MANAGEMENT OF CHANGE

In response to changes in industrial conditions and other competitive challenges, firms commonly adopt new practices, policies, and technologies to sustain their competitiveness. In many cases, the implementation of these changes within the workplace fails to deliver the expected benefits of improved work quality and increased productivity. Instead, the results are often a disrupted work flow, unanticipated downtime, worker dissatisfaction, and loss of productivity. Some authors argue that most firms incur a substantial “adjustment cost” in implementing new technology that prevents them from initially realizing any net benefits from their investment (1). This period of adjustment arises because of a mismatch between the new technology, existing processes, and the organization itself. It can be a long and costly process for any firm. Yet the phrase “no pain, no gain” may aptly characterize this adjustment period, since ultimately organizational change may be essential for the long-term survival of the firm.

The adoption of a new technology highlights some of the issues associated with managing change because it requires the institution of new policies and procedures, the restructuring of technical work, and the acquisition of new skills. Firms considering a major technological change need to recognize that implementation is itself a learning process. Clearly, there is a need to understand and account for learning curve effects in the use of the new technology. More importantly, organizations need to learn how to integrate human resources into implementation strategies in order to minimize the *resistance to change* exhibited by workers and managers. Resistance to change can manifest itself in a wide range of behavioral problems from absenteeism to all-out sabotage of the technology. In general, worker resistance is caused by the fear of being replaced or the uncertainty about developing required new skills. Managerial resistance often stems from perceived changes in status or power base (2). A plan for managing technological change helps alleviate resistance (3). Computer-aided design (CAD) is an example of a technology adoption prevalent in the electronic/telecommunications industries that requires a plan for managing technological change.

Introducing a new technology requires the development of a change management strategy addressing two stages: preadoption and implementation. The change strategy, as a component of the technological adoption plan, should be an interactive and dynamic process of integration between the technological resources and the organizational environment. Communication and training are key elements in managing the technological change. This article proposes a number of methods for managing technological change. It examines the development of a plan for the management of technological change that aligns the organizational structure with the selection of training methods. It also discusses the effects of technology on worker resistance and how a change management plan can overcome this resistance. The introduction of a new CAD system is used as an example to illustrate the idea of technological change and demonstrate the methods of change management.

COMPUTER-AIDED DESIGN

CAD is widely used in many industries today, including the automotive/transportation industry, electronics/telecommunications, and architecture and engineering services. As new applications of CAD are developed and add-on software becomes popular, the use of CAD will become even more widespread. Many manufacturers use CAD in product development. Given the complex designs used in many products today, it would be difficult to produce and revise the required designs without the use of a CAD system. Most firms that use CAD have reported substantial time savings in their design work and improved quality (4). However, CAD is more than a drafting tool; it can serve as a managerial tool as well. The use of CAD can help integrate a product development team by allowing the design process to proceed in parallel. Different engineers can retrieve the design data from the CAD database and work on complementary features of the product in synchronized fashion. The result can be a dramatic reduction in the engineering time needed to complete a customer’s order or to develop a new product.

Although firms may adopt CAD for many different reasons, a firm using CAD can no longer assume that it holds an advantage over its competitors. With so many firms using CAD, the technology has been reduced to a *qualifying requirement* for sustained competitiveness in design work. While failure to adopt CAD could result in a substantial loss of competitiveness, the use of CAD only implies that the firm is at parity with its competitors. However, CAD use does not guarantee success. Studies suggest that a majority of U.S. firms experience some type of failure when CAD is implemented (5). Yet firms have achieved a variety of strategic benefits, including cost savings, improved design flexibility, and better coordination with partners, suppliers, and customers, through the development of a technology strategy that addresses both human resources and organizational issues. Human resources includes the development of all CAD users—technical support staff, engineers, and managers—in order to smooth the implementation process, improve the skills and abilities of all users, and decrease worker resistance.

BACKGROUND

Resistance to Change

The adoption of a new technology often requires firms to overcome the obstacle of employee resistance in order to realize the full benefits of that technology. Technological changes create uncertainty for employees by disrupting organizational factors such as job task, role, internal relationships, and decision-making processes. Changes in these factors can produce either positive or negative psychological effects, which, in turn, can lead to positive or negative outcomes. Figure 1 illustrates the many factors creating resistance and the possible psychological effects and associated outcomes (6). The primary motive for resistance is change in the job task. Technology often reshapes the nature of the job task and requires new knowledge, skills, and abilities to perform these new tasks. Individual employees may interact with CAD in vastly different ways and thus require different levels of understanding of the operation of the new system. Since implementation and training may be staggered throughout the organization, the employee who does not yet understand the system may feel disadvantaged with respect to the ability to perform. Fear of a negative performance review can manifest itself in a negative view of the new technology and feelings of stress,

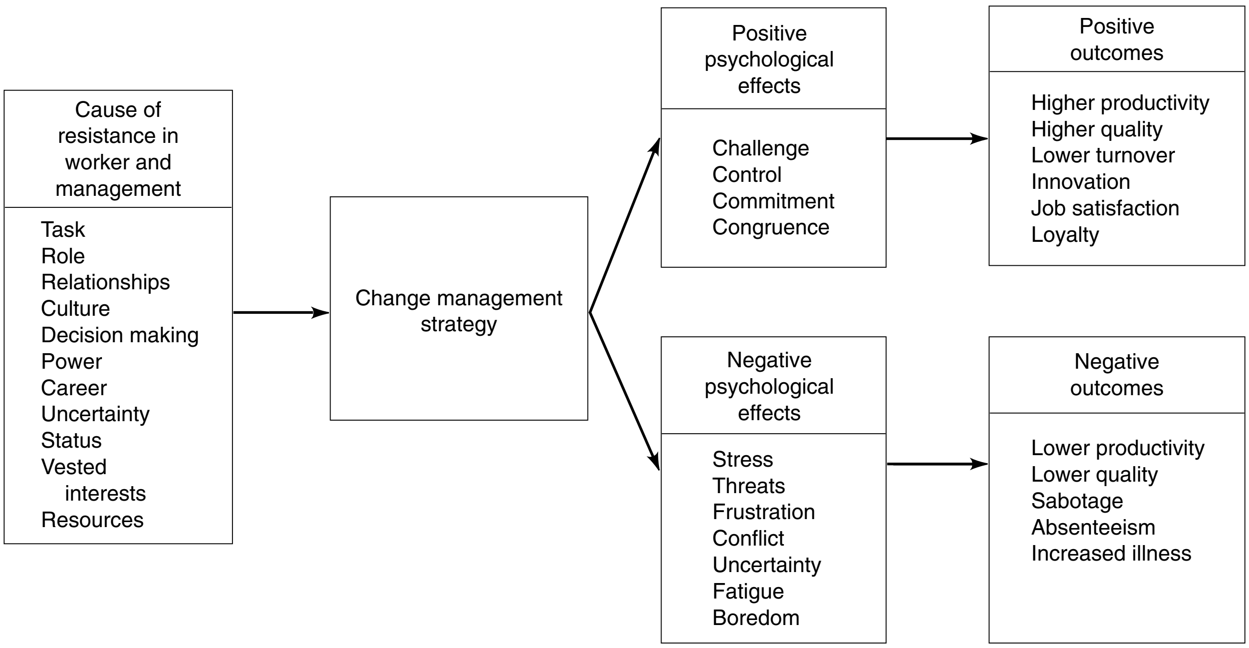

Figure 1. Causes of resistance to change.

frustration, and anger. Employees become less motivated and express these feelings through lower productivity and poor quality. Organizations may also experience an increase in absenteeism as well as extreme sabotage. For example, draftspeople have been known to pour coffee into their CAD station or stick paper into the computer's disk drive.

Unfortunately, management can also resist change. Managers may believe that the new technology will negatively impact their decision-making power and control over employees. In the case of a CAD adoption, managers lose some control to computer system administrators, who often dictate how designs and programs are stored and accessed. Managers may suffer during the "period of adjustment." The inevitable productivity downturn during implementation may be blamed on the manager, who is often evaluated on the basis of departmental performance (1). Management resistance to change creates a work atmosphere in which uncertainty is higher. The result can be a decrease in office morale, and a higher turnover can occur (3).

Another problem that contributes to resistance during the new technology implementation stage is the misalignment between the technology and the user environment. The misalignment usually occurs when there is conflict among the technical specifications of the work, the computer delivery system, and the performance criteria by which the user is evaluated (1). For example, CAD may be adopted on the basis of automating routine design tasks, ease of designing in three dimensions, allowing the electronic transfer of designs to manufacturing, or reducing paper in the design function. CAD's potential to be a tool of integration and communication between different work groups is often overlooked, and in many cases CAD is used only as an electronic drawing board. The lack of change within the user environment, in either the work structure and process, stymies the expected benefits of CAD. As Forslin and Thulestedt (Ref. 4, p. 201) state, "In hierarchic organizations, competition between functions and defending of territories are inherent. This creates barriers for the necessary cooperation in technical changes." Thus, until the user environment becomes more cooperative, the integrative capabilities of CAD can rarely be realized.

Successful management of technological change attempts to reduce organizational barriers and produces a number of positive outcomes by boosting employee morale. Employees become challenged and committed to the adoption of new technology, which leads to higher job satisfaction. This, in turn, limits the duration of the period of adjustment, reduces the productivity downturn, and results in higher quality. The successful management of technological change also creates a congruence between management and employee expectations, which reduces employee fear and uncertainties.

Change Strategies

There are a variety of methods for dealing with resistance to change. The key elements in any plan for technological change management are knowledge and communication (7). To develop a change strategy effectively, management must first understand the impact of the organizational structure on workers and work flow.

Organizational Structure. Organizational structure can effect the adoption of a technology while at the same time the technology can influence and change the organizational structure. Understanding the organizational structure's impact on the adoption of technology can help the manager choose an appropriate change management strategy. Burns and Stalker (8) have examined the importance of organizational structure to successful business ventures. Their studies show that organic firms experience more success in innovative environments than mechanistic organizations.

Organic firms exhibit characteristics of flexibility and pushing decision making down the chain of command. They are environments in which the individual worker is given a great deal of independence, and thus relationships between manager and worker tend to be less formal. Organic environments are more team oriented, more professional, and less formal than mechanistic structures (8,9). Davis and Wilkof (10) define the organic system as a professional organization that draws its cohesiveness through formal and informal norms derived from a communality of interest. It is this common interest that keeps the organization together. The rules tend to be less rigid, and the manager's spans of control are smaller. In organic environments, task accomplishment and innovation are moved from management to the most knowledgeable parties.

In contrast, mechanistic environments are more formal and structured than organic systems. They have more authoritative and hierarchical relationships between managers and worker. Managers are the decision makers and resolve work-related problems. Workers have little control of their own environment and the way they do their work (8).

Research indicates that organic and mechanistic environments are linked to different organizational activities and competitive conditions. For example, Link and Zmud (11) discovered that organic structures are the preferred environments in research and development (R&D) activities. Their study indicates that organic structures encourage greater R&D efficiency. Covin and Slevin's (12) study of small firms found that organic structures are more successful in hostile, competitive environments, while mechanistic structures are more successful in situations in which there is no hostility and a less competitive environment. Davis and Wilkof (8), while researching the transfer of scientific and technical information, observed the relationship between organizational structure and efficiency of information transfer. They concluded that one of the best ways to improve communication and information transfer is to alter the organizational structure to a more open, organic system. Clearly, research has shown that the work environment is distinctly different for organic and mechanistic structures.

Organizational Structure and CAD. In practice, design departments exhibit different characteristics in the use of CAD. Organic firms allow employees more autonomy. This feature of an organic environment is visible when workers are allowed to have influence over the decision process concerning work issues. Employees in organic environments exhibit more independence from their managers (8). The level of autonomy can be measured by the amount of contact the worker has with his or her manager. Workers in independent, organic structures have less contact with their managers and receive less direction on work methods. In organic structures, the workers are assigned work and allowed the freedom and responsibility to complete it in a way they deem appropriate (8,9). Another indicator of a firm's organic nature is the workers' involvement in the decision process of purchasing a CAD system. In organic structures, consideration is given to the employees' opinions about which system to use. Although the level of organic characteristics may seem difficult to measure, answers to simple questions such as "Where is the manager's office in relation to the employees?" and "How frequently do employees interact or speak with their manager or coworkers?" tend to reveal the work environment and structure quite quickly.

CAD firms with mechanistic structures have a different work approach. They are organized in a top-down fashion. Unlike organic structures, workers in mechanistic structures have little say in the day-to-day decisions that affect their occupations. Instead, management decides what CAD system to purchase and how it is used. In general, management in mechanistic firms makes itself more visible to the worker than in organic structures. Management is more likely to dictate rules and policy then to ask for the opinion and input of the workers. For example, when implementing a CAD system, management will choose the menus, naming conventions and drawing management procedures without consulting the workers.

Change Methods

There are a number of approaches for dealing with resistance to change. Table 1 lists six approaches and describes the advantages and disadvantages for each method. Kotter and Schlesinger (3) in their research found that the most fre-

Table 1. Method for Dealing with Resistance to Change

Method	Tactic Used in the Case	Organizational Structure	Advantages	Disadvantages
Training and communication	Where there is a low level of information	Mechanistic and organic	People will not hinder the change in the short term	Can be time consuming
Participation	When groups have the power to resist	Organic	People can become very innovative, gives higher quality	An unsuitable program may be designed
Facilitation and support	When work restructuring causes adjustment problems	Organic	Works best with adjustment problems	Very expensive and can still fail
Negotiation and agreement	Where there are status issues and a power struggle—also across department changes	Mechanistic	An easy way to smooth resistance between interdepartmental groups	Is expensive and cause inefficiencies
Coercion and cooptation	Where speed is essential	Mechanistic	Quick and easy solution to change in the short term	Leads to future problems
Explicit and tacit force	Where the initiator possesses great power	Mechanistic	Quick and overcomes any kind of resistance	Lower productivity and less integration

Adapted from J. P. Kotter and L. A. Schlesinger, Choosing strategies for change, *Harvard Business Rev.* March/April, 1979.

quently used methods are (1) explicit and tacit force and (2) training and communication. Explicit and tacit force is most frequently used in situations in which speed is a necessity. This method is more common in mechanistic organizations because managers are more authoritarian and employees tend to have less control over their work environment. Although this method has the advantage of being inexpensive, employees can become angry over being forced to perform tasks. In contrast, training and communication persuade employees to participate in the implementation. Because many people are involved, this approach can be very time consuming. However, it promotes innovative behavior and increases long-term productivity. While training and communication are used in both mechanistic and organic organizational structures most methods are more commonly used in either one or the other.

When implementing new technologies, organic organizations tend to solicit the involvement and opinions of the employees. These firms tend to use strategies in which communication is an important component (6). Beatty and Gordon (13), in an in-depth study of CAD implementation of ten companies, found that teams are among the best means of integrating technology into an organization. They also found that successful implementation has a technology "champion," a worker who has a great deal of political sensitivity and good communication skills that can be used to persuade and motivate employees. A technology champion and teams are often present in the participation and facilitation procedures. Organic firms often have communication channels and internal mechanisms that promote easy development of these strategies. Both the participation and facilitation methods for managing change bring full employee commitment and control adjustment problems to work restructuring. However, these methods are liable to take more time and sometimes fail (3).

Unfortunately, mechanistic structures are unable to implement participation and facilitation methods. Their internal structure tends to inhibit group planning. As can be seen in Table 1, mechanistic organizations tend to choose strategies that use power or coercion to gain employee acceptance. Such strategies are commonly used in situations where the job tasks are more structured and the employee has little voice in the implementation process. Firms using these methods observe a quicker implementation time and a lower cost. However, these methods run the risk of causing worker dissatisfaction. As long as time is not an issue, the best option to smooth implementation and maximize technology benefits is training and communication (14).

Training Issues. The implementation of a new technology often alters the occupational structure and changes the required skills. Training, when used properly, can do much to enhance the change process and the adoption of new technology. When implementing new technologies, companies must make decisions regarding user training so that the new skills required by the technology may be obtained by the organization in an effective manner. This makes training a perfect tool for implementing a change strategy. It becomes a vehicle that allows managers the opportunity to communicate and involve the employees (7,15).

Training issues can be broken into two stages: preadoption and implementation. Preadoption training issues are those in which training is considered prior to a firm's final decision regarding purchase of the new technology. These issues are critical because unless a firm is cognizant of the important issues (such as the extent to which the entire work force *needs* to be trained, or whether the present work force is willing and/or able to *be* trained for the new technology) prior to the purchase of the technology, there exists a potential danger that the adoption will not be successful. Implementation issues are those in which the firm has *already committed* to the adoption of the system and is designing the implementation process in order to maximize the usefulness of the system while keeping costs in check. Examples of implementation issues include such decisions as choice of the method of training and the use of lower skilled workers to use the new technology.

Preadoption Issues. One question that needs to be considered in adoption decisions is whether or not it is possible to retrain the present work force to perform the tasks that will be required under the new technology. This question encompasses two possibilities. It is possible that the potential users might not possess the necessary skills or education to be able to learn the new system within a reasonable time period. In other situations, the existing workers decide that they are not interested in learning and using the new technology; for example, such nonadoptive behavior was found in certain instances of CAD implementation (16). Without worker support, firms have found it extremely difficult to implement the new technology successfully. It is critical, therefore, that the firm has the ability to assess the workers' ability and desire to use the new system accurately.

A firm considering the adoption of new technology also needs to estimate accurately the total expense of educating the work force. For example, the expense of purchasing a CAD system is much more than just the price of the computer hardware and software. A more complete estimate of expenses will include both training program expenses and a "cushion" for loss of productivity while the trainee masters the new equipment. A price estimate that does not include these costs can cause financial problems for the firm. Underestimation of training and education expenses is a major reason for failure in the implementation of CAD systems (17). The underestimation of the costs of CAD has caused firms to overextend themselves to the point where they could no longer remain competitive, resulting, in some instances, in the ultimate demise of the business (15).

Another closely related issue that needs to be considered initially is the extent to which training needs to be integrated throughout the firm. It is often critical to train employees besides those who come in direct contact with the technology in order that the equipment can be used at a level closer to its full potential. Examples of such employees might be CAD supervisors, secretarial staff, and manufacturing employees. Some new technologies are so radically different from existing systems that anyone who will have the slightest contact with the new system should receive training. For example, a recent survey of firms that have CAD systems showed that almost 50% of all companies with CAD/CAM training provided training to *all* occupational groups related to design, manufacturing, and materials management within the whole company (5). CAD systems were found to be so different from traditional design methods that workers who did not receive any training in CAD were at a tremendous disadvantage when they were needed to use the system in any way. Thus, with the implementation of CAD technology, many firms appear to have found a need to educate anyone who might come into contact with the system. It is therefore critical that management is aware of these needs (and costs) before choosing to adopt.

Implementation Issues. Implementation issues are those confronting the firm when it is already committed to the new technology. The main concern of these issues is how to develop a work force most efficiently and effectively that is sufficiently skilled at operating the new technology so that the system can achieve its potential. Some implementation issues are similar to preadoption issues, while many are completely different.

When a new technology is brought into a firm, management needs to decide the extent to which they are going to train the work force. Specifically, they must decide which workers *within* specific functional groups are to receive training. Although much is being done in universities to provide future workers with specialized technological skills (18), almost all firms find the need to retrain a group of their existing employees to operate and work with the new technology. From a financial standpoint, it might sound appealing for management to set up a specialized group within the firm to be trained while the rest of the employees are left alone. By doing this, the firm would only be spending training money on a percentage of the workers within the functional group. This might be possible, for example, if only *part* of the work in design utilizes a new CAD system, while the remaining work is done using traditional methods. But this does not work when the output designs must be CAD drawings.

The literature on electronic data interchange (EDI), another emerging technology, provides insight into another training implementation issue. The firm bringing in a new technology must decide how the workers will be trained. The firm must decide whether the training will be done in-house by their own personnel or if it will be done externally by either a vendor or an outside consultant. The firm also needs to decide if the training program it offers will be formal (classroom type) or a more tutor-oriented system. Internal training programs can often be more tailor-made for the specific system and can allow for a more informal and open exchange of ideas than their external counterparts. External education, on the other hand, is frequently more formal and has the advantage of being less expensive and is often the only option for smaller firms that may not have the money, facilities, or personnel to have internal training (19,20). Externally provided training programs have the disadvantage of being more generic and therefore frequently less useful.

Although researchers appear to agree upon the list of advantages and disadvantages, there is no consensus about which type of training is better. Engleke (21), for example, recommends that the training be done on site, without vendors, while Hubbard (22) feels that the best training sessions "are highly organized, relatively formal, classes taught by professional instructors at off-site locations." One study examined this issue with respect to the firm's managerial style and firm environment. It found that the mechanistic firms chose more formal methods of training while organic firms took a hands-on approach. Size of the firm may also influence the method of training (23). Majchrzak (Ref. 5, p. 200) found that 45% surveyed had in-house company-sponsored training programs. She also found that bigger firms generally chose to use the in-house, more focused training, while the smaller firms did not.

Another tactic used for keeping training costs down limits the training to those who are new hires. These policies may sound appealing, but in practice they have often led to disastrous results (10,24,25). These studies on deliberate separation of a portion of workers from a training program show that these policies often lead to feelings of exclusion. The workers feel that there is segregation into an "elite" group of workers and a group of workers that are being "put out to pasture." These feelings frequently lead to bad morale and poor worker/manager relationships. Some firms have also tried to hire employees from other companies that already have been trained in the new technology (21). In larger firms with substantial, established design teams, this has led to similar bad feelings and yielded similar results to situations in which workers were excluded from training. It is interesting, but not surprising, to note that when companies choose to offer training to some employees and not others, there are distinct patterns concerning which workers receive the offers to be trained. Liker and Fleisher (25) found that, although managers would not *say* that age entered into their decision process, the probability of being chosen to be a CAD user drops by 2% for each year of your age. For example, a difference in age of six years would correspond to a 12% difference in the probability of being selected. In their study, the average age of users was 39, while the average age of nonusers was 48. This apparent bias may not be unfounded—a study that analyzed the ability of a worker to learn new computer software found that younger workers (under 45 years of age) did significantly better than their older counterparts on comprehensive exams given after the training session (26).

An important issue in implementing a training program is determining when to train workers, before or during technology implementation. Managers should be particularly concerned with the transfer of training, which is the application of material learned in the classroom to the workplace. The length of time that passes between the time of training and the time of actual hands-on usage of the new technology greatly affects the transfer of training. Beatty (16) tells of a company that trained its employees six months in advance of the receipt of a new CAD system. The results were disastrous. Most of the information taught in the training sessions was forgotten in the period between training and actual usage. Ideally, little time should elapse between training and routine usage. Engelke (21) has found that the half-life of advanced package training is about two weeks if not applied immediately.

Many firms face a dilemma in training. If training is given before installation of the new system, the worker is allowed the benefit of learning the system prior to installation and will help to reduce productivity losses that might occur if the worker were trying to learn the new system after installation. The problem with prior training is that the purchased equipment often arrives later than scheduled or does not run properly immediately after installation, and the worker quickly forgets the training that was given. To avoid this problem, some firms opt to wait to train the worker until after the system has arrived and is functional, even though there will be productivity losses from downtime while learning (6).

Another critical concern for managers is the development of tacit skills. Tacit skills, which come from experience, tend to diminish in relative importance when compared to implicit skills, which are generally acquired through some form of a training program (27). It is not necessarily true that the tacit skills are actually reduced with the introduction of a new technology (as the previous examples of failed attempts to use computer operators clearly illustrate), but the number of new machines or technology skills that must be learned reduce tacit skills to a partial role in the education process. A fully trained worker must possess both tacit and implicit skills for the system to work at its fullest potential (6).

Implementation issues involving training for the multiple layers of the firm must also be considered. One might approach this subject by deciding to train only those workers who work directly with the new technology. In CAD, this would mean that training would only be given to the design group and not to any of the peripheral workers who might come in contact with but would not use the system routinely. The literature, however, suggests that training multiple layers of the firm is beneficial, if not necessary, in many applications (16,18). Brooks and Wells (28) found that managers who are not familiar with the new CAD system frequently experience difficulties. One common problem is the loss of status for a supervisor, especially if a skill differential develops between worker and supervisor. The literature in EDI agrees with the previously noted findings of CAD experiences. Carter et al. (Ref. 29, p. 14) notes that management training in EDI is "a key to increasing the likelihood that managers assigned the task of implementing EDI will succeed." Another problem that an untrained supervisor faces is the difficulty of effectively planning and controlling the work flow if he or she has no basis from which to estimate drawing and alteration times. The supervisor may also encounter great difficulty in evaluating a worker's progress and assessing performance of an individual. The combination of these problems often leads to the untrained supervisor "losing track" of the workers, thus causing a strained relationship and loss of productivity (15).

One mechanism to decrease worker resistance during the training period is to choose a pilot project that will help develop tacit skills and implement the technology. For example, in CAD implementation the pilot project should include the following characteristics: (1) a great deal of drafting and design work, (2) extensive design revision, (3) designs that are used by other functions and work groups, and (4) the need for extensive visual demonstrations and presentations of the design to customers and other projects. Workers involved in the pilot project would be among the first to receive CAD training. Such a pilot project would showcase CAD's capabilities in improving design/drawing productivity, integrating diverse users of design work, and communicating the output of design work. The successful use of CAD can be documented by an evaluation of the time savings and the quality improvements that were achieved. Often a single demonstration of success is enough to mitigate possible worker resistance. An illustration of this implementation strategy, often called the "quick slice" approach, occurred in a firm that implemented EDI in only one distribution center. Soon the workers in the distribution center were telling others in the organization of the benefits that were being achieved by using the technology. In no time at all, workers in other areas decided that they wanted the technology as well and were clamoring for EDI training (30). Thus, minimizing worker resistance to a technology can be achieved through the prudent choice of a pilot project, the development of a training program suited to the project needs and the organizational structure, and the demonstration of a successful use of the technology.

RESTRUCTURING DESIGN WORK THROUGH CAD

Traditionally, design work has encompassed both high-value-added activities (e.g., creative thought, problem solving, and design innovation) and low-value-added activities [e.g., producing a hard copy of an existing design, making minor design changes, and executing engineering change notices (ECNs)] that have *all* been performed by engineers and other technical professionals. In the *work restructuring* process, the low-value-added activities associated with design work are made routine and automated via CAD, and thus less-skilled workers who may not have design experience are capable of performing these tasks, which were previously performed only by engineers and draftspeople (31). Engineers and other technical professionals then have more time to devote to the higher-value design activities. The results are more opportunities for intellectual enrichment of their work, increased job effectiveness, and more time to integrate design activities with other areas of the organization (4). The work restructuring process in CAD reallocates tasks that were once considered *design work* across a broader spectrum of personnel. The work process is changed to incorporate more collaboration and coordination between engineers and other employees. Since work restructuring promotes both a team approach to design and better time utilization the result is designs that are completed sooner at a lower cost.

The use of technology as a facilitator in restructuring work has created debate with respect to the long-term implications for the work force. Two different effects have been hypothesized: deskilling and intellectual specialization. *Deskilling* refers to the devaluation of workers' intellectual skills when technology assumes the tasks previously performed by those workers, thus rendering their skills unnecessary. The deskilling effects of technology on workers has been debated with some arguing that technology-induced deskilling will lead to both a fragmentation of work content and an erosion of required work skills and ultimately will create a large class of unskilled workers (32). However, the deskilling proposition has not been empirically supported in studies of the effects of numerical control machining in the metal working industry and office automation on Canadian clerical workers (33,23). Although some skills were rendered unnecessary in these cases, workers were required to develop new skills to use the technology effectively, and a wide variety of new jobs was spawned by the technology.

A different impact of the new technology may be intellectual specialization, in which the knowledge domain of the design engineer or technical professional is profoundly changed from that of a generalist to a specialist. The shortening of product life cycles and the rapid pace of technological obsolescence so prevalent in the electronics and telecommunications industries imply that the design engineer must simultaneously increase his or her overall level of technical knowledge as well as his or her familiarity with increasingly sophisticated technology to remain at a state-of-the-art level. With more and more routine and low-value-added design activities performed through CAD, the design engineer may "intellectually specialize" by devoting the majority of his or her time to those activities that require the highest level of cognitive skills with which the engineer is qualified to perform (31). Thus, the use of CAD may promote increased specialization in design work—not because of work simplification or a degradation in the skill requirements—but because the task breadth and the knowledge intensity of the remaining design work create such a level of technical complexity that only a staff of narrowly focused or "specialized" professionals can perform it (20). Carried to an extreme, intellectual specialization is sometimes hypothesized as creating a division in the work force with an increasingly larger staff of professional workers performing highly specialized yet cognitively challenging work, while the other workers are relegated to performing relatively lower-level tasks. In these cases, intellectual specialization does not necessarily imply cost savings, since the organization must increase the size of its professional staff, many members of which represent some of the most highly paid individuals in the organization.

However, the success of work restructuring and the balance between deskilling and intellectual specialization are highly dependent on the effectiveness of the training program. In a study of the German mechanical engineering CAD industry (34), emphasis on *computer literacy* at the expense of actual design techniques during the training process limited the scope of tasks that could be relegated to less-skilled employees. Two other failures were documented when workers trained only as computer operators lacked sufficient design background to perform design work successfully (31). Many of these failures have been attributed to a conventional mindset in CAD training that tends to equate humans with machinery. The Swedish project UTOPIA represented a major departure from this mindset by designing training programs that focused on the development of both design and negotiation skills on the part of the nontechnical worker and on advocating the restructuring of design work so as to use CAD in order to enhance, not replace, the skills of the design worker.

DISCUSSION

Research provides general support for the idea that there are relationships among change management strategies, organizational structure, the formality of the training program, and the restructuring of design work. Managing the technological change process depicted in Fig. 2 suggests a very proactive approach in deciding what kinds of programs to establish when implementing a new technology. Figure 2 implies that for an effective technological change strategy, selection of an approach should be based on the organizational structure.

In the case of implementing a new CAD system the type of training program utilized by a firm is closely related to the organizational structure of the firm. For many companies, the choice of training program is more a matter of finding the best "fit" to the specific organizational structure of the particular firm than just a decision based on firm size alone. However, it appears that if firms are particularly concerned with benefits associated with the deskilling process, then it might be in their best interest to use more informal methods to train their workers.

In a recent study on CAD adoption (23), a mechanistic firm was observed using *informal* training methods specifically to

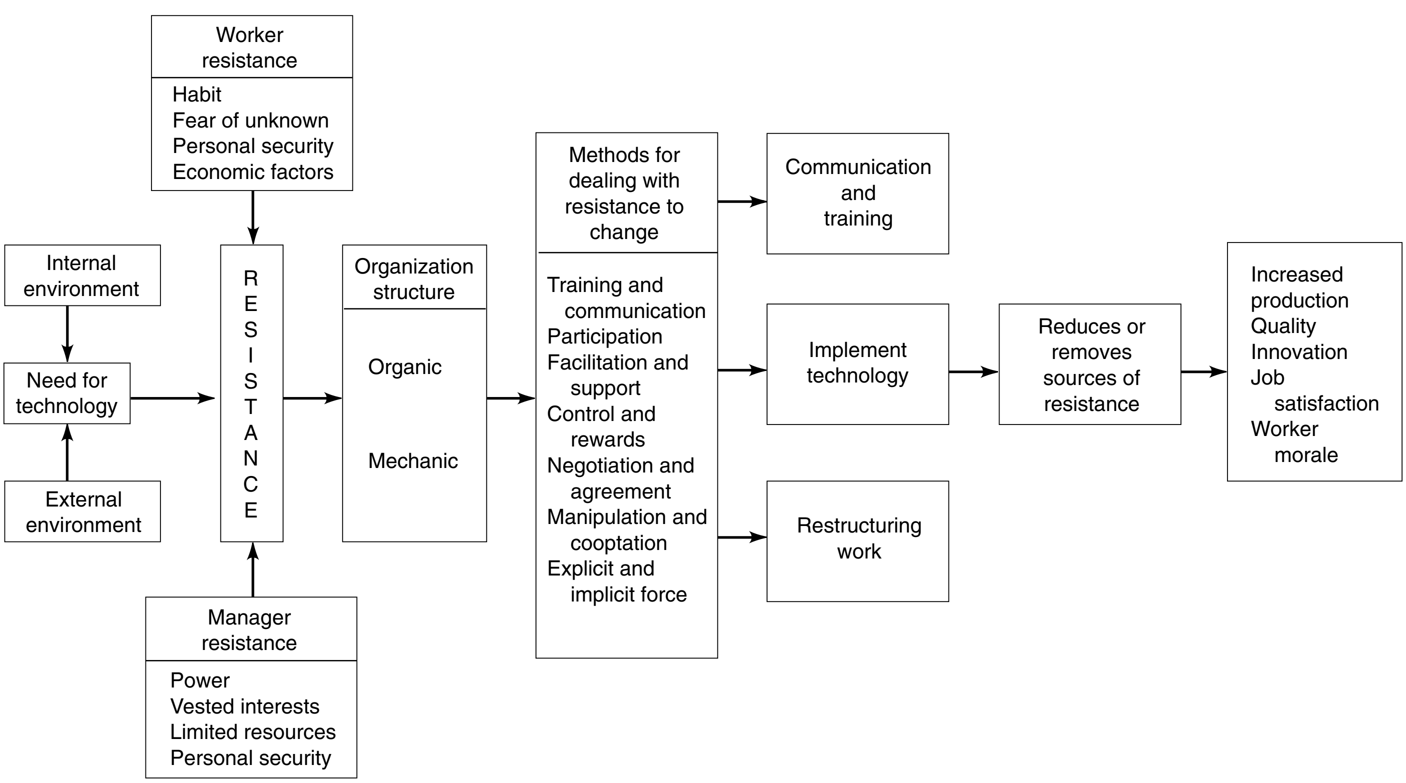

Figure 2. Managing the technological change process.

take advantage of the deskilling process. It might be suggested that other mechanistic firms alter their training format to do the same. By allowing for more informal, loose flows of information, these mechanistic firms might be able to achieve the same quality of CAD education. Organic firms concerned with management training, on the other hand, might be advised to pursue more formal methods of educating CAD managers. As noted previously, the literature strongly suggests that this is highly beneficial for making the management of the systems run smoothly.

In the firms involved in the study noted previously, only those using informal, tutorlike training programs were found to have lower-skilled workers contributing through the CAD system. Those firms relying exclusively on formal methods had no such work restructuring. This difference could be significant, for work restructuring holds the potential of providing firms with financial savings in the use of CAD by allowing for the use of lower-paid workers in routine design activities and the use of more highly paid professional workers for the most intellectually challenging design tasks.

In the telecommunications and electronics industries, the penalty for not adopting or successfully implementing CAD is prohibitive—total noncompetitiveness to the point at which the firm must essentially abandon its markets and leave the industry. Adoption of other technologies such as third party design software, groupware, email, project management software, and processing technologies all result in changing the work environment. To successfully adopt these technologies, managers must match the change in the management program with the goals (work restructuring) and organizational structure.

Suggested Areas of Future Research

Although the observations of this article are strongly related to CAD adoption, it is important to recognize that other technological adoptions may have a wider impact on an organization's coordination ability and work processes. For example, incorporating new processing technologies can often have wide ranging consequence which effect the management and work structure of multiple departments (1). However this article does give a general overview on the major considerations involved when managing a technological change. In addition, there are many different factors besides organizational structure and training that can influence a CAD implementation. The development of a contingency model is clearly beyond the scope of this article. Future studies may explore these contingencies and look at other technological adoptions. This observation raises a number of interesting research questions.

Questions

1. Does the implementation of technology or change within organic structures take longer than those in mechanistic structures? Is the long-term outcome of technology adoption better with one structure than the other?
2. What are the dynamics when adopting a technology across a number of departments? What are the coordinating mechanisms that help to implement change within multiple departments? Are these mechanisms the same for the two organizational structures?

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