An Expert Systems Technology Transfer Model for the Architecture-Engineering-Construction Industry

by

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(ABSTRACT)

Increased complexity of constructed facilities, owners' changing needs and international competition have created strong demands for advanced construction technology. Recent developments in computer technologies provide the Architecture-Engineering-Construction (AEC) industry with significant potential for innovation. However, the adoption of state-of-the-art computer technologies by a majority of AEC firms faces many hurdles.

The objective of this research is the development of methodologies for accelerating the adoption of Expert Systems (ES) technology by the AEC industry. This is accomplished with the development of a Technology Transfer (T^2) model for ES. The T^2 model has been based on the models of innovation developed by Rogers, Shaffer, and Tatum, as well as on case studies of ES adoption by several organizations.

The ES T^2 model has focused on the following issues: 1) the stages of the T^2 process and the managerial actions required for successful adoption of ES technology; 2) the economical, technological and organizational factors affecting the T^2 process; and 3) alternative strategies that managers can deploy to successfully transfer the technology to their firm. The T^2 model provides a useful framework that can significantly enhance managers' ability to expedite the transfer of ES technology in the AEC industry.

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1. Introduction

1.1 Need for Technological Innovation

During recent years the construction industry has faced productivity and competitiveness problems. Increased complexity of facilities, owners' changing needs, inadequate construction methods, and international competition have created strong demands for advanced construction technology.

The demand for technological innovation in the construction industry has been well identified and documented. The Business Roundtable Report (The Business Roundtable 1983) found that construction is far less progressive than many other industries in adopting technological innovations and concluded that this inertia is one of the reasons for the rapid increases in construction costs in recent years. Inadequate research and development (R&D) and the slow adoption of new technologies have also been identified as two of the major factors affecting productivity (The National Research Council 1986). Finally, the ability to develop and apply advanced design and construction techniques have been identified as prime determinants of survival for U.S. Architecture-Engineering-Construction (AEC) firms in the international construction market (Tatum 1988, 1989a, Halpin 1988, Paulson 1988).

Construction innovation and technology transfer are means for satisfying the challenges posed by new owners' demands, increased complexity of facilities and foreign competitors (Tatum 1986, 1989b, Hansen and Tatum 1989, Madewell 1986, Zaist 1986). In the construction industry technological innovation stems from many sources. As examples, a firm may develop new technologies as a result of R&D activities, or the firm may incrementally improve existing technologies, or the firm may adopt new technologies from external sources (Tatum 1987).

Technological advancements in other industries have always been an important source of new technologies for the AEC industry. Recent developments in computer technologies, such as Computer-Aided Design (CAD) and expert systems (ES), provide the AEC industry with a tremendous potential for improvement through automation and integration (Teicholz 1989, Tatum 1989c). While CAD technology provides new methods of sharing data across organizational boundaries, the development of ES technology offers new tools to support the retention and dissemination of construction knowledge.

This research is motivated by the need to accelerate the adoption of emerging computer technologies by the construction industry. Although CAD and ES technologies have matured over the last years, only a small group of AEC firms have adopted them. However, for effective improvement of the industry to be realized, the new technologies must be adopted by a broad majority of AEC firms and not just by the innovative firms. Technology Transfer (T^2) is the process through which a new technology is transmitted to individuals and organizations and ultimately leads to its adoption. Technology transfer implies the adoption of a new technology developed outside the adopting organization, and is viewed as a subset of innovation.

1.2 Research Objectives

The primary objective of the research is to develop a technology transfer model for expediting the adoption of expert systems technology by the AEC industry, and identify a set of alternatives for performing the technology transfer process. For this objective to be accomplished, this research must understand and analyze the T^2 process in a construction organization, and identify the financial, organizational and technological factors affecting the process. Thus, the analysis will focus on the following points:

1. identify the stages of the T^2 process and the operations performed at each stage;
2. identify the actors involved at each stage and the roles they play;
3. identify the factors which affect the success of the T^2 process in an organizational setting; and
4. develop a conceptual T^2 model. The model will form the basis for the development of practical recommendations concerning the actions that construction

practitioners should take in order to accelerate the adoption of state-of-the-art computer technologies in their firms.

1.3 Scope and Limitations

The findings of this investigation develop a useful framework for accelerating the adoption of advanced computer technologies by all engineering-oriented disciplines. However, this research is limited to the study of the transfer of ES technology to the AEC industry. The proposed ES T^2 model has undergone limited testing. Thus, although broad generalizations have not been possible, specific and practical components of an overall ES adoption philosophy did emerge.

1.4 Research Methodology

The development of the T^2 model for ES has been accomplished by the execution of the following five major tasks, as shown in Figure 1.1:

1.4.1 Literature review

This task has included the study of the most relevant literature in innovation and technology transfer theories. The following models of innovation have been studied and analyzed in the context of technology transfer for ES:

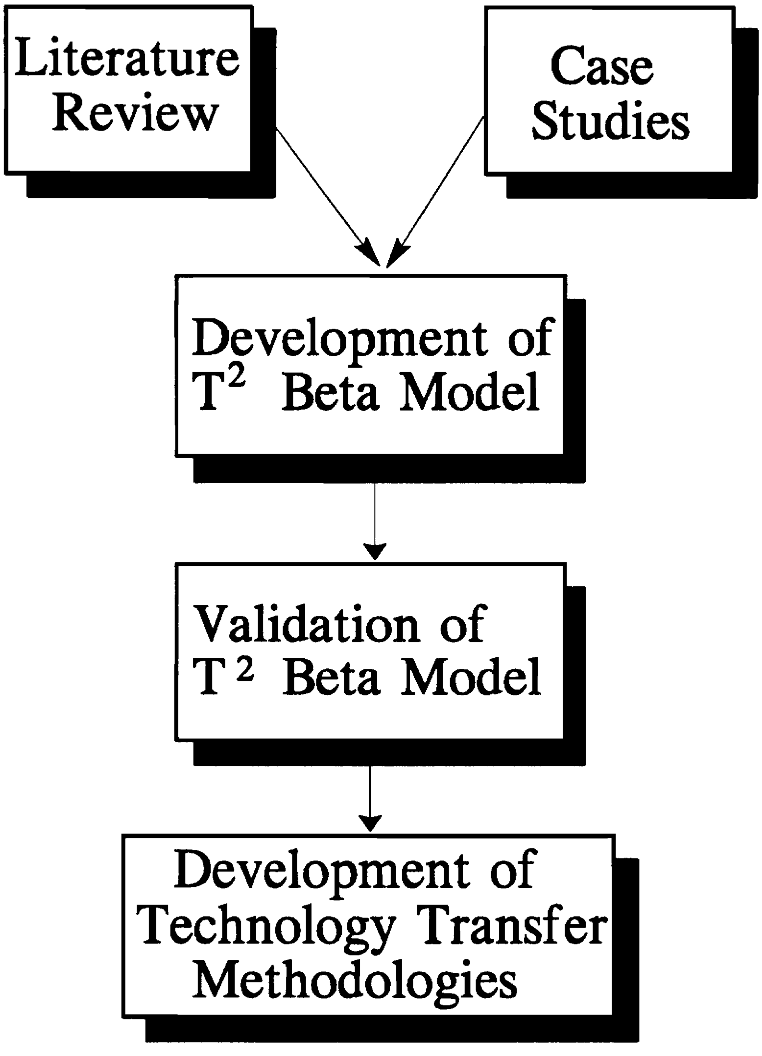


Figure 1.1 Structure of research methodology.

1. Rogers' innovation-development and innovation-decision processes (Rogers 1983);
2. Shaffer's innovation-development process (Shaffer 1985);
3. Rogers' authority-innovation process (Rogers 1983); and
4. Tatum's process of innovation in construction firms (Tatum 1987, Tatum and Funke 1988).

1.4.2 Case studies

During this task, analysis of documented case studies about the adoption of ES technology in several industries has been performed. The lessons learned from these attempts to transfer ES technology to the industry are identified. While the information concerning the case studies has been collected from the literature on ES adoption, the analysis and discussion of the case studies is the author's own assessment.

1.4.3 Development of T^2 beta model

Based on the literature review and the case studies, a T^2 beta model for ES has been developed. This included:

1. identification of the stages and operations of the T^2 process;
2. identification of the players involved and their roles; and
3. identification of the major factors affecting the T^2 process.

1.4.4 Validation of T^2 beta model

The purpose of this task has been to test the T^2 beta model on the design and construction practitioners group. This task has been performed by:

1. identifying US AEC firms currently using ES technology;
2. conducting interviews with the firms' managers; and
3. developing case studies of successful ES technology transfer.

For the identification of US AEC firms currently using ES technology the following tasks have been performed: 1) articles and publications pertaining to the use of ES by AEC firms have been reviewed; and 2) vendors of ES shells have been contacted and asked about AEC companies which had bought their products. These tasks resulted in the identification of six US AEC firms using ES technology. The AEC firms were contacted by the Committee Chairman, Dr. J. M. De La Garza, and three of them agreed to participate in the research.

On site interviews have been performed by Dr. De La Garza. For this purpose, an interview guide has been developed by the author, and reviewed by Dr. Robert Frary from the Virginia Tech Learning Resources Center. The interview guide is presented in Appendix A. Finally, the analysis of the interviews has been performed by the author.

1.4.5 Development of T^2 methodologies

The T^2 beta model has been refined and expanded based on its testing on the construction practitioners group. This task has resulted in the following:

1. identification of the factors which most effectively affect the transfer of ES technology to the construction industry; and
2. identification of technology transfer strategies which most efficiently assist construction practitioners in adopting ES technology.

1.5 Contents of Thesis

The thesis is divided into eight chapters. This first chapter provides an introduction to the research. The need for technological innovation in the AEC industry is addressed, as well as the research objectives and methodology.

Chapter two provides an overview of the existing literature concerning the processes and problems involved in technology transfer. It also identifies the important points to be examined during the investigation of the T^2 process.

In chapter three, six case studies of ES adoption are presented and analyzed. The cases presented come from several industries, such as manufacturing, telecommunications and construction and the information about the cases has been provided by the literature.

In chapter four, a T^2 beta model for ES technology is presented. The model identifies the major stages of the T^2 process and the factors affecting the success of the process. Additionally, the variations of the process are presented and analyzed.

In chapter five, three cases of ES technology transfer in US AEC firms are used to validate the T^2 beta model. These case studies have been developed by conducting interviews with managers of design and construction firms.

In chapter six, a model of the factors affecting the T^2 process is presented. The model identifies the economical, technological and organizational factors affecting the occurrence and success of the T^2 process in an organizational setting.

Chapter seven presents a refined T^2 model for ES and provides a set of alternatives concerning the actions that managers and practitioners can take for the successful adoption of ES technology in their organization.

Finally, chapter eight summarizes the methodology and the research findings. The benefits and contributions of the thesis are outlined. Finally, issues for further research are identified.

2. Literature Review

This section provides an overview of the existing literature concerning the processes and problems involved in technology transfer. It relies mainly on the models of innovation developed by Rogers (Rogers 1983), Shaffer (Shaffer 1985) and Tatum (Tatum 1987, Tatum and Funke 1988).

2.1 Rogers' Innovation-Development Process

Rogers (Rogers 1983) defines a six-step process through which an innovation comes into existence and is transferred into the social system. This innovation-development process is depicted in Figure 2.1 and consists of the following stages: 1) problem identification; 2) research; 3) development; 4) commercialization; 5) diffusion and adoption; and 6) consequences.

The innovation-development process starts with problem identification. At this point, the developer of the technology identifies a problem or need in the social system which

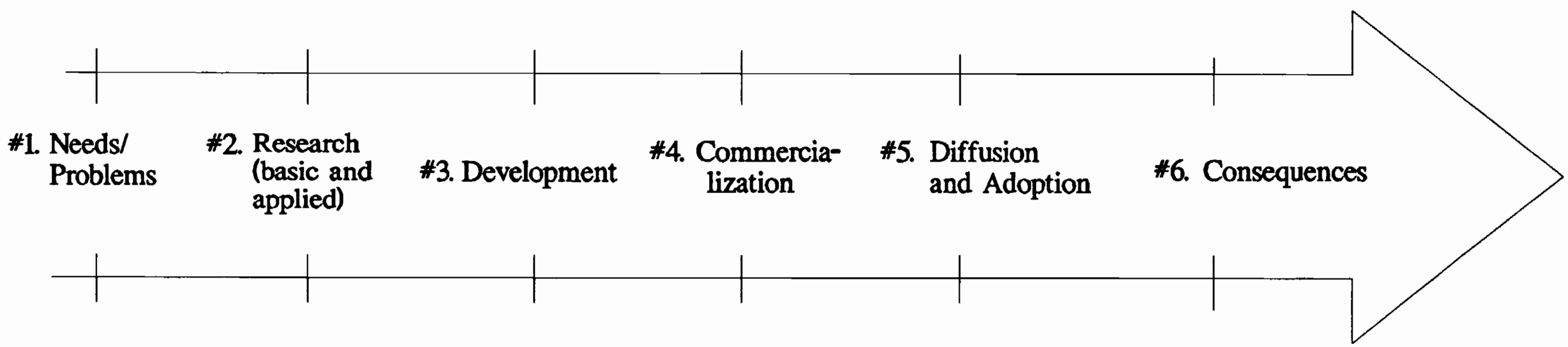


Figure 2.1 Six phases in the innovation-development process (taken from Rogers 1983, p. 136)

stimulates research and development activities. During the research and development stages the new technology is developed into a product. Rogers treats innovation as a product packaged in a form ready to be adopted by users. The production, manufacturing, packaging, marketing and distribution of the product take place during the commercialization phase.

The diffusion and adoption phase includes all the communication activities necessary to inform potential users of the technology's existence and potential applications. In order for the diffusion phase to start, a decision must be made by individuals who have the authority to decide when transfer activities should occur. At this point, change agents start communicating the innovation to potential users, which can be individual users or organizations. The consequences stage is an evaluation of whether the technology solved the problem for which it was intended. This evaluation also attempts to identify whether new problems are created by the use of the new technology.

Rogers points out that these six phases are somewhat arbitrary in that they do not always occur in exactly the order shown here, and that certain phases may be skipped in some innovations.

2.2 Shaffer's Innovation-Development Process

Shaffer (Shaffer 1985) analyzes the development and transfer of an innovation inside a US Army organization, and defines the innovation development process somewhat differently. Shaffer's model is depicted in Figure 2.2, and consists of the following five steps: 1) problem identification; 2) research and development; 3) field demonstration; 4) product/system authorization; and 5) product/system application.

The process begins with the problem identification phase. During this phase, Army researchers identify needs of practicing engineers or field personnel, who will be the potential users of the innovation. The research and development activities are identified as one phase. This phase also includes a pilot test to ensure that the technology meets the needs of users. The major difference between Shaffer's and Rogers' model is that the Shaffer model places more emphasis on the diffusion of the innovation by recognizing three technology transfer phases: 1) the field demonstration; 2) the product/system authorization; and 3) the product/system application.

The field demonstration phase is the first step in the transfer of the technology. During this, the innovation is demonstrated to show all users how it can be used to solve a problem. The demonstration also aims to identify new problems created by the use of the innovation, which need to be resolved before formal transfer starts. At the product/system authorization phase, a decision has to be made to begin transferring the technology to

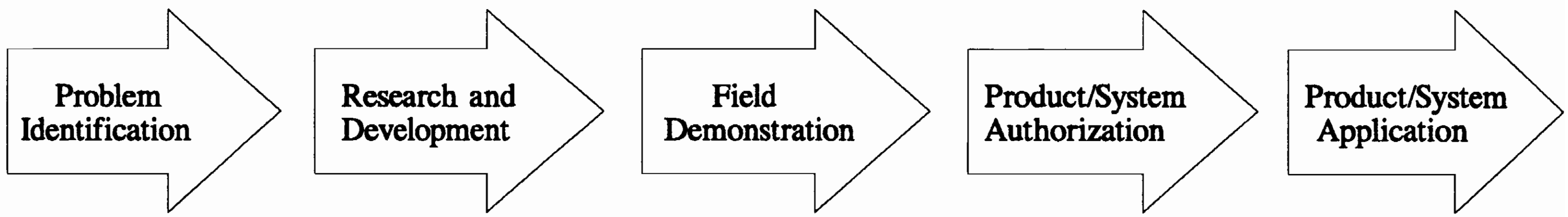


Figure 2.2 Shaffer's innovation-development process.

potential users. In the Army, the decision can be made by personnel at Corps headquarters or by Army committees which have the authority to make such decisions. The product/system application phase is similar to Rogers' diffusion and adoption phase. This phase consists of an extensive awareness program and the technology starts to be used outside the demonstration sites. Additional training activities and field support are needed to achieve successful implementation.

2.3 Rogers' Innovation-Decision process

The two innovation-development models described above focus on the operations to be performed by the groups responsible for the development and diffusion of the new technology. Both models recognize that transfer activities are an important part of the development process with the ultimate goal of having individuals and organizations adopt the technology. This section describes Rogers' innovation-decision process and focuses on the adoption of new technology by an individual.

According to Rogers (Rogers 1983), an individual's decision to adopt a new technology is not instantaneous, but a process that consists of the following five stages, as shown in Figure 2.3: 1) knowledge; 2) persuasion; 3) decision; 4) implementation; and 5) confirmation. Communication activities between the potential user and the change agency, which is the group responsible for the diffusion of the innovation, are present at every step of the process.

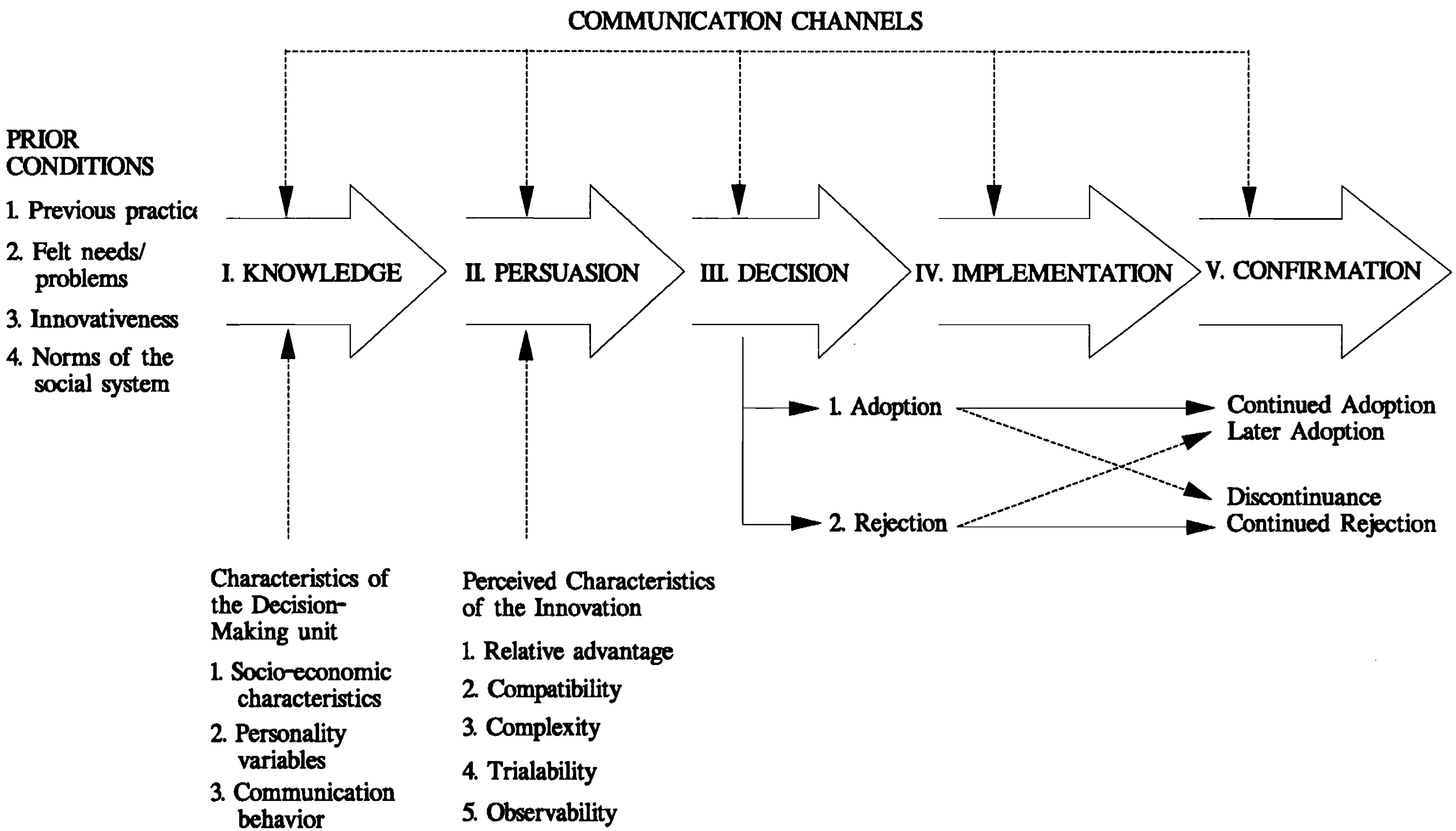


Figure 2.3 A model of stages in the innovation-decision process (taken from Rogers 1983, p. 165).

At the knowledge stage, the potential user is exposed to information on the technology and gains some understanding of how the new technology functions. An existing need may lead an individual to seek a new technology or the existence of the new technology can reveal a need or an opportunity for improvement. The initial information on the innovation can come from two major sources: mass media or interpersonal communications with developers, users or vendors of the technology.

During the persuasion stage, the potential user learns more about the new technology and evaluates it according to ones own needs. Rogers suggests the following five attributes by which a technology can be described and classified: 1) relative advantage; 2) compatibility; 3) complexity; 4) trialability; and 5) observability. At this stage, the potential user develops a favorable or unfavorable attitude towards the innovation.

At the decision stage, the individual either decides to adopt or reject the innovation. The following factors affect its decision: 1) the attributes of the technology; 2) the degree of the individual's understanding of how the technology works; 3) the financial and personal risk involved in trying the untested technology; 4) other cue-to-action factors which may affect the individual's decision, i.e., market share erosion, reduced ability to compete, technologic base obsolescence, desire to change social status, etc., may lead to adoption.

During the implementation, the individual puts the technology to use and is continuously looking for information and assistance to solve the new problems which may be brought on by the innovation. At this stage, re-invention of the technology may occur. Re-invention is the degree to which a user changes or modifies the technology in order to fit special needs. The reasons for re-invention can be found in the technology itself or in the individual that is adopting the new idea. An innovation with many possible applications (such as a computer) or an innovation that is implemented to solve a wide range of users' problems is more likely to be re-invented. Local pride of ownership of an innovation may lead to minor modifications. Finally, re-invention may also happen due to inadequate knowledge about the innovation.

At the confirmation stage, the individual evaluates its decision to implement the technology. The decision can be reinforced or may be reversed if the performance of the innovation is not satisfactory. Discontinuance can be of two types: disenchantment or replacement. Disenchantment discontinuance occurs when the user is dissatisfied. This can occur if the technology is inappropriate for the user or if the technology is misused. Replacement occurs when the innovation is replaced with a better idea.

The major communication link between the potential user and the change agency is the change agent. The conventional role of the change agent is to diffuse innovations to users. However, for this process to be effective, the change agent must also direct users' needs and problems to the change agency. For the success of the transfer, the change agent must be able to diagnose the user's problems, build an awareness in the user as to how the new technology can satisfy specific needs, develop an intent for change in the user and translate the intent into action. Training and support activities are necessary through the entire process.

2.4 Rogers' Authority Innovation-Decision Process

The innovation-decision model described thus far has been concerned with the adoption of an innovation by an individual. The process of technology adoption by an organization is more complex because different groups are involved in the decision for adoption and implementation. The decision group occupies a position of higher authority in the organization than the end-users group, and can force the end-users group to conform with any decision. The process of innovation in this scenario is defined by Rogers as authority innovation-decision process.

Rogers (Rogers 1983) argues that the major difference between the innovation-decision process and the authority innovation-decision process lays in the existence of communication activities between the decision group and the end-users group. A key aspect for the success of the innovation is the acceptance of the innovation by the end-users because negative attitude towards the new technology may lead to misuse and discontinuance.

Rogers identifies the authority innovation-decision as a process which consists of a sequence of the following five stages, as depicted in Figure 2.4: 1) agenda-setting; 2) matching; 3) redefining/restructuring: 4) clarifying; and 5) routinizing.

The agenda-setting and the matching steps constitute the initiation phase, defined as information gathering, conceptualizing and planning for the adoption of an innovation, which leads to the decision to adopt. The agenda-setting implies that some individuals in the organization identify an important problem and then seek an innovation as the means to cope with the problem. Rogers points out that awareness of an innovation may also launch the innovation process. During the matching stage the feasibility of the innovation in solving the problem is tested. The decision on adoption separates the initiation from the implementation phase. The implementation includes all the actions involved in putting the innovation into use and consists of three steps: 1) redefining/restructuring; 2) clarifying; and 3) routinizing.

During the redefining/restructuring stage the imported innovation is re-invented to fit the organization's needs and environment, and the structure of the organization changes to accommodate the innovation. Restructuring may consist of the establishment of a new department, changes in the organizational policies and procedures, or reallocation of functions. Information technologies have been found to have the following effects on the organizational structure: 1) a decline in the span of control; 2) a decline in the number of levels in the organizational hierarchy; 3) a consolidation of departments; 4) a shift from

STAGE IN THE INNOVATION PROCESS	MAJOR ACTIVITIES AT EACH STAGE IN THE INNOVATION PROCESS
I. Initiation:	All of the information-gathering, conceptualizing and planning for the adoption of an innovation, leading up to the decision to adopt.
1. AGENDA-SETTING	General organizational problems, which may create a perceived need for an innovation, are defined; the environment is searched for innovations of potential value to the organization.
2. MATCHING	A problem from the organization's agenda is considered together with an innovation, and the fit between them is planned and designed.
The Decision to Adopt	
II. Implementation:	All of the events, actions and decisions involved in putting an innovation into use.
3. REDIFINING / RESTRUCTURING	(1) The innovation is modified and re-invented to fit the situation of the particular organization and its perceived problem, and (2) organizational structures directly relevant to the innovation are altered to accomodate the innovation.
4. CLARIFYING	The relationship between the innovation and the organization is defined more clearly as the innovation is put into full and regular use.
5. ROUTINIZING	The innovation eventually loses its separate identity and becomes an element in the organization's ongoing activities.

Figure 2.4 Stages in the authority-innovation process (taken from Rogers 1983, p. 363).

parallel departmental configurations to functional forms; and 5) an increase in the centralization of control.

At the clarifying step the innovation is put into wider use and the new idea becomes clear to all organization's members. Rapid implementation at this step may lead to misunderstandings and misuse of the innovation with negative results. During the routinizing step the innovation becomes a regular tool in the organization's activities.

2.5 Tatum's Model of Innovation in Construction Firms

Based on investigations of innovation in several construction firms, Tatum's innovation model (Tatum 1987, Tatum and Funke 1988) identifies the following elements in the process of innovation in construction firms, as shown in Figure 2.5: 1) recognizing forces and opportunities for innovation; 2) creating a climate for innovation; 3) developing the necessary technological and entrepreneurial capabilities; 4) providing new construction technologies; 5) experimenting and refining; and 6) implementing. Tatum identifies the process of innovation as a top management's function and responsibility and pays much attention to the actions that senior management must take for successful development of new technologies within a construction firm or adoption of external technologies.

Recognizing forces and opportunities is a senior management's action and is the result of internal and external forces which include market and competitive demands, regulatory

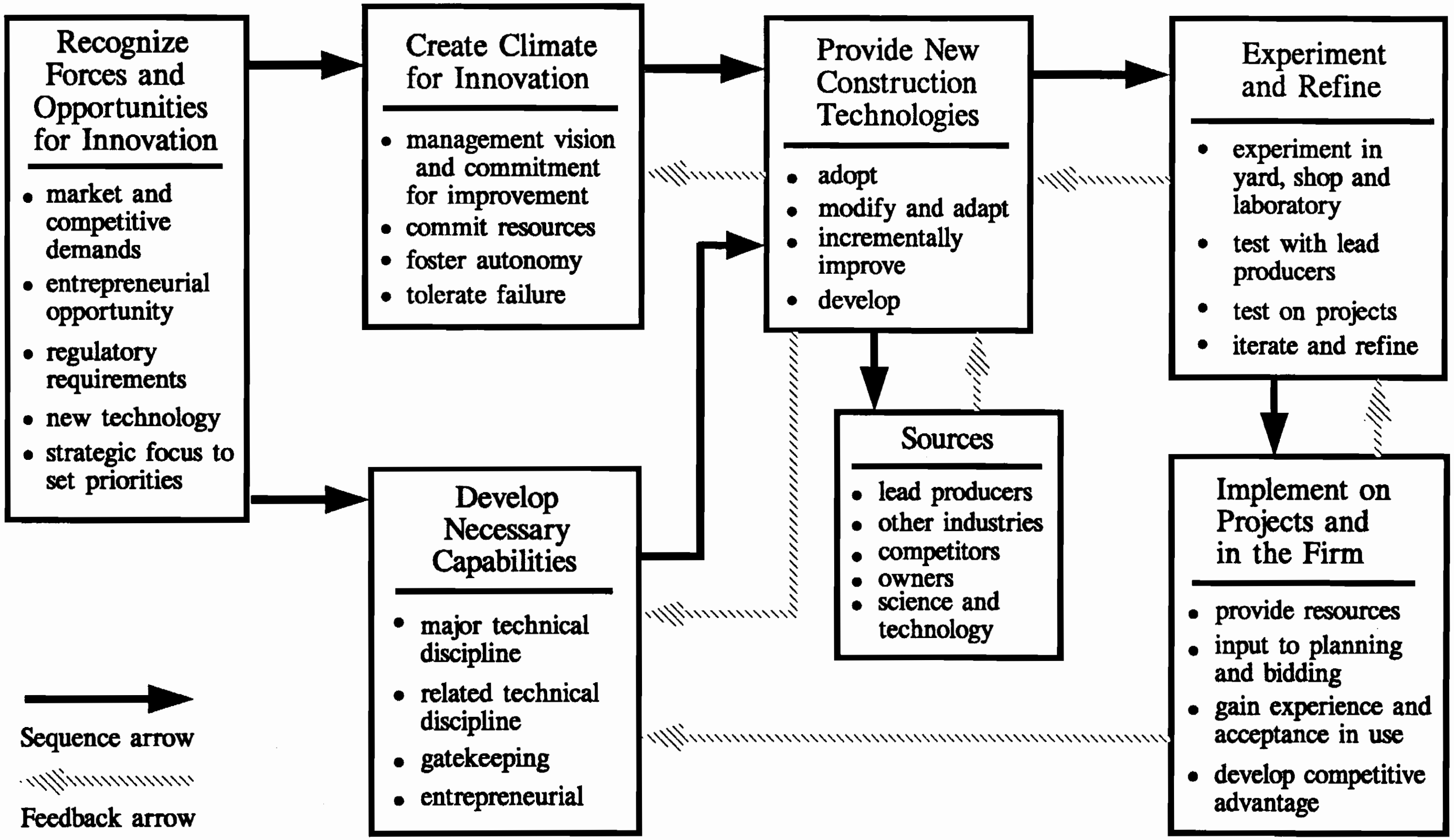


Figure 2.5 Model of innovation in construction firm (taken from Tatum 1987, p.650)

requirements, entrepreneurial opportunity and the existence of new technology. A strategic focus to set priorities is also necessary to direct the resources of the firm to the best opportunity.

Creating a climate for innovation is also senior management's responsibility. This includes a vision and commitment for continuous improvement, commitment of financial and human resources, giving freedom to the members of the firm to experiment with new technologies and toleration of failure to increase risk taking.

Developing technical and entrepreneurial capabilities is necessary for the successful development or adoption of new technologies. Knowledge of technology is needed to keep the firm aware of new technical developments. Strong technical capabilities in major and related technical disciplines give the confidence to try the unfamiliar. Entrepreneurial capabilities provide support for the innovation through difficult development steps.

New technologies can be provided by several ways: adopting new technologies developed outside the firm, modifying and adapting existing technologies, incrementally improving present technologies or developing new ones in the firm. New technologies can be supplied by several sources such as lead suppliers, or other industries.

Experimenting and refining is a vital step in order to make a new technology satisfy specific requirements. Even the most promising technologies require extensive iterations and changes. Involvement and cooperation of all the functional elements of the firm is critical for the successful evaluation and refinement of the innovation. This stage also includes the persuasion of the entire organization.

The implementation of the innovation on projects and in the firm requires a commitment of financial and human resources. Experience in use and acceptance are gained with the use of the innovation. Diffusion and implementation of the innovation throughout the firm becomes the basis for competitive advantage.

2.6 Rate of Adoption and Adopter Characteristics

Rogers (Rogers 1983) identifies five categories of adopters, as shown in Figure 2.6: 1) innovators; 2) early adopters; 3) early majority; 4) late majority; and 5) laggards. The adopter categories are classified on the basis of when they first begin using a new technology.

The innovators are the first adopters to take the risk of implementing a new technology. Rogers considers as the main characteristics of the innovators the control of substantial financial resources and their high technical knowledge. When the limitations of the technology are high, the innovators have to make important refinements in the technology to suit to their own needs. Early adopters play an important role in the diffusion of the innovation because they are considered the opinion leaders. Early majority is the group

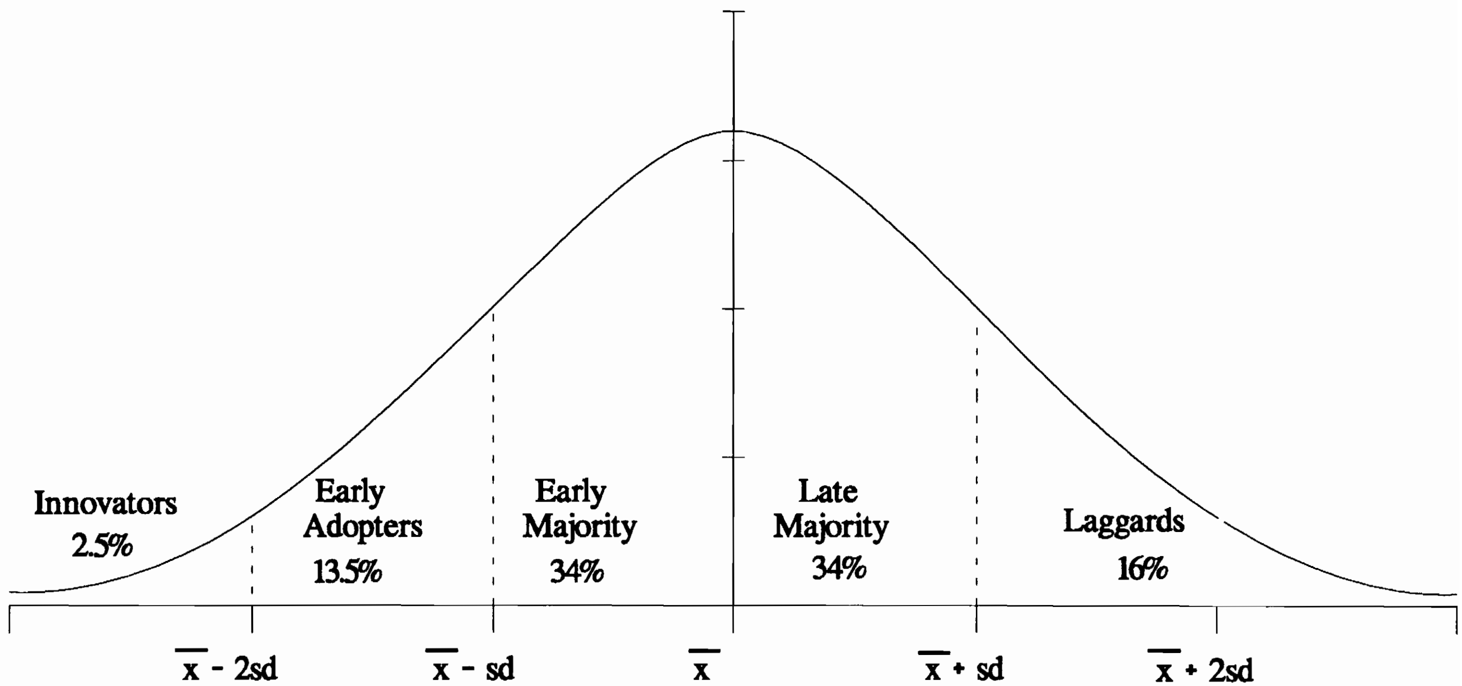


Figure 2.6 Adopter categorization (taken from Rogers 1983, p. 247)

of users who is willing to make changes but wait until more information on the innovation is available. The late majority is described as the skeptics who will decide on the adoption because of increasing pressure from other peers who have adopted. Finally, the laggards are the traditionalists who do not take the risk of committing resources for implementing a new technology.

2.7 Obstacles to Technology Transfer

The main reasons hindering the adoption of new technologies fall into two areas: 1) organizational; and 2) human nature.

2.7.1 Organizational barriers

Communicating information about new technologies to potential users is critical in order to initiate the technology transfer activities. In an organization, additional communication problems may occur, as different groups are involved in the T^2 process, and the communication among them is critical for the adoption of the technology (Tatum 1989a, 1989b).

Tatum classifies the organizational factors which affect innovation in three groups: 1) organizational structure; 2) organizational environment, and 3) the role of key individuals (Tatum 1989b).

Organizational structure. A large number of hierarchical levels as well as high separation of departments and functions work as a barrier for diffusion of innovations because it impedes the communications among the groups involved in the T^2 process. Tatum argues that many innovative firms use small organizations with limited number of hierarchical levels and small teams where different specialists work together for development of new products. These groups can be task forces (temporary groups with a specific mission), skunk-works (isolated development groups) or other type of independent teams.

Organizational environment. The organizational characteristics which encourage innovation include: the existence of individuals who take the responsibility for innovation; the freedom of the doer to decide how to proceed with the innovation; the commitment of patient money to isolate innovations from the pressure of annual budgets; tolerance of risk, failure, and mistakes; cross functional teams and high levels of informal communication.

Role of key individuals. The importance of the role of key individuals in the technological development of the organizations has been recognized by many researchers. Maidique (Maidique 1980) identifies the champions as highly committed individuals who absorb the risks and drive the change in the organizations. These individuals support the innovation during the entire T^2 process, and take the financial and technical risks involved in this effort.

For successful adoption, the innovation must be supported at all the levels of an organization. Thus, the literature identifies three types of technology champions (Tatum 1989a): 1) the technical champion who carries an idea from its initial concept through development into a viable product or process, 2) the business champion who provides a business framework for a technical idea, and 3) the executive champion who sponsors the idea at the highest level.

Tatum, from his investigations of construction innovation also identifies the role of a technological gatekeeper as another important role for the success of the innovation process. The technologies developed in other industries are an important source of new technology for the construction industry. The role of the gatekeeper becomes critical, as the gatekeeper is the person who identifies external technology and has the perception to visualize potential applications in the firm (Tatum 1989b).

Tatum (Tatum 1984, 1986, 1988, 1989a) argues that innovation is management's responsibility. Top management must take specific actions to increase the rate of innovation in an organization. These actions will aim to create a more flexible organizational structure, create an appropriate environment, and support the technology champions to their task by providing them with financial resources and freedom. Tatum also identifies the following managerial actions which are critical for technological advancements in construction industry: maintain strategic vision of technology, take broad view of risk, provide technological challenges and leadership, and prompt integration within the organization, as well as with suppliers of technology, owners and competitors.

2.7.2 Human nature barriers

The ultimate goal of technology transfer is to produce a behavior change. An individual who adopts a new technology has to change its work habits. Human resistant to change is an important obstacle for the success of transfer activities, and includes: 1) problems in learning a new technology; and 2) financial and personal risk involved in trying something new.

Problems in learning new technology. Learning to use a new technology is a process that requires both time and capabilities. An individual's reluctance to learn a new technology may be due to pressures brought on by other tasks that the individual must complete within a limited time frame. Especially in an organization, where the individuals are under pressure to justify their productivity, time spent in learning activities is not usually considered productive time.

The uncertainty involved in trying something new prevents most individuals from trying a new technology. Tatum (Tatum 1989a) identifies several types of risk which affect managers' decisions in a construction firm: financial risk, technical risk, safety risk, and risk of worker rejection.

Financial and personal risk. The use of a new technology requires financial commitment by the individual. If the technology fails to perform as expected, the individual will have to account for its decision to use the technology, and may be considered responsible for any economic damage. Technical risk means the risk of the technology not meeting the technical requirements for performance or quality of output. Safety risk includes the risk of injury to people or damage to equipment. Finally, the risk of rejection of a new technology by the workers also appears important in construction.

2.8 Observations Derived from the Literature Review

The purpose of this section is to identify the important points to be examined during the investigation of Technology Transfer in organizations. These points are derived from the literature review and will define the basis on which case studies will be analyzed.

From the literature review one can identify the following three major phases in the T^2 process in an organization: 1) initiation; 2) decision; and 3) implementation. During these phases, specific operations must be performed in order for the technology to achieve regular use in the organization.

During the initiation phase, a member of the organization identifies a new technology either as a solution to an existing problem or as an opportunity for improving an organizational activity. Then, the technology is evaluated to determine whether it can serve the needs of the organization and how it must be used to satisfy these needs. During the decision phase, senior management decides to adopt or reject the technology. The decision is based on the evaluation of the technology as well as on other factors, such as the management's attitude towards technology and the financial risk involved in the adoption.

If a decision for the adoption is made, the implementation phase starts. The success of the implementation depends on whether the technology becomes a regular tool in the organization's activities. To achieve this, two main tasks must be performed in this phase: 1) the technology must be modified to fit the desired applications and end-users capabilities; and 2) the technology must be transferred to the end-users group who implements it. End-users training may be required in order to achieve effective use of the technology, and even more important, end-users acceptance must be built in order to avoid misuse which may lead to ultimate rejection of the technology.

The main actors during the initiation phase are the members of the organization who identify a new technology and envision its applications in their firm. These individuals typically play the role of the technology gatekeeper and in turn, the role of technical or executive champion of the technology. Their position can be at any level in the organizational hierarchy. Senior or middle managers, engineers or technicians may champion the technology by committing the necessary resources to evaluate and experiment with it.

During the decision phase the main actor is senior management, because it is the authority which decides on the adoption or rejection of the technology. The champions also play an important role by persuading senior managers to support the technology and commit resources for its implementation.

During the implementation phase the main actors are the future end-users of the technology. At this point the champions take the role of change agents and the task of educating and persuading the entire company. The champions' most important task at this phase is to transfer the technology to the end-users and persuade them to use it.

The senior management, the end-users group, and the individuals who champion the technology are the three main actors involved in the T^2 process. The different roles that the actors undertake during the process, are as follows:

2.8.1 Technology gatekeeper

The gatekeeper is the individual or group who identifies an external technology and develops a vision for the implementation of the technology throughout the organization. The gatekeeper may or may not be appointed to this role by senior management. The position of this individual can be in any level of the organizational hierarchy. The gatekeeper is the link between the organization and the sources of technology and should have high technical capabilities in order to be able to interact with these sources.

2.8.2 Champions

After an innovation is identified, there are many other tasks to be performed until the new technology is successfully adopted. These tasks include the evaluation of the technology according to the organizational needs, and the persuasion of senior management to adopt the new technology. The champions are the individuals who will perform these tasks and they are the central characters in the process of innovation. The champions' role starts from the moment that these persons undertake the responsibility of performing these tasks and assume the technical, financial and personal risk involved in this effort. For the success of the adoption two types of champions must be present: 1) the technical champion who carries the innovation until its successful implementation and also assumes the technical risk; and 2) the executive champion who supports the innovation at the highest level and allocates resources to the technical champion.

The roles of the champions and the gatekeeper may be performed by the same or different individuals. Their capabilities are important for the success of their task. Additional factors affect the success of the technology transfer operations. These are, among others, the capabilities and actions of the other two groups (senior management and end-users) involved in the process, the coordination between the groups, and the organizational culture and environment. How these factors actually affect the T^2 process will be one of the goals of this research to identify.

2.8.3 Task force

The task force is defined as a temporary team with a specific mission. Many of the tasks that the champions have to perform cannot be performed by only one individual. Thus, the formation of a task force is required under the leadership of the champion. After the decision to adopt is made, the task force typically becomes the group responsible for the implementation of the technology in the organization.

2.8.4 Change agent

During the implementation phase, the champions and the task force usually take the role of change agents. The change agent is the individual or group who undertakes the task of diffusing the new technology through the entire organization. For the success of the T^2 process, the end-users in the organization must be persuaded to use the technology and develop the necessary capabilities for its proper use. The change agent's task is to persuade, train and support the end-users during the implementation stage.

In the following section, cases of successful implementation of expert system technology are analyzed. The analysis of these case studies will focus on the following issues: 1) the stages of the T^2 process and the tasks performed at each stage; 2) the main actors involved at each stage and their roles, and 3) the factors which affect the T^2 process and its success in an organization setting.

3. Case Studies of ES Technology Transfer

In this section, six cases of ES technology transfer are presented. Three case studies come from the manufacturing industry (Du Pont, FMC, and Johnson & Johnson), one from telecommunications (Southwestern Bell Telephone Co.), and two from the construction industry (Lend Lease Corporation of Australia, and Kajima corporation of Japan). These cases were studied to gain an early understanding of the adoption philosophies developed in the above firms. Such insight has become the spring-board for the development of the T^2 beta model described in chapter four.

The analysis of each case study consists of two sections: 1) description and 2) discussion. The case description sections are totaly based on information provided by the literature. The "Rise of the Expert Company" (Feigenbaum 1988) and technical periodicals (Bonnet 1989, Helton 1990) were the sources of information presented in the case descriptions. Subsequently, the discussion sections represent the author's analysis of each case and assessment of the stages of the T^2 process, the actors involved, and the roles performed. Additional information concerning the adoption of ES in four of the above firms (Du Pont, FMC, Lend Lease Corporation of Australia, and Kajima corporation of Japan) has been acquired through telephone communications between the Committee Chairman, Dr. J. M. De La Garza, and the managers of these firms, in January 1991.

3.1 ES Implementation in E.I. Du Pont de Nemours

The information presented in the case description has been acquired from "The Rise of the Expert Company" (Feigenbaum 1988), and the "Executive Briefing: Implementation Strategies for Expert Systems" (Mahler 1989). The information has been confirmed during Dr. De La Garza's personnal communication with Du Ponts' management in January 1991. In section 3.1.2, the case discussion presents the author's evaluation of the T^2 process in Du Pont.

3.1.1 Description

Du Pont is a large, diversified company manufacturing a broad product line. Its annual R&D budget exceeds $1 billion and its businesses include automotive paints, coal, fibers, industrial chemicals and petroleum. The firm is highly decentralized with each operating department having its own manufacturing, R&D, and Information Systems Department (ISD). However, a central Engineering, R&D and ISD also exist to provide some centralization. Du Pont prides itself on innovation and technical excellence. In recent years, Du Pont has struggled to reduce cost and improve its competitive position. A significant effort has been spent in promoting organizational effectiveness by pushing decision making towards the lowest possible level.

Ed Mahler, a high level manager in the Corporate Plans Department has been evaluating emerging technologies that might be useful to Du Pont, when he became aware of the possibilities of expert systems. Mahler's corporate knowledge and technical capabilities enabled him to identify the opportunities ES offered for in-house applications. After spending months interacting with vendors and evaluating several commercially available ES tools, Mahler was convinced that ES technology was not appropriate for use by du Pont because ES development required specialized hardware and programmers who were not available in the company. Later, when the first PC-based ES tools became available, Mahler decided again to investigate the feasibility of the technology.

In order to evaluate the technology, an unofficial task force was formed under Mahler's leadership. The task force included six members which were loaned from other departments and its formation marked the first commitment of resources to ES technology. At this point, Mahler became the champion of the technology by funding the operation out of his office automation budget, and taking a great personal risk. The following characteristics of the task force members played an important role in the fullfilment of its charter: technical diversity and technical competence, ability to influence other members of the organization, willingness to take risks, and commitment to the vision of implementing the ES technology.

During the next five months, the task force learned and experimented with different ES shells and started working on a few applications in order to gain experience and evaluate the technology. The technology was tested for two primary characteristics: 1) the ability to solve real-life problems; and 2) dispersability, that is, whether it was teachable and compatible with the people and hardware at Du Pont. As many people in Du Pont were familiar with PC technology, Mahler was convinced that the PC-based ES tools could achieve wide acceptance in the firm, and solve many real-life problems.

Before an organized effort started for the diffusion of ES technology to potential users throughout the company, the decision had to be made by the company's Executive Committee to formalize the task force and provide the necessary resources. In this effort the Vice President of the ISD played the role of the executive champion by supporting the idea at the executive level. The Executive Committee decided on the formalization of Mahler's group and supplied it with $2 million annually. It also gave them the freedom to try a new management approach towards implementing the new technology. This approach was focusing on motivating and supporting potential ES users in Du Pont to develop their own systems.

After securing high-level commitment, Mahler and the task force undertook the task of persuading the entire organization to use the new technology. For the highly diversified and decentralized Du Pont, the fundamental principal of the task force was not to build any systems centrally, but rather to persuade the users to build their own systems according to their own needs. Mahler identified three major tasks to be performed which led to successful adoption: 1) build user's awareness; 2) build user's acceptance; and 3) develop functional capabilities.

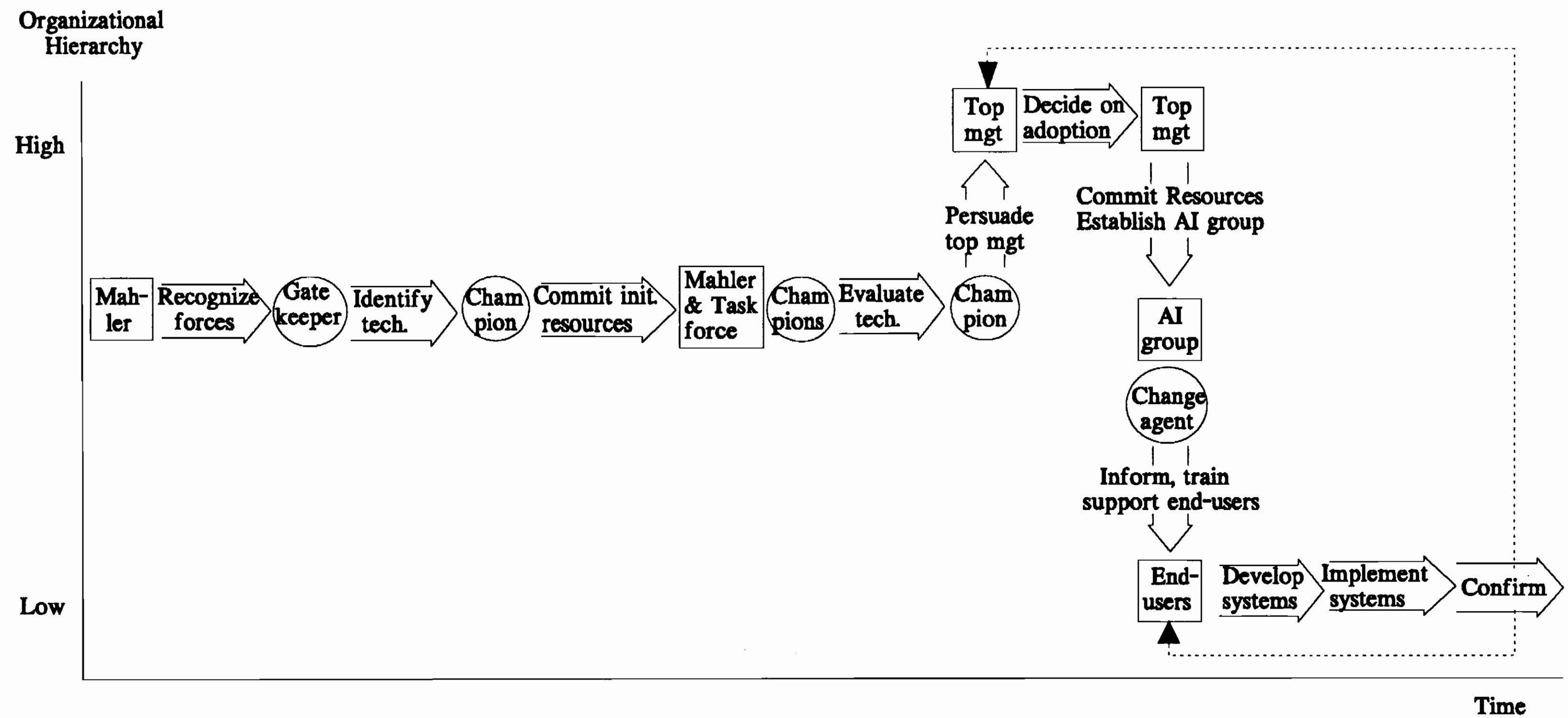
User's awareness was the first and most effective continuing step. This was achieved by an informal information network and word-of-mouth. User's acceptance was built with management-awareness lectures given by Mahler. Additionally, the development and implementation of systems by the first users built awareness and acceptance to more users and created a user's pull. Training followed to give users the necessary capabilities to build their own systems. The fundamental principle in Du Pont's implementation strategy was to create a user's pull through informal communication and to keep the entry barrier low for any user interested in ES technology so that the users could build their systems according to their own needs.

By the end of 1987, Mahler reported to "Computerworld" a 1500% return on software and labor costs, and an aggregate savings of $10 million. In Du Pont, most of the payoff from ES has come from the replication of expertise, which either frees experts to do the most difficult jobs or moves processes down from the responsibility of experts into the hands of nonexperts. Another source of payoff has been improved quality, and still another, consistency in decision making. Finally, ES are considered a form of preserving corporate expertise in a way that supports decision-making.

3.1.2 Discussion

The study of the ES implementation in Du Pont has resulted in the identification of the following stages of the T^2 process: 1) recognize forces for innovation; 2) identify technology; 3) commit initial resources; 4) evaluate technology; 5) decide on adoption; 6) develop and implement systems; and 7) confirm technology's value. Figure 3.1 depicts the stages and operations of the T^2 process, the actors involved and the roles they undertook, as well as the organizational level where each stage was performed.

The main actor in this process was Ed Mahler, who undertook several different roles during the process. His position in Corporate Planning enabled him to recognize the need for new technologies. In turn, he performed the role of technology gatekeeper and identified ES technology. Initially, as the limitations of the technology made impossible its wide use in the firm, he rejected its adoption. Later, when the limitations were being reduced, he envisioned the potential benefits from its use in Du Pont and became the champion of the technology.



Stages	Recognize forces	Identify technology	Commit initial resources	Evaluate technology	Decide on adoption	Develop & Implement systems	Confirm
Actors	Mahler	Mahler	Mahler	Mahler / Task force	Top mgt	AI group / End-users	Entire organization
Roles		Gatekeeper	Champion	Champions		Change agent / Developers	

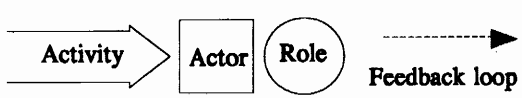


Figure 3.1 T^2 process in EI du Pont de Nemours.

As champion he took the risk to commit resources to the technology and persuaded other managers to do the same. He also took the leadership of the task force and evaluated the technology. Subsequently, Mahler persuaded the senior management of the firm to adopt the technology and commit full scale resources. During the development and implementation stage, Mahler and the task force became the change agents of ES technology.

In Du Pont, it was decided that the development and implementation of ES would be the end-users' responsibility. Thus, the role of the change agent was to inform, persuade, train, and support the end-users in developing systems. This implementation strategy resulted in widening the circle of users throughout the diversified and decentralized Du Pont. Today, Du Pont is convinced that T^2 is a work-practice change process whose success is achieved through awareness, motivation and functional capabilities. In order to develop these, a persistent champion is required to seduce the sponsors and empower the masses.

3.2 ES Implementation in Southwestern Bell Telephone Co.

The implementation of ES technology in Southwestern Bell Telephone Co. is described by Tom Helton, in his paper "AI infusion: Getting Your Company Involved" (Helton 1990). In his article, Helton presents the major phases of the T^2 process and focuses on the firm's implementation strategy. Helton's assessment of the adoption process in Bell

Telephone Co. is presented in the following case description. Subsequently, the case discussion in section 3.2.2 provides the author's analysis of the T^2 process in Bell Telephone Co.

3.2.1 Description

Southwestern Bell Telephone Co. is a multi-billion dollar organization providing telecommunication services in five states. The company has a very democratic infrastructure. Individual managers have flexibility in the system-mechanization process they choose to implement. Technical managers do not feel threatened by innovations, and many of them constantly try new things and bring new methods into the company.

Helton identifies four major phases from the moment that his company started exploring ES technology to the point that it became a regular tool in every day's operations. The four phases are: 1) awareness; 2) early implementation; 3) acceptance; and 4) intensification.

Awareness. This phase started in August 1986 and lasted approximately one year. At that time, the company embarked on a program to improve its awareness of certain technologies. Top management identified specific technologies which could be important to the firm and assigned certain technical managers to evaluate these technologies. Tom

Helton was assigned the responsibility of evaluating ES technology, thus becoming the technical champion. This is the first commitment of resources to ES technology.

Helton learned about the technology by attending a university seminar and identified the potential of ES in telecommunications. Senior management gave Helton the freedom to commit most of his time to the evaluation of the technology and provided the resources for the procurement of several ES shells. During this phase, Helton with a group of other employees interested in ES learned about the technology, and evaluated several ES shells.

The experimentation and evaluation resulted in the selection of one PC-based ES shell to become the company's standard. At that time, the first ES applications started being built and Helton started presenting the first series of seminars to company's managers focusing on the importance of ES for the company.

Early implementation. During the following twelve months, the development and implementation of the first ES applications took place by a small group of users. With respect to the existing company's resources in hardware and users capabilities, a second ES tool was also selected to serve the needs of mainframe users. At the same time, an AI committee was formed to provide some centralization, prevent duplicate ES applications development, and evaluate proposals for ES application development. By the end of this period, about sixteen relatively small ES application were developed. These first applications did not target large benefits, but rather focused in building end-users' acceptance and capabilities.

During this period, Helton also started a campaign to disseminate knowledge about ES to interested managers by supplying them with technical literature and demonstration material. Helton compares this campaign with Du Pont's informal network that Mahler used to build awareness and acceptance by managers and end-users.

Acceptance. During this period, which lasted approximately six months, the technology started to be used widely through the company. The first training courses started and new applications continued to be developed. The company's information-systems plan for the future, which was published under the title "Maximize Operational Effectiveness To Be The Best Cost Provider - Implement Expert Systems", reflected the importance of ES for the future of the company. At the end of this period, about thirty ES applications existed in various stages of development.

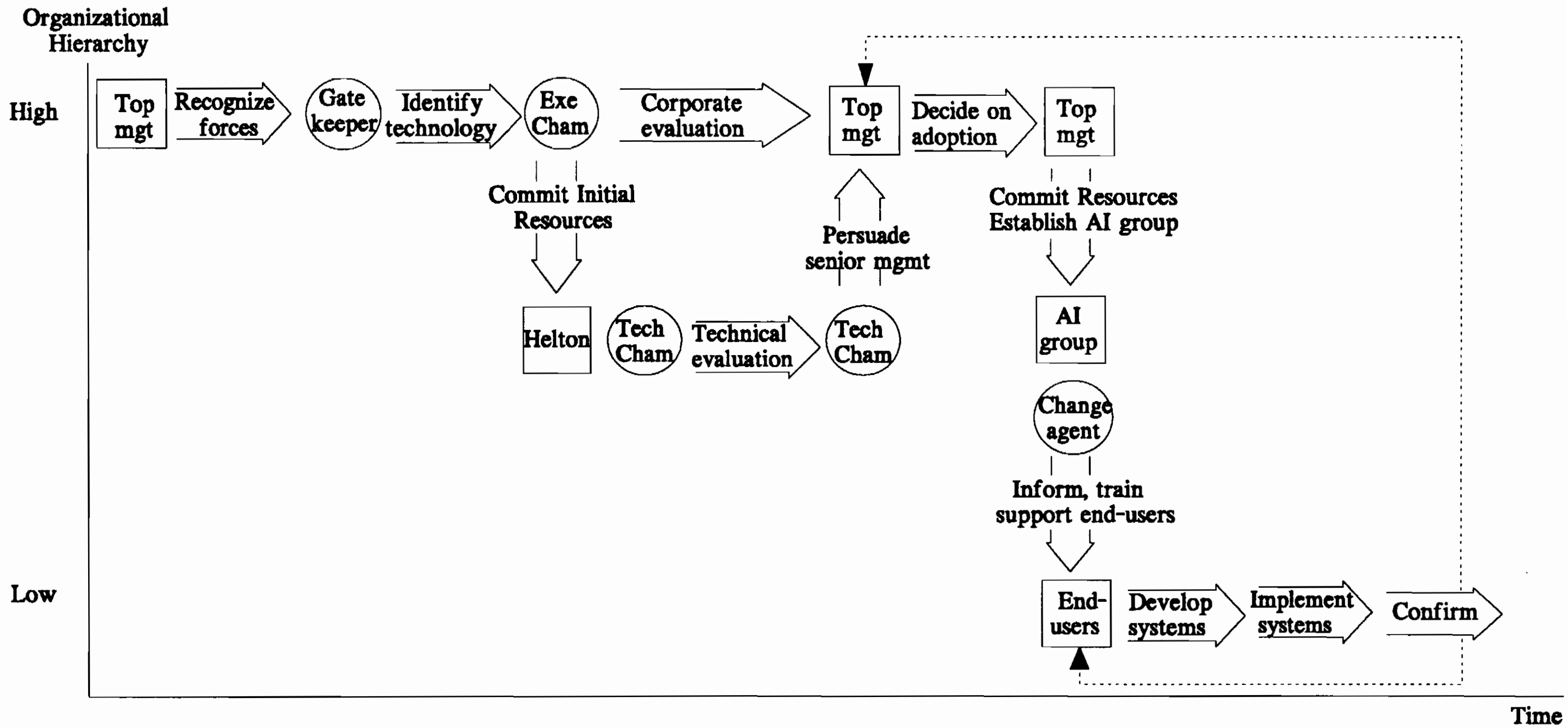
Intensification. During this phase, the technology became a regular tool in the company and the first ES applications were developed for strategic applications. At this point, support was provided only to projects with the higher payoffs.

3.2.2 Discussion

The analysis of the T^2 process in Bell Telephone Co. has resulted in the identification of the following stages of the T^2 process: 1) recognize forces for innovation; 2) identify technology; 3) commit initial resources; 4) evaluate technology; 5) decide on adoption; 6) develop and implement systems; and 7) confirm technology's value. Figure 3.2 provides the author's representation of the stages, actors and roles involved in the T^2 process.

During Helton's awareness phase, the first five stages of the T^2 process have been identified: 1) forces for innovation were recognized; 2) the technologies were identified; 3) initial resources were committed for evaluation; 4) evaluation of ES technology was performed; and 5) decision on adoption was made.

In Bell Telephone Co., senior management initiated the process of technology transfer by performing the following three tasks: 1) embarked on a program to improve its awareness of certain technologies; 2) performed the role of technology gatekeeper by identifying specific technologies to be explored; 3) committed the initial resources needed for the evaluation of the technology. This included the assignment of Helton to the role of technical champion and the procurement of several ES tools. Top management's support removed the largest part of the risk from Helton and gave him freedom to experiment with the technology.



Stages	Recognize forces	Identify technology	Commit initial resources	Evaluate technology	Decide on adoption	Develop & Implement systems	Confirm
Actors	Top mgt	Top mgt	Top mgt	Top mgt / Helton	Top mgt	AI group / End-users	Entire organization
Roles		Gatekeeper	Exe. champion	Exe / Tech champion		Change agent / Developers	

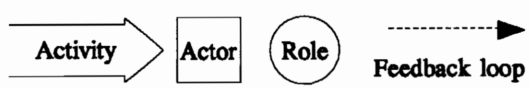


Figure 3.2 T^2 process in Southwestern Bell Telephone Co.

As technical champion, Helton performed the evaluation of ES technology with a task force which consisted of other potential ES users in the company. With the support of top management already given, Helton did not have problems in persuading senior management to adopt the technology. After this point, Helton undertook the role of the change agent by setting the direction of change in his organization.

Helton's early implementation and acceptance phases have been performed during the development and implementation stage of the T^2 process. The diffusion strategy which was followed resulted in wide acceptance of the technology through the company. Although Helton uses different terms to describe the implementation strategy in his firm, the diffusion was similar to Du Pont's and aimed at having end-users develop their own systems.

In Bell, the early implementation phase was similar to Mahler's users awareness and users acceptance steps. At this point, in both firms an effort to inform and persuade every potential user took place. In Du Pont this effort included the use of the informal network, lectures to company's managers, and the development of the first applications. In Bell this effort included the large campaign organized by Helton, and the development of the first small applications by the first users of the technology.

In both companies, these efforts led to create a users' pull. The development of functional capabilities in Du Pont was similar to Helton's acceptance phase. At this point, in both companies the ES technology was widely accepted, and the established AI groups provided training and support to many users. During Helton's intensification phase, the confirmation of the technology's value led to the development of larger systems for strategic applications.

3.3 ES Implementation in FMC Corp.

"The Rise of the Expert Company" (Feigenbaum 1988), and the article "From Grassroots to Grand Plan" (Bonnett 1989) are the sources of information presented in the case description. Personnal communication of Dr. De La Garza with FMC's management in January 1991 has confirmed the information presented below. The discussion presented in section 3.3.2 provides the author's assessment of the T^2 process in FMC Corp.

3.3.1 Description

FMC Corp. is an international chemical firm with manufacturing and mining facilities all over the world. At a strategic level, FMC had determined it would be a low-cost phosphorous producer. Low-cost production requires experts and FMC had a mature work force. Many experts at FMC were near retirement or had already retired. Thus, FMC decided to use expert systems to substitute the disappearing expertise.

The investigation of ES technology in FMC started with Robert Malott, FMC's Chief Executive Officer in the role of the gatekeeper who accidentally heard about the new ES technology and identified a variety of internal use opportunities. With the ardent support of Ray Tower, FMC's president, an AI group was established under Perry Thorndyke, program manager for strategic programs, who became the technical champion.

In 1984 ES was still a technology for specialists and many of the needed applications required advances at the frontiers of the field. FMC decided to develop ES centrally with the collaboration of specialists from Teknowledge, a firm that FMC considered so significant to its future that it bought a 10% interest in it. Thorndyke, head of the AI group, was convinced that FMC's divisions would benefit most by relying on computer scientists in the AI group.

For four years, thirty-five ES specialists, headed by Thorndyke served the entire company by developing several large systems for many divisions of the firm and making sure that the systems developed served the company's long-term goals. The AI group had to understand the division's business strategy and source of competitive advantage in order to identify the best opportunity for the development of systems. At that time, the AI group began to uncover more opportunities for developing systems than it could possibly exploit. Thus, some of the smaller systems had to be built outside the AI group by the divisions themselves. However, because of the complexity of the first ES applications, the division managers considered ES projects very risky, and were reluctant to invest resources for developing ES applications in their divisions.

As the limitations of the technology were reduced and more opportunities appeared, the company decided to revise its implementation strategy and provided the divisions with some simple system-development know-how in order to build cost-effective simple applications. Thus, FMC started a training and awareness program to build understanding and enthusiasm across the organization.

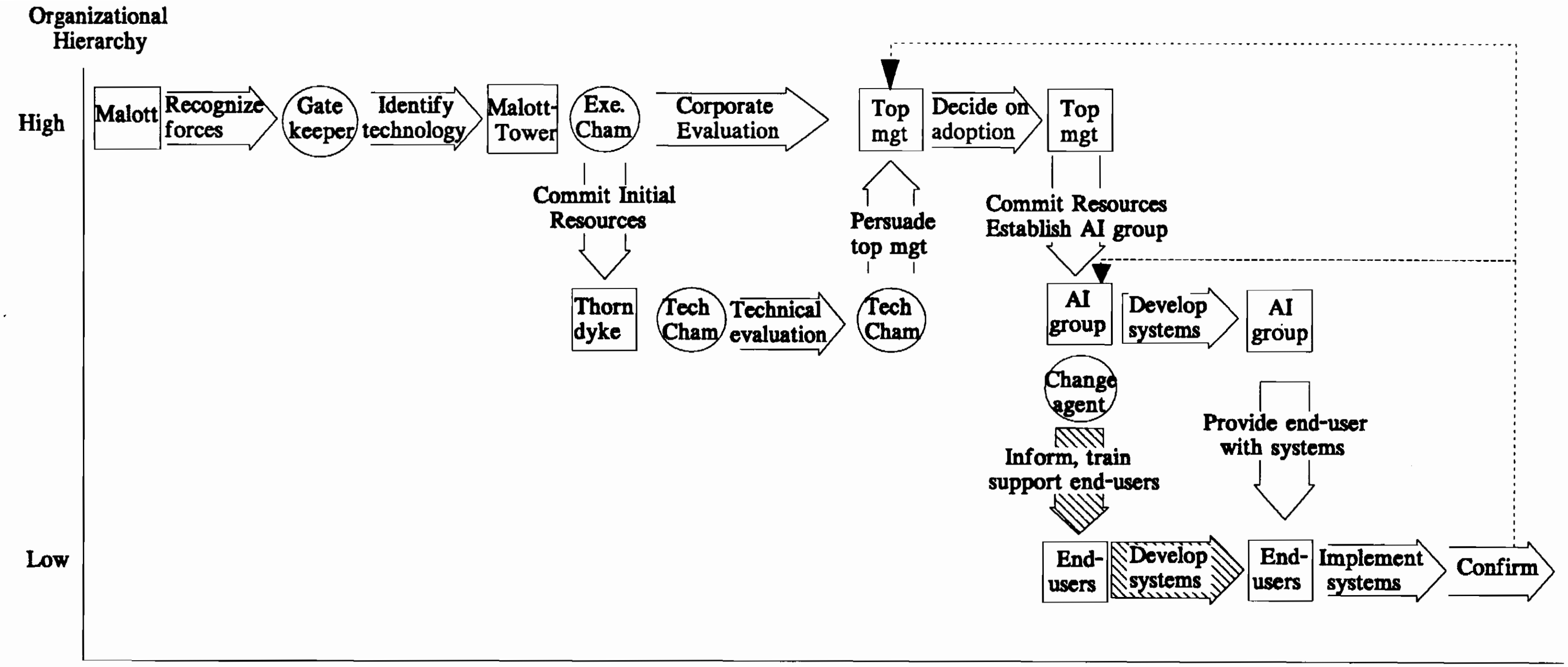
This program included six five-day application development courses and expected to have 1,500-2,000 trained employees by 1992. Additionally, a one-day introductory course for middle and upper management explained the purpose of the training, the value of the technology for enhancing competitive advantage, and how to identify potential problems. FMC's top management is convinced that successful use of the technology requires the support of both managers and ultimate users.

3.3.2 Discussion

The analysis of the ES implementation in FMC Corp. has resulted in the identification of the following stages of the T^2, as depicted in Figure 3.3: 1) recognize need for new technologies and opportunity for innovation; 2) identify technology; 3) commit initial resources; 4) evaluate the technology; 5) decide on the adoption; 6) develop and implement systems; and 7) confirm technology's value.

In FMC Corp. senior management initiated the T^2 process. The strategic vision of the technology that Malott maintained, enabled him to recognize the opportunity that expert systems offered and become the technology gatekeeper. After the technology was identified, both Malott and Tower became the executive champions and appointed Thorndyke to the role of the technical champion in order to evaluate the technology. Although the limitations of the technology were high, the executives of the company viewed it as a long term investment and were not afraid to take the financial risk involved in their decision.

The president of the firm did not hesitate to commit all the resources necessary for the adoption of the new technology, although this required hiring expensive outside specialists. The implementation strategy deployed in this case was forced by the desired applications and the state of the technology. FMC was one of the first adopters of ES technology. A large investment was necessary for the development of their systems. As the technology confirmed its value after the first strategic applications and new opportunities were revealed with the evolution of the technology, the implementation strategy was re-evaluated, and an effort started to diffuse the technology in all the divisions of the firm.



Stages	Recognize forces	Identify technology	Commit Initial Resources	Evaluate technology	Decide on adoption	Develop & Implement systems	Confirm
Actors	Top mgt	Malott	Malott / Tower	Malott & Tower / Thorndyke	Top mgt	AI group / End-users	Entire organization
Roles		Gatekeeper	Exe. champions	Exec / Tech champion		Developers / Users -> Change agent / Developers	

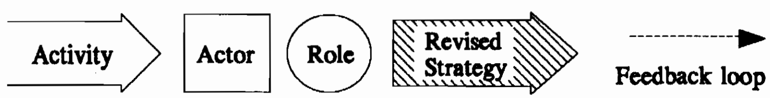


Figure 3.3 T^2 process in FMC Corp.

In order to get the most out of the technology, its wide use was required. The training and support programs introduced the importance of the end-user's acceptance, as well as the large number of opportunities that expert system technology offers. These opportunities do not only exist in large scale applications with high payoff, but also in the improvement of everyday's operations in a firm.

According to FMC's management, today FMC is pursuing simultaneously the strategic as well as the diffusion approaches. The AI group is being re-flagged under the conventional computing group and continues to build large systems. Development and refinement of second generation tools has been the product of the first wave of ES development, and these are providing multiple FMC Divisions with the capability of addressing generic engineering problems.

3.4 ES Implementation in Johnson & Johnson

Johnson & Johnson (J&J) is another large manufacturing company which introduced expert systems in its plants. Kendra Bonnett's article "From Grassroots to Grand Plan" (Bonnett 1989) has provided the information presented in the case description section. The case discussion in section 3.4.2, presents the author's evaluation of the T^2 process in J&J.

3.4.1. Description

In J&J the implementation of ES technology was initiated in 1986 by Joe Bryan, a technical-services scientist. Bryan researched the subject and eventually bought a PC-based expert system shell. Making a commitment of personal time and money, he learned the software quickly but had the problem of identifying the first application. Finally, with the molding manager and the maintenance supervisor as experts, he built in six months a system to help equipment operators to assign causes for out-of-control points indicated by the data collection system.

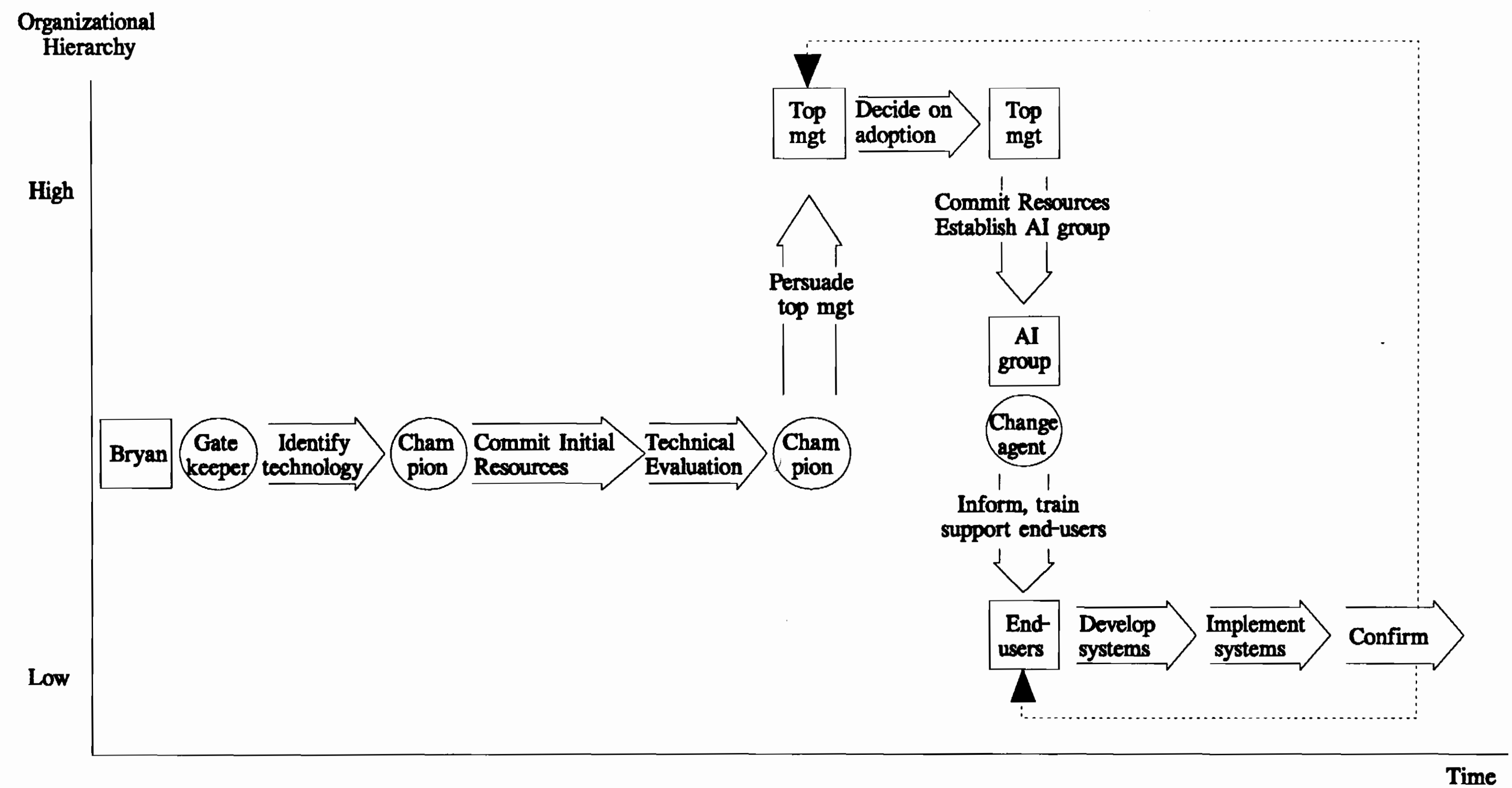
In a fraction of this time and with the same experts he built a second troubleshooting system. The systems were tested and endorsed by the operators because they solved many common equipment problems. In the meantime, he taught the maintenance supervisor how to write programs and develop simple applications. Bryan presented the systems to senior managers who assigned one member of each department to meet regularly with him in order to learn the technology. However, most of them could not find the time to learn the technology, as they were not released from other assignments. Some of the first small applications were successful and interest and enthusiasm started growing among more employees.

Three years after ES technology had been introduced in J&J, twenty systems in different stages of development had been developed and 10-15 people were involved in systems development. To support the development of ES applications, a task force had been established which constituted of Bryan, the plant's maintainance supervisor, an engineer, and two information-services employees. The task force met monthly to develop training programs, look at new software, and coordinate the effort through the company. It was also working to move more applications to the manufacturing floor, and encouraging other J&J business units to use expert systems.

3.4.2 Discussion

During the T^2 process in J&J, the following stages can be identified, as shown in Figure 3.4: 1) identify new technology; 2) commit initial resources; 3) evaluate the technology; 4) decide on adoption; 5) develop and implement systems; and 6) confirm technology's value.

The implementation of ES in Johnson & Johnson was a bottom-up process, because it was initiated by a lower level member of the firm. In this case, Bryan's positive attitude towards technology led him to identify ES technology, thus becoming the technology gatekeeper of the ES technology. As the gatekeeper, Bryan explored the new technology, although initially, he could not identify potential applications. Subsequently, Bryan became the champion of the technology by committing his own resources for learning and experimenting with the technology. The collaboration with other managers, supervisors and operators in the plant allowed the evaluation of the technology in real-life conditions.



Stages	Identify technology	Commit Initial Resources	Evaluate technology	Decide on adoption	Develop & Implement systems	Confirm
Actors	Bryan	Bryan	Bryan / Task force	Top mgt	AI group / End-users	Entire organization
Roles	Gatekeeper	Champion	Technical champion		Change agent / Developers	

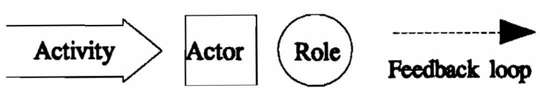


Figure 3.4 T^2 process in Johnson & Johnson.

Management decided on the adoption by recognizing that expert knowledge is costly to obtain and easy to lose and by believing that expert systems would protect that investment. However, limited resources were committed for the implementation and this led to a slowly growing interest. Management wanted systems developed by departmental experts and not centrally by a group of knowledge engineers. The implementation strategy followed in this case stemmed from management's decision to have the end-users build their own systems.

During the implementation, the champion and an established AI group became change agents of the technology by training and supporting a few individuals at a time. The diffusion strategy deployed in J&J was aimed at expanding the circle of involvement from a few innovators to whole plants and companies within the corporation. Its success, however, depended on continued support from top management.

3.5 ES Implementation in Lend Lease Corporation of Australia

"The Rise of the Expert Company" (Feigenbaum 1988) has provided the information presented in the following case description. The telephone communication between Dr. De La Garza with Lend Lease's management in January 1991 has revealed that the implementation of ES technology in Lend Lease has not been successful. The use of the first ES application the firm developed has been discontinued and no other applications have been developed. The case discussion, section 3.5.2 provides the author's assessment concerning the T^2 process in Lend Lease Corporation.

3.5.1 Description

Lend Lease Corporation is the largest construction company in Australia. It builds, develops and manages commercial property all over the South Pacific. In addition, Lend Lease provides a variety of financial and insurance services connected with property development. However, the corporation's heart is construction. Lend Lease has a wholly owned subsidiary named Civil and Civic Property, which builds large buildings, office towers, industrial complexes, shopping centers, and sports stadiums.

In 1983, Lend Lease appointed one of its top executives, Alan Stretton, to be the gatekeeper of new technologies which could be useful for the future of the firm. Stretton accidentally heard about ES technology and decided to investigate it. At this stage, the ES literature did not increase his interest. But in 1984, after participating in the World Future Society Conference in USA, and after contacting a university researcher, he was convinced that ES technology was accelerating at an enormous speed.

When he returned to Australia, he confirmed with Civil and Civic's CEO that expert systems was what the firm should be doing. The CEO and Stretton became the champions of the technology in their firm and identified the first application to be developed. This application was an ES to estimate the duration of construction projects.

Time estimates required knowledge of how the design would develop, including many of the details, services and finishings, and expertise on construction methods, resources and restrictions. Geoff Stevens was the expert who had this experience, and was going to be the source of knowledge for the expert system.

For the development of the system, Lend Lease collaborated with Digital Equipment Corporation (DEC), a computer manufacturing company, which had already established an AI group in the US. DEC assigned two knowledge engineers to work with the expert, but Stevens being the best expert in his firm, could not commit enough time to them. Stretton recommended that Stevens be pulled out of day-to-day work to have his knowledge captured without interruptions. The board agreed to give Stevens time by considering this costly procedure as a long-term investment.

For more than a year, Stevens and Stretton had been traveling to the headquarters of DEC's AI group in Massachusetts every other month. Additionally, with the DEC's knowledge engineers traveling to Sidney in alternate months, and with continuous use of E-mail, the prototype ES was developed.

The expert system, named Predicte, enabled the estimation of the construction time for a high-rise building before any design is developed beyond the initial concept stage. It can analyze and compare completion times for alternative designs and allows the user to perform what-if scenarios. The extensive use of graphics permits the user to see exactly what is being considered. The system asks questions about the project, the site and the design, decides on likely construction methods, assesses the resources available to do the work, estimates how long the project is likely to take, and explains how it arrived at these results. In this way, it allows the cost estimators to make much more accurate estimates for the construction cost at an early stage.

For Lend Lease the value of the system has been long range. The company perceived that expert systems are likely to be the most important computer technologies, and decided that the best way to learn it is to participate in it. The corporation saw the development of the system as an investment in its future and treated it as long-term investment.

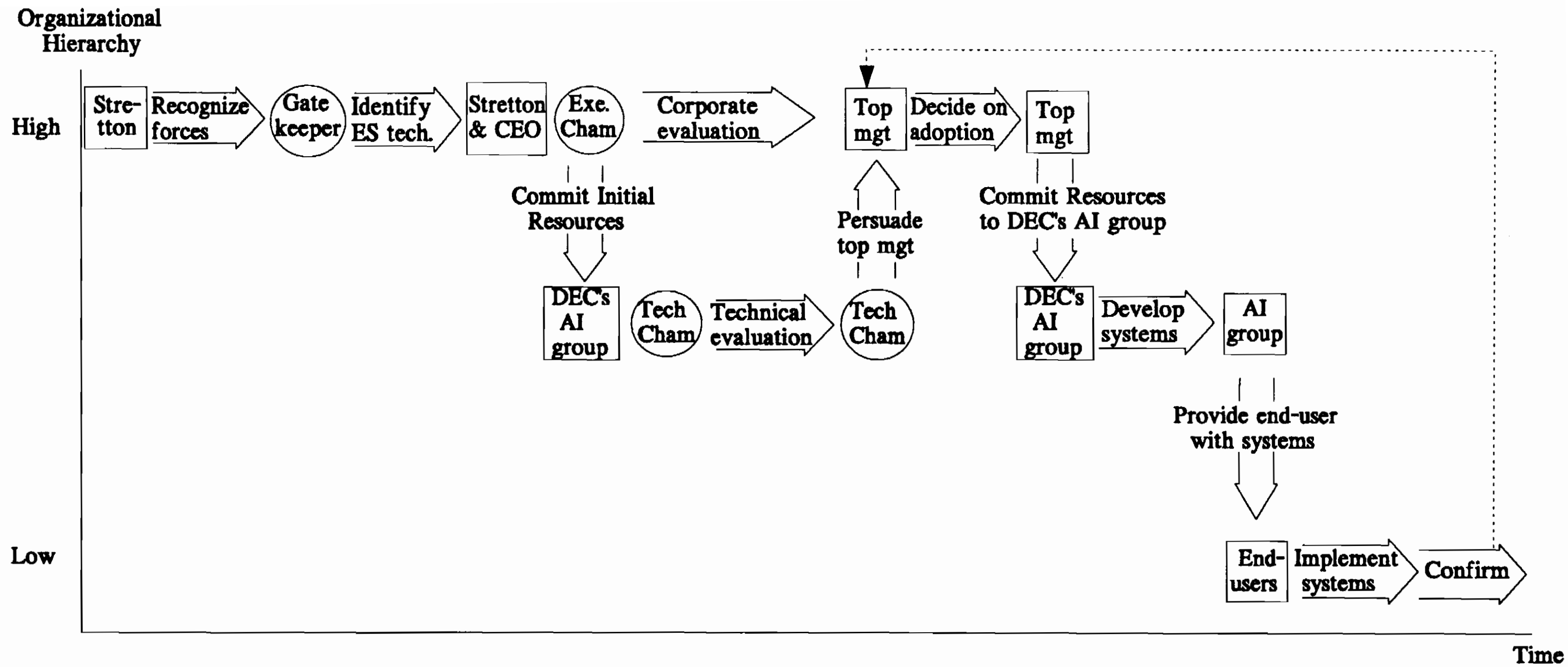
Today, the only application developed has fallen into a substantial discontinuance because both the technology champion and the human expert (who was the primary user) have left the company. Disuse of the application was also precipitated by the absence of an established company-wide users-group and of enthusiastic support from key individuals capable of influencing others within the company.

3.5.2 Discussion

The analysis of the ES T^2 process in Lend Lease has resulted in the identification of the following stages, as shown in Figure 3.5: 1) recognize forces for innovation; 2) identify technology; 3) commit initial resources; 4) evaluate the technology; 5) decide on adoption and commit resources; and 6) develop and implement system.

The implementation of ES in Lend Lease was a top-down process, as it was the senior management who introduced the technology in the company. Top management's positive attitude to technology resulted in the appointment of an executive manager to the role of gatekeeper. Stretton identified the technology and the opportunities that were offered. At the corporate level, the evaluation was performed by Stretton, who became the champion of the technology. The technical evaluation was subcontracted to the DEC's AI specialists.

Stretton and the CEO of the firm decided on the adoption of the technology and committed all the resources needed, including the time of the most experienced engineer in the firm. For the development of the first expert system outside specialists from DEC's AI group were used. The main reason for this was the complexity of the application, the state of the technology, and the lack of adequate in-house technological capabilities.



Stages	Recognize forces	Identify technology	Commit Initial Resources	Evaluate technology	Decide on adoption	Develop & Implement systems	Confirm
Actors	Top mgt	Malott	Stretton & CEO	Stretton & CEO / DEC's AI group	Top mgt	DEC's AI group/End-users	Entire organization
Roles		Gatekeeper	Executive Champions	Exec / Tech champion		Developers / Users	

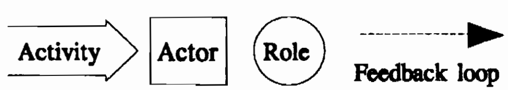


Figure 3.5 T^2 process in Lend Lease Corporation of Australia.

This case study highlights the importance of evaluating the technology at the corporate level. Senior management decided on the adoption of ES as soon as they identified the opportunity for improvement that the technology offered, and committed all the required resources for the successful implementation without fear of financial risk. However, the failure of the implementation effort proves that top management's commitment to technology is not sufficient for successful adoption. A retrospective analysis of the adoption process would indicate that more people should have been involved in the early phases of evaluation and development; that employees needed to be educated about ES technology; and that a long term view should be applied to ES technology.

3.6 ES Implementation in Kajima Corporation of Japan

"The Rise of the Expert Company" (Feigenbaum 1988) has provided the information presented under the case description section. The successful adoption of ES technology by Kajima has been confirmed through Dr. De La Garza's communications with Kajima's management in January 1991. The author's analysis of the case study is presented in the case discussion, in section 3.6.2.

3.6.1 Description

Kajima is one of the largest construction companies in Japan. It builds towers, power stations, dams, airports, manufacturing plants, and harbors all over the world. The company has a long tradition of innovative construction methods, with a large R&D division devoted to improving construction techniques and diminishing hazards. Kajima has also taken up expert systems, introduced by its electronic data-processing people.

In 1982 the Japanese Ministry of International Trade and Industry formed the Institute for New Generation Computer Technology (ICOT). At that time, a middle management engineer at Kajima's information processing center, Motoo Matsuda, was convinced that what was happening at ICOT was very important. Matsuda persuaded several of his colleagues at Kajima to begin learning about expert systems. In this way, Matsuda became the gatekeeper and the champion of ES technology, before any official commitment was made by the firm.

In 1983, an official proposal to management was made and accepted. The proposal involved the formation of a team to study the basics of AI, acquire the expert system shell KEE, and build a prototype for gaining experience. The first exploratory application was a system for configuring stairways in buildings, based on building codes and architectural design.

Immediately after the first application was finished, top management committed full scale resources and formalized the ES group. Thus, the team was expanded and with ten knowledge engineers and thirty domain engineers it began designing expert systems for everyday construction use. Two years later, approximately 140 areas across the company were under study for ES treatment. Kajima's expert systems are available to construction sites by means of computer network and communication lines.

Two of the systems Kajima uses are the following: a) an ES which assesses the probability of liquefaction at different depths in different layers under the ground. It is based on boring data and various standard interpretations; and b) an ES which advises on the best type of pilings for a structure and the best ways for driving them, permitting the selection of the best combination of feasibility and cost.

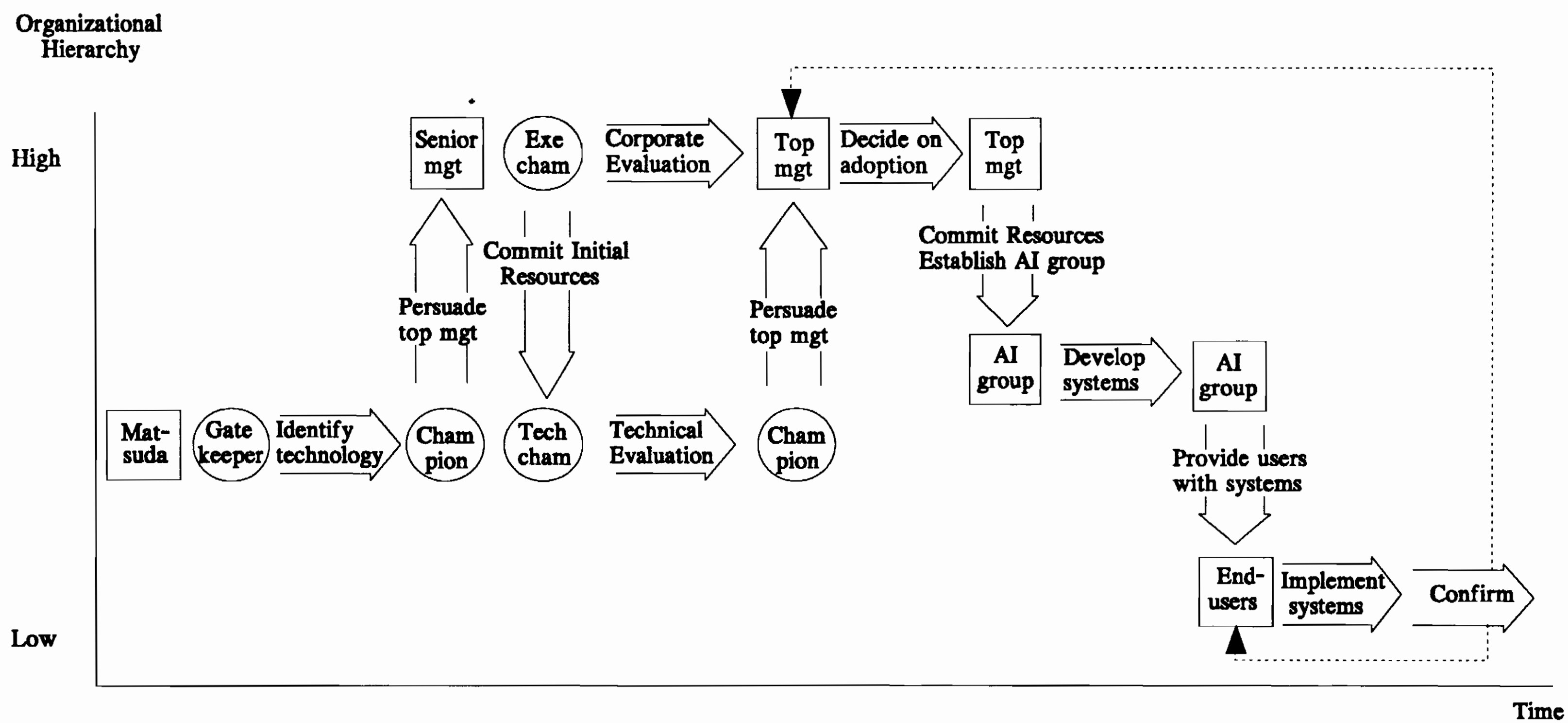
The Kajima knowledge engineering group had the following rule of thumb for choosing the best problems for ES treatment: seek a problem that usually requires an expert one day to solve. Using an expert system the problem is transformed into ten minutes work of a non-expert. The immediate savings was one day of an expert eliminated from a design or estimating job. Kajima estimates that the savings from the pile selection system are between $50,000-$400,000 US dollars per year. In addition, Kajima saves time and increases the quality of job performance since the ES has pooled the knowledge of several construction experts. The cost of a system of this size was a knowledge engineer and a domain expert working with KEE for a month.

Kajima believes that current savings are not the most important benefits from expert systems. Experienced engineers are the most important asset of the firm and expert systems allow to preserve this expertise. Kajima's company managers argue that high-quality work no longer guarantees high sales and high profits. To increase sales requires innovative design, new products and innovative planning. Today its not enough for Kajima to automate high-quality production; it must also introduce automation for high-quality planning and design. Expert systems are Kajima's key to automating that high-quality construction planning and design.

3.6.2 Discussion

The implementation of ES technology at Kajima was a bottom-up process initiated by a middle management engineer. From the study of the case, the following stages of the T^2 process in Kajima have been be identified, as depicted in Figure 3.6: 1) identify technology; 2) commit initial resources; 3) evaluate the technology; 4) decide on adoption and commit resources; 5) develop and implement systems; and 6) confirm technology's value.

The positive attitude towards technology was the force that led the unofficial gatekeeper to identify the technology and to start learning it. The same individual became the champion of the technology by persuading top management to commit resources for the evaluation of the technology. These resources included the formation of a task force, financial support, and the time of some experts. The results of the technical evaluation, as well as the long-term benefits which senior management identified, persuaded them to decide on the adoption and commit additional resources for the implementation.



Stages	Identify technology	Commit Initial Resources	Evaluate technology	Decide on adoption	Develop & Implement systems	Confirm
Actors	Matsuda	Top mgt	Top mgt/ Matsuda/ Task force	Top mgt	AI group / End-users	Entire organization
Roles	Gatekeeper	Champion	Exe / Tech champions		Developers / Users	

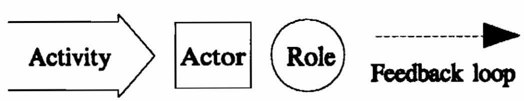


Figure 3.6 T^2 process in Kajima Corporation of Japan.

Kajima's case highlights how an innovative company does not hesitate to commit resources in order to explore promising technologies. Furthermore, it highlights the long-term view that innovative companies maintain for the technology. Today, the company has six expert systems in every day use serving approximately 100 users. The eight-member AI group at Kajima continues to develop systems for the entire company.

3.7 Summary of T^2 Processes in the Six Case Studies

Table 3.1 summarizes the characteristics of the six ES T^2 case studies presented in this chapter. Although several differences exist between the T^2 processes, major common stages have been identified.

The study of the literature review and the analysis of the cases of ES implementation presented in this chapter have resulted in the development of a T^2 beta model for ES technology. The model is presented in the next chapter and focuses on the identification of the stages of the T^2 process, the actors involved and the roles they perform. The variations of the T^2 process as well as the factors affecting it have also been identified.

Table 3.1 Summary of characteristics of T^2 case studies.

T^2 stage / Firm		EI du Pont de Nemours	Southwestern Bell Telephone Co.	FMC Corp.	Johnson & Johnson	Lend Lease Corp. of Australia	Kajima Corporation of Japan
Forces for exploring new technologies		Mgt's commitment to technology Competitive demands	Mgt's commitment to technology	Mgt's commitment to technology Competitive demands	Employee attitude towards technology Technology push	Mgt's commitment to technology Market demands	Employee attitude towards technology
Gatekeeping		ISD manager	Top mgt	Top mgt	Technical services scientist	Top mgt	Middle mgt
Source of initial resources		Department's budget	Firm's overhead budget	Firm's overhead budget	Personnal resources	Firm's overhead budget	R&D budget
Evaluation		Cham. & task force Prototype development	Cham. & task force Development of demos	AI group Prototype development	Unofficial task force Prototype development	DEC's AI group Prototype development	AI group Prototype development
Decision on adoption		Maintain expertise Increase efficiency	Maintain expertise Automate tasks	Maintain expertise	Maintain expertise Increase efficiency	Maintain expertise Automate critical task	Maintain expertise Increase efficiency Automate tasks
Systems development and implementation	Development strategy	Diffusion	Diffusion	Initially: Strategic Today: Strategic & Diffusion	Diffusion	Strategic	Strategic
	Type of systems	Tactical / Small	Tactical / Small Strategic / Large	Strategic / Large Tactical / Small	Tactical / Small	Strategic / Large	Tactical / Small
	Source of funds	Departments' budget	Firm's overhead budget	Firm's overhead budget Departments' budget	Firm's overhead budget	Firm's overhead budget	Firm's overhead budget
	Factors affecting adoption	Users' acceptance Mgt's support Peer pressure Innovative culture	Users' acceptance Mgt's support Peer pressure Innovative culture	Mgt's support High technological capabilities	Users' acceptance Mgt's support	Lack of continuous support Low utilization	Users' acceptance Mgt's support
Confirmation of benefits		Improved efficiency Product quality Decision consistency	Improved efficiency Product quality Competitive advantage	Improved efficiency & experts' utilization Competitive advantage	Internal savings	No benefits confirmed	Improved efficiency & experts' utilization Competitive advantage

4. T^2 Beta Model for ES Technology

In this chapter, a T^2 beta model for ES technology is presented. The model first identifies the stages of the T^2 process, the players involved and the roles they perform. Subsequently, the variations of the process are presented, and finally, the major factors affecting the T^2 process are identified.

4.1 Stages of T^2 Process

From the case studies of ES implementation, it becomes apparent that the T^2 process was not the same in all cases. However, major common steps have been identified. As shown in Figure 4.1, the major stages in the technology transfer process are the following: 1) recognize forces and opportunities for exploring new technologies; 2) identify ES technology; 3) commit initial resources; 4) evaluate technology; 5) decide on the adoption; 6) develop and implement systems; and 7) confirm technology's value.

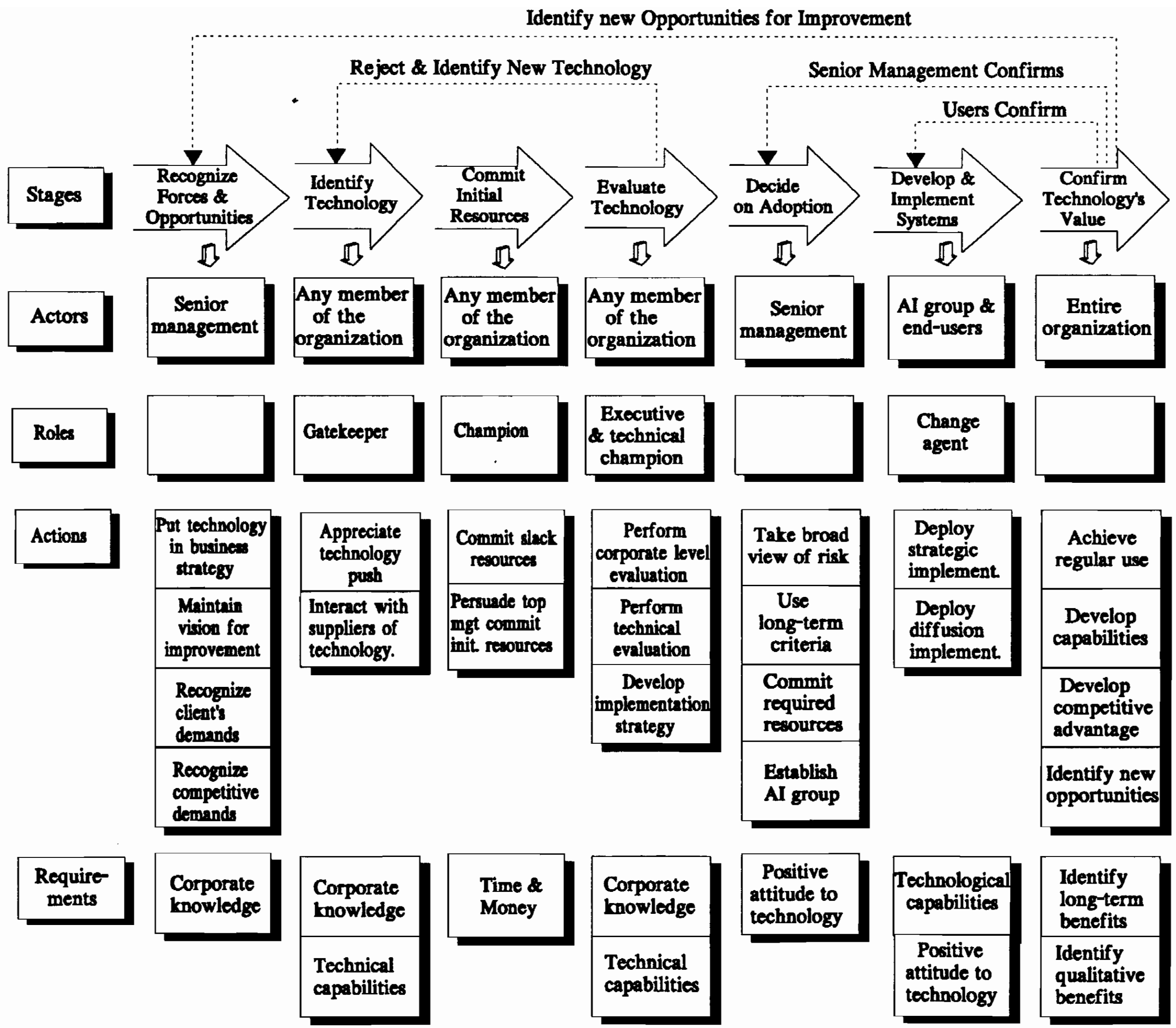


Figure 4.1 T^2 beta model - Stages, actors, roles and requirements.

4.1.1 Recognize forces and opportunities for exploring new technologies

A strong incentive must exist for a company to decide to explore new technologies. Thus, internal and external forces may push a firm to seek new technologies. Management's commitment to technology and employees attitude towards technology constitute the primary internal forces. Market and competitive demands, as well as the technology push created by new technologies are the major external forces.

Management's commitment to technology. This is a strong incentive which may lead top management to seek new technologies which can improve the firm's operations. Thus, senior management at Du Pont, FMC and Lend Lease Corporation considered new technologies so important for the future of their firms that appointed executive managers to keep their firms abreast of new technologies. However, strategic focusing is required to set priorities and direct the resources of the firm towards those technologies that can better serve the long-term business goals. The necessary alignment of the technological and business objectives can be achieved with the assignment of an executive manager, with the required corporate knowledge, to the role of technology gatekeeper.

Employees' positive attitude towards technology. Positive attitude towards technology may lead any member of the organization explore new technologies. Management's commitment to technology defines the climate for innovation in the firm, as well as the level of resources committed to new technologies. Thus, in an innovative environment all members of the organization will be encouraged to seek new technologies that can serve the firm's needs.

Market demands. In the construction industry, the market demands can be of two types: 1) client' pressure for new, cheaper or technologically improved facilities, which require technologically advanced methods in design, planning, construction, and control; and 2) client's requirements for application of specific technologies during the planning or construction of projects. For example, an owner may require a contractor to use specific advanced scheduling or construction methods notwithstanding the contractor's response to competitive demands.

Competitive demands. The competitive advantage that innovative firms gain because of advanced technology forces other firms to adopt new technologies in order to provide a product equivalent to their competition. An important business problem or loss of market share may also lead to the adoption of a new technology. For example, Du Pont was actively seeking to improve its organizational effectiveness in order to improve its competitiveness and its position in the international market.

Technology push. The existence of new technologies creates a force for exploring them. For example, the existence of ES technology led a technical service scientist in Johnson & Johnson to experiment with the technology, although, initially he could not identify possible applications.

4.1.2 Identify ES technology

T^2 denotes the adoption of new technologies developed outside the firm. The technology gatekeeper is the individual or group in the organization who identifies a new external technology, and visualizes potential applications in the firm. The role of the gatekeeper may be performed by any member of the organization. Typically, the gatekeeper will be appointed by senior management, but can also be self appointed. Senior management's attitude towards technology defines the position of the gatekeeper in the hierarchical ladder, and the resources which will be committed for the identification of new technologies.

In innovative organizations, where technology is considered an important competitive advantage, high level managers are assigned the role of the gatekeeper because their position allows them to identify those technologies which better support the business objectives. Gatekeeping may also be performed by persons or groups lower in the organizational hierarchy. Middle or lower managers, technical scientists or engineers may identify a new technology useful to the firm. An innovative organizational environment allows more members of the firm to be unofficial gatekeepers and introduce new technologies to their firms.

The connections of the firm with sources of new technology also depend on the attitude of top management towards technology. Innovative firms establish relations not only with vendors of technology, but also with universities and research laboratories in order to remain informed of recent technological advancements. Strong technical capabilities are necessary for the gatekeeper to be able to interact with these sources. In addition, knowledge of the needs and objectives of the firm is necessary in order to identify whether the technology can serve these goals.

After the gatekeeper has identified a new technology, several other tasks must be performed before the technology becomes a regular tool in the firm's operations. The gatekeeper, being the first person who envisions the implementation of the technology, plays an important role during the next stages of the T^2 process. Usually, the gatekeeper becomes the champion of the specific technology in the firm. In this way, the position of the gatekeeper becomes important and affects not only the success of the innovation, but the T^2 process as well.

In innovative firms, where gatekeeping is performed by executive managers, the innovations are supported from the top, thus, increasing the possibilities for successful adoption of new technologies.

4.1.3 Commit initial resources

After a new technology has been identified, it must be evaluated to determine whether it matches the needs and capabilities of the organization. However, commitment of resources is necessary to make the evaluation possible. At this point, the gatekeeper who envisions the implementation of the technology usually becomes the champion of the technology.

The champion has to perform two tasks: 1) provide the necessary resources for the evaluation of the technology; and 2) evaluate the technology. These tasks can be performed by the same or different individuals. When the gatekeeper is a senior manager who takes the risk to commit resources to the technology, this manager becomes the executive champion. The executive champion supports the new technology from the top and appoints a technical champion who will undertake the responsibility of evaluating and experimenting with the technology. When the gatekeeper's position is low and an executive champion does not exist, then the same person must perform both tasks, i.e., find the necessary resources and evaluate the technology.

For the evaluation of the technology, individuals with strong technical capabilities are required. These people typically form a task force, which under the leadership of the technical champion evaluates the technology and its impact on the organization. The task force must be provided with the time and freedom to perform its task. For an adequate technology evaluation, the task force must include members from all the important functional departments of the firm. Relatively speaking, the financial resources needed at this stage are not large.

Senior management's attitude towards technology is the main factor that defines if adequate resources will be committed to the new technology. Innovative firms do not hesitate to commit their best people and provide them with all the resources they need for the evaluation of the new technology. Senior management's attitude also defines the organizational environment where the champion will operate. This defines how the entire organization faces the new ideas, and the people who carry them. Providing autonomy and tolerating failure makes it easier for the technology champions to take the personal risk which is involved in the effort of promoting a new technology.

When strong support from top management does not exist, the task of the champion and the task force become more difficult. The evaluation of the innovation becomes an unofficial operation performed by a group of friends. The resources are committed by the champion. These can be personal resources or slack resources from other projects. The cooperation of the immediate supervisors of the champion and the task force is also needed. These managers will allow the members of the task force to commit some of their time to the evaluation of the technology.

4.1.4 Evaluate the technology

The evaluation stage is one of the most critical steps for the success of the innovation. As the technology is new and untested, the purpose of this stage is to identify how the technology must be used in order to offer the most possible benefits to the firm. In the case of ES technology, this step becomes more important as the technology is a tool with many different applications. The evaluation of a new technology is, in other words, a feasibility study which includes evaluation at two levels: 1) at the corporate level; and 2) at the technical level. Both tasks should be successfully performed before an organized effort for implementing the technology starts.

At the corporate level, the technology must be matched with the organization's needs and operations. This will define the potential applications and benefits to the firm, as well as who the end-users will be. Knowledge of the firm's needs, functions and operations is necessary for this task and requires the involvement of senior management to ensure that the technology serves the business objectives.

This task requires the involvement and cooperation of top management as well as managers of several departments of the firm. The best way to achieve this evaluation is the formation of a task force with representatives from all potential affected organizational groups. When senior management is championing the technology, the evaluation at corporate level is followed with the official assignment of the technical champion and the task force for the evaluation of the technical features of the new technology.

After defining what the technology can do, the technical evaluation addresses how the technology must be used, and includes: 1) learning how the technology works; 2) experimenting with different applications; and 3) testing it in real-life problems. Strong technical capabilities of the champion and the task force are necessary in order to be able to learn the technology, experiment with it, and test it.

The technical evaluation will define the capabilities required for proper use of the new technology, which depend heavily on the developmental state of the technology. At this point, the technology must be matched with the organization's technological capabilities and resources in order to define if the desired applications can be achieved using the existing in-house capabilities or if new capabilities are required. If additional capabilities are required and cannot be developed inside the organization, then outside specialists must be hired for the proper use of the technology. The evaluation may lead the champions to reject the technology if it does not prove appropriate for the organization, and recommend the identification of a new one. This creates a loop between the identification and evaluation stage.

By the end of the evaluation stage, the champion has identified how the technology must be used in the firm. This includes what the desired applications are, who the end-users will be, what capabilities are required for the successful implementation, and how the firm will get these capabilities. In this way, the period of evaluation becomes the most critical because at this stage the direction for the deployment strategy is developed, that is, whether the desired applications will be developed by specialists or whether the end-users will be the developers of their own systems.

4.1.5 Decide on adoption

Senior management is the group which will make the decision whether to adopt the new technology. The decision on adoption is, in other words, a decision on whether substantial resources will be committed for the implementation of the new technology. The financial risk involved, the attitude of senior management towards technology, and its participation in the evaluation stage have important effects on what the decision will be and when it will be made.

The financial risk involved in trying a new technology is always an important factor affecting senior management's decision. The uncertainty of the payoffs usually dissuades management from gambling with perhaps non-matured technology. The attitude of senior management towards technology is another force that affects the decision. Positive attitudes may lead to adoption decision. However, attitude is a matter of faith and does not remove the risk involved in the decision.

One way to remove much of the uncertainty involved in the decision to adopt is by involving senior management during the evaluation stage. The knowledge of what the technology can do, how it does it, and what are the problems involved in its use reduces the uncertainty and familiarizes top management with the potential problems involved in its implementation. In this way, the expectations concerning the payoffs and their timing are more realistic. In innovative firms, top management treats new technologies as long-term investments and takes the risks of committing the required resources.

When senior management is not involved in the evaluation, two additional problems occur. First, top management is more reluctant to invest in the technology based in someone else's evaluation; and second, important potential applications may be overlooked. When top management is not involved in the evaluation, it becomes the champion's task to persuade it.

The criteria which senior management uses to evaluate technology vary according to the degree that the technology is considered a competitive advantage. Traditionally, computer systems have been evaluated in terms of the same cost/benefit analysis used for most capital investment projects. The use of hard measures is increasingly difficult to apply as computer systems become more and more concerned with assisting the management decision-making process rather than with automating existing procedures.

The qualitative benefits, such as improved decision-making, which are the real impetus for development of expert system, are hard to translate into dollar figures and are often treated as a side issue or ignored. Top management, not unreasonably, will reject a capital investment proposal presented in terms of such vague payoffs. Quantifying the qualitative value of expert systems is the key to convince senior management. However, such calculations are at best approximations. An alternative is to accept the notion that computer systems are largely a problem of selling to top management the idea that an investment of $X dollars will be somehow worth it. Phrases such as "keeping up with our competitors" or "maintaining our current technological position" are very useful in arguing this position.

Long-term competitive advantages, automation of processes, and cost and quality control drive innovative companies to invest in untested technologies. Big business problems (such as loss of market share), short-term profits or simple entrepreneurial opportunity for reducing expenses may force companies to adopt a new technology.

4.1.6 Develop and implement systems

This stage includes three main tasks. First, the establishment of a task force as the group responsible for the implementation of the technology in the firm; then, the modification of the technology in order to satisfy the specific needs of the organization; and finally, the transfer of the technology to the users who will implement it. For the ES technology, a simple modification is not enough. ES technology is a tool with many possible applications, therefore, each company which adopts the technology must develop its own systems according to the desired applications.

The desired ES applications have been identified during the evaluation stage. During that stage, the technological capabilities required for the development of the systems have also been identified and matched with the existing capabilities in the organization. The capabilities required depend heavily on the state of maturity of the technology. As the limitations of the technology are being reduced, less technological capabilities are required for the development of any expert system. The following factors affect the implementation strategy that a company will deploy: 1) the technological capabilities required for the proper use of the technology; 2) the existing technological capabilities in the firm; and 3) the size and complexity of the desired applications.

From the case studies of ES adoption, two extreme implementation approaches that a company might consider have been identified: strategic and diffusion. The strategic implementation implies the application of the technology on a few critical business areas. Diffusion aims at the use of the technology as a regular tool through the entire organization by making the potential users able to develop their own systems.

Strategic approach. The strategic approach addresses large applications which are very important for the firm. As a result, special skills are required to build the desired systems. The requirements posed by the applications and limitations of the technology make necessary the formation of an AI group which consists of specialists. The AI group develops expert systems centrally for the entire company and then transfers the systems to end-users.

The advantages of the strategic approach include the improved managerial control over the development and implementation stage, the centralization of ES capabilities, and the potential for high payoffs from large strategic applications. A disadvantage of this implementation approach is the requirement for large investment, both in human resources and specialized equipment. Thus, only innovative companies with many available resources, such as FMC and Lend Lease, took the financial risk to commit all the required resources. However, as ES technology matures and new tools are developed, the financial investment requirements are also reduced. For example, the reduced limitations of the technology enabled Kajima to develop in-house capabilities and adopt ES technology with relatively small cost.

Another disadvantage of the strategic approach is that end-users' participation during the systems development may be limited, thus threatening end-users acceptance. To avoid misuse and rejection, management should facilitate involvement of end-users throughout the development process.

Diffusion approach. The diffusion approach aims to make all the members of the organization end-users of the technology and enable them to build expert systems to fit their needs. The main difference between diffusion and strategic implementation is that under the diffusion approach, the end-users are also the developers of the systems. The AI group does not simply transfer to end-users expert system programs, but it transfers the technological skills for developing ES applications. This was not possible when ES technology was in its early stages of development, and for this reason the technology was rejected by some firms at that time. However, as the limitations were reduced, several firms have begun adopting the technology. For the success of the diffusion approach two main tasks must be performed: 1) the technology must achieve wide acceptance through the entire organization; and 2) training must be provided in order for the end-users to develop the necessary capabilities.

The task of diffusing the technology through the organization is undertaken by an AI group, who becomes the change agent in the firm. In this implementation strategy, the responsibility of the AI group is not to build any systems centrally, but to inform, train and support the potential end-users in the company and make them able to develop their own systems. The first goal of the task force is to build awareness company-wide. This is achieved by extensive campaigns to inform managers and staff about the technology and the benefits from its use. This campaign, accompanied with sample implementations by the first end-users, influences more end-users to learn and use the technology. Subsequently, the task force provides training and support to every interested user, expanding in this way the end-users group from a few individuals to entire business units.

4.1.7 Confirm technology's value

The evaluation of the benefits derived from the technology is a very important part of the T^2 process because it defines whether the technology will continue to be used in the firm.

During this stage, the benefits from the use of the technology are evaluated and resources continue to be allocated to the technology or rejection and discontinuance may occur. In this way, there is a continuous feedback loop between the confirmation and the decision to adopt stage.

The criteria to evaluate the benefits are not only financial, but qualitative as well. Senior management must evaluate how the technology has served the long-term objectives of the firm, and must also identify new opportunities for improvement. As the technology becomes a regular tool in the organization's operations, new capabilities are developed and new forces and opportunities for improvement are revealed. The confirmation stage led FMC Corp. which was initially developing only strategic ES applications, to revise its implementation strategy and diffuse the technology to the entire company.

At this stage, the technology is not evaluated only by senior management, but by end-users as well. The end-users evaluate the changes that the technology brought in their work and develop a positive or negative attitude towards the technology. Therefore, a feedback loop between the confirmation and the implementation stage is also identified.

4.2 Variations of the T^2 Process

For the successful implementation of ES technology, all the stages described above must be successfully performed. However, as the case studies illustrate, the process does not always follow the same path. According to the position in the organization of the individual who introduces the technology, one can identify two different types of the T^2 process: 1) top-down approach; and 2) bottom-up approach.

4.2.1 Top-down approach

In the top-down approach, senior management initiates the T^2 process, as shown in Figure 4.2. As a result of internal or external forces, an executive-level manager performs the role of the gatekeeper and identifies the technology. Subsequently, this manager becomes the executive champion and performs two tasks: 1) the evaluation of the technology at the corporate level; and 2) the allocation of resources for the technical evaluation of the technology. The resources include the assignment of a manager with high technical skills, who becomes the technical champion, and the formation of the task force. The executive manager also provides the necessary financial resources for the technical evaluation. Based on the corporate and technical evaluation of the technology, senior management decides whether to adopt the technology. When a senior manager is championing the technology, this task is not difficult, as the position of the champion allows to influence other senior managers. The decision to adopt includes the commitment of resources, and it is followed with the establishment of the task force as the group responsible for the implementation of the technology in the firm.

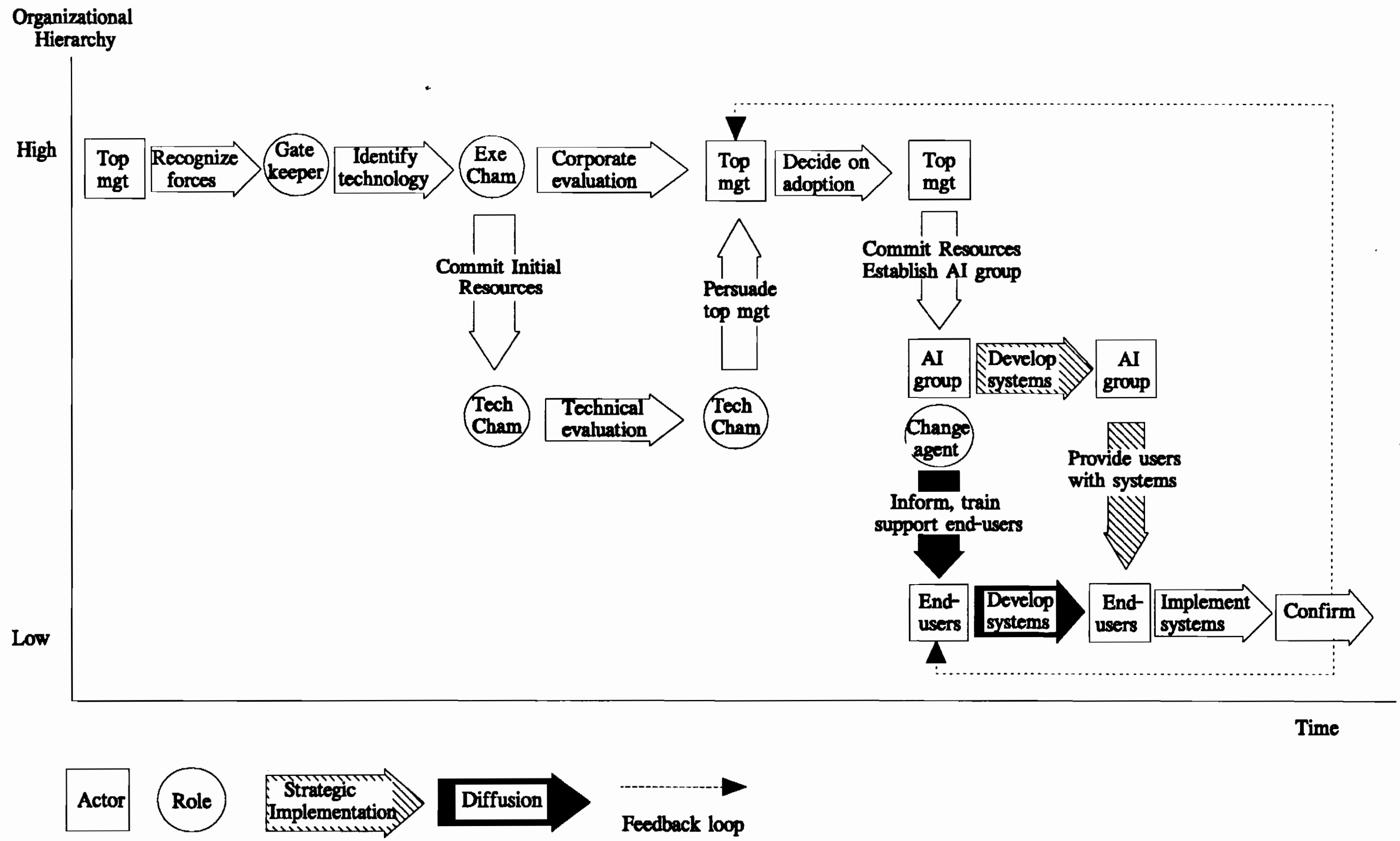


Figure 4.2 Top-down T^2 process.

The implementation strategy to be deployed depends on the technological capabilities required for proper use of the technology and the existing capabilities and resources in the firm. In case of strategic implementation, the task force with or without help from outside specialists develops the expert systems with little participation from the end-users, and simply provides the end-users with the systems to be implemented. If the firm select the diffusion approach, the task force undertakes a different role. Its goal is to inform, train and support the end-users in the firm, who develop and implement their own systems.

4.2.2 Bottom-up approach

The main characteristic of the bottom-up approach is that the technology is introduced in the organization by a member which does not belong to the senior management group. This member of the organization occupies a lower position in the organizational hierarchy and does not have enough corporate knowledge to match the technology with the firm's long-term business goals.

This individual performs the role of the gatekeeper and identifies a new technology, usually as a result of a technology push. Subsequently, the gatekeeper becomes the champion of the technology. The position of the gatekeeper affects the degree to which the individual can influence senior management to support the technology, and the ability to allocate seed resources to evaluate the new technology.

After the technology has been identified, the champion must persuade senior management to take the role of the executive champion and provide the required resources for the evaluation of the technology. In this case, the executive champion supports the technology from the top and undertakes the evaluation of the technology at the corporate level, while the gatekeeper becomes the technical champion. This process is depicted in Figure 4.3.

If an executive champion does not support the technology, the technical champion must commit the initial resources by taking them from other projects or committing personal resources, as shown in Figure 4.4. For the evaluation of the technology, the participation of other members of the organization is required. Thus, when the technology is not supported from the top, the evaluation becomes an informal operation. However, in this case, the technology may not be adequately evaluated, as the champion may not have the corporate knowledge required for the proper integration with the long-term business objectives.

If the champion is sold on the technology's value, senior management must be persuaded to adopt the technology. Again, the position of the champion defines how much clout the individual can exert over senior management. After the decision for adoption is made, the implementation follows. The implementation strategy can be strategic or diffusion, depending on the organizations technological capabilities and the state of maturity of ES technology.

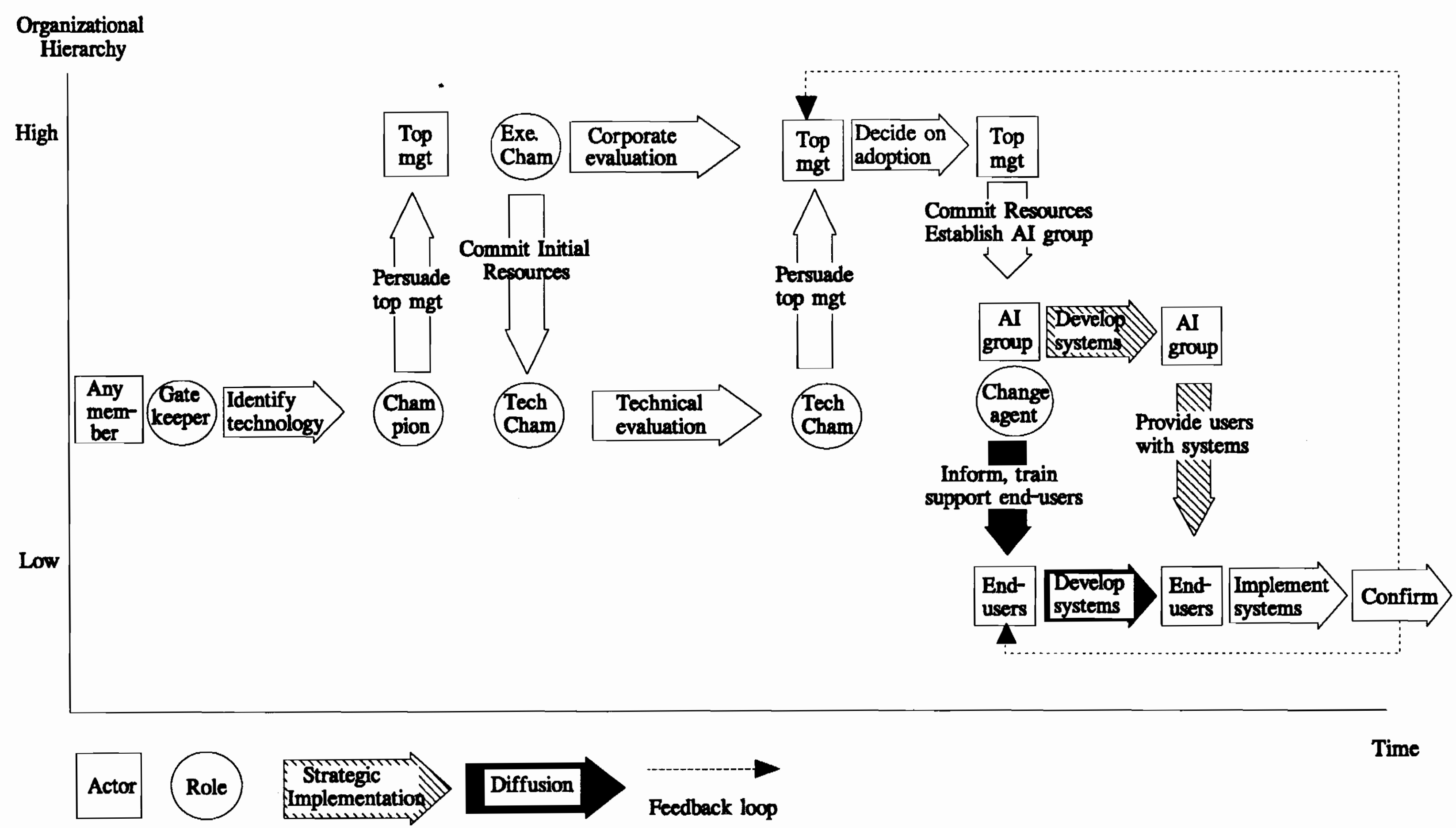


Figure 4.3 Bottom-up T^2 process with top management's support.

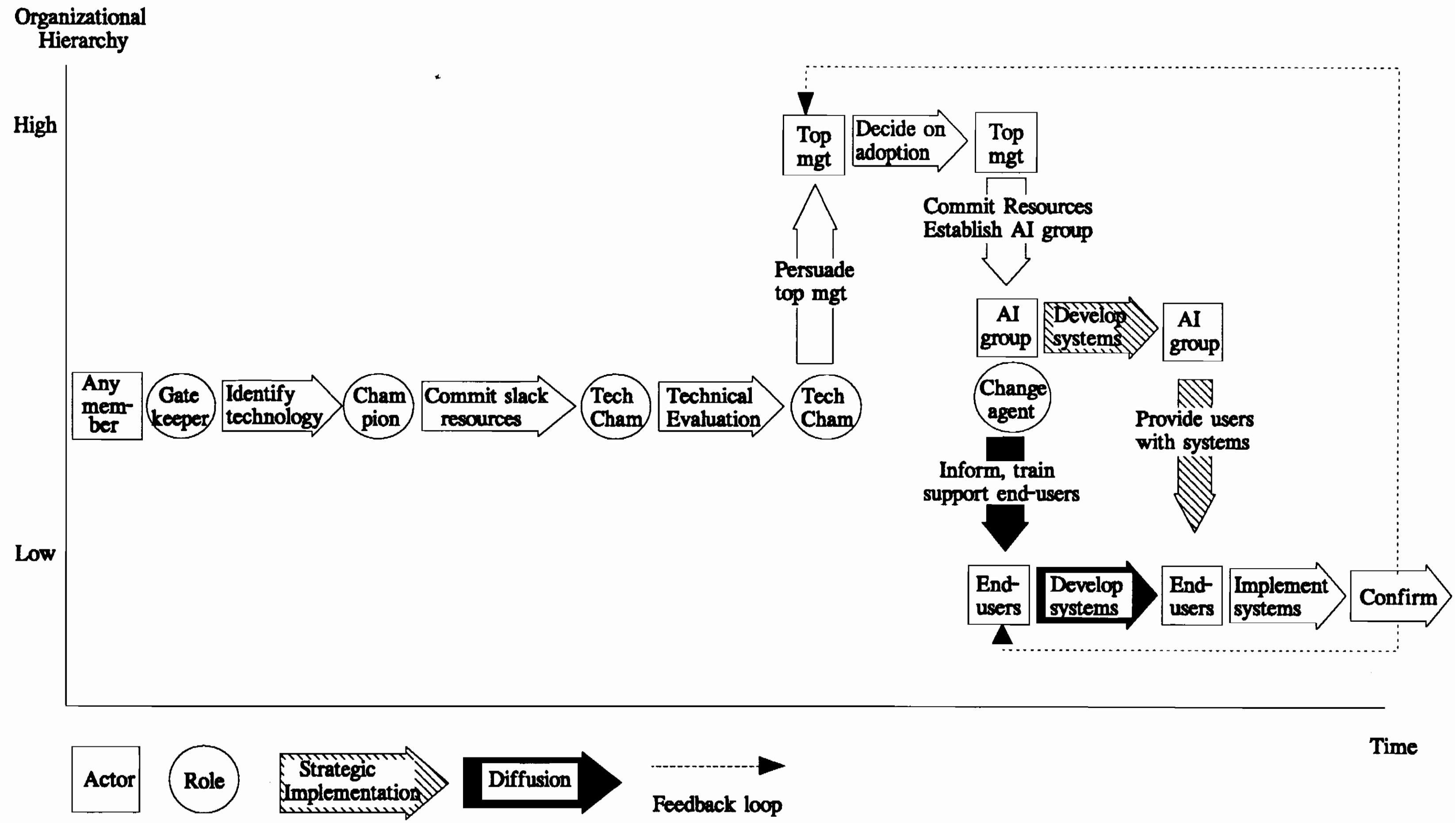


Figure 4.4 Bottom-up T^2 process without top management's support.

4.3 Factors Affecting the T^2 Process

The main factors which affect the path of the T^2 process and the success or failure of the implementation are: 1) senior management's attitude towards technology; 2) the innovative organizational environment; 3) the position of the gatekeeper in the organizational hierarchy; 4) the organizational technological capabilities; and 5) the state of maturity of the ES technology. Figure 4.5 depicts the stages of the T^2 process and the effect of each factor on every stage.

4.3.1 Senior management's attitude towards technology

The attitude of senior management towards technology is reflected in the degree to which senior management considers advanced technology as an important ingredient for the future survival of the organization. Senior management's attitude defines both the resources that the organization commits to new technologies and the organizational innovative environment. In this way, the attitude of senior management affects all the stages of the T^2 process.

The recognition of the importance of technology in achieving the business objectives creates a strong incentive for exploring new technologies. In this case, senior management appoints an executive manager to be the technology gatekeeper of the firm. During the evaluation stage, senior management commits all the resources required for

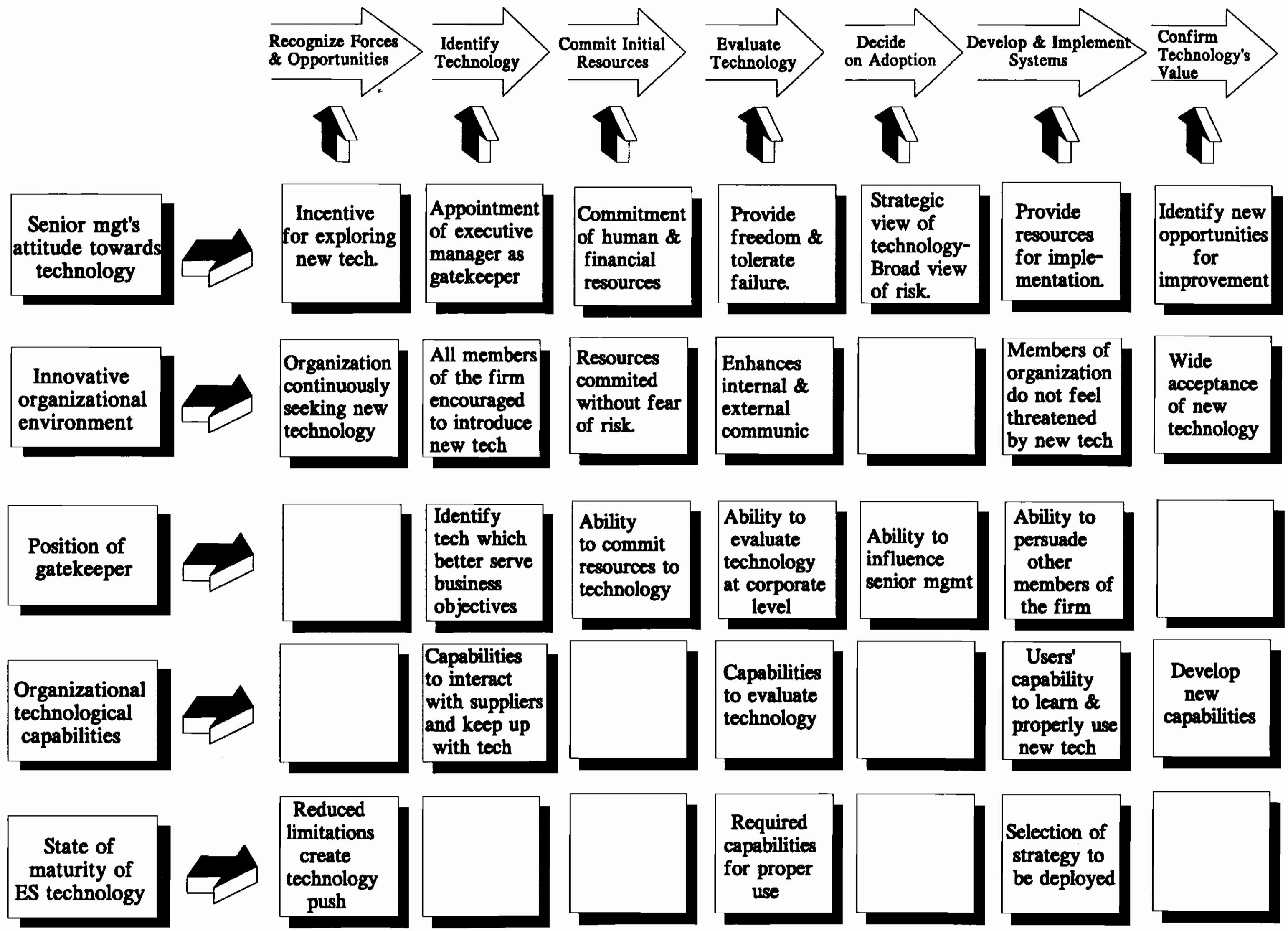


Figure 4.5 Factors affecting the T^2 process.

the best evaluation of the technology, by allowing the champions to commit their time to the new technology and by supporting them with financial resources. Tolerating failure allows the champion to experiment with the new technology without fear of retaliation. Finally, senior management's participation in the evaluation stage, ensures that the technology will serve the long-term business goals.

When senior management maintains a strategic view of the technology, the decision on the adoption of a new technology is based not only on short-term financial criteria, but also on long-term and qualitative advantages. Thus, the resources necessary for the implementation for the technology are committed without fear of risk.

When senior management maintains a negative attitude towards technology, unsurpassable barriers exist in all the steps of the T^2 process. The firm does not seek new technologies unless an important problem emerges. Time spent exploring and learning new technologies is considered lost and resources are not provided for identification and evaluation of new technologies. In this environment, the task of the champions becomes much more difficult, and many times they have to bend the rules in order to find the necessary resources. Lack of cooperation among the functional departments makes communications and evaluation of the technology difficult. Finally, the risk for adoption is not taken except if an emerging problem exists and no other solutions seem possible.

4.3.2 Innovative organizational environment

The organizational environment defines how the entire organization faces new ideas and the people who carry them. In an innovative organizational environment, new technologies are explored even if initially it is not obvious how they can improve the firm's operations. All members of the organization operate as unofficial gatekeepers with top management's support. The freedom to experiment with new technologies and the enhanced communication within the organization allow adequate evaluation of the technologies.

The organizational innovative environment is the most important factor affecting the success of the implementation, as it reflects the degree to which the entire organization is conducive to change. Therefore, in an innovative firm, the resistance to change is not a barrier, as end-users do not feel threatened by new technologies.

4.3.3 Position of the gatekeeper

The position of the gatekeeper in the organizational hierarchy has an important impact on the T^2 process and its success. The gatekeeper is the first member of the organization who identifies a new technology and visualizes its potential applications in the firm. Thus, the gatekeeper becomes the champion of the technology in the firm and works for its adoption. The position of this key individual is important and affects the T^2 process in the following ways.

During the identification stage, the position of the gatekeeper defines which technology is most appropriate to serve the business objectives. During the evaluation stage, the gatekeeper usually becomes the champion of the technology. At this point, the position of the gatekeeper defines the degree to which this individual can influence senior management in supporting, and ultimately, adopting the technology. Additionally, it defines its ability to commit resources to the technology. All these tasks are more effectively performed when the gatekeeper is a senior manager.

When the gatekeeping is performed by a low position member of the organization, the success of the process depends mainly on the organizational innovative environment. Support of top management is necessary for the success of the process, as the gatekeeper may not be able to commit the required resources for the evaluation, or persuade senior management of the importance of the technology.

4.3.4 Organizational technological capabilities

The organizational technological capabilities are an important factor affecting the success of the adoption of a new technology. Without major technical capabilities, a firm cannot keep up with the technological advancements, and cannot recognize the opportunities for improvement that new technologies offer.

In order to learn and evaluate a new technology, it is important for the champion to have high technical skills. However, for successful adoption of a new technology the entire organization must have the technological skills required for proper use of the technology. The managers and the end-users of the technology must be able to understand and use it. If these capabilities do not exist company-wide, the new technology will most likely be misused and negative attitudes may be developed leading to the ultimate rejection of the technology.

4.3.5 State of maturity of ES technology

The state of ES technology defines the technological capabilities required for its proper use. The existence or non-existence of these capabilities in the organization defines mainly the implementation strategy which will be deployed.

In its early stages of development, ES was a technology requiring LISP programmers and specialized hardware. The first organizations which adopted the technology had to make large investment in specialized personnel and hardware. Under these conditions, the technology was implemented only on those strategic applications which could produce the highest payoff.

As the technology matured, the user's capabilities needed for its implementation as well as the equipment's requirements became less demanding. The development of PC-based ES tools made ES technology accessible to a large group of PC users. The evolution of the ES technology affects the T^2 process. Such evolution creates a technology push force by allowing more individuals to experiment with ES, and makes possible the diffusion of ES technology inside an organization by making every computer user a potential user of ES technology. In this way, the requirement for outside specialists become less, as this can be achieved by training the existing computer users. As a result, more organizations have adopted ES technology.

In some cases, the diffusion of the technology occurred first and as ES became a regular tool in the firm and new capabilities were developed, the technology was applied to larger strategic applications with in-house forces. Similarly, the evolution of the technology enabled companies who initially adopted a strategic approach to reconsider their strategy and work towards diffusion.

The T^2 beta model presented in this chapter has identified the stages and operations of the T^2 process, the actors involved and the roles they perform. The variations of the T^2 process and the factors affecting it have also been identified. For the validation and refinement of the T^2 beta model, additional case studies of ES adoption in US AEC firms have been developed. The case studies and their comparison to the T^2 beta model are presented in the following chapter.

5. Validation of T^2 Beta Model

For the validation and refinement of the T^2 beta model the following tasks have been performed:

1. Three US AEC firms currently using ES technology have been identified. These firms are: 1) Morrison-Knudsen Environmental; 2) Stone & Webster Engineering Corp.; and 3) CRS Sirrine. In order to identify the three AEC firms the following steps have been taken: 1) articles and publications related to the use of ES by AEC firms have been reviewed; and 2) vendors of ES shells have been contacted and asked about AEC firms which have bought their products. These tasks resulted in the identification of six US AEC firms using ES technology. Subsequently, the AEC firms have been contacted by the Committee Chairman, Dr. J. M. De La Garza, and three of the firms agreed to participate in the research.

2. Interviews have been conducted on the adoption process of ES technology in these firms. The on-site interviews have been performed by Dr. De La Garza. For this

purpose, an interview guide has been developed by the author, and reviewed by Dr. Robert Frary of the Virginia Tech Learning Resources Center. The interview guide is presented in Appendix A.

3. The information gathered during the interviews has been analyzed by the author, and case studies of the T^2 process in these companies have been developed.

In this chapter, the case studies of successful implementation of ES technology are presented. Each case study consists of three sections. The first section presents a description of the case based on the information provided by the managers interviewed. The second section provides the author's interpretation of the T^2 process in the studied organization and a comparison with the T^2 beta model. The third section identifies the factors that contributed the most to the successful adoption of ES technology in each firm. Finally, at the end of the chapter, a comparison between the three case studies is presented, and similarities and differences of the T^2 processes are identified.

5.1 ES Implementation in Morrison Knudsen Environmental

Morrison Knudsen (MK) Corporation is a large diversified firm with operations expanded all over the world. In 1990, MK's total volume was 3,9 billions dollars (ENR 1991). The company's operations include heavy and industrial construction, mining, manufacturing, engineering and environmental services.

5.1.1 Description

In late 1970, top management of MK Mining Division decided to introduce extensive computerization of the division's operations. Although a few people in the division were developing some computer applications, a formalized effort did not exist. As a result of this decision, Dr. Khosrow Badiozamani was hired in 1979 to organize the MK's scientific computing and application development group. This group would be responsible for developing the necessary applications to support the Mining Division's operations.

The first large application the group developed was a mining resource management system which subsequently was marketed successfully and became a money-making operation. Thus, the role of the application development group expanded to include software development for marketing purposes. The successful marketing of the software freed the group from budget constraints and provided it with the freedom to experiment with and work on the development of new applications. Since then, Dr. Badiozamani has moved to other Divisions continuously supporting the MK's operations, and today he is General Manager of the Integrated Software Technology (IST) Group of MK-Environmental Services Group.

The venture of MK into AI started as a result of the demands created by a projects's complexity. A big contract with the Defense Department required the development of a system which would assist in the coordination of several disciplines during the construction of a large underground facility. The system would allow technical personnel as well as decision makers to develop what-if scenarios and quickly evaluate the impact of changes in one area of the project on other disciplines. The solution to this problem was found in the tools and techniques of AI, with which Dr. Badiozamani and his group were familiar before coming to MK Environmental.

In another major project, AI techniques were used to analyze the required changes in a project's schedule and operations which would result if a change on the project's budget was made. As champion of the technology, Dr Badiozamani had to sell both clients and top management the technology's value. These externally funded projects became the catalysts for further examination of ES technology for potential internal application.

Based on the success of the first applications, it was easy for Dr. Badiozamani to persuade top management to adopt the technology. Top management's awareness and understanding of new technologies was the most important factor for the decision to adopt the new technology for internal use.

The IST Group is responsible for developing the systems the company needs. New internal applications are identified in two ways: 1) the IST Group, who keeps an eye on the Division's operations, identifies a potential application; and 2) the department managers, who continuously look for opportunities for improving operations with ES applications, identify applications the end-users need.

The role of department managers is critical for the successful implementation of the new applications the IST Group develops. Because the IST Group is developing all ES applications centrally and a formalized effort to disseminate new systems throughout the firm does not exist, department managers' support is required for the new systems to achieve high acceptance by the end-users.

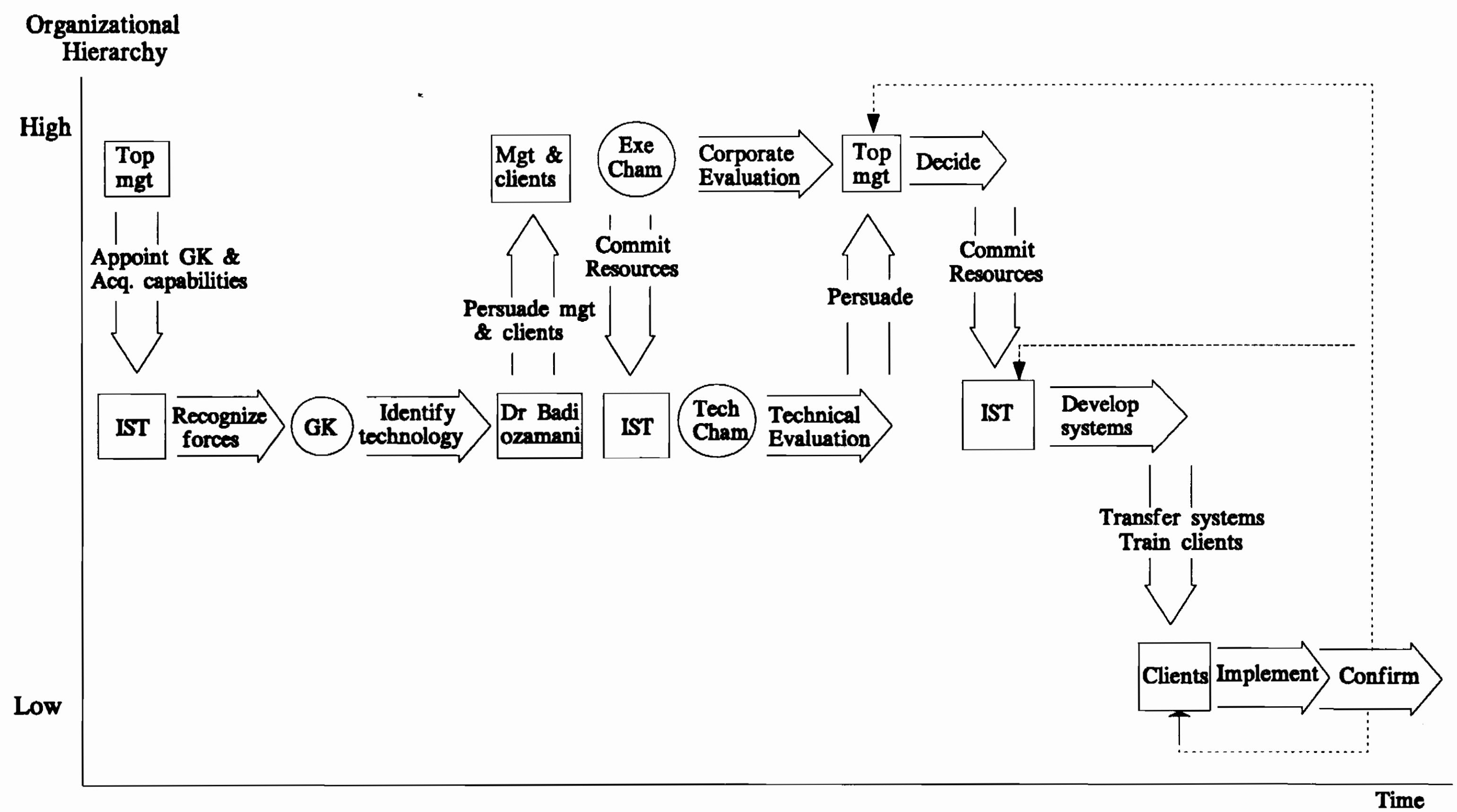
MK believes that the best way to infuse a new technology in the firm is by creating a "pull" force by the potential users of the systems and their managers. Thus, word-of-mouth and peer pressure are important for creating interest and acceptance by end-users and their managers. The innovative culture of the company and the freedom of the technical personnel to introduce improvements are also significant factors affecting the acceptance of new systems. The continuous feedback the IST Group receives from the end-users leads to further improvements in the systems.

MK identifies the major impact of ES technology mainly in the areas of training new personnel, and automation of processes MK knows how to do well, such as interpretation of regulatory requirements. These result in better decisions, improved quality of product or design and reduced errors and delays.

5.1.2 Comparison with T^2 beta model

The T^2 process in MK is similar to the top-down approach of the T^2 beta model and the implementation strategy is similar to the strategic approach. The following stages of the T^2 process in MK have been identified: 1) recognize forces for exploring new technologies; 2) acquire in-house technological capabilities; 3) identify ES technology; 4) commit initial resources; 5) evaluate ES technology; 6) decide on adoption; 7) develop and implement ES applications; and 8) confirm technology's value. Figure 5.1 illustrates the stages of the T^2 process in MK, the actors involved and the roles they performed.

Recognize forces for exploring new technologies. Top management's appreciation of technology as means for gaining competitive advantage was the major force for MK to start exploring new technologies. Thus, top management adopted a proactive technology strategy and established the IST Group to keep the firm abreast of emerging computer technologies. The IST Group identified ES technology as a solution to a technical problem created by a project's complexity.



Stages	Recognize forces	Acquire capabilities	Identify technology	Commit Resources	Technical & corporate evaluation	Decide on adoption	Develop & implement systems	Confirm
Actors	Top mgt	IST group	IST	IST & clients	IST & Dr. Badiozamani / Top mgt	Top mgt	IST / End-users	Entire organization
Roles			Gatekeeper	Champion	Tech. & Exe. Champion		Developers / Users	

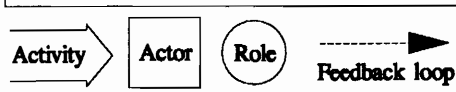


Figure 5.1 T^2 process in Morrison Knudsen Environmental.

Acquire in-house technological capabilities. The acquisition of technological capabilities was accomplished with the recruitment of additional staff with high technological capabilities, and the establishment of the IST Group who was assigned the role of the technology gatekeeper.

Identify ES technology. The strategic role of the IST Group requires continuous monitoring in three fronts: 1) understanding the company's internal needs; 2) understanding the customers' needs and requirements; and 3) identifying new technologies and their potential importance for MK. The characteristics of the IST Group that contribute most to successfully perform its role include: 1) adequate technological capabilities; 2) strategic position, which enables IST understand the company's objectives and the clients' needs; 3) focus on those technologies that can support the division's operations rather than staff functions (accounting, payroll, etc.); and 4) ability to allocate its own resources to investigate new technologies and potential applications. This is achieved through the successful commercialization of software IST develops, and the re-investment of some of the profits into R&D activities.

Commit initial resources. The resources required for developing the first ES applications were provided by the clients. However, the overall operations of the IST Group are supported by the reinvestment of the Group's profits from the successful marketing of other software. This provides IST with freedom from budget constraints and flexibility in allocating resources to investigate new technologies.

Evaluate ES technology. At the technical level, the technology's potential was tested during the development of the first applications. With respect to the corporate evaluation, the strategic position and role of the IST Group enabled it to evaluate the impact of new technologies on the business objectives of MK.

Decide on adoption. Because ES was a new technology for the company, Dr. Badiozamani, as champion of the technology, had to sell both clients and top management the technology's value. Top management's awareness and understanding of new technologies are the most important factors influencing the decision to adopt the new technology for internal use.

Develop and implement systems. The IST Group centrally develops the systems for the entire Environmental Division. Potential applications are identified either from the IST Group who continuously monitors the organization's and clients' needs, or from managers and technical personnel who look for new ways to improve their work.

The lack of a formalized effort to disseminate new technologies in the company puts the task of the diffusion of ES technology on the shoulders of department managers who become change agents of the new technology. Thus, the following factors are critical for the highest acceptance and utilization of the technology: 1) middle managers' acceptance and understanding of the technology; 2) end-users capabilities and attitude towards new technologies; and 3) top management's continuous support of the technology and communication of the technology's importance to all managers. The centralized evaluation and development of the applications ensures that resources are allocated to systems that will pay off.

Confirm technology's value. Improvements in training of entry level personnel as well as improvements in operations dealing with complex tasks are the major benefits identified by MK. As a result, improvements in operational efficiency, product cost and quality, and technological image to the customers have been identified.

5.1.3 Factors affecting ES T^2 in MK

The following factors have contributed the most to the successful adoption of ES at MK: 1) top management's attitude towards technology; 2) position of the gatekeeper in the organizational hierarchy; 3) availability of adequate funds; 4) organizational technological capabilities; and 5) innovative culture of MK.

Top management's attitude towards technology. Top management's awareness and understanding of computer technology has led them to consider new technologies important for the future of the company, and to commit the required resources for the establishment of the IST Group to perform the role of the technology gatekeeper.

Position of the gatekeeper in the organizational hierarchy. The strategic position of IST enables it understand both the clients' needs and the internal operational needs. In this way, IST is able to select those technologies which can provide the firm with competitive advantage.

Availability of adequate funds. The IST Group is not part of MK's office overhead. Through re-investment of a portion of the profits generated by the successful marketing of software, IST has been capable of allocating its own resources in investigating new technologies and potential applications.

Organizational technological capabilities. Top management's technological background enables it understand and support technological innovation. Technological capabilities of middle managers and end-users result in high acceptance and utilization of ES technology.

Innovative culture of MK. MK believes that innovation is critical for the firm's success. Thus, both management and engineering personnel are continuously looking for opportunities for improving internal operations and providing better services to clients.

The self sustainment of the IST Group is a new finding. This finding highlights the existence of alternative ways for funding development of new technologies in-house. The case of MK also highlights the fact that investment in increasing the technological capabilities of the organization can payoff in many ways. In this case the unexpected payoff was the creation of a new product line.

5.2 ES Implementation in Stone & Webster Engineering Corp.

Founded in 1889, Stone & Webster Engineering Corp. (S&W) is one of the largest US engineering/ construction companies, with 4,7 billion dollars in contracts during 1990 (ENR 1991). S&W's activities expand all over the world and include engineering and construction of manufacturing, transportation and building projects as well as software development. Additionally, S&W is a leader in the use of the latest available design, construction, maintenance and control technologies.

5.2.1 Description

S&W's senior management has always recognized the importance of new technologies in gaining competitive advantage. As a result, S&W has adopted a proactive technology strategy focusing primarily on clients' needs and how technology can be used to satisfy them. Thus, S&W is continuously looking for new technologies and examining how they can support the business objectives.

The identification and adoption of ES technology was a result of this proactive technological strategy. In 1982, a senior engineering executive made a proposal to the

Executive Office to initiate an investigation of ES technology and its potential in assisting the operations of the engineering corporation. With the support of top management, a project was initiated and was provided with a budget to examine ES technology. The novelty of the technology required additional in-house technological capabilities which were acquired with the recruitment of additional staff.

From the beginning, S&W saw the ES technology as a tool for maintaining organizational expertise and improving its competitive position. The first project was an equipment diagnostics expert system for centrifugal pumps. The objective of the pilot project was to examine the usefulness of ES techniques in real world engineering applications. Therefore, mainstream computer hardware was selected as the platform for implementing ES. Despite the state of development of ES technology, which at that time required specialized hardware, the project team successfully developed the first applications.

Until that time, no strategic commitment had been made to ES technology. However, as new PC-based tools became available, the ES group identified the opportunity offered for both development of applications to support the internal operations of the firm and development of applications to satisfy external clients' needs.

As a result of the successful evaluation of ES and the simultaneous development of advanced CAD and database technologies, S&W made the decision to establish the Advanced Systems Development Services (ASDS) division which was chartered with two basic roles: 1) develop and market new software products to support internal operations and external clients' engineering operations; 2) provide consulting services to clients.

By entering the software market, the ASDS division grew both in size and in capabilities, and became a leader in the development of Computer-Aided Engineering systems. Clients' awareness of S&W's ES technological capabilities is raised through mainstream marketing techniques and procedures. During the first years of its operations, ASDS was using ES tools only on external projects. Subsequently, ASDS started developing systems which incorporated ES technology for internal use.

Before a decision to develop a system is made, a need of the company must have been identified. Thus, there are two ways that a project can start: 1) a proposal can be made from division managers who identify a specific need. In this way, the awareness of division managers about new technologies is a critical factor for the technological improvement of the firm; and 2) the ASDS identifies a potential application which could support operations and proposes the development of a system to the division managers.

Potential internal ES applications are screened by senior management who decides which applications are developed and allocates the resources accordingly. For the development of the system, a team is formed with the participation of the experts, the developers and representative end-users. After the system is developed, it is transferred to the end-users who are provided with training and support during the implementation.

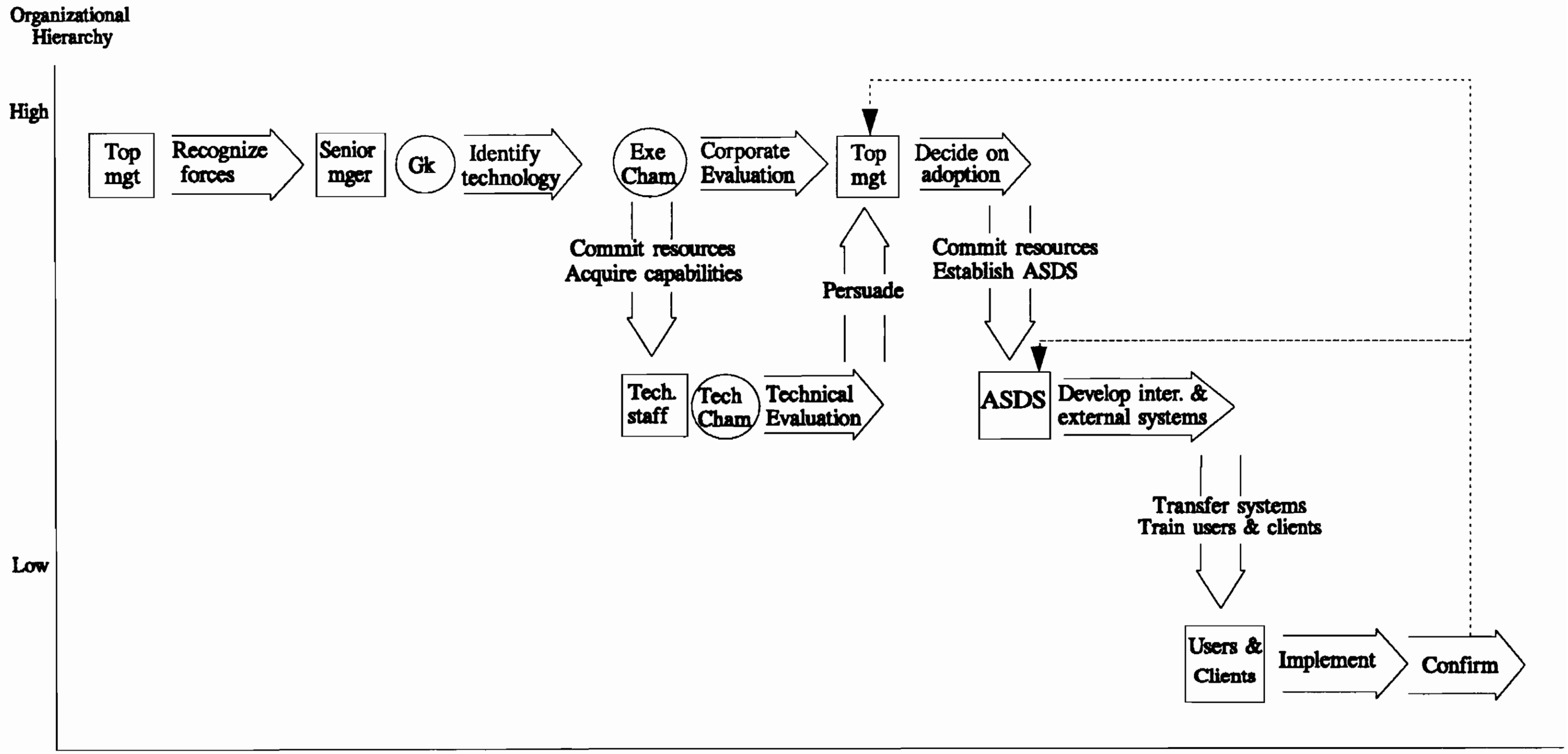
Until today, ASDS has developed a significant number of client-financed and in-house funded expert systems in the areas of construction, structural and mechanical engineering, which support all the areas of the firm's operations.

5.2.2 Comparison with T^2 beta model

The T^2 process in S&W follows the top-down approach of the T^2 beta model, and the implementation strategy in S&W is similar to the strategic approach. The following stages of the T^2 process in S&W have been identified, as shown in Figure 5.2: 1) recognize forces for exploring new technologies; 2) identify ES technology; 3) commit initial resources; 4) acquire in-house ES capabilities; 5) evaluate ES technology; 6) decide on adoption; 7) develop and implement systems; and 8) confirm technology's value.

Recognize forces for exploring new technologies. Senior management's recognition of the technology's importance for the company's future has been the primary force which led S&W to investigate new technologies. As a result, S&W is continuously looking for technologies which can provide the company with a competitive edge.

Identify ES technology. The role of the technology gatekeeper was performed by an executive manager at the Engineering Corp. who initiated the investigation of ES technology. Although at that time, the technology was in its early stages of commercial development, the gatekeeper's technological capabilities enabled him to foresee its



Stages	Recognize forces	Identify technology	Commit Resources	Acquire capabilities	Evaluate technology	Decide adoption	Develop & implement systems	Confirm
Actors	Top mgt	Exe. manager	Top mgt	Additional staff	Top mgt / ES group	Top mgt	ASDS / End-users / clients	Clients & organization
Roles		Gatekeeper	Champion		Tech. & Exe. Champion		Developers / Users	

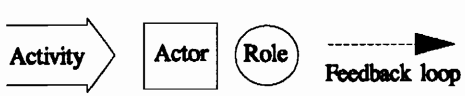


Figure 5.2 T^2 process in Stone & Webster Engineering Corp.

potential.

Commit initial resources. The position of the gatekeeper enabled him to become the executive champion of the technology and persuade senior management to provide the required financial resources.

Acquire in-house ES capabilities. The acquisition of the required ES development capabilities has been the next step of the T^2 process. This has been accomplished with the recruitment of additional technical staff who became the technical champion of ES technology in S&W.

Evaluate ES technology. The technological evaluation was performed with the development of an equipment diagnostic prototype system in the centrifugal pumps domain. Although the development of this first application verified the potential of the technology and raised top management's enthusiasm, the state of maturity of the technology created limitations for its wide use in engineering applications. However, the development of new PC-based ES tools uncovered the opportunities ES technology offered.

Decide on adoption. As a result of the evaluation S&W's senior management identified the opportunity ES technology offered for supporting both clients' needs as well as internal engineering operations. Thus, the ASDS division was established in order to develop and market new software products, and provide consulting services to clients. An additional benefit management expected was that many of the ASDS's clients would become mainstream S&W clients.

Develop and implement systems. S&W follows the strategic implementation approach. ASDS develops the ES applications needed both by the firm and the clients. For the development of an internal system, senior management evaluates the potential applications and subsequently, commits the required human and financial resources. Subsequently, the systems are transferred to the clients or the end-users in the firm who are provided with training and support throughout the implementation.

The factors that affect the success of the implementation strategy are the following: 1) the explicit support of new technologies from top management who has recognized ES as of strategic importance for the firm's future; 2) division managers technological awareness; 3) the involvement of end-users in the development of the systems; and 4) the evolutionary strategy S&W adopted. S&W believes that companies embarking on ES technology should follow an evolutionary, as opposed to revolutionary, approach to avoid discontinuance or disenchantment from the failure of the first application.

Confirm technology's value. S&W has identified several benefits from the adoption of ES technology. The retention of S&W's valuable expertise is considered the most important benefit from the internal use of ES technology. This enables the company to make better utilization of its human assets, and respond to the changing market environment with products and services of lower cost and higher quality. The creation of a new business line which resulted in additional profits for the firm is another major benefit from ES adoption. S&W is today one of the pioneers in software development for engineering systems.

5.2.3 Factors affecting ES T^2 in S&W

The following factors have contributed the most to the successful adoption of ES at S&W: 1) corporate commitment to technology; 2) organizational environment; 3) position of technology gatekeeper; 4) organizational technological capabilities; 5) stage of development of ES technology; and 6) quality of ASDS employees.

Corporate commitment to technology. Top management has recognized the importance of new technology in achieving the business objectives, and has developed a proactive technology strategy focusing on customers' needs.

Organizational environment. As a result of top management's commitment, the entire organization is actively looking for new technologies. While ASDS focuses on computer-technology applications, other groups are also looking for innovation that can improve S&W's operations. Such a group is the Construction Innovation Committee which is chartered with the objective of finding better ways of executing construction.

Position of the technology gatekeeper. ASDS's strategic position enables it identify those technologies which better serve the clients' needs and the engineering operations.

Organizational technological capabilities. The company's managers have strong technical background, and are kept abreast of new information technologies. Additionally, the employees recruited in the ASDS group have a strong engineering background before they work in Computer-Aided Engineering and become Systems Engineering Application specialists.

Stage of development of ES technology. The evolution of ES technology enabled its wide implementation in engineering applications and its integration with other information technologies.

Quality of employees. Last but not least, S&W believes that the quality and motivation of the employees is a major factor for the success of the ASDS division and the organization overall.

This case study highlights two new findings: 1) the adoption of ES technology by an engineering/construction firm for creating a new business line; and 2) the importance of staffing the AI group with individuals with strong background in engineering, which enables the system developers to better understand the end-users' needs.

5.3 ES Implementation in CRS Sirrine

CRS Sirrine (CRSS) is one of the top ten US AEC companies, with 10,3 billion dollars in contracts during 1990 (ENR 1991). Its operations include architecture, engineering, design and project management services for a large gamut of projects including power, industrial, pharmaceutical, food production and other facilities.

5.3.1 Description

CRSS has always recognized the importance of advanced technology in satisfying customers needs and improving its competitive position. As a result, CRSS top and middle management are continuously looking for new technologies and how they can support the company's business objectives. The Industrial Division of CRSS is a leader in the search of advanced technologies. This role is performed by the Integrated Systems Services (ISS) group, which is part of the Computer Integrated Manufacturing (CIM) department. ISS is continuously investigating state-of-the-art technologies and looking for new ways to support both customers needs as well as internal operations.

The CRSS technological strategy and the high technological capabilities of middle managers resulted to the identification and adoption of ES technology. In 1989, Mr. Hansel McAbee, manager of CIM, first initiated an investigation of ES technology. His continuous interaction with sources of technology (software developers, competitors, etc.)

as well as his technological knowledge and background enabled him to identify the technology and appreciate its importance for improving the company's services to clients.

With top management's support, and especially the support of the Vice President for Processing and Manufacturing Technology, the necessary resources for the evaluation of ES technology were committed. The resources included both the financial resources as well as the time of some employees in order to be trained in ES tools and techniques.

After the initial ES development capabilities had been acquired, the evaluation of ES technology followed, which included the acquisition of and experimentation with several ES tools, and development of demos. The evaluation of the technology revealed the opportunity ES offered for enhancing the quality of the product and services CRSS provides to its customers. With continuous training and experimentation more people in the ISS group have become involved in ES development. Today, the ISS group consists of eighteen employees, with five of them experienced in ES development.

Based on the evaluation of the technology, CRSS decided to deploy ES techniques as another means to support the clients' operations. Thus, although ISS is planning to develop ES applications for internal use, it is proposing to develop primarily external ES applications that enable the customers of CRSS Industrial Division to improve the effectiveness and efficiency of their operations.

CRSS pays much attention to informing and educating its customers on state-of-the-art technologies and how they can enhance their industrial operations. This is accomplished with the establishment of the Emerging Technologies seminars that CRSS offers to its clients. Thus, before developing an external system, CRSS informs its customers about the potential of ES and how they may assist their operations, such as in production scheduling, maintenance, quality control and other applications. Subsequently, if a customer is interested in an application, a proposal to the customer follows concerning the cost and development time of the system. After the development of a system, CIM also provides assistance to the client in the implementation and maintenance of the system.

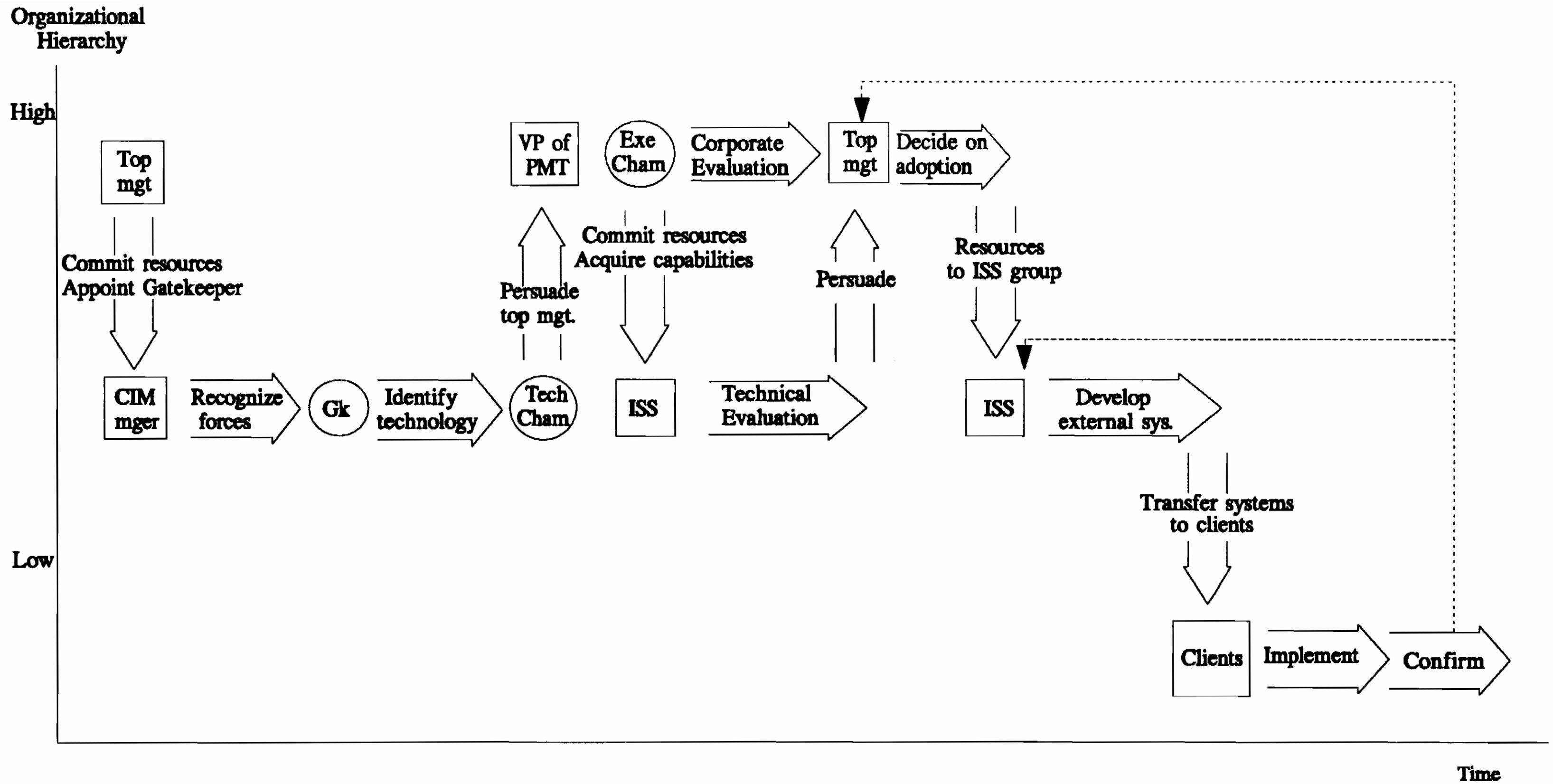
CRSS management is sold on the importance of ES technology for gaining competitive advantage both by offering new services to its clients as well as by improving the company's technological position and image to the clients. As a result of this confirmation, top management continuous to increase the company's ES development capabilities both by hiring people with experience in ES development, as well as by allocating a budget for employees on-going training.

Furthermore, the ISS group continuous to examine potential ES applications for internal use in order to improve the company's managerial and operational performance. Internal applications include systems to assist in training junior engineers, staffing project teams, equipment maintenance, and others. The development of applications for internal use is funded by the company's overhead budget. However, the current external orientation of the ISS group does not always allow enough time for more extensive development of internal systems.

5.3.2 Comparison with T^2 beta model

The T^2 process in CRSS follows the bottom-up approach of the T^2 beta model. The following stages of the T^2 process in CRSS have been identified, as shown in Figure 5.3: 1) recognize forces for exploring new technologies; 2) identify ES technology; 3) commit initial resources; 4) acquire ES capabilities; 5) evaluate ES technology; 6) decide on adoption; 7) develop and implement systems; and 8) confirm technology's value.

Recognize forces for exploring new technologies. Several forces have led CRSS to investigate the potential of emerging technologies. The most important force is the company's focus in providing more services to its customers. In this way, CRSS top management is receptive to technologies that can contribute in satisfying customers needs. Middle management's positive attitude to technology is another significant force for investigating new technologies. Finally, the knowledge that other large AEC firms are using emerging technologies to improve their competitive position, created an additional force to CRSS for investigating state-of-the-art technologies.



Stages	Recognize forces	Identify technology	Commit resources	Acquire ES capabilities	Technical and corporate evaluation	Decide external adoption	Develop & implement systems	Confirm
Actors	Top & middle management	CIM manager	Top mgt / VP of PMT	ISS / In-house	Top mgt / ISS	Top mgt	ISS / Clients	Top mgt / ISS / Clients
Roles		Gatekeeper	Exe Champion		Tech. & Exe. Champion		Developers / Users	

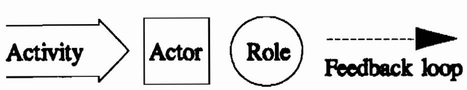


Figure 5.3 T^2 process in CRS Sirrine.

As a result of the above forces, the ISS group was established under the CIM in order to identify and evaluate the potential of new computer technologies, and develop computer application for marketing and internal use.

Identify ES technology. In CRSS, the role of the technology gatekeeper was performed by Hansel McAbee, the manager of the CIM department. His technological capabilities and his continuous contact with external sources of information enabled him to identify and experiment with ES technology.

Commit initial resources. Hansel McAbee subsequently took the role of the champion of ES technology in CRSS. With the support of the Vice President of Processing and Manufacturing Technology, who took the role of the executive champion, the first resources were committed to the technology.

Acquire ES capabilities. The initial resources enabled CRSS to acquire in-house ES development capabilities by providing the resources for training some already computer-educated employees in ES tools and techniques.

Evaluate ES technology. The initial resources also enabled the evaluation of ES technology. This was performed with the acquisition of the first ES tools and the development of some prototype systems in-house. This was a period of experimentation and development of additional capabilities, as more people in the ISS group became involved.

Decide on adoption. After the evaluation of the technology had proven the high potential of ES, the decision was made for the adoption of the technology. The decision was based on the belief that ES can contribute to the improvement of the competitive position of CRSS in the following ways: 1) provide additional services to customers by assisting them in improving their operations; 2) improve the company's technological image to the clients; and 3) establish a new product line and an additional source of income for CRSS.

Develop and implement systems. The development of ES applications in CRSS is driven by the customers needs. Thus, CRSS has adopted the strategic implementation approach. The ISS group is responsible for developing the required ES applications. To accomplish this, the ISS group continues to expand its ES development capabilities. This is accomplished in two ways: 1) by hiring employees already experienced in ES techniques; and 2) by providing additional training to more ISS employees.

Confirm technology's value. Until today, only a few external applications have been completed. However, the positive clients' reaction has convinced CRSS' top management that ES technology is an important means for gaining competitive advantage. Thus, management continues to allocate a significant budget for employee training in ES tools. Additionally, ISS has started investigating more thoroughly the potential of ES for internal applications that will improve CRSS' engineering operations. Currently, the ISS group is experimenting with applications that can assist in equipment maintenance, training junior engineers, staffing project teams, etc.

5.3.3 Factors affecting ES T^2 in CRSS

The following factors have contributed to the successful adoption of ES technology at CRSS: 1) company's focus on clients' needs; 2) organizational technological capabilities; 3) position of technology gatekeeper; and 4) stage of development of ES technology.

Company's focus on clients needs. CRSS' commitment to the customer is not limited in providing high quality product, but extends to assisting the clients during their operations. Thus, CRSS is continuously searching for ways to provide its customers with additional services.

Organizational technological capabilities. The strong technological background of department managers enables them recognize the importance of emerging technologies for satisfying customers' needs. Additionally, the technological capabilities of the employees enabled CRSS to acquire the necessary ES development capabilities in-house.

Position of technology gatekeeper. In CRSS, the role of the gatekeeper for computer technologies is executed by the CIM department. Thus, the fact that ES technology was identified and championed by the manager of CIM reduced the possibility for rejection of the technology by top management.

Stage of development of ES technology. The reduced limitations of the technology enabled CRSS to develop in a short period of time, and with relatively small expenses, its own in-house ES development capabilities.

The case of CRS Sirrine verifies some of the findings of the previous case studies. In addition to the S&W case, this case illustrates that ES technology provides an AEC firm with the opportunity to establish a new business line and provide additional services to its customers.

5.4 Comparison of the T^2 Processes in the Three AEC Firms

In the following section, the similarities and differences of the three T^2 case studies are identified. The characteristics of the T^2 process in each firm, and the actions that each organization performed at each stage of the process are summarized in Table 5.1.

Table 5.1 Characteristics of T^2 case studies.

	AEC Firm / T^2 stages	Morrison Knudsen	Stone & Webster	CRS Sirrine
	Forces for exploring new technologies	Top mgt's attitude to technology Proactive technology strategy Improvement of operations Project demands	Top mgt's attitude to technology Proactive technology strategy Improvement of operations Client's needs	Middle mgt's attitude to tech. Proactive technology strategy Improvement of operations Client's needs
	Gatekeeping	IST manager	Executive manager	CIM manager
	Source of funding for evaluation	Client funded projects IST own resources	Company's overhead budget	Company's overhead budget
	Acquisition of capabilities	Existing in IST	Hiring additional staff	Training ISS personnel Hiring additional staff
	Evaluation	IST group Client's projects Top mgt's participation	ASDS group Prototype development Top mgt's participation	ISS group Prototypes for demos Top mgt's participation
	Decision for adoption	External systems: Firm's technological image Additional services to clients New business line Internal systems: Improve training Automate complex tasks	External systems: Firm's technological image Additional services to clients New business line Internal systems: Maintain organiz. expertise Automate tasks and processes	External systems: Firm's technological image Additional services to clients New business line Internal systems: Not decided yet Currently at evaluation stage
Systems development and implementation	Development strategy	IST & clients identify needs IST develops systems centrally	ASDS & clients identify needs ASDS develops systems centrally	ISS & clients identify needs ISS develops systems centrally
	Type of internal applications	Tactical Evolutionary development	Tactical and strategic Evolutionary development	Internal application not completed yet
	Resources	Company's overhead IST own resources	Company's overhead	-
	Factors affecting implementation	Top mgt's explicit support Middle mgt's support End-users acceptance Organizational commitment to innovation Evolutionary strategy	Top mgt's explicit support Middle mgt's support End-users acceptance Organizational commitment to innovation Evolutionary strategy	-
	Benefits confirmed	Improved technological image New source of income Improvements in operations	Improved technological image New source of income Improvements in operations	Initial positive reactions from clients

5.4.1 Forces for exploring new technologies

The following forces for exploring new technologies have been identified:

1. Top management's technological background and appreciation of technology as means for gaining competitive advantage has been the primary force for the investigation of emerging technologies. As a result, in all three firms top management adopted a proactive technology strategy, either by initiating an investigation of new technologies, or by authorizing and supporting it.
2. The complexity of the projects and the engineering operations has created a strong demand for new methods and tools;
3. A commitment to client is another common characteristic. All three firms are continuously looking for ways to improve and expand the services they provide to their clients.
4. The existence of individuals with strong motivation to improve the company's current operations.
5. Finally, the adoption of the technology by the competition has forced firms to investigate new technologies.

5.4.2 Technology gatekeeping

The appointment of a computer group with adequate technological capabilities to the role of the technology gatekeeper was a common action in all three cases. The strategic position of this organizational unit enables it to identify the needs of both the firm and the clients. This unit is also responsible for the development of the computer applications required to support the firm's internal engineering operations.

5.4.3 Source of funding for evaluation of ES technology

From the case studies, different sources of funding the evaluation of new technologies have been identified:

1. the company's overhead budget;
2. a project's budget in cooperation with the client; and
3. freedom of the gatekeeping unit to allocate its own resources.

5.4.4 Acquisition of in-house capabilities

In all cases, the AEC firms acquired their own in-house ES development capabilities either by hiring additional staff experienced in ES development, or by training personnel in ES tools. The evolution of ES technology reduces the capabilities required for ES development, thus reducing the cost and time of training. However, all firms already had personnel with background in software development.

5.4.5 Evaluation of ES technology

The technical evaluation was performed by each firm's appointed computer group. The prototype systems developed during the evaluation addressed a real world application. Top management's participation at this stage enabled them identify the potential business benefits from the adoption of the technology.

5.4.6 Reasons for adopting ES technology

The top management at each firm identified several opportunities ES offered to improve the firm's competitive position. The expected benefits from the development of external and internal systems are summarized as follows:

Benefits expected from development of external systems:

1. provide new services to customers by assisting them in their operations;
2. improve the firm's technological image to clients, thus attracting more clients; and
3. establish a new business line, thus increasing the company's income.

Benefits expected from development of internal systems:

1. improve the engineering operations by automating complex and unstructured tasks;
2. improve the quality of the product and engineering services the company offers;
3. retention of organizational expertise; and

5. better utilization of the company's human resources, by improving and accelerating the training of entry level personnel.

5.4.7 ES development strategy

In the three AEC firms studied, the development of both the external and internal ES applications is performed in-house centrally by the appointed computer groups. The development of an external application takes place as a typical software development project, with the client providing the required funding. The development of an internal application is funded either from the company's overhead budget, or the group's resources, when the development group has the freedom to allocate its own resources.

The factors that have been identified as contributing to acceptance and successful implementation of ES in the firms are the following:

1. the strategic position of the computer groups and their involvement in the engineering operations of the firm which enables them to identify the users needs, and evaluate and select applications;
2. top management's continuous and explicit support of the technology;
3. the evolutionary development of internal applications, that is, the initial development of small, tactical systems which address a real end-users' need. In this way, the risk of failure of an application is limited and the impact on the operations is small. After the technology has proven its potential, the

development of strategic systems (applications with a significant impact on the company's operations) can follow with higher possibility for success;

4. middle management's and engineering personnel's acceptance of technology. In the studied firms, employees share top management's motivation for innovation and are looking for opportunities to implement new technologies.

5.4.8 Benefits identified from ES adoption

The major benefits identified from the adoption of ES technology are the following:

1. the improved technological image resulted in attracting more customers;
2. the new software services offered by the AEC firms resulted in creating a new source of income. Also, some of the software clients became mainstream clients of the firms' engineering services;
3. the automation of complex tasks and processes as well as the improvements in training resulted in improvements in the quality of the firm's product, cost savings and better utilization of the company's human resources.

As the technology has proven its value, the early adopters of ES technology continue to investigate and reveal new opportunities for further benefits. For example, the integration of ES with other computer technologies and the automation of entire processes are envisioned not only to create large cost savings, but to have a significant impact on the basis of competition of the entire industry.

The analysis and comparison of the case studies of ES implementation, has resulted in the following: 1) more thorough understanding of the factors affecting the T^2 process; 2) development of a refined T^2 model for ES technology; and 3) identification of alternative strategies that AEC firms can follow in order to successfully adopt ES technology.

In the next chapter, a model of factors affecting the adoption and successful implementation of ES technology is presented. Finally, chapter seven presents the stages of the T^2 process as well the "flavors" from which managers can choose to introduce ES technology in their firms.

6. Factors Affecting ES Adoption

In the previous chapters, nine cases of ES implementation have been studied and the major stages of the T^2 process have been identified. The analysis of the cases has revealed that despite the differences in the T^2 processes, the studied organizations present common characteristics which led top management to adopt ES technology. However, as demonstrated in the cases, the different organizational, technological and economical conditions in each company have required different implementation strategies. In order to increase the likelihood of successful adoption, it is necessary to identify those factors that facilitate or impede the implementation of ES technology in an organization.

This chapter consists of two sections. The first section presents a model of factors affecting the transfer of ES technology in an organizational setting. The second section identifies the characteristics of the US AEC industry which create barriers to the adoption of ES technology.

6.1 Model of Factors Affecting T^2 of ES

The model presented in this section identifies the factors affecting top management's decision to adopt or reject ES technology, as well as the factors affecting the success of T^2 in an organization. As illustrated in Figure 6.1, top management's attitude towards technology, environmental factors, organizational factors, and technological factors influence top management's decision to adopt ES technology. The decision on adoption is based on the perceived attributes of the technology and the financial risk involved in the decision. However, the decision to adopt ES technology is not sufficient for the success of the T^2. For ES technology to contribute to the improvement of the organizational performance, the following requirements must also be satisfied: 1) the ES applications must have real value for the organization; 2) the applications must be technically correct; and 3) the applications must be properly utilized by the end-users. Finally, top management evaluates the technology's contribution to the improvement of the organizational performance, and decides whether the technology will continue to be used or not. In the following sections, the factors affecting the adoption and implementation of ES are analyzed.

6.1.1 Top management's attitude towards technology

Top management is the group who decides whether ES technology will be adopted or not. Thus, management's attitude towards technology is the primary factor affecting its

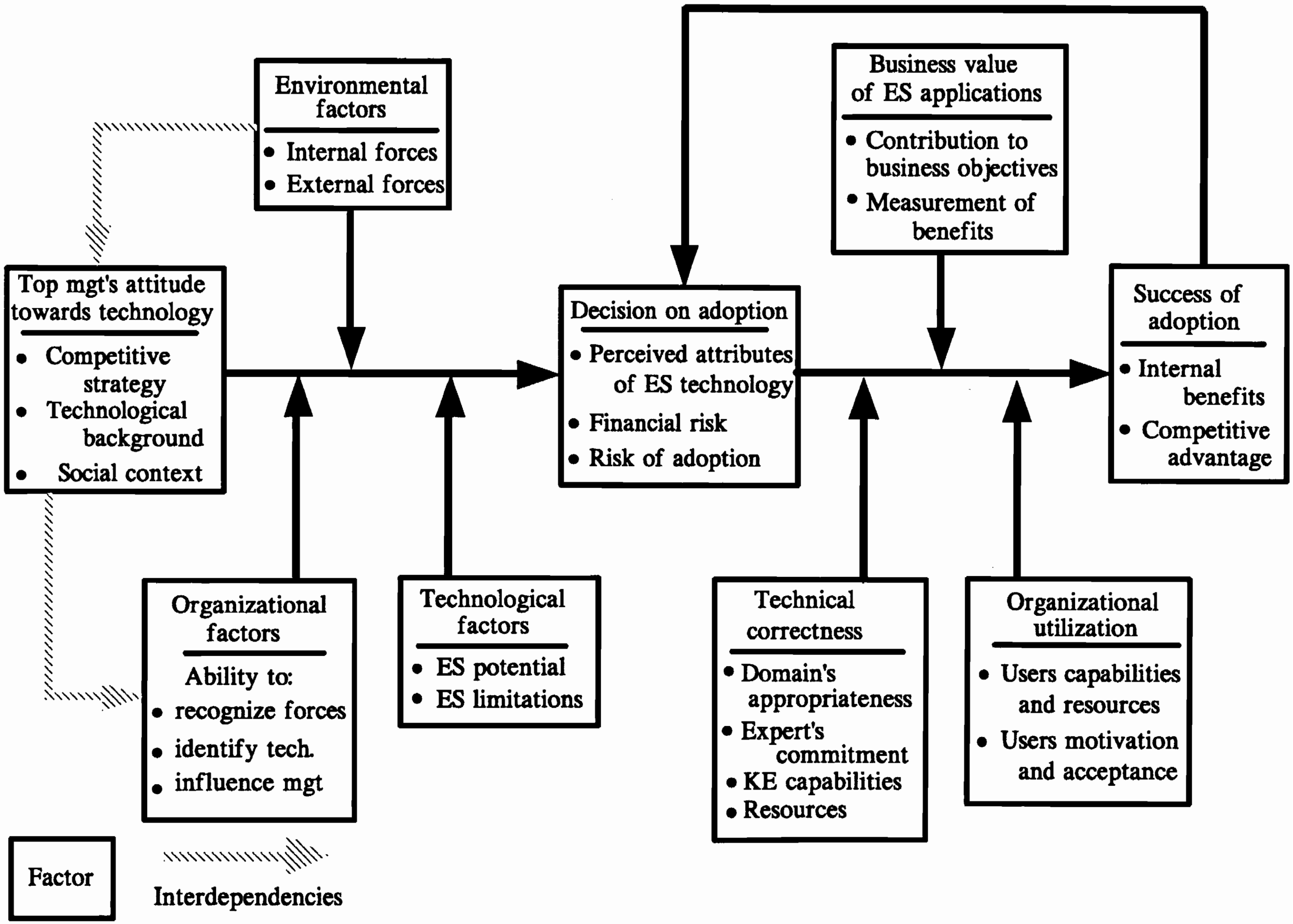


Figure 6.1 Model of factors affecting T^2 of ES.

behavior, that is the decision on adoption or rejection of the technology. Top management's attitude towards technology is the degree to which top management believes that new technologies are important for achieving the business objectives. As depicted in Figure 6.2, the primary factors which shape top management's attitude are: 1) firm's competitive strategy; 2) top management's technological background; and 3) the social context.

Competitive strategy. The firm's competitive strategy determines in large degree how important top management considers new technologies for gaining competitive advantage. Thus, a strategy focusing on cost leadership may impede the adoption of new, untested technologies because they result in disruption of learning curves and reduced efficiency. On the contrary, when top management emphasizes differentiation, new technologies are viewed as an opportunity for the firm to provide new, unique services to customers and increase its image.

Management's technological background. Strong technological background and capabilities enable top management understand the potential of new technologies and how they can contribute to the accomplishment of business objectives. For example, the technological capabilities of a senior manager in S&W enabled him identify ES technology and foresee its potential.

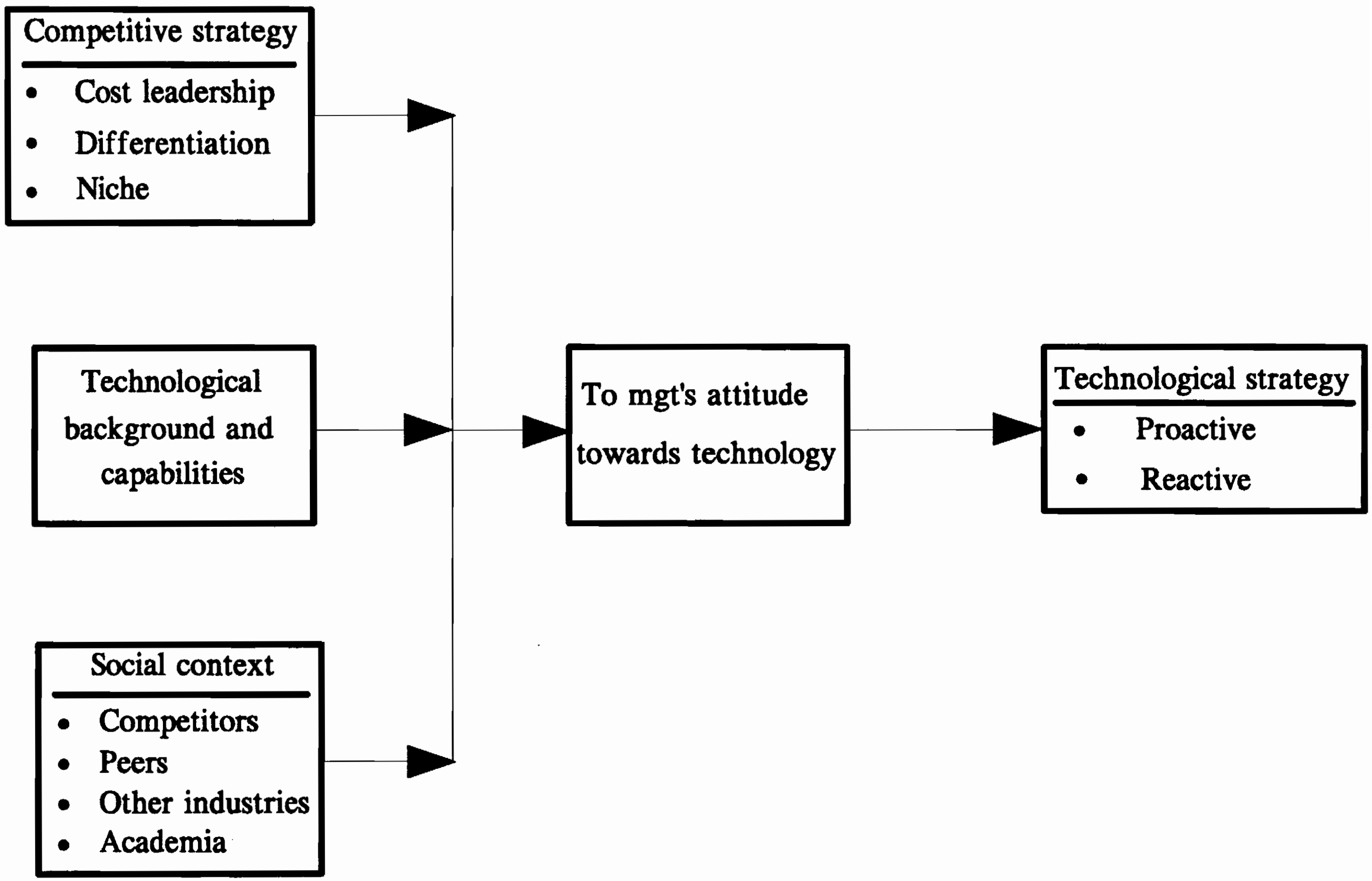


Figure 6.2 Factors affecting top management's attitude towards technology.

Social context. The social context provides information which influences top management's attitude. Sources of information include peers and competitors, other industries, universities, mass media, etc, and have different influence over top management's attitude. Top management appears to be more influenced from information coming from competitors, peers, and industry opinion leaders, than information coming from other industries, universities, etc.

Top management's attitude towards technology results in the development of the organization's technological strategy. Positive attitude leads to a proactive strategy. As the cases of MK and S&W demonstrate, top management commits the human and financial resources for investigating how new technologies can support the firm's objectives. Reactive strategy results from a negative or indifferent attitude and constitutes in other words, lack of a technology strategy. In this case, a technology will be adopted only if other factors create forces strong enough to overcome this attitude.

6.1.2 Environmental factors

The business environment creates strong forces which influence top management's decision to adopt/reject a technology. As Figure 6.3 depicts, the business environment includes both the internal and external forces applied on the organization.

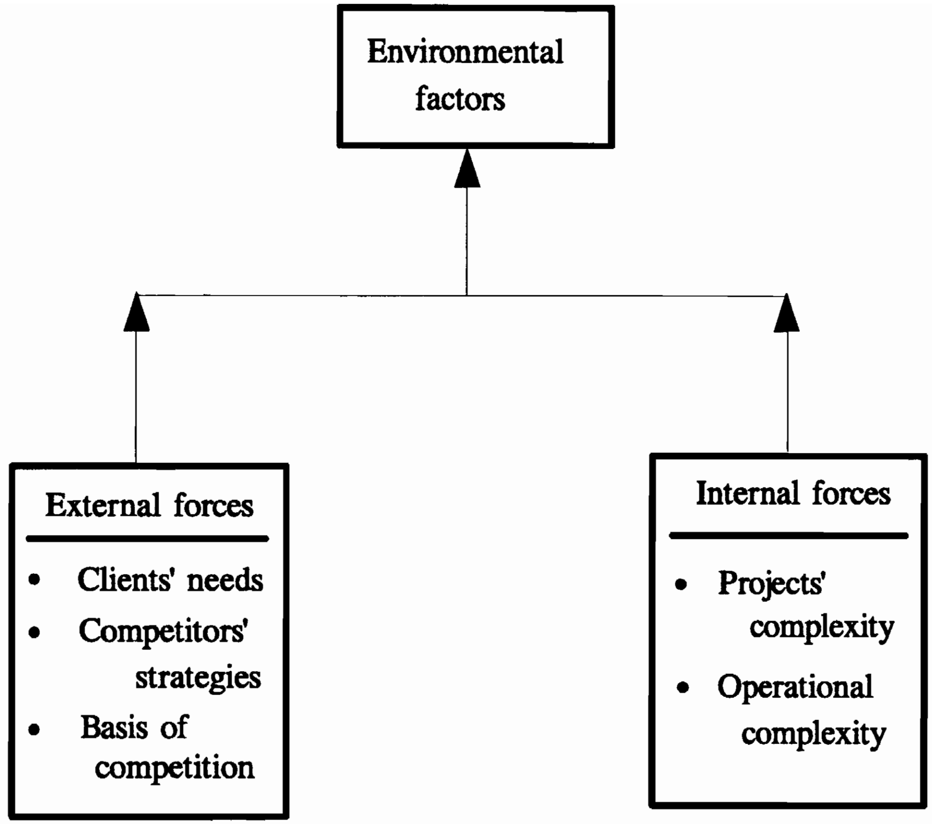


Figure 6.3 Environmental factors affecting the T^2 process.

Internal forces. The increasing technical complexity of projects and internal operations present strong demands for adoption of advanced technologies. For example, a project's complexity led MK to identify and adopt ES technology. The identification of operational problems as well as the potential for improvement of the firm's tasks and processes also create forces for its adoption. For example, the opportunity for automating some of the engineering operations led Kajima to adopt ES technology.

External forces. The clients' needs and the industry's basis of competition constitute the external forces that influence top management's decision to adopt a new technology. The increasing technological sophistication of clients creates higher demands for use of advanced technologies by AEC firms. Furthermore, the clients' operational needs present new opportunities for AEC firms to adopt state-of-the-art technologies and provide their clients with additional services. For example, the adoption of ES by S&W and CRSS was driven by the clients' operational needs.

The changing basis of competition present another type of pressure for adoption of new technologies. The basis of competition is influenced by the competitors' strategies as well as by special characteristics of the industry. Until recently, non-technological advantages have dominated the competition in the US AEC industry, such as the ability to manage organized labor or train open-shop labor, scope of services offered, familiarity with the type of project or local area and administrative strengths (Hansen and Tatum 1989). However, the successful competitive strategies of foreign firms which are partly based on technological advantages, are forcing US firms to adopt advanced technologies in order to maintain their competitive position in the international and domestic market. In this way, the external forces influence in some degree the competitive strategy of the firms, and in turn, top management's attitude towards technology.

6.1.3 Organizational factors

The organizational factors affecting the adoption of new technologies, as shown in Figure 6.4, are: 1) ability to identify forces and opportunities; 2) ability to identify and evaluate new technology; and 3) ability to influence top management's decision. These factors define the potential for innovation within an organization.

Ability to identify forces and opportunities. A force or opportunity for change must be identified before top management decide to adopt a new technology. According to the firm's competitive strategy, top management is sensitive to different forces. Thus, in innovative firms, such as MK, S&W, CRSS and Kajima, top management is very sensitive to clients' needs, and opportunities for operational improvements even if a pressing problem does not yet exist. Less innovative companies resist the adoption of new technologies unless they become a norm for the industry.

Ability to identify and evaluate new technology. The organization's ability to identify and evaluate new technologies depends on the following factors: 1) existence of

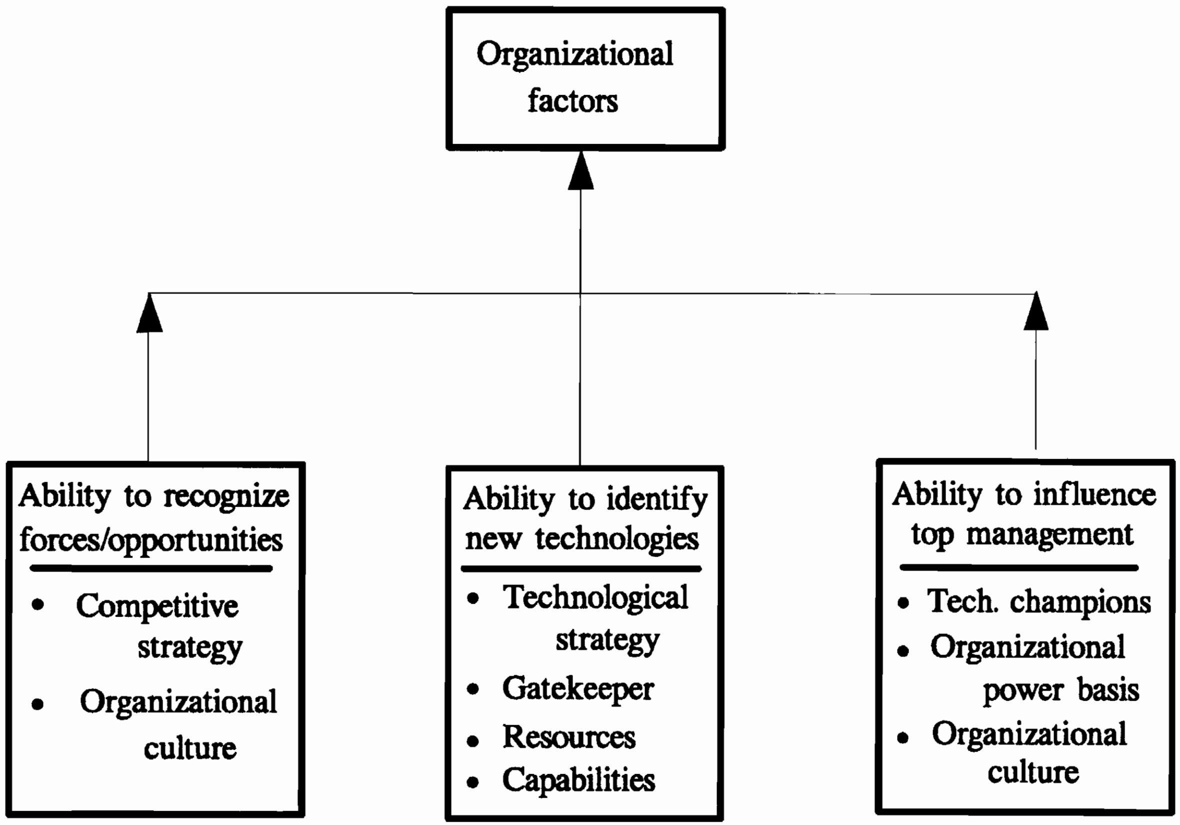


Figure 6.4 Organizational factors affecting the T^2 process.

technology gatekeepers; 2) in-house technological capabilities; and 3) availability of resources.

The technology gatekeepers are the external linkages of the organization with the sources of new technology, such as vendors, universities, and other industries. The role of the gatekeeper may be performed by appointed individuals or groups, or by any other individual highly motivated to keep up with technological developments. The technological capabilities and high position of the gatekeepers in the organizational hierarchy in du Pont and S&W enabled them understand the potential of the technology and how it can serve the business objectives. Finally, human and financial resources are also required for the identification and evaluation of new technologies.

Top management's attitude towards technology affects the organization's ability to identify and adopt new technologies. As the case studies demonstrate, a proactive strategy results in the commitment of resources, acquisition of technological capabilities and appointment of gatekeepers, thus facilitating the identification of new technologies.

Ability to influence top management. The existence of technology champions creates another significant force that can influence top management's decision to adopt a new technology. The champions are individuals highly motivated to introduce a new technology in their firms, and go beyond (and sometimes against) what the organization requires from them. The influence that champions have over top management depends on the champions' credentials, their position in the organizational hierarchy as well as on the culture and characteristics of the organization.

The organizational culture significantly influences an organization's ability to innovate. The Construction Industry Institute (CII) has identified four types of cultures in engineering and construction firms: 1) the Adhocracy type, which encourages entrepreneurship and innovation; 2) the Clan type, which encourages participation and teamwork; 3) the Market type, which focuses on production and maximization of output; and 4) the Hierarchy type, which focuses on stability and is characterized by policies and procedures to secure standardization of behavior (Maloney and Federle 1990).

An entrepreneurial culture which values innovation and individual initiative (Adhocracy type) encourages and rewards individual efforts for introduction of new technologies. On the contrary, organizational cultures which emphasize stability and maximization of output or formal rules, procedures and hierarchy (Market or Hierarchy type) impede individual initiative and innovation.

6.1.4 Technological factors

As depicted in Figure 6.5, the potential and limitations of ES technology constitute the technological factors which facilitate or impede its adoption by an organization.

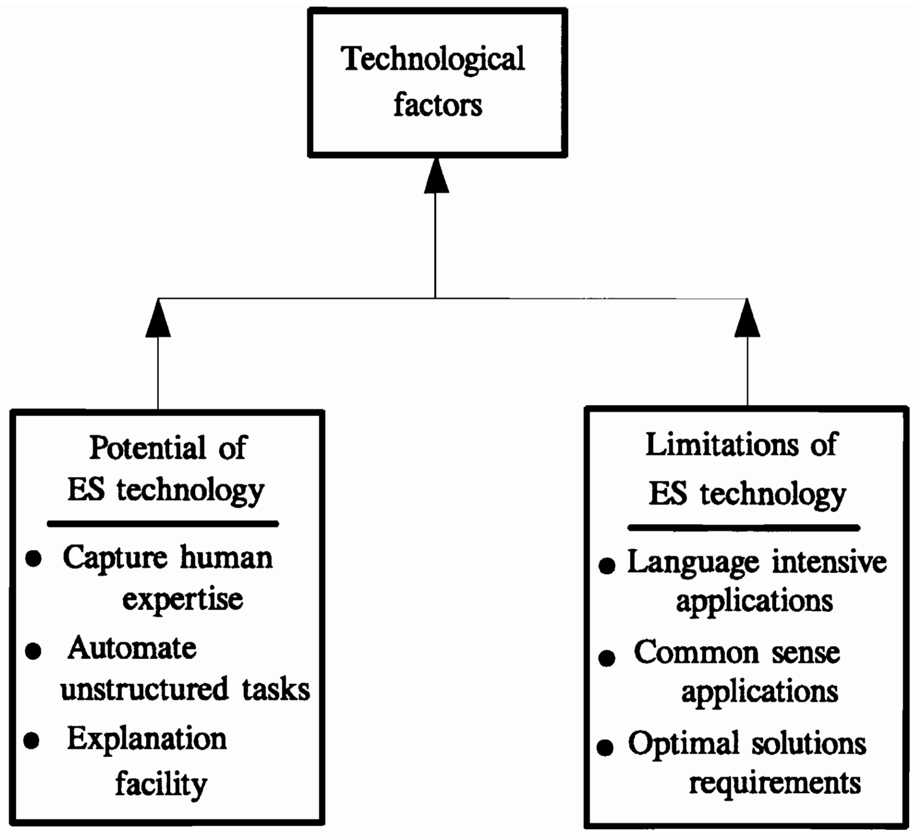


Figure 6.5 Technological factors affecting the T^2 process.

Potential of ES technology. Expert systems are computer programs incorporating judgement, rules of thumb, intuition and other expertise to provide knowledgeable advice about a variety of tasks (Fenves 1986). Thus, while ES are a branch of computer technology, they have distinct differences from other information technologies. Traditionally, information technology has made its greatest impact on well-structured decision processes. These activities constitute well defined optimization problems; the information needed to solve them are clearly identified and quantified, and the procedures for handling them are definite and organizationally independent.

Expert systems (knowledge technology) have the ability to automate the unstructured decision processes. These activities are characterized by lack of formalization, ambiguity as to the appropriate criteria for evaluating solutions, high complexity and large number of constraints to be satisfied. Unstructured decisions are organizationally dependent because the criteria for solution may differ from one organization to another.

Experts are the resources required for solving unstructured problems, thus an organization's ability to solve them depends on the existence and availability of experts. However, expertise requires years to be developed, and is usually a limited resource for many organizations. Thus, the experts may not be available when and where needed.

By capturing and automating human expertise, ES provide an organization with the ability to preserve the corporate knowledge and automate complex tasks. Thus, the importance of ES technology for an organization depends on the degree to which the organization needs to solve frequently unstructured problems as well as the availability of experts. Additionally, the ability to explain their line of reasoning makes ES a very important training tool.

Limitations of ES technology. Understanding the opportunity ES offer for organizational improvement is essential for the adoption of the technology. However, in order to avoid unrealistic expectations, management should be aware of the technological and economical limitations as well.

For a task to be appropriate for ES treatment, it must be sufficiently narrow and self-contained, and should not require knowledge from a large number of areas. Application tasks with the following characteristics are also inappropriate for ES technology: 1) language intensive applications; 2) application tasks that require reasoning with common sense; 3) tasks that require optimal solutions. Finally, tasks that change quickly and will not continue to be performed in the future are inappropriate for ES applications because they do not have the potential to generate payoffs over time (Prerau 1985).

The cost of the technology is another factor that affects the likelihood of its adoption. The cost of adoption includes all expenses related to the development and proper use of ES technology. It depends primarily on the stage of development of the technology, and secondarily on the company's existing in-house technological capabilities. Thus, when

ES technology was at its initial stage of development, the increased requirements for specialized software, hardware and capabilities for using it limited its adoption to only a few companies. As the technology has matured, the requirements for its adoption have been reduced and more companies have started investigating and adopting it.

6.1.5 Decision to adopt/reject ES technology

The actual decision for adoption of ES technology depends on top management's perception of the importance of the technology for the organization, as well as on the availability of resources and the financial risk involved in the decision.

Perceived attributes of technology. The management's attitude towards technology, as well as the environmental, organizational and technological factors identified previously, influence top management's perception of the importance of ES technology for the organization.

Rogers (Rogers 1983) has identified the following perceived characteristics of an innovation that contribute more to its adoption:

1. Relative advantage is the degree to which the new technology is perceived to be better than the one that precedes it. Thus, ES technology will be adopted more easily if it is perceived to be better than the decision-support systems an organization is currently using.

2. Compatibility is the degree to which the new technology is consistent with existing values, past experiences, and the needs of the adopting organization. Thus, ES technology is more likely to be adopted when it can satisfy a perceived organizational need.

3. Complexity is the degree to which a new technology is difficult to understand and use. Thus, the likelihood of adoption reduces when the technology is not understood.

4. Observability is the degree to which the results of a new technology are observable. Thus, high observability of positive outcomes increases the probability of adoption, while uncertainty regarding outcomes reduces it.

5. Triability is the degree with which new technology may be experimented on a trial basis. Thus, rapid prototyping of ES applications which can demonstrate the technology's use can significantly facilitate its adoption.

Financial risk. The decision for adoption of the technology is a decision for commitment of resources. Thus, the cost of adoption, the availability of resources and top management's view of risk ultimately influence the decision. However, as the case of Lend Lease demonstrates, top management's support and commitment of full scale resources are not sufficient for the success of the adoption. The following requirements must also be satisfied: the ES applications must have real value for the organization, the applications must be technically correct, and the applications must be properly utilized by the end-users. In order to increase the probability of success, management must evaluate the technological, business, and organizational risk involved in the adoption of ES technology.

6.1.6 Business value of ES applications

As mentioned earlier, the significance of ES technology lays in its ability to automate unstructured problems that until now could not be treated with traditional computer methods. However, for an ES application to have some value for the organization, it should contribute to the attainment of the company's business objectives. Thus, before a commitment of resources is made for the development of an application, management should identify the organizational benefits from automating the activities under consideration.

The benefits from automating an organizational activity have been expressed as follows (Mahler 1989):

Benefits = (Value of activity) x (Degree of improvement) x (# of activities)

Thus, ES applications with the highest potential of payoff are those that automate tasks of critical importance for the organization (strategic). However, the automation of activities of smaller importance but highly repetitive (tactical), may also contribute to significant payoffs.

However, for an ES application to generate benefits, it should also result in the improvement of the activity it automates. If an application does not improve the activity or the outcome decision in any way (quality, speed, etc.) it will not have any payoff. At this point two problems arise. First, the benefits from ES are difficult to quantify. As shown in Table 6.1, the benefits from decision support systems (DSS) are not only difficult to quantify, but also difficult to measure (Keen 1981). Second, managers must ensure that the applications are relevant to the organizational goals, and select those applications that better serve the business objectives.

Managers need a method to evaluate both the expected benefits from potential ES applications (so that they can commit resources only to systems that will payoff), as well as the actual benefits from an application. The method of Critical Success Factors (CSF) is a structured process that can assist managers in identifying which decisions and tasks are critical for the attainment of the organization's objectives, and developing measurements for their performance. In the following section, the CSF method is briefly discussed. An extended discussion of the method can be found in (Rockart 1979, Henderson, Rockart, and Sifonis 1984, and Bullen and Rockart 1981).

The CSF method was introduced by Dr. J. Rockart to assist managers define their information needs (Rockart 1979) and was expanded later to the identification of critical organizational decisions as well (Henderson, Rockart, and Sifonis 1984). Critical success factors are the limited areas in which satisfactory results will ensure successful

Table 6.1 Benefits from decision support systems (taken from Keen 1981).

	Benefits	Easy to measure?	Benefits can be quantified in a "bottom-line" figure?
1.	Increase in number of alternatives examined	Y	N
2.	Better understanding of the business	N	N
3.	Fast responce to unexpected situations	Y	N
4.	Ability to carry out ad hoc analysis	Y	N
5.	New insights and learning	N	N
6.	Improved communication	N	N
7.	Control	N	N
8.	Cost savings	Y	Y
9.	Better decisions	N	N
10.	More effective teamwork	N	N
11.	Time savings	Y	Y
12.	Making better use of data resource	Y	N

competitive performance for the individual, the department, or the entire organization.

Four different hierarchical levels of CSFs are identified: 1) industry level; 2) corporate level; 3) department level; and 4) individual level. Also, for any company, five prime sources of CSFs are described: 1) industry structure; 2) corporate strategy, industry position, and location of the firm; 3) environmental factors; 4) temporal factors; and 5) functional factors.

As illustrated in Figure 6.6, the development of CSFs follows a top-down approach. The industry structure dictate the CSFs at the industry level. Subsequently, industry CSFs and corporate strategy combined with temporal and environmental conditions determine the CSFs at the corporate level. Thus, each corporation in a specific environment has a unique set of CSFs. In turn, corporate CSFs become input for the determination of departmental CSFs. Each department or division also has a unique set of CSFs according to its function and environment and temporal conditions. In a similar way, each manager's CSFs are dictated by the departmental CSFs, the manager's role and responsibilities and other temporal and environmental factors.

After the CSFs are identified, critical measures are determined. This is important for an organization in order to define what constitutes success and what failure. When CSFs cannot be measured, subjective indicators, such as customer satisfaction surveys, can be used. An example of CSF measurements is illustrated in Table 6.2. In this example, the

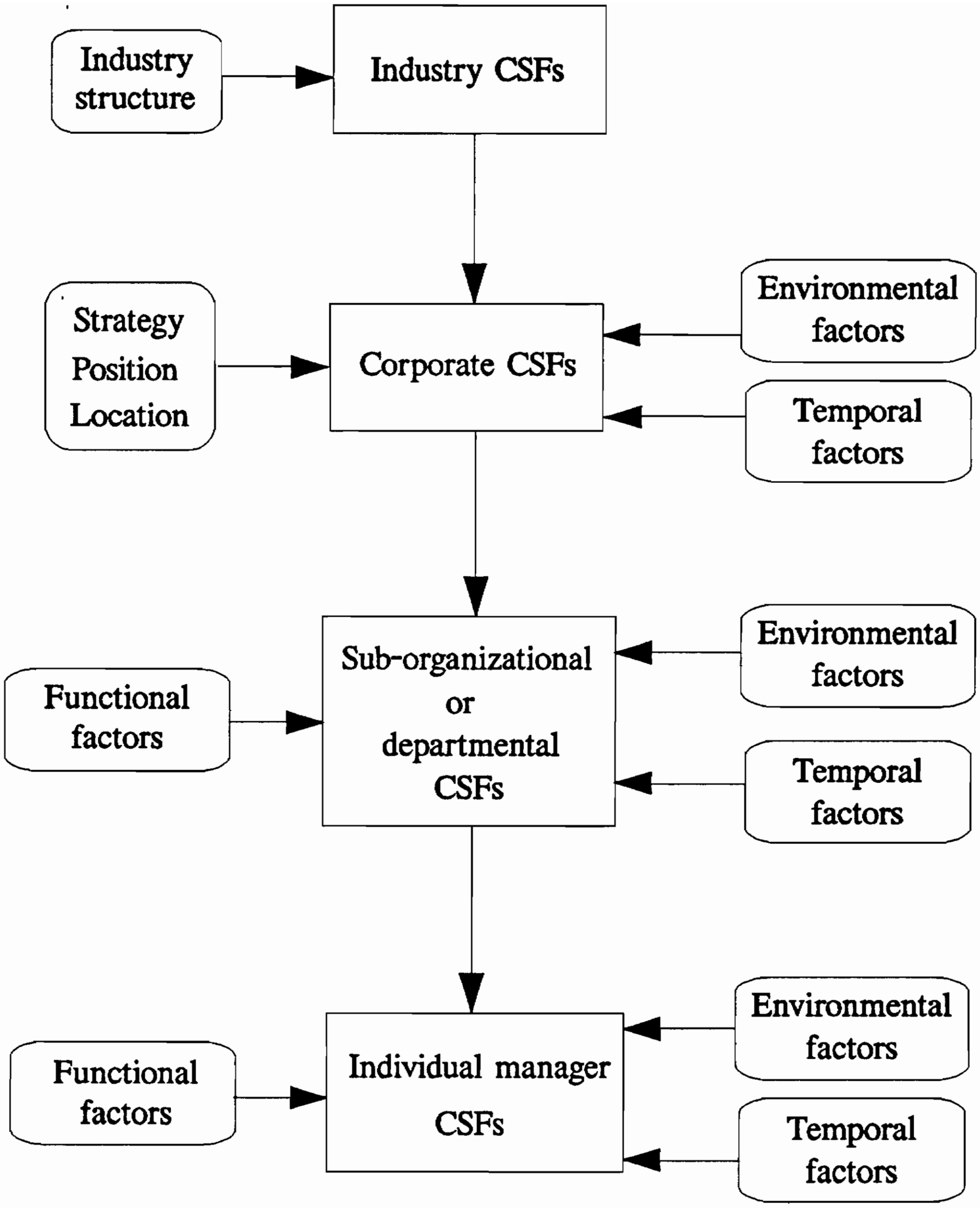


Figure 6.6 Hierarchy of critical success factors (adapted from Bullen and Rockart 1981)

Table 6.2 Example of CSF measures (taken from Rockart 1979)

Critical Success Factors	Prime Measures
1. Image in financial markets	Price/Earnings ratio
2. Technological reputation with customers	Total orders/Total bids ratio Customer "perception" interview results
3. Market success	Change in market share (each product)
4. Risk recognition in major bids and contracts	Company's years of experience with similar projects "New" or "old" customer Prior customer relation
5. Profit margin on jobs	Bid profit margin as ratio of profit in similar jobs in this product line
6. Company morale	Turnover, absenteeism, etc. Informal feedback
7. Performance to budget on major jobs	Job cost budgeted/actual

technological reputation with customers is a CSF for the firm, because a significant number of the firm's jobs requires state-of-the-art technology. Thus, customers' confidence in the company's technological capabilities is critical in order to attract this type of contracts. The two measures illustrated are two extremes of hard and soft data. The ratio of total orders to total bids is the hard measure and can be easily quantified. However, the most direct measure is the soft data provided by person-to-person interviews with customers.

After the measurements for each CSF have been defined, the Critical Decision Set (CDS) can be identified. The CDS includes those operations of the firm where improvement in decision making can significantly contribute to attainment of the CSFs. For example, if the need to obtain and retain skilled personnel is a critical success factor and training is a critical activity for the attainment of this goal, an expert system that improves training can be justified according to this CSF.
In this way, management can ensure that resources will be allocated only to those ES applications that can improve decision making in critical areas. By ensuring the business value of an ES application, managers reduce the business risk of the new technology, that is, whether the application will payoff for the company. However, to increase the probability of success of an ES application, the technical risk and the risk of acceptance must be also addressed.

6.1.7 Technical correctness

To reduce the technical risk of an ES application, management's attention is required on the following issues:

1. task appropriateness;
2. expert's existence and commitment;
3. adequate ES development capabilities; and
4. commitment of adequate resources.

Task appropriateness. The type of problem the application addresses must be suitable for ES technology with respect to the technology's limitations. Also, if a conventional (algorithmic) approach to the task is possible the technical risk will probably be less.

The size and complexity of the task must also be taken into consideration. Thus, the task must be difficult enough to require the presence of an expert, but not extremely difficult. As a guide, the task should take between fifteen (15) minutes and eight (8) hours for an expert to complete (Slagle and Wick 1988).

Expert's existence and commitment. A human expert is the source of expertise that will be embedded in the ES. The expert should be able to commit a substantial amount of time to the development of the system, and should be cooperative and eager to work on the project. Finally, the expert should be able to communicate his/her knowledge, judgement, and experience and the methods used to apply to the particular task.

Adequate ES development capabilities. The knowledge engineers are the specialists who extract the expert's knowledge and embed it in the application system. Therefore, adequate knowledge engineering capabilities are required for the successful development of the system. Failure to capture and represent the expert's knowledge, will result in reduced usefulness of the system. For example, an ES can be effective when used by the expert who provided the knowledge, but ineffective when used by others. Holes in the embedded knowledge that can be implicitly identified by the expert, may be invisible to a naive user and may lead to misuse.

The required capabilities depend on the state of development of ES technology as well as on the size and complexity of the selected application. When ES technology was at its initial stages, very experienced programmers were required for the development of even the simplest application. Today, with the development of easier-to-use computer tools, the capabilities required for ES development have been significantly reduced. Finally, the technical risk involved in an ES application is proportional to the size and complexity of the application.

Commitment of adequate resources. The state of development of the technology and the size of the ES application also affect the cost of the system and in turn, the financial risk involved in the development of the system. Thus, in order to minimize the financial risk, a firm can develop small, relatively simple applications which require less resources. This strategy is demonstrated in the Du Pont's case.

The financial investment required for the development of an ES also depends on the organization's in-house technological capabilities. Thus, when adequate in-house capabilities do not exist, the cost of development will be higher, because they have to be acquired, or the development of the system will be assigned to an outside group, like in the case of Lend Lease. Today, the maturity of ES technology enables a firm to acquire in-house capabilities with relatively small cost, either by hiring specialized personnel or by providing further training to computer educated employees.

6.1.8 Organizational utilization

The risk of organizational rejection is another critical issue that management must take into consideration when introducing ES technology in the organization. For an ES application to payoff, not only it should address a real business need and be technically correct, but it should also achieve full and proper utilization by their intended users. For this to be accomplished, the following requirements must be satisfied:

1. the users must be provided with the resources and capabilities required to use the system; and
2. the users must accept the system and be motivated to use it.

Resources and capabilities. For the successful implementation of the new technology, management must commit the resources required for the utilization of the system. These resources include the acquisition of software and hardware that will enable the intended users to access and use the system. In order to avoid misuse or rejection of the technology due to lack of understanding, management should also provide the users with adequate training and continuous technical support during the implementation.

Acceptance and motivation. The introduction of a new technology in an organization requires a change in the work behavior of the users. Users' acceptance is critical for the success of the adoption, because their rejection of the technology will result to misuse and discontinuance. In order to reduce the risk of rejection, management should be aware of the potential sources of resistance and the methods to overcome it. The sources of potential resistance to a new technology are both individual and organizational. Individual sources of resistance include economic factors, job security, fear of the unknown, lack of awareness, social factors, and work habit (Moorhead and Griffin 1989).

The new technology will be resisted if it threatens the job security of employees or if it disrupts the comfort and security involved in doing things the old way. Lack of awareness may lead to false perceptions and fears concerning the new technology. Thus, education and communication is necessary to dissipate these fears. Social factors also influence the attitude towards the technology. For example, employees may resist the change because it hurts their image among their peers or because of strong group norms.

Work habit may create strong resistance for change. When an individual has learned to do the job in a specific way, learning an entire new set of steps for performing the same job requires additional effort, thus making the job more difficult. Also, the unfamiliarity with the new method may create delays and a feeling that nothing is accomplished. However, if the individual has felt a need for improvement of the job due to problems or ineffectiveness of the old method it will be more motivated to use the new method.

Organizational factors which may impede the implementation of a new technology include threatened power and expertise, and structural and cultural characteristics of the organization.

Any redistribution of decision-making authority may threaten an individual's or group's power relations with others. For example, the impact of computer technology on decision making is demonstrated by: 1) an integration and consolidation of previously separated decision systems; 2) a shift in the locus of decision making in the organization; and 3) changes in decision making functions of middle and lower management, thus leading to shrinkage of middle management (Sankar 1991). By allowing information to flow freely from the shop floor to the executive without the editing, monitoring and second guessing that have been the primary function of middle management, they change both the nature and the need for middle management jobs, and lead to leaner corporate structures based less on hierarchy and more on flexibility. New knowledge technology may also threaten specialized expertise that individuals have developed over the years. For example, the implementation of an ES application may transfer the responsibility of a specialized task from a current expert to someone else, thus threatening the expert power of an individual or group.

The organizational structure is another important factor that influences the implementation of new technology because it affects management's ability to control the implementation process. Structures emphasizing hierarchy and authority facilitate the implementation of a new technology through the processes of formalization and centralization (Sankar 1991). Formalization provides the rules, procedures, and control for the implementation, while centralization provides the authority to mobilize resources, information and work. Finally, the effective implementation of technological change is also influenced by the organizational culture, that is the attitudes, values, and behavioral patterns of organizational members. Thus, the degree of "fit" between the technology and the organizational values will influence the likelihood of its acceptance.

Finally, the success of the implementation depends on the implementation strategies designed by managers. The leadership capabilities and management style of the change agents plays a very important role in to influencing changes in individuals' behavior. As the case studies of successful ES adoption demonstrated, there is no one best way to implement the technology. The implementation strategies that management can adopt range along a spectrum from "authoritarian" (such as the FMC's initial strategy), to "consultive" and "supportive" (such as the Du Pont's strategy). However, for the development of a successful strategy, management must consider all the economical, technological and organizational factors affecting the success of implementation.

The importance of the organizational acceptance is illustrated in the failure of the effort to implement ES technology in a US Navy unit (Sloane 1991). In this case, the primary factors that resulted in the failure had been the following:

1. Lack of adequate training to potential end-users. The users were not provided with formal training and support during the implementation.
2. Lack of middle management's support.
3. Conflict with organizational values and norms. This conflict occurred in two areas. First, the development of the ES applications by the end-users was in conflict with navy operational requirements and routines. Second, the crew did not accept the idea of leaving decision-making to the computer. Although the US Navy is a high-tech organization, its essential value, that is the concept of human

accountability, contradicted with ES technology and implied the superiority of the machine over the individual.

4. The failure to implement the technology in an incremental way did not allow the organization adapt to the use of the technology.

In summary, an ES application is more likely to be accepted by its intended end-users when it has the following characteristics:

1. learning it does not require much effort. However, the effort needed for learning the new method depends on the individual capabilities and work attitudes;
2. it solves an existing firm's or users' problem;
3. it has top and middle management's support;
4. it is not threatening the expert power of any organizational group or individual; and
5. it does not contradict any organizational values or group norms.

Participation and involvement of the intended users during the development of an ES application can significantly reduce the users' resistance. This is especially useful when employee commitment is essential for the success of the implementation.

6.1.9 Success of ES adoption

For the adoption of ES technology to be successful, the technology should contribute to the improvement of the performance of the adopting organization. From the case studies of ES adoption, the following five major reasons for adopting ES technology have been identified: 1) offering of additional services to clients; 2) establishment of a new business line; 3) automation of complex tasks; 4) preservation of organizational expertise; and 5) improvement of training.

The benefits from ES can accrue from both improvements in operational efficiency as well as from improvement of the competitive position of the firm. The efficiency benefits result from the cost and time savings. These savings come from automation of complex tasks, the improved utilization of human resources and organizational expertise and the increased control and integration of the operations.

The competitive advantages result from the improved product quality and price, the additional services and the improved technological image to the clients. Finally, with the adoption of new technology a firm increases the standards of competition, thus creating barriers to competitors. The ability to measure the payoffs from ES technology is critical for the confirmation of the technology's value and continuation of top management's support.

6.2 ES Technology in the US AEC Industry

Despite the reduced limitations of ES technology and the opportunity it offers for both internal benefits and competitive advantage, the US AEC industry has been slow in adopting it. Understanding the forces that result to this inertia is important because it will lead to the identification of the barriers that managers should overcome in order to accelerate the adoption of ES in their firm.

The primary factors impeding the adoption of advanced computer technologies by the US AEC industry include the competitive conditions of the industry, R&D investment reluctance, and institutional framework (Tatum 1986b). Additionally, lack of top management's technological background, and organizational characteristics reduce the ability of engineering and construction organizations to innovate.

6.2.1 Competitive conditions

The competitive conditions limit the willingness of construction firms to take the technical and financial risk associated with new technologies. If a firm maintains an adequate share of a market (regional or by specialty operation), then pressures to take the risk of innovation are reduced.

6.2.2 R&D investment reluctance

The low capital intensity of the industry limits interest in R&D investment. The high levels of competition in the US industry limits profits available for investment in new technologies. Furthermore, new technologies require learning of new methods and reduced efficiencies in the short-term. Although the long-term benefits may be significant, the short-term focus of construction companies prevents investment in untested technologies.

6.2.3 Institutional framework

This framework includes the large number of construction firms, the contractual and legal background, the treatment of risk and liability, and regulatory requirements. The fragmentation of the industry, and the specialization by geographic region and by type of construction limits the resources available for innovation. The increased concern for limitation of liability creates strong forces for technological inertia because it encourages proven methods. As the case of MK demonstrates, cooperation with customers and sharing of the financial risk involved in new technologies can significantly expedite innovation.

6.2.4 Top management's technological background

Top management's lack of strong technological background is another significant barrier to innovation. Lack of understanding may lead to rejection of a technology or to adoption based on unrealistic expectations. In this case, when the expected results are not achieved, the technology will be discontinued. Another problem with computer technologies is the difficulty to measure the benefits from their adoption. Thus, when management focuses only on cost savings, the justification or confirmation of the technology's value becomes extremely difficult.

6.2.5 Organizational characteristics

The organizational structure of the majority of the AEC firms significantly reduces organizational receptiveness to new technologies. The classical design of organizations is based on authority and power as its rationale. The design of the bureaucratic structure was aimed at enhancing predictability, consistency, control, order, stability, standardization and efficiency. However, the characteristics of the traditional organizations such as the centralization of decision making, the formalization of rules and procedures, as well as hierarchical status and job specialization create significant horizontal and vertical barriers to innovation because they reduce the linking mechanisms to coordinate information flow, resource flow and work flow (Sankar 1991).

Today, the principles of classical organizational design are not able to cope with the complex and the dynamic business environment. The structure of the organization should be designed to facilitate communication and information inputs to decision centers. Thus, the information domain must be the primary design parameter for the organization in the information age.

Understanding the factors that facilitate or impede the adoption of ES technology by an AEC firm is a necessary step for the success of the innovation effort. Although the managers and practitioners cannot affect all these factors, they can take specific actions in order to reduce the risk and facilitate the adoption of ES technology in their organization.

In the next chapter, methodologies for successful adoption and implementation of ES technology are discussed. The methodologies include the required steps for the adoption and implementation of the technology, as well as alternative strategies that managers can adopt for performing these steps.

7. ES T^2 Methodologies

The validation of the T^2 beta model and the identification of the factors affecting the T^2 process have resulted in the development of a refined T^2 model. In this chapter, the refined model is presented and a set of alternative strategies for adoption of ES technology are identified.

In the following sections, the term "T^2 flavors" is used to describe the alternative ways for performing each stage of the T^2 process, and the term "T^2 mixin" is used to describe a combination of T^2 flavors. The chapter first presents the stages and the flavors of the T^2 process. Subsequently, some T^2 mixins from which managers can choose in order to introduce ES technology to their firms are identified. The T^2 mixins correspond to the five AEC firms studied during this research. Finally, the discussion at the end of the chapter develops recommendations for managers seeking to transfer ES technology to their firms, and identifies the T^2 mixins with the highest and lowest probability of success.

7.1 Stages and Flavors of T^2 Process

As depicted in Figure 7.1, the T^2 process consists of three major phases:

1. identification;
2. evaluation; and
3. implementation.

During the identification phase two stages are performed that initiate the T^2 process: 1) a need or opportunity for exploring new technologies is recognized; and 2) ES technology is identified by a member of the organization. In turn, during the evaluation phase, the following three stages are performed: 1) initial resources are committed; 2) ES capabilities are developed; and 3) technical and corporate evaluation are performed. Finally, during the implementation phase, three stages are performed: 1) the decision to adopt the technology is made by senior management and full scale resources are committed; 2) ES applications are developed and implemented; and 3) the payoffs from the use of the technology are measured and the technology's value is confirmed. The confirmation stage provides feedback to management who continues to commit resources for the implementation, or rejects the technology.

In the following section, the stages of the T^2 process and the required managerial actions are only briefly described because they have been already analyzed in previous chapters. The refined model centers on the identification of the flavors of the T^2 process, which are

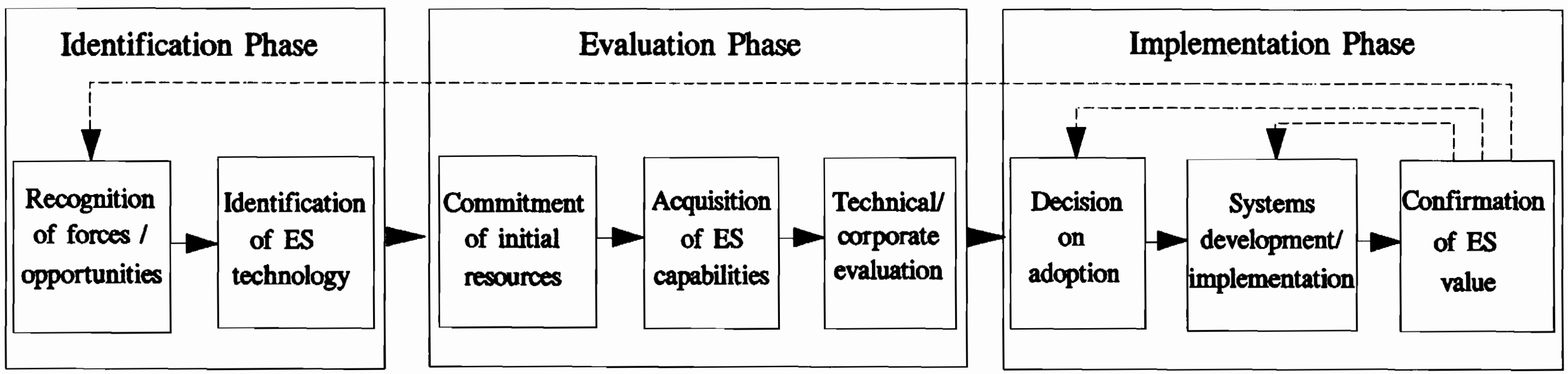


Figure 7.1 Refined T^2 model - Phases and stages.

depicted in Figure 7.2.

7.1.1 Recognition of forces and opportunities

The major factors that create strong forces for exploring advanced technologies are the following:

1. the changing clients' needs;
2. the changing competitors' strategies;
3. the increased complexity of engineering and construction projects;
4. the increased complexity of the firms' internal operations; and
5. the positive attitude towards technology which leads organizational members investigate new technologies even if an obvious need does not exist.

The above forces have led top management of innovative firms to adopt a proactive technological strategy and commit human and financial resources to investigate state-of-the-art technologies. In some firms, a specialized computer group was establish to perform the role of the technology gatekeeper. This role requires the following actions:

1. monitoring the clients' needs and requirements;
2. monitoring the technological developments and identifying those technologies that can better serve the business objectives; and
3. identifying the company's internal needs or opportunities for improvement and developing the required software applications.

Phases of T^2 process	Identification		Evaluation			Implementation					
Stages of T^2 process	Recognition of forces / opportunit.	Identification of ES technology	Commitm. of initial resources	Acquisition of ES capabilities	Technical/ corporate evaluation	Decision on adoption	Systems development and implementation				Confirmation of ES value
							Type of systems	Size/cost of ES	Development	Source of funding	
Flavors of T^2 process	Positive attitude towards technology	Appointed computer group	Company's overhead budget	Training existing personnel	Appointed computer group	Establish new business line	Strategic	Large / complex High cost	In-house central	Customers	Additional source of income
	Customers' needs	Senior mgt	R&D budget	Hiring experienced personnel	Temporary task force	Provide new services to customers	Tactical	Small / simple Low cost	In-house diffused	Company's overhead budget	Improved image to customers
	Competitors' strategies	Middle mgt	Dept's budget	External consulting services	External consultants	Preserve organ/tional expertise			External	Dept's budget	Improved product cost & quality
	Projects' complexity	Other eng/ring personnel	Computer group's own resources			Automate complex tasks				Computer group's resources	Improved operational efficiency
	Operational needs		Customers			Improve training					Improved utilization of human assets

Figure 7.2 Phases, stages and flavors of T^2 process.

7.1.2 Identification of ES technology

The existence of a computer group officially appointed to the role of the gatekeeper ensures that new technologies will not go unnoticed. However, the identification of ES technology may also be performed by any member of the organization who is highly motivated to keep up with technological developments. Thus, the role of the technology gatekeeper may be performed by any of the following organizational members:

1. computer group appointed to the role of the technology gatekeeper;
2. top management;
3. middle management; and
4. other professional personnel.

For top management to accelerate technological innovation, the appointment of technology gatekeeper should be accompanied with policies and procedures that encourage and support individual initiative at all levels of the organizations.

7.1.3 Commitment of initial resources

Commitment of initial resources by an executive champion is the required step for the evaluation phase to start. These resources will be used for the acquisition of ES capabilities, ES tools and prototype development. The required funds for the evaluation of ES technology may be provided in the following ways:

1. top management allocates resources from the company's overhead budget;
2. top management allocates resources from the R&D budget;
3. department managers commit resources from the department's budget;
4. clients commit resources for development of an ES application that supports the needs of a project; and finally
5. the computer group has the freedom to allocate its own resources. These resources may come from revenue generated from the successful marketing of software.

An organization may not have all the above alternatives available. However, the existence of many funding options and the freedom of individual departments to commit their own resources, facilitates and accelerates the evaluation process.

7.1.4 Acquisition of ES development capabilities

The acquisition of ES development capabilities can be performed with one of the following ways:

1. training personnel in-house;
2. hiring additional personnel with experience on ES development; and
3. subcontracting to external consultants.

The option that management will select depends on the state of development of ES technology, as well as on the size and complexity of the desired applications. During recent years, the development of ES technology has significantly reduced the technological capabilities required for development of ES applications. Thus, AEC firms are able to acquire in-house capabilities by providing computer educated personnel with some ES tools and time to experiment with the technology. Hiring additional personnel with experience in ES is another way to acquire in-house ES capabilities.

The development of large, complex systems requires the hiring of experienced personnel or external consultants. The consultants can provide special training to employees or undertake the development of the ES applications.

7.1.5 Technical and corporate evaluation

The technical evaluation is performed with the development of one or more prototype systems. The technical champion is the individual who takes the leadership of the group that performs the evaluation. This group can be one of the following:

1. the appointed computer group, if there is one;
2. a temporary task force; or
3. an external consulting group.

Top management's involvement during the evaluation is critical in order to identify the potential business benefits the technology may offer. Participation of end-users is also important, because it will enable them identify useful features of the technology, as well as opportunities for internal use of ES.

The existence of an in-house computer group ensures that a thorough evaluation will be performed for the following reasons: 1) the strategic position of this group enables it recognize the business benefits from the technology; and 2) the knowledge of the firm's operational needs enables it identify those operational areas that can benefit the most from the technology.

When the evaluation is performed by an external group, the insight into potential internal and external applications is limited. This may result in unidentified opportunities as well as in increased organizational resistance during the implementation.

7.1.6 Decision on adoption

During this stage, top management decides whether resources will be committed for the adoption of ES technology. Before an investment is made, management must be convinced that the technology can satisfy existing company's needs. The primary reasons that may lead top management to invest resources in ES technology are the following:

1. opportunity to create a new business;

2. opportunity to offer additional services to clients;
3. ability to preserve valuable organizational expertise;
4. ability to automate complex unstructured tasks, thus improving the cost, speed and quality of decisions; and
5. opportunity to improve and accelerate training of junior personnel.

An organization may adopt ES technology for one or more of the above reasons, according to its unique business objectives and operational needs.

7.1.7 Development and implementation of ES applications

During this stage, the full scale development and implementation of ES applications takes place. The implementation strategy defines how this stage will be performed. In order to select the implementation strategy most appropriate for their organization, management should consider the following issues:

1. the type of ES applications developed;
2. the cost of the applications;
3. the developers; and
4. the source of funding.

Type of applications. In regard to the benefits that management expects, an application can be characterized as strategic or tactical. Strategic applications address tasks of critical importance for the organization, and any improvement in these tasks will result to large benefits for the firm. Tactical applications address smaller, less critical activities. Thus, the benefits from tactical applications are generated from the automation of highly repetitive tasks.

Cost of applications. The cost of development depends on the size and complexity of the application. Large, complex systems require more expenses and involve higher financial and technical risk. Furthermore, the systems' requirements for high ES capabilities may prevent in-house development and necessitate hiring of external specialists. Thus, in order to minimize the cost of development, and subsequently the financial risk, management can choose to develop small applications.

Developers. According to the selected applications, management can choose one of the following flavors to perform the development:

1. in-house, centralized;
2. in-house, diffused; and
3. externally, by a specialized ES group.

During the in-house centralized development, an appointed ES group develops all the applications for internal or external use. This flavor provides better managerial control over the development and implementation process, and presents the following advantages:

1. it enables more thorough evaluation, thus ensuring that the selected applications serve a real need of the company;
2. there is specialized personnel appointed to ES development and free from other duties, thus enabling the development of both large and small systems;
3. it facilitates end-users' participation during the development, thus improving the likelihood of organizational acceptance; and
4. it provides end-users with organized training and support during the implementation.

During the diffused in-house development, the end-users develop their own systems based on their own expertise, thus performing the roles of expert, developer and user simultaneously. This strategy enables the development of a large number of small systems. However, the users may not have the required time, resources, or capabilities, and the value of the systems may be small. Additionally, opportunities for development of larger systems may not be identified. The success of this strategy depends on the acceptance of the technology by the end-users and their managers. Managers' acceptance is critical because the users are not free from other responsibilities during the development of an application. The existence of a group who performs the role of the internal change agent is required in order to inform, persuade and motivate potential users and their managers, and provide support and training to interested users.

The development of systems by an external specialized ES group is more appropriate when the desired applications are large and complex, and adequate in-house capabilities are not available. However, the cost involved in this case is higher and the end-users participation is lower. As a result, both the financial risk and the risk of end-users rejection are higher, and a potential failure of an application to payoff may result to rejection and discontinuance of the technology.

Source of funding. Potential sources of funding for the development of ES applications are the following:

1. clients;
2. computer group's own resources;
3. company's overhead budget; and
4. departments' budget.

In the case of external ES applications, the clients provide the required resources. The successful marketing of software applications provides another source of funds for the development of internal and external applications through re-investment of a portion of the profits.

The company's overhead budget is another option. In this case, top management screens proposals and selects the ES applications to be developed. Finally, the company's departments may have the freedom to allocate their own resources for ES development.

7.1.8 Confirmation of ES technology's value

For the confirmation of the technology's value, managers need to identify and measure the contribution of ES to the achievement of the organizational objectives. The following benefits have been identified from the adoption of ES technology:

1. establishment of new business line and new source of income;
2. improved technological image to customers;
3. increased organizational effectiveness, through improved product cost and quality;
4. increased organizational efficiency, through internal savings and increases in productivity; and
5. better utilization of human and knowledge resources.

The significance of the above benefits will vary according to each firm's business objectives and goals. The confirmation stage results in three feedback loops in the T^2 process:

1. the organization appreciates or rejects the importance of advanced technologies for achieving the business objectives;
2. top management continues or stops committing resources to the technology; and
3. the implementation strategy is re-evaluated and a different strategy may be adopted.

The identification of the stages of the T^2 process and the required managerial actions significantly enhances the managers' ability to transfer ES technology in their firms. Furthermore, the identification of T^2 flavors will enable managers select those most appropriate for their organization.

7.2 Mixins for ES Adoption

The following section presents combinations, i.e., mixins, of T^2 flavors from which managers can choose in order to transfer ES technology to their organizations. The T^2 mixins presented here correspond to the five AEC firms studied during this research, and include four successful and one unsuccessful T^2 efforts.

7.2.1 T^2 mixin in Lend Lease Corporation of Australia

The T^2 effort in Lend Lease Corporation was unsuccessful because the only system developed has fallen into substantial discontinuance. As shown in Figure 7.3, the T^2 mixin in Lend Lease Corporation consists of the following flavors:

1. Top management's appreciation of technology was the primary force that led to active investigation of new technologies.
2. The role of the technology gatekeeper was performed by an executive manager.
3. Top management committed the initial resources from the company's overhead budget.

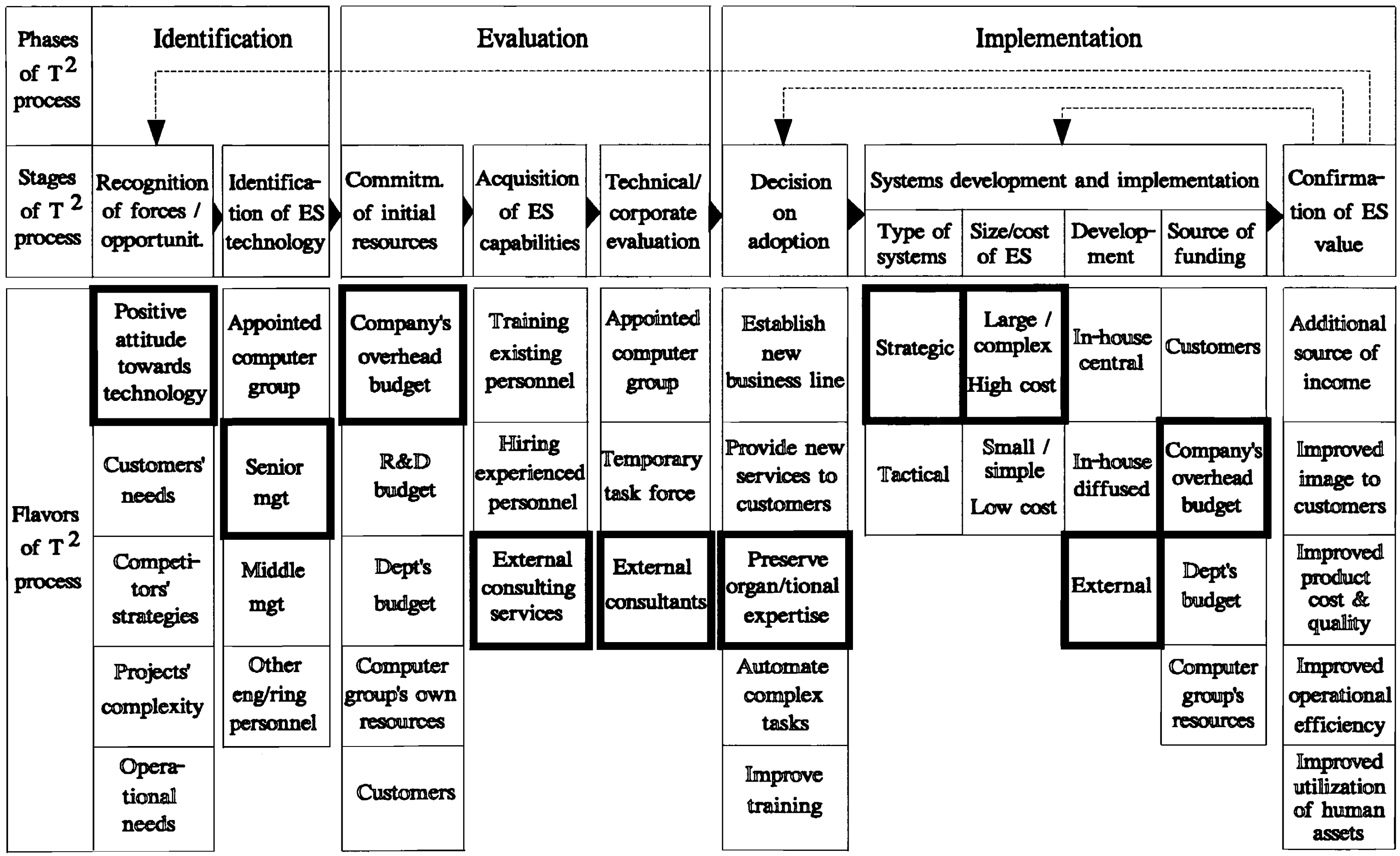


Figure 7.3 T^2 mixin in Lend Lease Corporation of Australia.

4. The required ES capabilities were acquired by hiring external consultants.
5. The evaluation was performed by an external AI group.
6. Top management decided to adopt ES technology in order to preserve valuable organizational expertise.
7. A strategic application was selected as the first ES to be developed. The large size and complexity of the system required a large investment of resources and an external ES group to perform the development and the project was funded from the company's overhead budget. As a result of the selected application, both the financial and the technical risk were high.
8. Lend Lease did not confirm any benefits, because the system did not achieve full utilization.

7.2.2 T^2 mixin in Kajima Corporation of Japan

The T^2 flavors that constitute the T^2 mixin in Kajima are highlighted in Figure 7.4:

1. The positive attitude towards technology led the gatekeeper investigate ES technology.
2. A middle management engineer performed the role of the technology gatekeeper and identified ES technology.
3. Top management provided the initial resources for the evaluation from the firm's R&D budget.

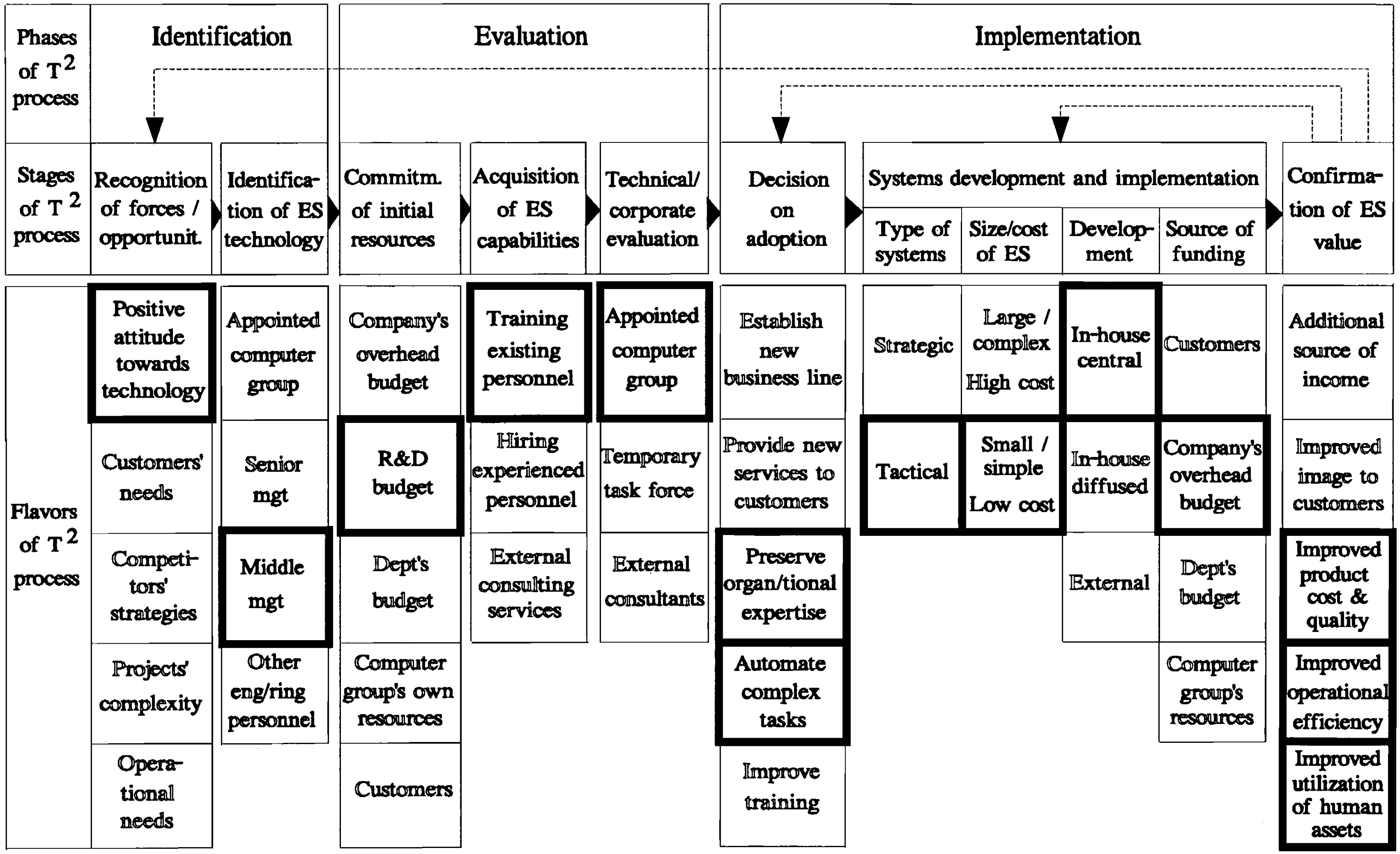


Figure 7.4 T^2 mixin in Kajima Corporation of Japan.

4. The ES capabilities were acquired by providing additional training to already computer educated employees.
5. The technical evaluation was performed by an appointed task force;
6. Top management decided to adopt ES technology in order to maintain organizational expertise and automate complex engineering operations.
7. The implementation strategy Kajima selected addresses tactical ES applications. An established ES group develops centrally all the systems the company needs. Top management provides the required resources from the firm's budget.
8. The major benefits Kajima has identified are improved product cost and quality, increased operational efficiency and better utilization of the company's human and knowledge assets.

7.2.3 T^2 mixin in Morrison Knudsen Environmental

As depicted in Figure 7.5, the T^2 mixin in Morrison Knudsen Environmental consists of the following T^2 flavors:

1. Top management's positive attitude towards technology led MK to explore computer technologies. With respect to ES technology, a project's complexity was the driving force for MK to initiate the investigation of ES.
2. The role of the technology gatekeeper was performed by the manager of the IST group. The IST group is responsible for the development of computer tools to support the clients and the firm's operations.

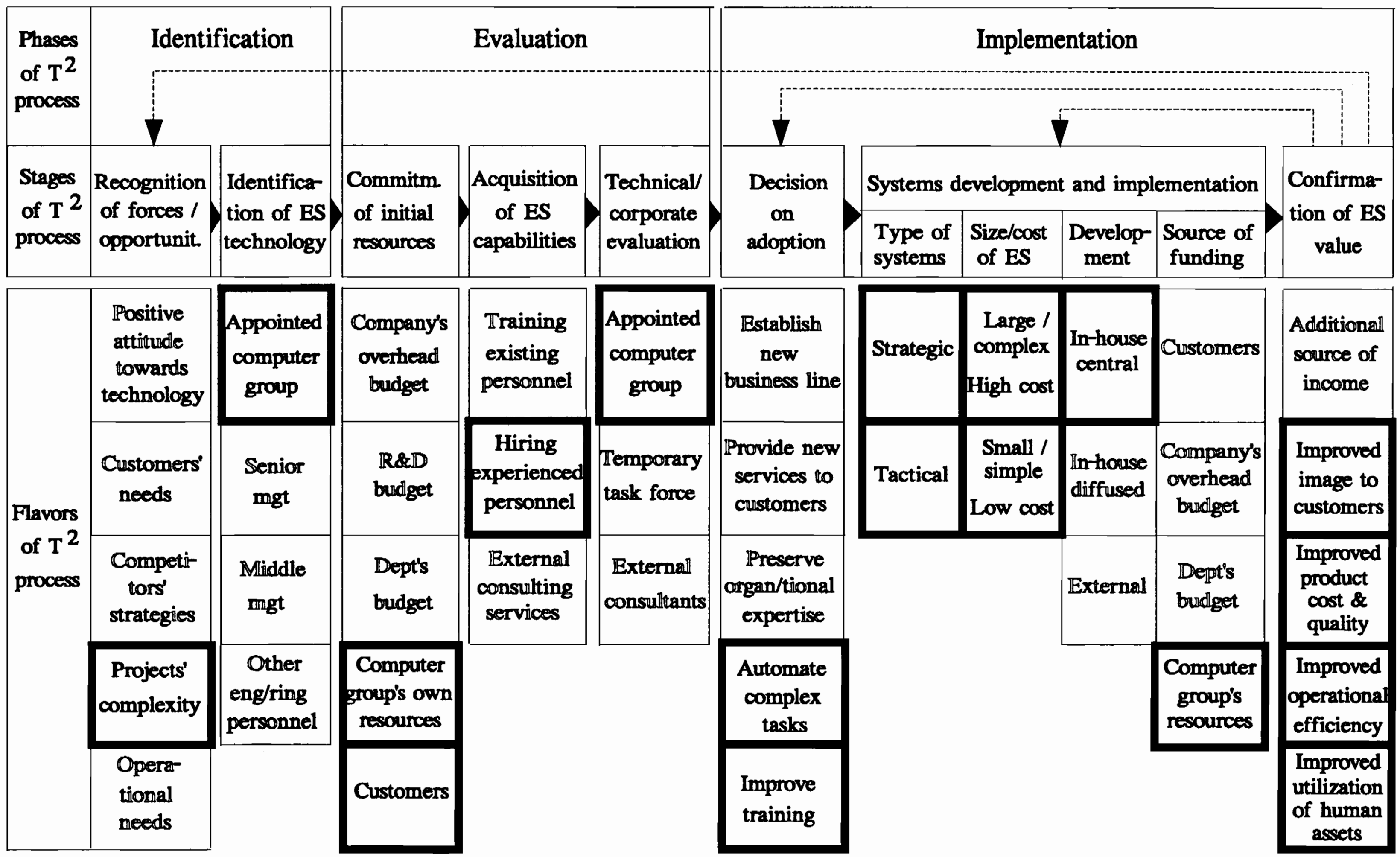


Figure 7.5 T^2 mixin in Morrison Knudsen Environmental.

3. MK's clients committed the resources for the development of the first ES application.
4. The primary means by which MK acquired ES capabilities was the hiring of experienced personnel.
5. The IST group developed the first ES applications and performed the evaluation of the technology.
6. Top management recognized the opportunity ES technology offered for automating complex operations and improving training of entry level personnel.
7. MK develops both tactical and strategic ES applications. However, it selects relatively small systems, thus reducing the financial and technical risk. The IST group develops all ES applications. The IST has the ability to commit its own resources for development of new applications.
8. The primary benefits MK has identified from ES adoption are the improved technological image to clients, improved product cost and quality, improved operational efficiency and better utilization of the firm's human resources. As a result of the confirmation, IST has started developing larger strategic applications.

7.2.4 T^2 mixin in Stone & Webster Engineering Corp.

The following T^2 flavors have been identified in S&W's T^2 mixin, as depicted in Figure 7.6:

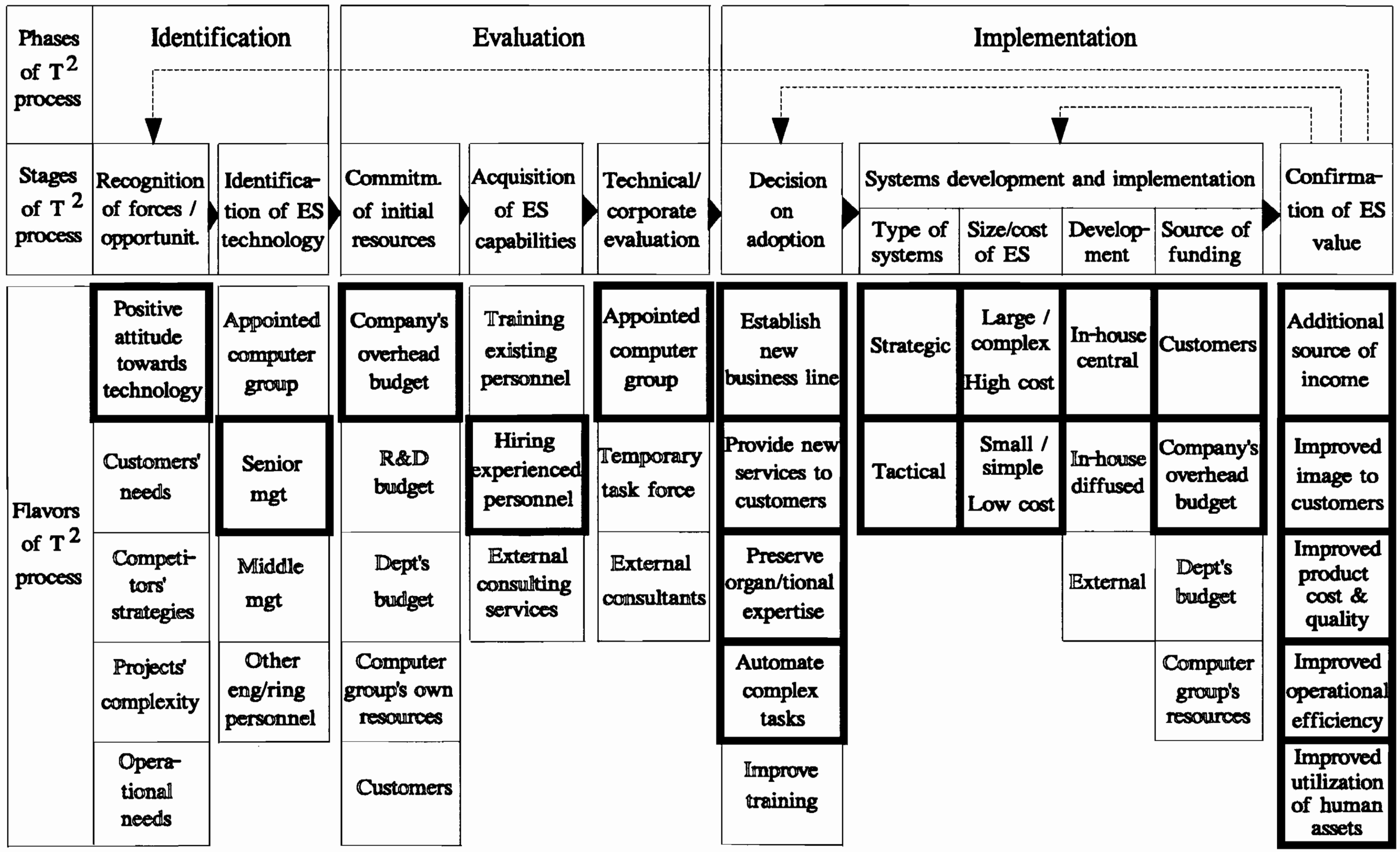


Figure 7.6 T^2 mixin in Stone & Webster Engineering Corporation.

1. The strong technological background and the positive attitude towards technology enabled the gatekeeper in S&W identify ES technology.
2. The role of the gatekeeper was performed by a senior executive.
3. The initial resources for the evaluation of the technology were provided from the company's overhead budget.
4. S&W acquired the initial ES development capabilities by hiring additional staff, experienced in ES development.
5. The evaluation was performed by the ASDS group, who is responsible for the identification and development of computer application that can assist the firm's and clients' operations.
6. The primary reasons for adopting ES technology have been the opportunity to provide new services to clients, start a new business line, automate complex tasks, and preserve the organizational expertise.
7. S&W started with the development of small, tactical systems, but today, S&W develops large strategic systems as well. Both the external and internal systems are developed in-house centrally, by the ASDS group. The resources for the external systems are provided from the clients, and the funds for internal systems are allocated from S&W's overhead budget.
8. The major benefits S&W experiences from ES technology are the retention of organizational expertise, improvement of internal operations, more competitive product cost and quality, improved technological image to clients, and additional income from the marketing of external applications. The confirmation led S&W

to reevaluate its development strategy and address larger strategic systems with potential for higher payoff.

7.2.5 T^2 mixin in CRS Sirrine

As shown in Figure 7.7, the T^2 mixin in CRS Sirrine consists of the following flavors:

1. Positive attitude to technology, as well as the technological strategies of CRSS' competitors were the forces that led a CRSS manager to investigate the potential of ES technology.
2. The CIM manager performed the role of the technology gatekeeper.
3. The initial resources for the evaluation were allocated from the company's overhead budget.
4. By training employees and hiring additional staff, CRSS acquired adequate ES capabilities.
5. The ISS group performed the evaluation of the technology by developing some prototype applications.
6. Top management's decision to adopt ES was based primarily on the opportunity to provide additional services to CRSS customers, and establish a new business line. CRSS is currently evaluating the technology's potential for supporting the firm's internal operations.

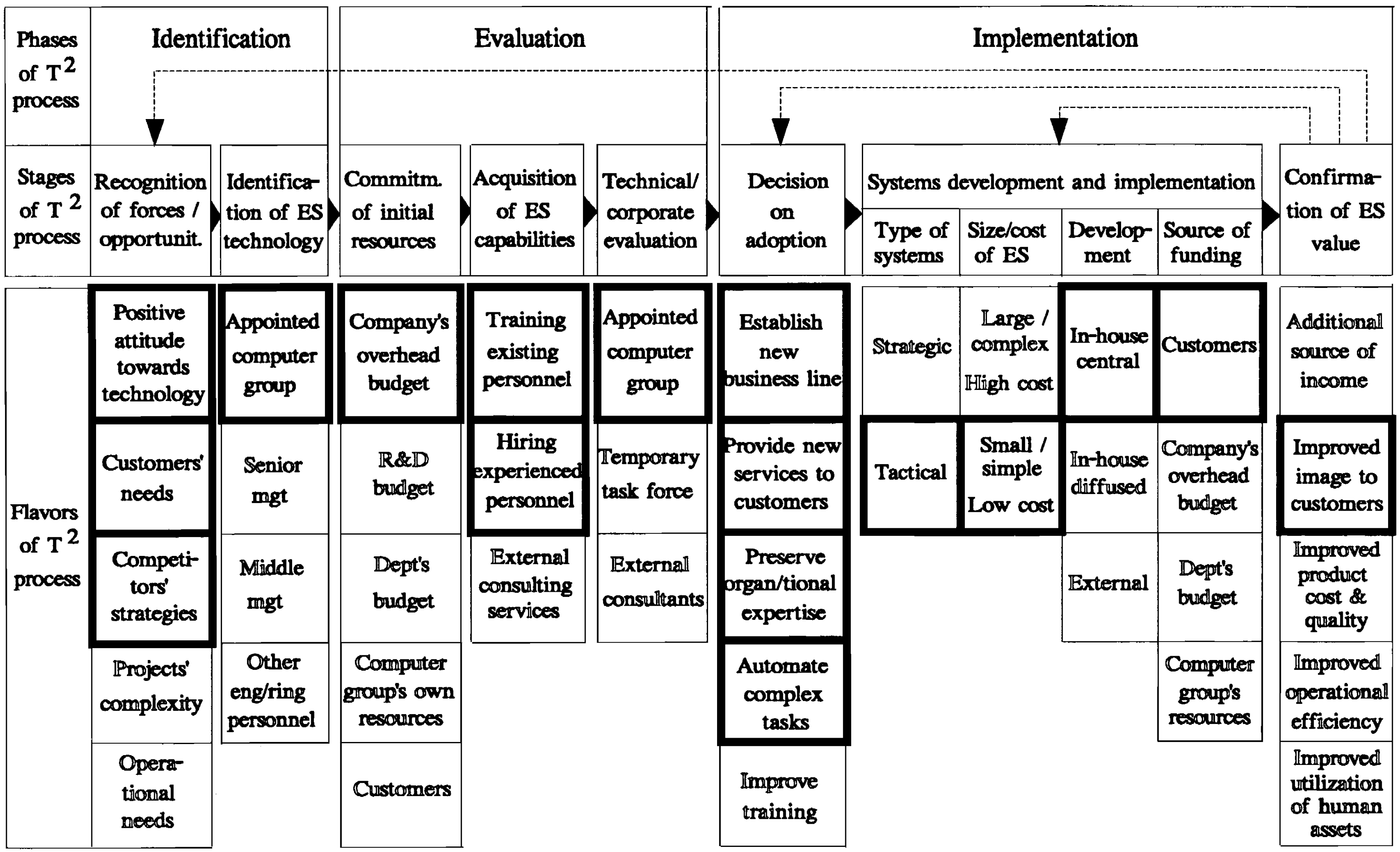


Figure 7.7 T^2 mixin in CRS Sirrine.

7. The implementation strategy of CRSS focuses on the development of tactical and strategic applications for clients. The ISS group develops all the applications.

8. Improvement of the company's technological image to customers is the major benefit CRSS has identified. Because CRSS has just recently started developing ES applications no other benefits have been confirmed yet.

7.3 Discussion

Based on the lessons learned from the five T^2 efforts in the above AEC firms, the following discussion develops recommendations concerning the T^2 mixins managers should adopt or avoid in order to successfully transfer ES technology to their organizations. Thus, in the following section two T^2 mixins are presented; the first is the T^2 mixin with the highest probability for success, and the second is the T^2 mixin with the lowest potential for success and includes the flavors that managers should avoid adopting.

7.3.1 T^2 mixin with highest potential for success

Figure 7.8 depicts the T^2 mixin that offers the highest probability for successful ES adoption. This mixin consists of the following flavors:

1. Positive attitude towards technology and customers' needs are the forces which lead innovative companies adopt a proactive technology strategy and investigate new technologies.

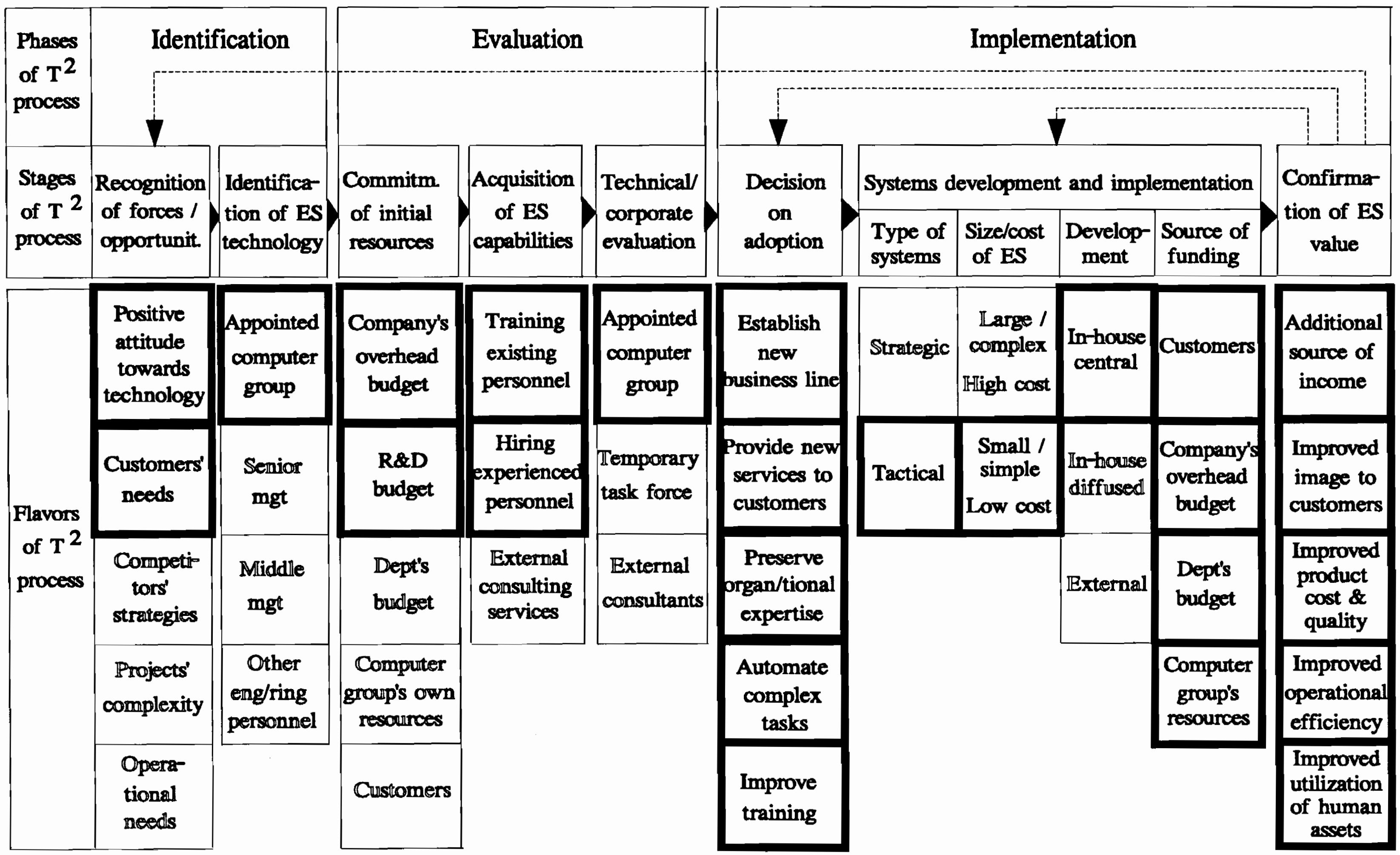


Figure 7.8. T^2 mixin with highest probability of success.

2. The existence of a computer group to the role of the technology gatekeeper enables the firm identify those technologies that can better serve the business objectives.

3. The commitment of initial funds from the overhead or R&D budget provides adequate resources for the evaluation, while department or computer group's budgets may be limited. However, what is important in that stage is the existence of several funding options.

4. The acquisition of ES development capabilities by training existing personnel or by hiring experienced people is critical for an organization in order to develop in-house ES capabilities.

5. The evaluation of the technology by an in-house computer group is critical because the appointed computer group understands both the business objectives and the operational needs of the firm. Thus, it can identify those operational areas that can benefit the most from the technology. The evaluation by an in-house computer group also enables the participation of the intended end-users at this stage, thus increasing the likelihood of end-users' acceptance during the implementation.

6. The decision on adoption of the technology can be based on any of the reasons shown in Figure 7.8 according to the firm's objectives, strategy and operational needs.

7. The development of tactical ES applications of low complexity and cost significantly reduces the financial and technical risk especially during the early

stages of the implementation. The in-house centralized development by an appointed computer group provides better managerial control over the development process and increases the likelihood of end-users' acceptance. The required funds for development of internal applications can be provided by the firm's overhead budget, a department's budget or the computer group's own resources. As the firm gains experience with tactical applications, a move can be made to strategic ones.

8. Finally, the successful adoption of ES will result to one or more of the benefits shown in Figure 7.8.

7.3.2 T^2 mixin with lowest potential for success

Figure 7.9 shows the T^2 mixin that offers the lowest probability for successful ES adoption. This mixin consists of the following flavors:

1. Competitors' strategies and operational problems lead the firms with a reactive technology strategy to investigate new technologies.
2. The role of the technology gatekeeper is performed by a hierarchically lower member of the organization. In this case two problems exist: 1) the gatekeeper cannot match the technology with the business objectives; and 2) it may be difficult for the gatekeeper to persuade top management commit the required resources.

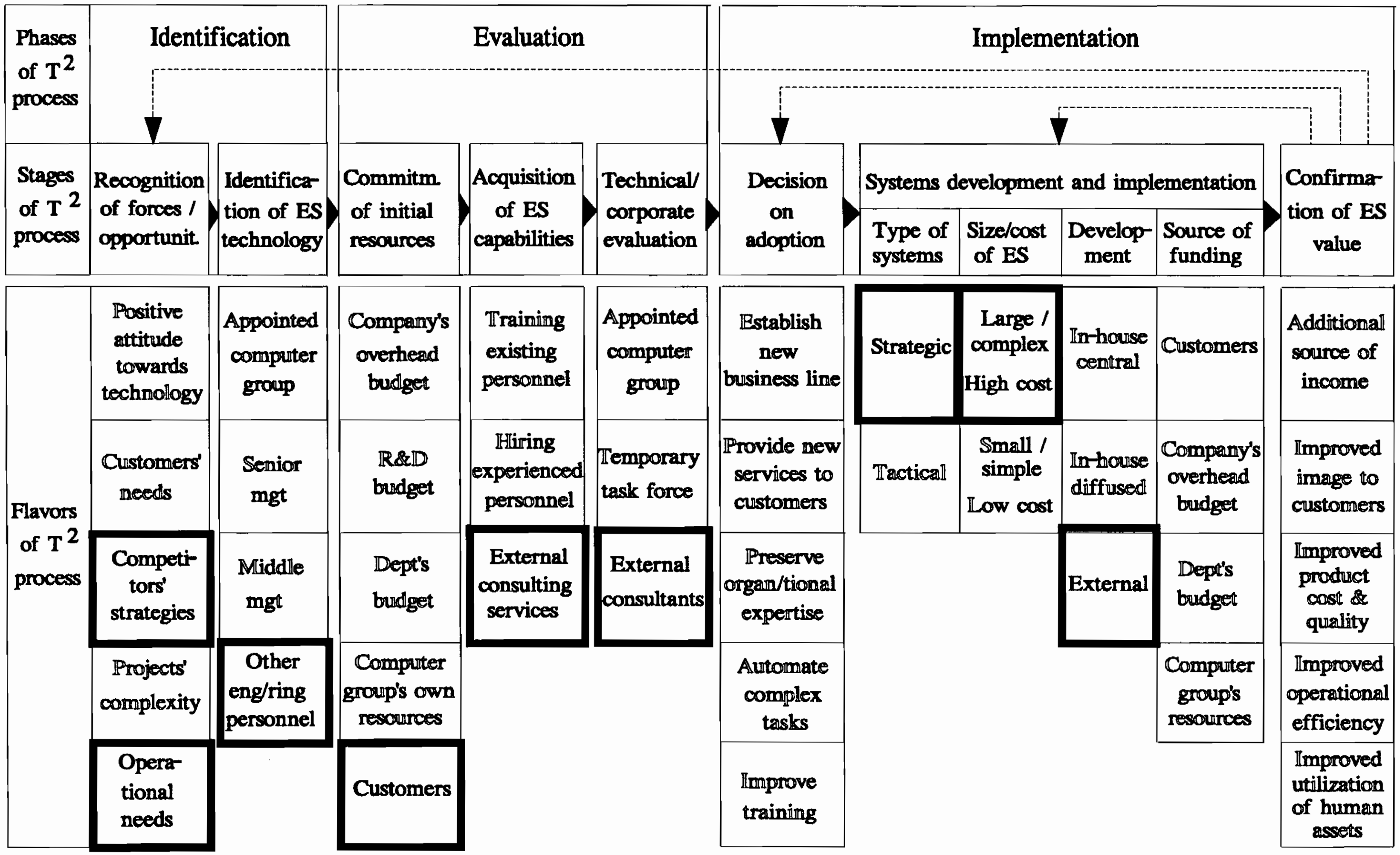


Figure 7.9. T^2 mixin with lowest probability of success.

3. When the resources for the evaluation are provided by a department, the computer group or the customers, the budget constraints may be higher and the freedom for experimenting with the technology may be limited.

4. The hiring of external consultants does not enable the acquisition of in-house ES development capabilities. Thus, the people in the firm do not become familiar with the technology.

5. The evaluation of the technology by external consultants presents the following disadvantages: 1) it is necessary for the consultants to understand the firm's objectives and operational needs before they identify the ES applications the firm needs; and 2) end-users' participation is limited, thus increasing the risk of organizational rejection.

6. The decision on adoption of ES technology can be based on any of the reasons shown in Figure 7.9 and does not affect the success of the T^2 process.

7. Strategic ES applications of high cost and complexity increase the financial and technical risk and should be avoided at the beginning because an early failure may lead to rejection of the technology. Also, the development of the systems by an external group limits end-users' participation and increases the risk of rejection.

8. Finally, if the T^2 effort is not successful, no benefits will be confirmed.

The T^2 mixins presented above provide useful guidelines for managers and practitioners seeking to implement ES technology in their firms. However, the different economical, technological and organizational factors in each firm should be thoroughly assessed before the most appropriate mixin is selected.

8. Summary and Conclusions

The research presented in this thesis develops methodologies for expediting the transfer of ES to the US AEC industry. This has been accomplished with the development of a T^2 model for ES technology and the identification of alternative strategies that managers of AEC firms can use in order to successfully introduce ES technology in their organization.

This chapter provides a summary and conclusions for the thesis. The development of the ES T^2 model is first summarized. Subsequently, the model's significance is evaluated. Finally, recommendations and directions for future work are presented.

8.1 Development of ES T^2 Model

The first step towards the development of the T^2 model has been the study of theories and models concerning organizational innovation and technology transfer. This task provided an initial understanding of the T^2 process, the players involved and the problems usually encountered in a T^2 effort. This step continued during the entire research with the study of organizational behavior theories which provided a deeper understanding of the organizational, human and economical factors that affect the T^2 process.

The analysis of documented case studies of ES adoption in several industries has been the second major task. The efforts of these technology pioneers have provided valuable lessons concerning the managerial tasks and problems involved in the T^2 process. Despite the numerous differences in the T^2 efforts, the analysis of the case studies revealed a pattern of the T^2 process, and resulted in the development of the T^2 beta model.

The development of the T^2 beta model has resulted in the identification of the stages and operations of the T^2 process, the players involved and the roles they perform, as well as the major factors affecting the process. The T^2 beta model has formed the basis for further examination of the ES T^2 process in the US AEC industry.

A limited validation of the T^2 beta model has been performed with the development of case studies of ES adoption by three US AEC firms. The interviews with managers of Morrison Knudsen Environmental, Stone & Webster Engineering Corporation, and CRS Sirrine have significantly contributed to the identification of the actions that AEC firms can take in order to successfully adopt ES technology. The interviews were conducted by the Committe Chairman, Dr. J. M. De La Garza. For the development of the case studies, the information provided by the interviews has been analyzed and compared with the T^2 beta model.

The above tasks have resulted in the development of the refined T^2 model. The refined model includes three major findings: 1) the stages of the T^2 process; 2) the factors affecting the T^2 process in an organizational setting; and 3) the flavors and mixins of the T^2 process.

The refined T^2 model consists of three major phases: 1) identification; 2) evaluation; and 3) implementation. The identification phase includes two stages: 1) the recognition of a need or opportunity for exploring new technologies; and 2) the identification of ES technology. The technology gatekeeper is the primary actor during this phase. During the evaluation phase, three stages are performed: 1) the commitment of initial resources is required for the evaluation to start; 2) the development of ES capabilities; and 3) the technical and corporate evaluation are performed. The existence of the technical and executive champions is critical in order to support the innovation during this phase.

During the implementation phase, three major stages are performed: 1) the decision to adopt the technology is made by senior management and full scale resources are committed; 2) ES applications are developed and implemented; and finally 3) the technology is re-evaluated by both management and users and its use is continued or discontinued. The change agents are the individuals managing the change effort and their role becomes critical during the implementation phase.

The economical, technological and organizational factors affecting the ES T^2 process have been classified in two sets: 1) factors affecting top management's decision to adopt ES technology; and 2) factors affecting the success of the implementation. The top management's attitude towards technology, the business environment, the organizational environment and the characteristics of the technology have been identified as the primary factors influencing top management's decision to adopt ES technology. Subsequently, for the success of the implementation, three requirements should be satisfied; 1) the ES applications should contribute to achievement of the firm's business objectives; 2) the applications should be technically correct; and 3) the systems should achieve organizational acceptance and utilization.

The T^2 flavors and mixins constitute another finding of this thesis. The T^2 flavors have identified the alternative ways for performing each stage of the T^2 process. Finally, the T^2 mixins have identified combinations of flavors that managers can choose to introduce ES technology in their organization.

8.2 Contributions and Benefits

The T^2 methodologies developed in this thesis provide a framework that can significantly enhance managers' ability to expedite the transfer of ES technology in their firms. The identification of the stages and operations involved in the T^2 process provides managers and practitioners with a knowledge of the required actions for successful adoption of ES technology. In turn, the identification of the economical, organizational and technological factors affecting the T^2 process enables managers to understand the issues and problems involved in a T^2 effort. Finally, the T^2 flavors and mixins provide managers with alternative strategies from which they can choose to implement ES technology in their firm.

8.3 Recommendations for Future Work

In this thesis, a limited testing of the ES T^2 model has been performed. A more extended testing and validation of the model is required in order to develop a more analytical ES T^2 model. Furthermore, the majority of the cases studied were cases of successful ES adoption. The study of cases of ES adoption failures is required for the development of a thorough understanding of the T^2 process and the problems involved in such an effort.

For successful adoption of the technology, top management's decision on adoption and commitment of adequate resources is not sufficient. The implementation of a new technology requires change in the work behavior of the users, as well as their managers. The sources of resistance to technological change are both organizational and individual. Thus, any future work in the area of technological change, should focus on the identification of the organizational and human barriers to change, and the investigation of methods to overcome this resistance.

Although the T^2 model developed in this thesis focuses on the transfer of ES technology to the AEC industry, the model provides a framework that can be used by all engineering disciplines for analyzing the transfer of other innovative technologies and the adoption of corporate policies requiring change to the status quo. Thus, the model can form the basis for the development of a generic T^2 model.

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Appendix A

A.1 Development of Interview Guide

For the development of ES adoption by US AEC firms, an interview guide has been developed by the author, and reviewed by Dr. Robert Frary of the Virginia Tech Learning Resources Center. The interview guide has been used by Dr. De La Garza during the interviews with managers of Morrison Knudsen Environmental, Stone & Webster Engineering Corp., and CRS Sirrine. The objective of the interview guide has been to inquire on the ES T^2 process of the interviewed firms, and identify the following issues:

1. stages and operations of the T^2 process;
2. actors and roles;
3. flow of the T^2 process; and
4. factors affecting the T^2 process.

The issues addressed by the interview guide and the corresponding questions are as follows:

Overview of T^2 process	Question #1
Identification of ES technology	
Gatekeeper	Question #2
Gatekeeper's position	Question #3
Gatekeeper's capabilities	Question #4
Gatekeeper's appointment	Questions # 5, 7
Sources of information	Question #10
Recognition of forces and opportunities	Question #6
Commitment of initial resources	Questions #20-22
Technical and corporate evaluation	Questions #11-20
Top management's support	Question #11
Technical champion	Question #13
Technical champion's position	Question #14
Technical champion's capabilities	Question #15
Evaluation group	Questions #16-17
Evaluation methodology	Question #18-20
Decision on adoption	Question #24-26
Systems development and implementation	
Developers	Questions #27-29

Resources	Question #31
User's involvement in development	Question #32
Training and support	Question #33
Confirmation of ES value	Questions #37-39
Factors affecting T^2 process	
Top management's attitude towards technology	Questions #5-9
Organizational environment	Question #23
Organizational technological capabilities	Question #30
Organizational acceptance	Questions #34-36
Impact on organization	Questions #40-41

A.2 Interview Guide

In the following section, the detailed interview guide is presented.

Q1. Please, provide an overview of the process from the time you started investigating ES technology until today.

____

____

Q2. Who started first investigating ES technology?

____

Q3. Technology gatekeeper's characteristics:

POSITION: ______________________________

DEPARTMENT: ______________________________

YEARS IN COMPANY: ______________________________

AGE: ______________________________

Q4. What technical knowledge does the gatekeeper have?

____

Q5. Was the gatekeeper appointed by senior management?

1. YES 2. NO

Q6. Why did the gatekeeper start investigating Expert Systems technology?

1. BUSINESS PROBLEM
2. OPERATIONAL PROBLEM
3. TEST THE TECHNOLOGY
4. OTHER ______________________________

Q7. Is there an individual/department responsible for investigating new technologies and their potential importance for the company?

____

____

Q8. How important for the firm's future does top management consider new technologies?

1. VERY IMPORTANT
2. MODERATE
3. LOW

Q9. What technical education does top management have?

1. HIGH
2. MODERATE
3. LOW

Q10. How did the gatekeeper become informed about ES technology?

____

____

Q11. Was senior management informed about the investigation of ES technology at that point? (Was a proposal made to top management for further investigation of the technology?)

1. NO

2. YES (If YES how did top mgt evaluate the technology?)

____

____

Q12. Did any experimentation with the technology take place in the company?

1. YES

2. NO (If NO go to Q23)

Q13. Who initiated the experimentation (taking the role of the technical champion)? Was this person appointed by senior management?

____

Q14. Technical champion's characteristics:

POSITION: ____________________________

DEPARTMENT: __________________________

YEARS IN COMPANY: ______________________

AGE: ______________________________

Q15. What technical knowledge does the technical champion have?

____

Q16. Was a task force established to perform the experimentation? Who were members of the task force?

____

____

____

Q17. What technical skills did the members of the task force have?

1. HIGH
2. MODERATE
3. LOW

Q18. What tasks were performed during the experimentation? (eg. selection of software, development of prototype system, etc.)

____

____

Q19. What aspects of the technology have you been looking during the evaluation? (desired developers, specific applications, compatibility with resources, implementation planning, etc.)

____

____

____

____

Q20. What was the involvement of the following groups during the experimentation?

Experts	..... HIGH .... MODERATE .... LOW
Potential Users:	..... HIGH .... MODERATE .... LOW
Managers:	..... HIGH .... MODERATE .... LOW
Other departments:	..... HIGH .... MODERATE .... LOW

Q21. Were the people involved released from other assignments?

____

____

Q22. Who supported the experimentation and provided the resources?

1. TOP MANAGEMENT
2. DEPARTMENT'S BUDGET
3. PERSONAL RESOURCES
4. OTHER SOURCES ______________________________

Q23. In what degree do the departments have the freedom to allocate own resources in experimenting with new systems?

1. HIGH 2. MODERATE 3. LOW

Q24. When did senior management make the decision to adopt and implement ES technology?

1. BEFORE THE EXPERIMENTATION
2. AFTER THE EXPERIMENTATION
3. ____

Q25. How easy or difficult it was to persuade senior management for the adoption of the technology?

1. EASY 2. MODERATE 3. DIFFICULT

Q26. What payoffs did management expect?

____

____

Q27. How was the implementation organized? (Was an AI group formed?)

____

____

Q28. Who was responsible for the development the systems?

1. OUTSIDE SPECIALISTS WERE HIRED
2. IN-HOUSE SPECIALISTS
3. EACH DEPARTMENT
4. OTHER ____________________________

Q29. Who decides what systems to be developed?

1. A CENTRAL GROUP
2. EACH DEPARTMENT
3. OTHER ____________________________

Q30. In what degree are the people in the company computer literate?

1. HIGH 2. MODERATE 3. LOW

Q31. Who provides the required resources for the development of the systems?

____

____

Q32. In what degree are the potential users of the systems involved in the development?

1. HIGH 2. MODERATE 3. LOW

Q33. What training and support is provided to users?

____

____

____

Q34. What was the users and managers' attitude towards the systems?

End-users' acceptance: HIGH.............MODERATE...............LOW

Managers' acceptance: HIGH.............MODERATE...............LOW

Q35. In what degree do you believe that the following factors affected the implementation of ES technology?

1. Top management's support: HIGH ..... MODERATE ..... LOW

2. Freedom to departments/individuals to experiment with new technologies: HIGH ..... MODERATE ..... LOW

3. Lack/Existence of champion(s): HIGH ..... MODERATE ..... LOW

4. Position of champion(s): HIGH ..... MODERATE ..... LOW

5. Lack/Existence of technical skills: HIGH ..... MODERATE ..... LOW

6. Maturity of ES technology: HIGH ..... MODERATE ..... LOW

7. Experts' acceptance: HIGH ..... MODERATE ..... LOW

8. Managers' acceptance: HIGH ..... MODERATE ..... LOW

9. End-users' acceptance: HIGH ..... MODERATE ..... LOW

Q36. What were the major problems during the process of the transfer of expert systems?

____

____

____

____

Q37. What benefits can you identify from the use of ES?

Q38. What new applications have been identified?

Q39. How many systems are in use today?

Q40. What changes occurred in every day's operations?

Q41. How did the use of ES technology affect your customers, suppliers or subcontractors?

Appendix B

B.1 List of Abreviations

AEC	:	Architecture-Engineering-Construction
AI	:	Artificial Intelligence
ASDS	:	Advanced Systems Development Services
CAD	:	Computer Aided Design
CDS	:	Critical Decision Set
CEO	:	Chief Executive Officer
Cham	:	Champion
CII	:	Construction Industry Institute
CIM	:	Computer Integrated Manufacturing
CRSS	:	CRS Sirrine
CSF	:	Critical Success Factors

DEC	:	Digital Equipement Corporation
DSS	:	Decision Support Systems
ES	:	Expert Systems
Exe cham	:	Executive champion
Gk	:	Gatekeeper
ICOT	:	Institute for New Generation Computer Technology
ISD	:	Information Systems Department
ISS	:	Integrated Systems Services
IST	:	Integrated Software Technology
J&J	:	Johnson & Johnson
Mgt	:	Management
MK	:	Morrison Knudsen
PMT	:	Processing and Manufacturing Technologies
R&D	:	Research & Development
S&W	:	Stone & Webster
T^2	:	Technology Transfer
Tech cham	:	Technical champion
VP	:	Vice President

Vita

Panagiotis Mitropoulos was born on October 30, 1961 in Greece. He received his Bachelor of Science degree in Civil Engineering from the University of Patras, Greece. From 1985 to 1983 he joined an A/E firm (Fragakis Tech, Co. From 1986 to 1988, he served his military service, and in !988 he returned to Fragakis Tech. Co. In September 1990, he started to pursue graduate studies at Virginia Polytechnic Institute and State University.