, and (3) unit-level applications.

At each level, work has been reported to demonstrate the capability of the method in modeling complex systems. However, concerted efforts have not been made to perfect the method for applications at these levels (45). Richmond (48), while discussing enlargement of the paradigm, has argued that a methodological extension is not needed; instead efforts should be made to demonstrate the utility and power of the approach by concentrating, and gaining expertise in a particular substantive arena. Keeping in view that the selected arena should possess four key characteristics: (1) fit well with distinctive strength of system dynamics, (2) be large enough to have its scope in the future, (3) concern the general public, and (4) not be already dominated by a paradigm; he has suggested the arena of corporations.

As discussed earlier, the objective of the research reported here is to create a generic operational model of SIC-36 SBU group of industries. Such a model can help in formulating a general theory for corporations, in developing unifying principles running vertically through industry, and in discovering the laws of strategic behavior, invariant across time and place, that would allow practitioners of the management science to prescribe strategies for large corporations. These strategies would then allow the corporations to gain a competitive advantage in their respective marketplaces (49). As evident from the above discussion, system dynamics provides the right tool for building a generic operational model of SIC-36 group of industries.

SYSTEM DYNAMICS

Davis and O'Donnell (46, p. 18) of Coopers & Lybrand, advocates of system dynamics, best introduced systems thinking and system dynamics. They commented: "We live in a complex world, a world full of interactions, where the simplest action can cause the most perplexing and counterintuitive reaction. This complexity can be divided into detailed or dynamic complexity. Detail complexity arises from the sheer number of items that need to be taken into account. Detailed complexity problems are amenable to breaking down into small pieces. We have become good at managing this, developing increasingly complex computerized systems—often databases or spreadsheets—that can handle this situation very well.

Dynamic complexity, on the other hand, rises not from the number of factors that affect us, but the way they relate to one another. In particular, most businesses operate in an environment of feedback loops. Feedback occurs when our actions trigger a series of responses, often leading to the opposite effect from the one intended.

To understand dynamic complexity we need to think about the whole picture. If we think of a production process as simply a means by which goods are produced we shall miss half of the picture. We need to think about the other half as well, from when goods are delivered to when the customer returns to us—with new orders or returned goods! Looking at the whole picture is called systems thinking. This enables us to see behind events to understand the structure that is causing them.

But systems thinking on its own is not always enough. Just as a marketing proposition needs to be based on sound, financial projections underpinned by a financial model, so too a systems thinking structure needs a model to discover how it will behave. While the financial model will be built in a spreadsheet, the systems thinking model will be built using system dynamics."

Historical Perspective

During the 1940s, formal analysis, often involving mathematical and statistical techniques, had been applied to the problems of fighting a war and, subsequently, to the running of industries and business firms (50). The first and most important foundation for industrial dynamics (now known as system dynamics) is the concept of servomechanisms (or information-feedback systems) as evolved during and after World War II. In the late 1930s the scientific papers in the field dealt with the dynamic characteristics of very simple control systems described by linear differential equations of two variables. By the early 1940s the field had developed into the concepts of Laplace transforms, frequency response, and vector diagrams (51).

As Kumar and Vrat (45) note, "The roots of system dynamics can be traced back to the pioneering work of Norbert Wiener on cybernetics published in the year 1948. The work deals with control and regulation of biological, engineering, social and economic systems. Wiener proposed that the same general principles may be at work in the market mechanisms of economic systems, in the decision-making mechanisms of socio-economic systems, and in the cognitive mechanisms of psychological systems. The broad principles of cybernetics were applied to industrial systems for the first time by Forrester."

Foundations of System Dynamics

Forrester explained the emergence of industrial dynamics in the early 1960s, in his famous book *Industrial Dynamics,* as a result of four factors:

1. *Information-Feedback Control Theory.* It was the first time this theory of information feedback control was found to be fundamental to all life and human endeavor, from the slow pace of biological evolution to the launching of the latest space satellite.
2. *Decision-Making Processes.* The second foundation for industrial dynamics was the better understanding of decision making achieved during the automating of military tactical operations. The resulting body of practical experience in determining the basis for decisions and the content of "judgment" now became available to the study of management systems.
3. *Experimental Approach to System Analysis.* The third foundation for industrial dynamics was the experimental approach to understanding system behavior. Mathematical analysis was not powerful enough to yield general analytical solutions to situations as complex as encountered in business. The alternative was the exper-

imental approach. As Forrester puts it, "The 'management laboratory' now becomes possible."

4. *Digital Computers.* The fourth foundation was the appearance of high-speed electronic digital computers that became generally available between 1955 and 1960, which removed the practical computational barrier.

Before moving to management systems, Forrester had an extended career in applied science and its application to engineering, military feedback control systems, computers, and air defense command and control. So his early work was in the management field, concerned with problems such as instabilities in production and employment, slack or inconsistent corporate growth, and declining market share. The field was then known as industrial dynamics. The method gained popularity only during the late 1960s through its application at the macro level in urban and global modeling by Forrester (47,51). It was then applied to a far wider range of problems, from managing a research-and-development project to combatting urban stagnation and decay, understanding implications of exponential growth in a world of finite and declining natural resources, and for testing theories relating to diabetes. The term "industrial dynamics" soon gave way to a more general term: "system dynamics" (52).

Philosophical Underpinnings

Different schools of thought rest on different philosophies about the nature of knowledge. As Forrester (53, p. 14) said, "I see the philosophy of the engineer and scientist as similar to that of the system dynamicist, but as quite different from the philosophy guiding much work in the social sciences. Those working with physical systems gather experience, filter observations through available theory, hypothesize designs, test the components of either equipment or theories, invent, assemble, field test, and redesign. Engineering systems are designed from the inside outward, that is, from components into a functioning whole. Behavior of the system is a consequence of interaction of its parts, parts that themselves must be understood and interconnected. The success of applied science and engineering is measured not so much by published papers as by working devices that do useful things. Engineering is intellectually dangerous. One works beyond the edge of reliable information; one never has resources to make all the tests one would like; a deadline exists; a budget must be met; and prudent risk-taking is the setting for every decision.

. . . in the social sciences we often see a very different value system and philosophical framework. The social scientist may be more social critic or analyst than social engineer. The goal is published paper, not a better social system now. Timeliness is not seen as an essential aspect of research. Individual research takes precedence over team projects that might have the power necessary to solve problems. There is less inclination to give up an intellectual approach that is failing to perform and to strike out in search of methods that are more suitable to the problems that beset society."

System dynamics needs a broader and deeper understanding about its underlying philosophies, in contrast with alternative methods. In the United States systems thinking is coming to mean an activity that has gathered momentum on the philosophies of system dynamics. As Forrester (54) said, "Systems thinking can serve a constructive role as a door opener to system dynamics and to serious work toward understanding systems."

Systems Thinking. Systems thinking carries with it principal world view assumptions. It's useful to couch these assumptions in terms of the skills that a person would need in order to "execute" the worldview. These are adapted from Richmond and Peterson (55):

1. *System as Cause Thinking.* The first worldview assumes that the dynamics being exhibited by that system or process is a result of the relationships within a system or process of causes (i.e., as opposed to the dynamics being driven by outside forces).
2. *Operational Thinking.* Operational thinking means looking at an activity, process, or system in terms of how it really works. The advantage from operational thinking skill is that it causes one to ask questions, which builds an understanding of how the real system actually works. Instead of predicting the behavior of a system through a series of high-level, abstract, correlational relationships, operational thinking has one getting right down to the utter facts of what's really going on (55).
3. *Closed-Loop Thinking.* Richmond and Peterson (55) explain that, from a closed-loop thinking perspective, causal relationships are seen as reciprocal. No absolute distinction is maintained between cause and effect. Each "factor" is at once both cause and effect. Indeed, "factors" cease to be the relevant unit of causality. They are supplanted by "relationships."

Systems Thinking and System Dynamics Go Together

As Forrester (54) puts it, ". . . unquestioning and superficial enthusiasm for systems thinking may lead some people into trouble. Some people attain enough revealing insights from systems thinking that they feel need for nothing else. Such people are in danger of finding that systems thinking does not help in solving their problems . . .."

Systems thinking on its own is not always enough. Senge (56, p. 183), an advocate of systems thinking said, ". . . systems thinking without computer simulation can short circuit the process by which we develop human intuition. Without modeling, we might think we are learning to think holistically when we are actually learning to jump to conclusions."

But system dynamics without systems thinking can also lead to error in our final results. Because of its origins in control theory and computing technology, system dynamics has a strong technical mathematical component. The novice student of system dynamics can easily mistake the subject for a purely technical course in a particular form of computer simulation (57).

The difficulty of dynamic systems modeling comes not from learning to use the system dynamics computer software, but from learning to represent reality faithfully. Translating a complex organizational issue into a model that makes sense is still a high-level craft, and the modeling programs contain no built-in criteria for helping to see whether a model is credible or appropriate (56).

System Dynamics and Systems Thinking Defined

Forrester (51, p. 13), the founder of system dynamics, defined it as: ". . .the investigation of the information-feedback characteristics of [managed] systems and the use of models for the design of improved organizational form and guiding policy."

Coyle (1970, p. 11) defined system dynamics: "System dynamics is that branch of control theory which deals with socio-economic systems, and that branch of Management Science which deals with problems of controllability."

Wolstenholme (58, p. 15) offered: "A rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies; which facilitates quantitative simulation modeling and analysis for the design of system structure and behavior."

None of these is completely satisfactory. Forrester does not say what type of models are involved. Neither of the definitions refer to time. Coyle does not mention information feedback. But it can be agreed that system dynamics is:

- A model-building attitude that attempts to include both qualitative as well as quantitative factors that are believed to influence the behavior of interest
- Focused on studying the system behavior over time
- The identification of system boundary such that the behavior of interest will be generated internally from feedback loops and the structure of the system
- A simulation tool to understand the policy alternatives of the model

Peter Senge (56, p. 6) defines systems thinking: "It is a way of thinking about, and a language for describing and understanding, the forces and interrelationships that shape the behavior of systems. This discipline helps us to see how to change systems more effectively, and to act more in tune with the larger processes of the natural and economic world."

System Dynamics Modeling of Strategic Business Process Reengineering

The concepts of system dynamics and philosophy of systems thinking provide both the necessary and sufficient conditions for application as a tool to model strategic BPR. In the next section a case study of a disguised manufacturing company, Power Savers, Inc., is presented. Using a real-life situation, it explains the need for implementing BPR. The need for a system dynamics based model for implementing BPR successfully is felt, as the discussion among the management team drifts from finding problems in the company to finding solutions.

CASE STUDY

Dr. Joe Burlingame, the founder of Power Savers, Inc., is an American hero. He grew up tinkering in the family workshop, convinced from an early age that he could be an inventor. In 1985, when Burlingame was 29 and was working on his doctoral dissertation, he had his big idea: a new way of saving electric power. He spent a few hundred dollars, bought simple tools, rented a small workshop, and went to work. In contrast to traditional power-saving equipment, the new breakthrough equipment he designed was more efficient on energy, effort, time, and money.

In 1987 Burlingame obtained patents for his concepts, and they were so general that he could fend off competitors for years. Soaring energy prices created overwhelming advantage for Power Savers. In 1991 annual sales were approximately US $4.5 million with 53 employees and those numbers had grown to US $13 million and 120 employees in fiscal year 1995.

In the past Power Savers had produced its products for industrial organizations where the profit margin was good. Power Savers then had no standard products and was primarily a make-to-order company. Like most start-up businesses Power Savers was born lean. However, by the early 1990s when the company began to make its product in volume, Burlingame felt a need to change the way the business was working. He hired an experienced manufacturing manager to run his new manufacturing plant, an engineering manager to create a variety of configurations of the basic concept, and a sales manager to manage a sales force of independent distributors, located in different parts of the country.

As Power Savers tried to move orders gathered by the independent distributors' sales force throughout the United States, complexity increased exponentially. The power-saving equipment had to be customized, depending upon the power usage at the customer site and hence no finished goods inventory could be maintained. So if there was an unexpected increase in demand, the manufacturing rate was increased but restricted by the raw material inventory and the capital equipment. A long lead time was introduced and the customers were kept waiting for the product. On the other hand, reduced demand resulted in abrupt production declines and instability in raw material control.

Research-and-design personnel were forced to create somewhat standard but different variations of a product to meet specific target markets. By 1995, it usually took six months to introduce a minor improvement and more than a year to introduce a new family of equipment. If these projects spent no time in queues and backtracking, it would take only a few weeks for minor improvements and four months for a new family of products. In summary, Power Savers conducted its three major processes—(1) concept to redesign or new designs, (2) raw material inventory management, and (3) manufacturing its equipment—in highly ineffective manners. Many steps added no value, customers were ignored, and managers focused on minimizing variations rather than pursuing the overall objective.

Until 1996, Power Savers was able to tolerate these deficiencies. Burlingame recalls, "Because of my patent position we were selling high priced products that had major advantages over competitors' products. The quality of products we offered was so-so. Minor improvements over previous models took about a year to get to the market. But we were making tons of money."

Then in 1996, with the patent period coming to an end, the competitors started offering lower-priced clones of Power Savers' equipment. The loss of patent made the market vulnerable to these lower-priced clones that had comparable performance. The new companies were regional and were able to provide quicker service because of their proximity to the customers. In the first quarter of 1997, company Power Savers suffered its first loss.

Managers attributed this loss of market to loss of patent, high price, and so forth. Being no quitter, Burlingame started trying out most of the popular remedies in the United States. He approached James Smith, an experienced management consultant, to recommend plans, which would help in improving his business.

James Smith knew that the underperformance of a company could not be attributed exclusively to changing external environmental conditions or due to bad management. In fact, Smith loved to flaunt, “A company’s functional managers combine their individual acts to self-destroy the company’s overall strategic objectives.” He explains, “Although functional managers act in what they feel to be the best interests of the company, it is interactions among the individual functional policies over time which lead to overall underperformance.”

Smith further recalls, “For Power Savers to achieve dramatic improvements in performance, it required the managers in the company to change their ways of thinking as well as what they do. Business Process Reengineering (BPR) programs promised such fundamental improvements in performance. But to reap the benefits of a BPR program, Power Savers needed to decide on right business process to reengineer to maximize positive impact on company’s strategic objectives. And doing so isn’t easy! A reengineering of a business process triggers changes of many kinds which interact with other functional level strategies to produce unexpected and undesired effects which increase over a period of time and rise to a degree of complexity which is incomprehensible by a human mind.”

When in school, Smith had studied the system dynamics based modeling approach, which was founded on the premises that the causes of dynamic behavior as exhibited by various systems lie in the policies of its subsystems and their interactions. And now when Power Savers needed a holistic view of the system rather than a narrow, reductionist perspective, Smith knew that a model based on such an approach would help management to make the right decisions.

So he proposed the following plan to Burlingame: Power Savers should start by identifying the business processes that really add value to the customers and have an impact on its strategic objectives. Next a system dynamics based model of these value-adding business processes and their interactions would be designed. Experimentation with the model would be done to find the business processes’ policies and components which should be reengineered to maximize the positive impact on strategic objectives and measure the impact of proposed changes before any damaging practices are implemented. Finally the BPR would be performed on the real system, based on well-informed decisions and with the confidence that it would work.

Burlingame took a long-term view and realized that the proposed plan had the potential of improving the business. To implement it he needed his managers to work as leaders of change. He recalls, “My managers were doing what they did best for more than the last ten years. Although the plan looked good on paper, asking them to radically change their ways of working, to improve what they were doing could trigger opposition and the plan would fail!”

Smith saw this coming. He knew that any change proposed would cause opposition. To convince the managers that BPR provided the right medicine for the otherwise going-to-be-sick company, he offered Burlingame a simple solution.

After working with Burlingame he decided that a small-simplified subset of the final model should be created with dual objectives:

(1) To show reengineering helps
(2) To show that reengineering a business process or two without measuring their effect on the strategic objectives does not help

In a brainstorming session with the management team, Smith said to the managers, “I am here to help you solve this company’s problems.” But when he asked them, “I want to know—why is Power Savers losing market?,” all of them were quiet.

Finally the general manager said, “Our sales force is no longer effective. We are way off our sales target. The competitors have better ways of dealing with local customers.”

“I don’t think so!,” said sales manager defensively. “We are losing orders not because of ineffective sales team but because the manufacturing is not able to deliver. Customers are losing confidence in our company because of long delivery times and this is giving us a bad name in the market. And our competitors are capitalizing on this!”

“I understand the need of low delivery times, but we’re getting really behind,” said the manufacturing manager. “Sometimes we have technical problems with the equipment and the production stops. Other times we run out of raw material inventory. We are doing our best, but we may have to think about adding more capital equipment.”

“Our budgets are too tight right now and we cannot afford to buy more equipment now. We will have to make the best of what we have,” said the finance manager.

To this Smith asked, “But why does inventory go low?”

“Exactly! Didn’t we decide on maintaining some minimum level of raw material inventory for safety?” asked the general manager.

“Yeah, we did and I am still maintaining this policy,” replied the production manager. “In fact we always check the current status of inventory before ordering raw material and if it’s low then we order more than average production rate in order to maintain a minimum level of inventory. You can’t blame me for it. Maybe the minimum safe level of inventory we decided on is not enough!”

“But we already maintain raw material inventory enough to cover fifteen days. Why do we need more when we want to keep investment in assets low?,” said the finance manager.

The discussion continued for the next fifteen minutes, with each manager shifting the burden on the other and jumping to short-term solutions. Before the discussion resulted in chaos, Smith asked, “Although the company is facing a variety of problems, am I right in sensing that raw material inventory is one of them?”

The production manager was the first one to speak. “Tell me about it!” There was no need to say more.

Smith suggested a small break so that the managers could recollect their thoughts. Later, after the break, working with the managers Smith prepared a simple system dynamics model of raw material inventory process and its interaction with production rate of the manufacturing process.

Before the model was constructed, the managers could not explain why raw materials inventory was fluctuating even though they were trying hard to maintain it.

After developing the model various tests were conducted. One of the tests on the model showed that even a slight increase in the production rate caused raw material inventory to oscillate and it took almost a year to stabilize. This trend exhibited by the model was similar to the behavior of raw material inventory in real-life situations. The model helped managers to develop a consistent hypothesis for the fluctuating raw material inventory. Further experimentation was carried out on the model to study the effects of traditional solutions such as expediting the raw material order process and/or increasing the minimum level of safe raw material inventory. The model showed that these solutions helped, but only in the short term. Even after making these changes raw material inventory fluctuated, except now these fluctuations showed up after some time lag.

All this time Burlingame was quietly listening. It soon became clear to him that the traditional thinking and quick fixes could not alleviate Power Savers problems. He was more than convinced that Smith had some right solutions. So he asked everybody in the room, "Where is it written that what we are doing with our inventory is right?"

"Nowhere!," uttered the manufacturing manager. "In fact it's in our beliefs."

"Honestly, I don't know," said the production manager. "But I can see that we are doing something that is basically wrong."

Everybody in the room was stunned by this simple fact. They felt frustrated. No point of view seemed to hold all the truth any longer; No conclusion felt definitive. After a few moments, seeing the panic on the faces, Smith asked, "Does everybody in the room feel that we need to radically change the ways we are thinking and the ways we are doing things here?"

The question made everybody think and realize that the assumptions which had maintained the business profitable for so long were no longer doing any good to the company. In fact, these assumptions were probably detrimental.

"Are you suggesting reengineering?" asked marketing manager.

"Yes, I mean Business Process Reengineering," replied Smith.

"But isn't that a risky proposition?," asked the marketing manager.

"So what! I mean if we are doing something so wrong maybe its time we change our ways if that can improve our business, even if there is risk involved!," replied the production manager.

Others were listening to this discussion when the manufacturing manager asked a question that was troubling him all this time, "But what if we may be operating similar wrong policies in a business process that interact with others, resulting in compounded problems which are not obvious or visible outright?"

"Exactly! I am bothered about the fact that we could be inadvertently implementing some policies in various business processes, which are wrong!," said the general manager.

Impressed by the way Smith was tactfully leading the discussion and knowing where he was heading, Burlingame asked, "So should we create similar models for all the business processes we have in our company?"

The marketing manager skeptically, "Don't forget the interactions among them."

"What do you mean?," asked the production manager.

"I mean, how can we account for every interaction among business processes in our model!," replied the marketing manager.

"We did it for inventory process, I guess we can do it for all the processes," said the production manager.

The finance manager, thinking that it all seemed logical, tried to precipitate his thoughts by asking, "So what we are talking about is creating a model of all the business processes in our company, trying to understand their systems, policies, and structures and then radically redesigning them to be more effective?"

"But do we need to model each and every thing we do in our company?," asked the sales manager.

"Isn't that what we are talking about?" replied the finance manager.

"Yes, but as in the case of our inventory model, we needed to reengineer so as to achieve our strategic objectives of minimizing investment in assets and to minimize delivery time. So maybe we should reengineer only those business processes that reflect directly on our strategic objectives."

"Yes, that's exactly what we should do!," Smith exclaimed.

The manufacturing manager, very excited about the idea, added, "And before reengineering is performed we should be able to select the business process which maximizes our gains in terms of strategic objectives and reengineer that business process first."

"Precisely!," said Smith while writing on the chalkboard. "So can I say that the objective should be to build an operational model of the value-adding business processes of the company. Such a model will help in identifying the business process that, through reengineering, can contribute the most to the company's strategic objectives."

It took several months for Power Savers's management and Smith to build such a model. After validating the model, trends were studied to understand undesired behavior. Various experiments were carried out by changing different components or policies of business processes, finding places of maximum leverage. The long-term effects of reengineering these business processes were investigated. After successfully experimenting and reengineering the model, a reengineering program was launched in the company and implemented successfully.

CONCLUSION

Business process reengineering is not a fad. Various discussions in academia and practice loudly proclaim that BPR is a risky endeavor, with a very high probability of failure. But everybody seems to agree that BPR, as a concept, is not a failure. Due to globalization and technological innovations, all the aspects of markets in which corporations exist, are changing. And to survive in such markets corporations are required to radically change the ways of doing things and move to better ways. All this is saying is that the organizations are moving away from the organizational structures of Smith, Taylor, and Sloan. With changing times, companies need to view their business processes as the customer sees it. BPR is asking companies to streamline these business processes to maximize the gains. And this is not wrong.

Before BPR was a fashion, various organizations benefited by carefully practicing concepts similar to BPR. In the 1990s, with so much help available from books, consultants, training courses, and research programs, many organizations initiated BPR programs. Reckless reengineering—investing in changes without measuring their impact on strategic objectives—created chaos and failures. System dynamics promises to provide an approach, which will help corporations in measuring the impacts of changes proposed by BPR. Such an approach will reduce the risk factor associated with reengineering and assist organizations to decide what to reengineer, and how to reengineer, to finally make it a success.

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BUSINESS, SMALL. See Entrepreneuring.