Strategies for Implementing Knowledge-Based Systems

Soumitra Dutta, *Member, IEEE*

***Abstract*— The effective management of knowledge is important for the competitivity of organizations. Rapid technological progress over the last decade has made knowledge-based systems (KBS's) (including expert systems, organizational memory information systems, and other advanced information technology solutions) an integral part of every organization's effort to manage its knowledge assets effectively. KBS's have an important impact on all levels of organizational knowledge: individual, group, organizational, and knowledge links. This paper outlines four generic knowledge processing strategies to guide the implementation of KBS's within organizations. These generic strategies are related both to the level of knowledge assets under consideration and the locus of responsibility for the development of KBS. The different knowledge processing strategies influence the management of knowledge possible within an organization and consequently influence the development of KBS within the organization. The paper also outlines different facilitators and barriers to the four knowledge processing strategies.**

***Index Terms*— Expert systems, implementation strategies for KBS's, knowledge-based systems (KBS's), knowledge management, knowledge processing, organizational memory information systems.**

I. Introduction

THIS section describes the evolution of knowledge processing and outlines the focus and structure of the paper.

A. Knowledge Management and Knowledge Processing

The effective management of knowledge is increasingly seen as an important basis of competitive advantage for corporations. While the basis for such thinking emerged more than a decade ago, primarily from a resource based approach to strategy [49], recent research by Hedlund [14], Hedlund and Nonaka [13], Nonaka [29], Kogut and Zander [18], and others (e.g., see the February 1991 special issue on Organization Science) have all further emphasized the importance of knowledge management in the emerging resource-based theory of the firm [35], [49].

Given the increased complexity of knowledge about most aspects of business today (such as products, markets, and technology) and the steady progress in technological capabilities, it is only natural that information technology (IT) is becoming an integral part of an organization's effort to manage knowledge [15], [42]. It is possible to identify three distinct waves in the evolution of business computing. Until the early 1970's, computers were used primarily for traditional *data processing* tasks. This gave rise to the large mainframe databases which (still) form the core of computer systems in most organizations today. The emphasis then was largely on building efficient data storage and retrieval systems. During the 1970's, the focus of computing shifted from data processing to *information processing*. While the emphasis in data processing was on the storage and retrieval of raw data, information processing focused on management information systems [6] to aggregate the raw data and provide the required information (i.e., the aggregated data) to management for decision support. The scope of computing has enlarged since the mid-1980's to include *knowledge processing* [7], [17] with knowledge-based information systems (KBS's). Broadly defined, KBS's use extensive domain specific knowledge to solve problems and support decision processes. Such information systems attempt to move the focus of computing a generation ahead by focusing on knowledge as opposed to information and enhancing the level of intelligence embedded in the IT systems.

The exact nature and definitions of terms such as "data," "information," "knowledge," and "intelligence," have been debated extensively and inconclusively the literature [5], [23], [28]. While it is possible to resort to "dictionary" definitions for these terms, it is perhaps most useful to illustrate their mutual distinctions (as considered in this research) with a simple example. The numbers which a corporation gets on sales of different products from various stores would constitute "data." These data are typically converted into management "information" by building reports such as "sales by region" and "sales per product category." When a manager looks at these reports, he or she utilizes specific "knowledge" to interpret the presented information (such as "why are sales low in this region as compared to another?") and to make decisions (such as "should we launch a new sales promotion campaign?").

Thus knowledge in KBS can be seen as being obtained from information by assigning it meaning and interpretation. This interpretation or meaning is typically given by humans, either individually or collectively, and represents the domain specific knowledge and/or cumulative experience which KBS attempt to exploit [7]. It is important to recognize that there is some overlap between the terms "information" and "knowledge," because domain-specific knowledge is needed to "organize data into information." For example with reference to the above example, some knowledge about the company and its business is needed to know that it makes sense to organize

Manuscript received February 26, 1993; revised January 1996.

The author is with INSEAD, Fontainebleau Cedex, France 77305 (e-mail: dutta@insead.fr); he is also with the Haas School of Business, University of California, Berkeley, CA 94720 USA (e-mail: sdutta@haas.berkeley.edu).

Publisher Item Identifier S 0018-9391(97)00688-0.

the data in terms of "sales by region" and "sales per product category."

Though expert systems [7], [9]–[11] represent the first (since the early 1980's) and probably the most widely publicized application of advanced IT for knowledge management, it is becoming more common for researchers [15], [42] to include a larger variety of IT systems (including databases and groupware systems) as playing a role in knowledge management. There are two reasons for this. First, the concept of knowledge within organizations is progressively becoming more generalized [13], [14] to include organizational memory [48] and interorganizational knowledge [13]. While expert systems traditionally focused on the knowledge of a single expert or in some cases a group of experts, broader definitions of knowledge implies that other forms of IT systems such as corporate databases and electronic data interchange (EDI) linkages with suppliers and other partner organizations also play a role in knowledge management. Second, advances in IT are rapidly blurring the distinctions between different categories of IT systems. For example, object-oriented and rule-based technologies, which have for long been the core components of classical expert systems, are increasingly becoming incorporated into databases, groupware and other IT applications. Or, in other words, traditional data and information-based IT applications are becoming increasingly "intelligent" and knowledge based.

For the purposes of this paper, the term "knowledge-based system" is used in a general sense to include expert systems, corporate databases and other organizational IT applications which help corporations manage their knowledge assets effectively. Section II defines the type of knowledge assets considered in this research more precisely.

B. Focus and Structure of Paper

Though the hype and media attention of KBS's peaked about a decade ago (with the introduction of expert systems), organizations are today witnessing a silent, but more widespread, permeation of KBS's. While technological issues in the development of traditional expert systems and KBS's have been described fairly extensively in the literature [10], [11], there has been relatively little research on strategic and organizational concerns in the implementation of such systems. This is important to note because with the maturation of the enabling technologies, the challenges in successfully implementing KBS's have moved from technical matters to organizational and strategic issues.

Strategic and organizational implications of implementing KBS's have been addressed by researchers such as Mumford [26], [27], O'Leary and Turban [30], Prerau [36], Sharma *et al.* [39], Stein and Zwass [42], and Sviokla [44], [45]. Sharma *et al.* [39] have postulated different conditions under which the deployment of expert systems is beneficial for an organization. These postulates are partly technical in nature (focusing on the task domain and the knowledge engineering process) and partly organizational (focusing on the "fit" between the expert system and the organization). Prerau's work [36] is useful in describing specific experiences from the development and implementation of large real-life expert systems. These experiences are used to present some general principles or recommendations for the process of developing expert systems. Mumford's [26], [27] research is similar to that of Prerau in analyzing the deployment of a large expert system within a company, but is more focused on the organizational conditions facilitating the successful deployment of expert systems. Sviokla has analyzed the development of expert systems [45] and has also described the organizational impact of expert system deployment in a real company [44]. Stein and Zwass [42] take a broader view of IT systems supporting "organizational memory" and define characteristics of desired IT support in relation to a framework of activities (such as acquisition, retention, maintenance, search, and retrieval) required for organizational effectiveness.

The focus of this paper is on strategies for implementing KBS's in organizations. The adoption of the perspective of knowledge asset management in analyzing the organizational impact of KBS's and formulating knowledge processing strategies for their implementation distinguishes this work from prior related research. There are two referent research streams for this paper. First, there is a large body of literature within strategic management focusing on the competitiveness of a firm as derived from a resource-based view of the firm [35], [49]. Within this research area, there is an emerging focus on the management of knowledge assets [13], [14], [29]. The research presented in this paper leverages prior work within this body of research and augments it with a specific focus on the role of IT systems in effectively supporting the management of knowledge assets (a theme which has not been addressed within this body of prior research). Second, there is a significant literature within information systems on KBS's, but the bulk of it [7], [10], [11], [16], [20], [21] focuses on technical concerns in the implementation of KBS's. Some prior research within this research stream does emphasize the organizational implications of implementing KBS's (as described above), but they do not adopt the perspective of knowledge-asset management.

The structure of this paper is as follows. The concept of organizational knowledge and the impact of KBS's on the management of a firm's knowledge assets are first developed in Section II. Next, Section III outlines different knowledge processing strategies for the development of KBS applications. Section IV describes the strategic implications of the different strategies for implementing KBS's. Section V concludes the paper.

II. Organizational Knowledge and KBS's

This section describes important issues in managing organizational knowledge and explores the interactions between KBS's and the management of a firm's knowledge assets.

A. Knowledge in Organizations

To effectively understand and evaluate the role of KBS's in organizations, it is important to understand the practical implications of "managing knowledge" in the general organizational context.

Knowledge exists in many different forms in organizations. Some of them are *tangible*, while others are more subtle and *intangible* in nature. Examples of tangible knowledge assets are patents, written procedures ("how to" knowledge about certain tasks), books, manuals, and research and development outputs such as papers published and new products. Tangible knowledge has also been referred to as "articulated" knowledge in the literature [14]. Intangible knowledge assets of a company include company "culture," the experience and expertise of employees, informal associations, synergies from group interactions and more generally all knowledge that is nonverbalized, intuitive, and unarticulated. Intangible knowledge has also been termed as "tacit" knowledge in the literature [13], [33].

Managing knowledge is an challenging task because it is hard to identify, and even more difficult to value and deploy to give the organization a competitive edge in the market place. While many tangible knowledge assets such as software programs can be identified easily, it is often difficult to value them, and thus they rarely make it into the company's balance sheets. It is a more difficult task to identify the intangible knowledge assets of an organization, and most executives do not understand how to value them (if at all they are identifiable).

Moreover, knowledge after identification has to be shared so that the organization is able to translate it into a competitive advantage. Isolated islands of knowledge are not very useful to an organization. A company derives true benefits from its knowledge assets only when they are leveraged via a knowledge network, and diffused throughout the organization (and its partners, if appropriate). Complicating the scenario further is the fact that knowledge is never static; it is continuously changing and evolving. Tracking and managing a dynamic asset is always harder.

Companies are today realizing the importance of the competitive differentials achievable by effectively managing knowledge assets. In a cover story on this subject, a leading business magazine [43] stated this concisely as:

> Intellectual capital is becoming corporate America's most valuable asset and can be its sharpest competitive weapon. The challenge is to find what you have—and use it.

B. Levels of Organizational Knowledge

An organization's knowledge assets can be analyzed in different ways. A useful classification is along the following four dimensions:

- *Individual:* the individual knowledge worker is the fundamental unit for knowledge creation, storage, and use within an organization.
- *Group:* networks, both formal and informal, are usually an intangible, but important knowledge asset within a company. Groups of individuals often represent a cumulative knowledge asset that is more than the sum of their individual skills, and can produce results of true competitive significance.
- *Organizational:* the entire organization with its own peculiar structures, division of functions, and processes can be viewed as embodying the result of a certain cumulative body of knowledge. The organization is designed to facilitate and direct knowledge flows, and evolves with changing knowledge needs.
- *Knowledge links:* every company develops specific links with other firms (such as suppliers and customers) to exchange knowledge. Analogous to groups, knowledge links between groups of organizations can lead to the development of interorganizational knowledge not possible with isolated organizations.

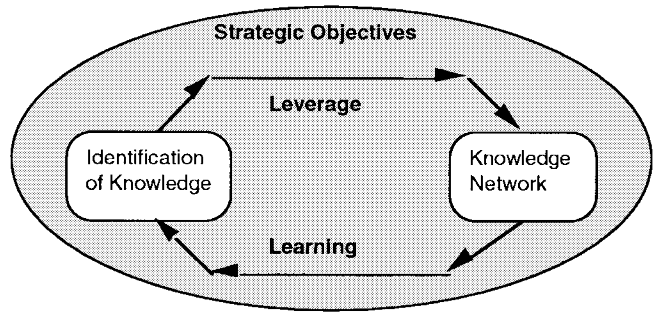

Fig. 1. The strategic management of knowledge.

The above model of knowledge levels is similar to that proposed by other researchers in the literature [13], [14]. While the exact terms used can vary, the common essence of the models is the recognition that there are different "levels" of knowledge assets within an organization. Some of these levels of knowledge assets may be more dominant in certain types of businesses and/or cultures. For example, Hedlund and Nonaka [13] note that the group and knowledge links levels appear to be more critical in Japanese companies as compared to Western organizations where the individual and the organizational levels appear to take precedence.

C. Managing Knowledge in Organizations

Fig. 1 reflects the essential components of the process of strategically managing knowledge. A company has to identify its knowledge assets, leverage them by sharing in a knowledge network, and learn from experience (to reflect the dynamic nature of knowledge). All of this has to be done, of course, within the context of the strategic objectives of the organization. This simple model contains the three major aspects of knowledge management often mentioned in the literature [14]: the storage, transfer, and transformation of knowledge.

Identification of specific assets at each of the levels of knowledge mentioned earlier is a challenging task for any organization. Individual expertise is not restricted to a company's professionals or its top management. Often the best experts are found low down in the ranks of an organization [37]. It is also sometimes difficult to distinguish between a true expert (a knowledge asset), and someone who just has better access to certain information based on the power of his/her position. Locating group knowledge assets is difficult because formal groups seldom mirror real intellectual assets. Rather,

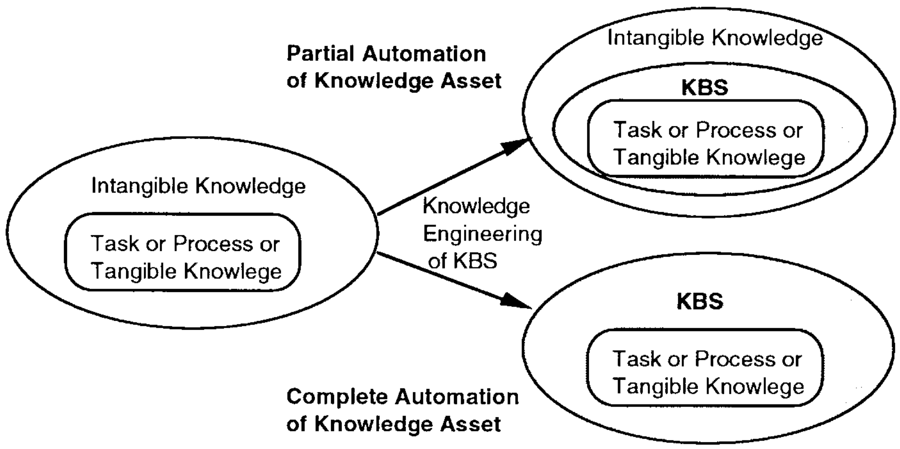

Fig. 2. Creation of a tangible knowledge asset using a KBS.

informal networks of individuals often tend to form the most effective knowledge assets. Similar identification problems are also experienced at the organizational and interorganizational levels.

Isolated knowledge is of little strategic benefit to an organization. The larger the extent to which knowledge is shared and disseminated within an organization, the higher the return on it. For example, most organizations are today making determined efforts to from groups of interdisciplinary and cross functional individuals in order to facilitate the transfer and dissemination of knowledge. This is helping them to design better products, reduce time to market, achieve a higher degree of customer satisfaction, and be more competitive on the whole.

The proper identification and articulation of (specially intangible) knowledge assets is vital for leveraging them in an appropriate knowledge network. Hedlund [14, p. 76] notes that articulation is essential for facilitating transfer of knowledge and that:

> ... organizations are to a large extent "articulation machines," built around codified practices and deriving some of their competitive advantages from clever, unique articulation.

Note also that an effective knowledge network implies a two way transfer of knowledge, i.e., a transfer of knowledge from the individual to the organization (termed as "extension" by Hedlund [14]) and also from the organization to the individual (termed as "appropriation" by Hedlund [14]).

Perhaps the most challenging aspect of knowledge management is that knowledge is inherently dynamic. To ensure long-term competitiveness in the marketplace, every organization has to be able to learn and update its knowledge assets. Beside being in touch with changes in the external and internal environments, knowledge creation requires an interplay between the processes of articulating and internalizing knowledge, both at and across the individual and organizational levels. This has been commonly observed during the process of building expert systems. When experts are asked to articulate their "expert knowledge," they are often forced to reexamine and question their intuitive assumptions about the task and this often leads them to adopt new solutions or modify old solution routines [7], [9]. Knowledge links with suppliers and other partner organizations also serve as valuable stimuli for organizations to question their existing routines at the individual and group levels, which eventually leads to the creation of new/modified knowledge assets at different levels within the organization.

D. KBS's and the Management of Organizational Knowledge

KBS's have a direct impact on the management of knowledge within organizations. A KBS aims to capture selected articulated aspects of an organization's knowledge assets in an information system. Thus, the development of a KBS results in the creation of a tangible knowledge asset which can be distributed and leveraged within the organization.

The knowledge targeted by a KBS can be either tangible (such as manuals and documents) or intangible (e.g., human experience) in nature. While a conventional information system can store the information in a document or a manual, the additional power of a KBS lies in its ability to also store how the document or manual is interpreted (used) by experts/users (i.e., capture the intangible knowledge associated with the use of the tangible knowledge asset). The degree of automation with KBS's can be either *complete* or *partial*, as shown in Fig. 2. In the former case, the KBS captures the tangible and intangible aspects of the knowledge asset in its entirety, and can be deployed as a complete or partial replacement for that knowledge asset. However, such situations are rare. The latter situation in which the KBS only partially captures the (tangible and intangible aspects of the) knowledge asset is more common. The KBS is usually used to augment the use of the knowledge asset and facilitate its dissemination in such situations.

Most commercially successful KBS's have captured (usually partially) the intangible knowledge associated with individuals (more often) and groups (less often). For example, it is important for American Express to take consistent (for enhanced customer image) and correct (to avoid fraud) credit approval decisions about credit requests from similar customer profiles. Achieving this consistency and accuracy is difficult in practice, because the staff taking such decisions differ in their levels of experience and knowledge, and are in addition, subject to a variety of local constraints. To solve this problem, American Express has been using an expert system since

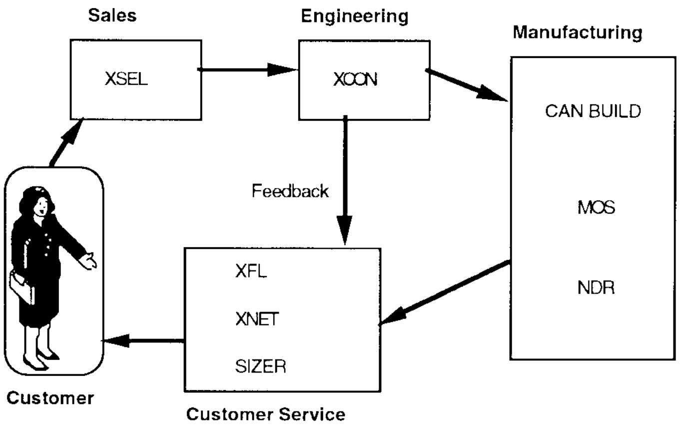

Fig. 3. Digital's VAX-based knowledge network.

1987 called Authorizer's Assistant [19] to support the decision processes of their credit agents. This KBS captures both tangible (documents about credit approval procedures) and intangible (the expertise of the best agents) knowledge about the credit approval process. Moreover, the knowledge in the KBS is constantly updated to account for changes and recently encountered exceptional situations. Most American Express credit agents use the Authorizer's Assistant KBS for increased consistency, speed, and accuracy in their decisions.

It is also possible for KBS's to capture knowledge at the organizational and knowledge link levels. A good example of this is Digital Equipment Corporation which has a VAX-based knowledge network (Fig. 3), integrating and facilitating knowledge flows related to the sale of computers across several different functions [1]. Major components in Digital's VAX-based knowledge network are: XSEL (used to support field sales people in translating a customer's computing needs into computer orders which can then be configured by Digital), XCON (used to validate the technical correctness of customer orders and guide the assembly of these orders), CAN BUILD (used for inventory scheduling), MOS (used for manufacturing planning), NDR (used to control the scheduling of trucks), XFL (used for diagraming a computer room floor layout for the proposed configuration), XNET (used for designing local area networks), and SIZER (used for sizing computing resources according to customer needs). These expert systems, databases, and conventional management information systems cumulatively form a powerful KBS capturing important aspects of Digital's organizational knowledge in the domains of sales, engineering, manufacturing, and customer service.

KBS's are tangible knowledge assets, and can be distributed widely within an organization. Thus they offer a practical and easy solution for companies to apply their critical knowledge at many different sites simultaneously and consistently. With the help of a KBS, an inexperienced employee can reach a higher level of performance faster. The slower the "normal" rate of learning, the larger the impact of the KBS in speeding up the learning process. KBS's can also help in enhancing the learning rate of the entire organization. As an example, consider the ExperTax KBS of Coopers and Lybrand. ExperTax assists junior accountants in the tax auditing and planning tasks. A central office in Coopers and Lybrand is responsible for maintaining all changes in the knowledge base of ExperTax. Whenever tax laws change (and they do so frequently), the central office in Coopers and Lybrand makes the appropriate changes in ExperTax's knowledge base, and the revised version is shipped out to the hundreds of Coopers and Lybrand field auditors all over the United States. As all field auditors use the same ExperTax KBS, the changes in tax laws are immediately reflected in their task performances. Thus Coopers and Lybrand is able to propagate the effects of changes in the knowledge contents of critical tasks effortlessly and rapidly. When the U.S. tax laws were changed radically in 1986, Coopers and Lybrand was able to incorporate and implement these changes nationwide within six weeks [8], and with minimal additional training. A short turnaround time in implementing such changes in a knowledge intensive company can lead to major competitive advantages in the marketplace.

It is obvious that KBS's can play a major role in improving organizational effectiveness through the effective management of organizational knowledge assets. The competing values model of organizational effectiveness proposed by Quinn and Rorhbaugh [38] can be used to describe the distinct ways in which KBS's can improve organizational effectiveness. This particular model has the advantage of being widely accepted and researched in the literature [4], [42] and has also been used by Stein and Zwass [42] in their analysis of organizational memory information systems. Based on research by Quinn and Rorhbaugh [38] it is possible to identify four distinct clusters of organizational effectiveness criteria.

1) *Integration:* this refers to organizational coordination and integration (both spatially and temporally) of information and knowledge across the organization.
2) *Adaptation:* this refers to the ability of the organization to adapt to changes in the environment, both internal and external.
3) *Goal Attainment:* this refers to the organizational capability of setting and measuring the attainment of goals.
4) *Pattern Maintenance:* this refers to the ability of the organization to maintain the cohesion, values, norms, personal routines, and development of its employees [42, pp. 101–102].

While it is possible to identify the previously mentioned examples of KBS's as contributing to the overall organizational effectiveness along multiple dimensions, certain dominant matches emerge. Digital's VAX-based knowledge network demonstrates how KBS's can help a company to achieve higher levels of integrative organizational effectiveness. Coopers and Lybrand's ExperTax system demonstrates how a KBS can help an organization adapt to changes in its environment more effectively. American Express' Authorizer's Assistant is a good example of how a KBS can help a company maintain the achievement of its critical goals at acceptable levels. While the examples presented in this section do represent a limited range of KBS applications, they provide evidence that KBS's can help organizations to become more effective by helping them to manage their knowledge assets more effectively.

III. Strategies for the Development of KBS's

This section outlines different phases in the development of KBS's and focuses on knowledge processing strategies for the development of KBS's.

A. Phases of Development

Five important phases can be identified in the process of managing the development of KBS's within organizations.

1) *Knowledge Processing Strategy:* The development of KBS's within an organization has to follow an overall strategy, which is determined by the knowledge profile and the desired knowledge management strategy of the organization.
2) *Strategic Application Identification:* Though many different KBS applications may be possible within an organization, competitive needs of the organization dictate the selection of an appropriate set of strategic KBS applications.
3) *Application Feasibility:* Available organizational resources place additional constraints on the feasibility of building competitively desirable KBS applications.
4) *Application Creation:* Once an application has been selected and deemed to be feasible, it has to be created, i.e., designed and implemented.
5) *Deployment and Maintenance:* After creation, a KBS application has to be deployed in the field, and suitable arrangements have to be made for its maintenance.

The last three phases listed above have received the most attention in the KBS's literature. It is common to find detailed lists and questions in prior research specifying conditions under which it is feasible to develop KBS's [16], [20], [36], [40], [45], descriptions of technological challenges in creating these systems [7], [10], [11], [47], and guidelines for their successful deployment and maintenance within organizations [7], [10], [11], [21], [26], [36], [46]. In comparison, the first two phases of knowledge processing strategy formulation and strategic application identification have received less attention in the literature. While the focus within the literature on application identification has been on task and domain characteristics (such as "cooperative and knowledgeable expert is available" and "domain knowledge is fairly structured"), little has been written about links to the desired knowledge processing strategy of the organization.

Some researchers [3], [22], [24], [25] have approached the idea of strategic planning for developing expert systems. With the notable exception of Meador and Mahler [24], few have focused on the importance of corporate strategies for developing expert systems. Most [3] touch upon the subject with a brief reference to the fact that expert systems should lead to a competitive edge for the company. Some others [25] mention that expert systems planning should address the creation, handling and dissemination of knowledge, but focus on issues related to knowledge engineering [7], [10]. Meador and Mahler [24] explicitly outline two strategies for developing expert systems using the experiences of Digital and Dupont and their ideas are incorporated in this paper. However, they do not emphasize links between the proposed strategies to the management of an organization's knowledge assets.

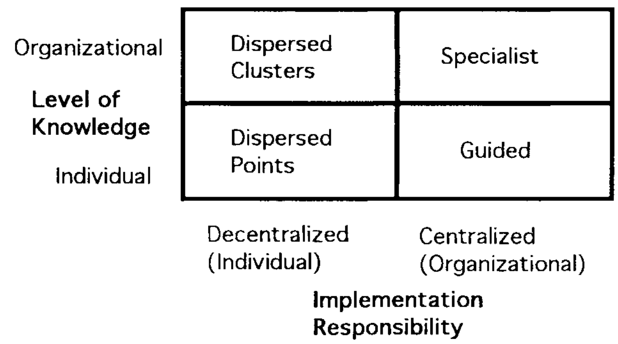

Fig. 4. Different knowledge processing strategies.

B. Knowledge Processing Strategies

As detailed in Section II-B, there are four distinct levels of (organizational) knowledge: individual, group, organizational, and knowledge links. We consider only two levels of knowledge in the following analysis: individual and organizational. KBS's focused at the individual level of knowledge tend to capture and encode the expertise of an expert (or a group of experts) for a specific task. KBS's targeted at the organizational level tend to impact knowledge flows across different tasks or functions within the organization.

Another important factor is the locus of responsibility for the implementation of KBS's. Restricting our analysis to the two levels mentioned earlier: individual and organizational, it is possible to identify two distinct loci of responsibility for KBS development. At one extreme, a central group can be made responsible for all aspects of the implementation of KBS's within the organization. Here, the organization assumes the responsibility for the implementation of KBS's. At the other extreme, it is possible to have a decentralized approach to KBS development in which individuals or groups (of end users) are responsible for most aspects of KBS implementation.

Based on the different possible values along these two dimensions—*level of knowledge* and *implementation responsibility*—four different broad strategies (Fig. 4) can be identified for KBS development within organizations as explained in the following subsections.

1) Guided: This reflects a centralized approach to developing KBS's targeted at the individual level of knowledge assets. Corporations adopting this strategy usually form a centralized task force/development group for exploring the utility of KBS's for enhancing the effectiveness of individual performances. The emphasis is typically on capturing and distributing the knowledge of specific experts within the organization, whose expertise would be of use to other employees performing the same (or similar) task. The centralized KBS development group provides all resources—such as tools and staff—for building the KBS's. It also usually controls all aspects of the development process. This is the cautious approach adopted by many companies experimenting for the first time with KBS technology. The developed systems are generally small in size as they attempt to capture the knowledge of one (or a few) individuals(s). Risks are low, and successful KBS's can be developed if the central group is capable, well qualified for the task, and has the support of management. Conventional expert systems such as American Express' Authorizer's Assistant are good examples of KBS's typically developed under such a strategy.

2) Specialist: This strategy[1] also requires a centralized KBS development group, but it differs from the guided strategy in being focused on the development of KBS's which span task/functional boundaries, and influence knowledge flows across the organization. Due to the large potential impact of the developed KBS's, the adoption of such a development strategy requires the total commitment of the top management of the company to the KBS development efforts. The central KBS development group is larger than in the guided strategy, and the developed KBS's are also more complex (usually a combination of databases, expert systems, management information systems, and other conventional software programs). The complexity arises from not only from an increase in the size and scale of the knowledge assets being tackled (organizational as opposed to individual), but also from a need to integrate the individual (and varied) components of the KBS's across functional or task boundaries with the aim of improving knowledge flows within the organization. The risks are high in this approach, and it calls for the highest caliber professional engineers, good funding, and total and sustained top management support.

A good example of a company adopting such a strategy is Digital [24]. Digital has established a major centralized KBS technology group called the Artificial Intelligence Technology Center (AITC) at Marlborough, MA. The AITC has about 300 specialized programmers and knowledge engineers devoted to implementing and maintaining Digital's KBS (VAX-based knowledge network). The VAX-based knowledge network integrates different functions and facilitates the flow of knowledge across different parts of the organization. For example, the XSEL, XCON, XFL, XNET, and SIZER KBS's (Fig. 3) integrate and facilitate the flow of knowledge regarding computer configuration across the functions of sales, engineering, and customer service within Digital. Building the VAX-based knowledge network requires experience in building KBS's and sustained top management support. Though the AITC does not control all aspects of KBS development within Digital, it serves as an important locus for activities related to KBS's, and for ensuring that the developed KBS's meet certain communication and data standards so that they can be easily integrated into the organization.

3) Dispersed Points: This strategy[2] is almost diametrically opposite to the specialist strategy in that it puts all (or most) of the burden of developing and managing KBS's on individual end users. In this approach a KBS tool (such as an expert system shell tool [11]) is promoted as a tool for enhancing personal productivity, in much the same way as spreadsheet and database packages. Individuals are trained on a particular KBS tool, and then given the freedom to develop KBS's to aid their own tasks or decision processes. These individuals are both the developers and the users of the developed KBS's. Most of the developed KBS's are targeted at the individual knowledge level, and are typically small (in size) and simple (in complexity). Consequently, they are also developed rapidly and maintained easily (by the users themselves). Risks and costs are fairly low in this approach, but it requires a reasonably large base of computer literate individuals who are willing to invest time and energy in learning about KBS tools, and developing working KBS's. As this strategy assumes little centralized control, there can be problems of coordination, duplication, and standardization among the developed KBS's. User groups (both formal and informal) are desirable for minimizing such problems.

A company such as DuPont is a good example for illustrating such a strategy. Since 1985, DuPont has been training its end users to develop their own KBS's. By 1990, they had approximately 600 different small PC based expert systems installed in their different business units [24]. This strategy is possible because DuPont had about 30 000 Lotus-literate managers in 1990, and this number is expected to grow to 60 000 by the end of the decade. As a direct result of this strategy, it is estimated that in 1990 about 1800 DuPont managers were able to use KBS tools (usually PC-based expert system shell tools [11]) as readily as spreadsheets, electronic mail, and other office automation packages. As most KBS's are developed on personal computers with shell tools, their development costs are small (about $40 000 each). Although DuPont follows the dispersed points strategy, a centralized initiative was necessary to start the process. This was provided by limited seed money ($3 million given by top management) and a small centralized task force of about a dozen people, which started and coordinated the process of training individual end users on KBS tools.

4) Dispersed Clusters: This strategy can be considered as a hybrid between the specialist and dispersed point strategies. There is no one strong locus of centralized control, but rather a few loci of activities related to KBS development. These clusters can exist in different business divisions, subsidiaries, or groups. Each cluster is responsible for the development of KBS's within its own span of control or interest. This strategy is conceptually similar to the dispersed point strategy, except for the difference that the "points" are not direct end users, but rather formal or informal groups. Problems of coordination can arise if there are many clusters. Thus such a strategy is useful if the organization is in a few distinctly different businesses.

Xerox is following a KBS development strategy that is a mix of the specialist and dispersed clusters approaches. Since 1989, Xerox's centralized Knowledge-Based Systems Competency Center (KBSCC) has initiated an innovative KBS Circles Program [22] to leverage Xerox's "Leadership through Quality" program. Each KBS circle consists of a group of individuals who are operating as a "quality improvement team." KBSCC provides hardware and software support to each KBS circle, and helps them to interface with departmental information management departments. Each KBS circle attempts to use KBS technology to address a high

[1] The term "specialist" has been used by Meador and Mahler [24] to describe the KBS strategy of Digital.

[2] The term "dispersed" has been used by Meador and Mahler [24] to describe the KBS strategy of DuPont.

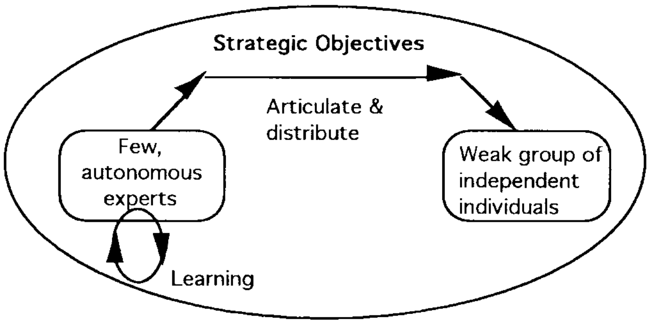

Fig. 5. The management of knowledge with the "guided" strategy.

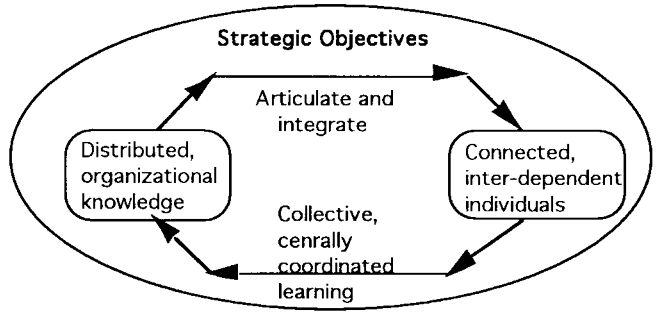

Fig. 6. The management of knowledge with the "specialist" strategy.

corporate priority, knowledge-intensive problem. Ten circles were started in April 1989, and the benefits from their efforts are estimated to be very significant in financial terms.

IV. Strategic Implications of Knowledge Processing Strategies

This section outlines the implications for knowledge management of the four knowledge processing strategies mentioned previously.

A. Impact on the Management of Knowledge

It is useful to revisit Fig. 1 of Section II-C to understand how the four knowledge processing strategies described in Section III-B impact the management of knowledge within an organization.

The management of knowledge with a guided strategy is depicted in Fig. 5. A guided strategy is well suited to an organization with a major part of its critical knowledge assets incorporated in a few autonomous experts and with the need to articulate and distribute this knowledge to several dispersed, relatively autonomous individuals within the corporation. This strategy can only function if: 1) it is possible to identify the experts, 2) the experts are able to articulate their knowledge, and 3) there is little interdependence for effective task performance in the resulting knowledge network (composed of several individuals using the KBS's). There is relatively little learning within the knowledge network; most of the learning occurs within the few experts and is coordinated by the central group.

The management of knowledge with the specialist strategy works well (see Fig. 6) if the organization's core knowledge assets are dispersed and a significant amount of coordination across and integration of these assets are required for effective organizational performance. The resulting knowledge network is composed of a group of interdependent knowledge workers and the collective learning of the organizational knowledge asset requires a centrally coordinated approach due to the complexity of the knowledge network and the resulting work processes. A barrier to the success of the specialist strategy is an inability of the organization to articulate the interdependencies between the distributed knowledge assets to a degree necessary for the successful implementation of KBS's. Failure in articulation would also imply an inability to coordinate the necessary learning. Sustained top management support is also

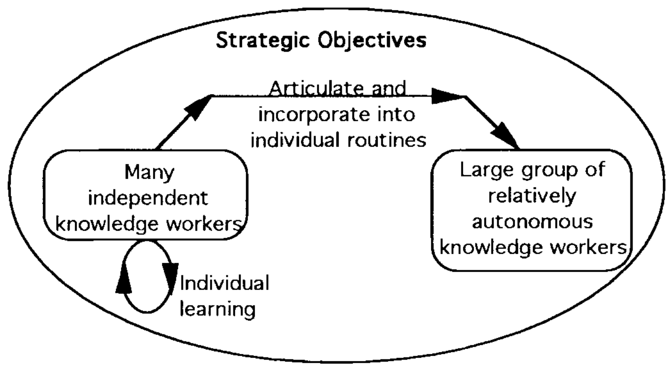

Fig. 7. Knowledge management with the "dispersed points" strategy.

necessary for creating and supporting a successful knowledge network within the specialist strategy.

Fig. 7 depicts the management of knowledge with the dispersed points strategy. This strategy is well-suited to an organization where the knowledge assets are contained within many relatively independent knowledge workers. There is no need for a widespread dissemination of these knowledge assets across the corporation; rather, effective organizational performance is achieved when each knowledge worker is able to articulate specific aspects of his/her knowledge and express them in KBS's which are used primarily by the knowledge worker and perhaps a limited number of other individuals. The knowledge network is a loose, sparsely connected group of knowledge workers and most learning occurs on a widespread but individual basis.

Fig. 8 illustrates the management of knowledge within the dispersed clusters strategy. The focus, as in the specialist strategy, is on knowledge at the organizational level. However, the emphasis is on selective integration of knowledge across the organization (such as across key processes or within related functions/departments). There are several knowledge networks within the corporation. These networks have a high degree of internal connectivity, but do not necessarily have strong links to each other. All learning is coordinated within each knowledge network by the members of the network (as opposed to by a central group within the specialist strategy).

B. Impact on Organizational Effectiveness

The impact of the different knowledge processing strategies on organizational effectiveness can be described in terms of

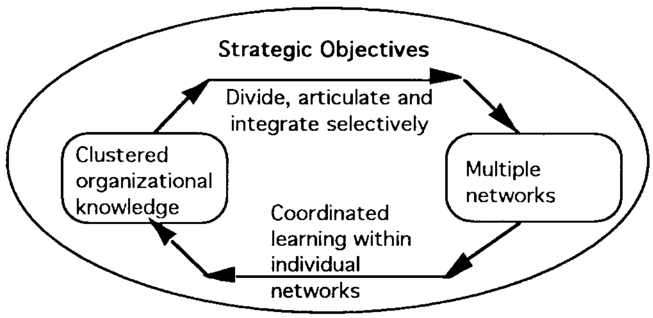

Fig. 8. Knowledge management with the "dispersed clusters" strategy.

the four organizational effectiveness dimensions of Quinn and Rohrbaugh [38] (see Section II-D): integration, adaptation, goal attainment, and pattern maintenance. An implicit assumption in the following analysis is that KBS's do actually cause the described changes in organizational effectiveness. While there is increasing evidence that the implementation of KBS's and advanced IT systems do improve organizational effectiveness [7], [15], [42], there are also numerous examples quoted in the literature where KBS's were neither implemented successfully nor used appropriately [7], [31]. In other words, with reference to the five phases of development of KBS's outlined in Section III-A, it is important to keep in mind that effective organizational performance would require the successful implementation of all five phases and not just the choice of the "appropriate" knowledge processing strategy.

The choice of a guided strategy results in a higher degree of spatial integration [42] of knowledge (i.e., application of knowledge more uniformly across the corporation); an enhanced capability to reflect changes in the core knowledge of the few experts across the corporation; a greater ability to achieve certain organizational goals resulting from the consistent and widespread application of the experts' knowledge; and finally an ability to enhance the cohesion within the work force (by supporting the use of similar individual routines) and thus contribute to the pattern maintenance dimension.

The organizational value achieved by the specialist strategy can be described as follows: a higher degree of integration (both spatial and temporal [42]) of knowledge and organizational performance throughout the corporation; a greater capability to adapt to the impact of changes in knowledge in parts of the organization; an enhanced ability to achieve organizational goals resulting from the integration of knowledge assets across the company; and an ability to maintain a greater degree of cohesion (through the support of mutually interdependent routines) in the work force.

The value of the dispersed points strategy can be witnessed in a greater ability of the organization to adapt to changes in its individual knowledge assets as reflected by the evolving knowledge of its knowledge workers. Organizational goals which are dependent on this adaptability are consequently better satisfied. Also, there is a positive impact along the pattern maintenance function due to the ability to contribute to the personal development of the knowledge workers.

The major benefits of the dispersed clusters strategy can be described as follows: a higher degree of integration of knowledge (both spatial and temporal [42]) within selected parts of the corporation and a proportionately enhanced ability to achieve organizational goals resulting from the selective integration of knowledge assets. There is a positive impact along the pattern maintenance dimension through the encouragement of teamwork and personal development of knowledge workers.

While each of the four knowledge processing strategies can be seen as contributing to different degrees along the four organizational effectiveness dimensions of Quinn and Rohrbaugh [38], certain dominant matches can be identified. The organizational effectiveness achieved along the goal attainment dimension is most significant with the guided strategy. This is because the guided strategy makes it possible for the organization to set and achieve higher goals through the appropriate dissemination of expert knowledge. The focus within the specialist strategy is on integrating organization-wide knowledge assets and thus can be seen as contributing most to the integrative aspect of organizational effectiveness. The dispersed points strategy empowers individual knowledge workers to leverage their individual knowledge assets autonomously. Thus a dominant match can be identified between this strategy and the adaptive dimension of organization effectiveness. The dispersed clusters strategy is a hybrid between the specialist and the dispersed points strategy. Thus its major contributions lie along both the integration and adaptation dimensions of organizational effectiveness.

C. Factors Affecting the Choice of Strategy

While the characteristics of the management of knowledge possible within the different strategies vary as described in the previous section, no one KBS development strategy is inherently superior. An organization is not limited to any one strategy for nurturing the development of KBS's. It may change strategies with time, and can even pursue more than one strategy simultaneously. For example, an organization may initially use the guided strategy to gain familiarity with KBS technology, and with time and increased confidence, adopt a combination of the specialist and dispersed points strategies. It is also possible to adopt different strategies in different parts of the organization depending upon their relative knowledge management needs.

The knowledge profile of the organization is a major factor influencing the choice of the appropriate knowledge processing strategy. An centralized approach, such as the specialist strategy, is desirable if there is a high degree of integration in knowledge flows across different functions in an organization. This integration can be easily seen in Digital, which is in the sole business of selling computers, and requires a tight integration of knowledge flows across sales, engineering and manufacturing, and customer service. Decentralized strategies are more preferable if the organization has many different subunits, each of which is relatively independent in its knowledge requirements. DuPont is a good example of such an organization: it has some 1700 different product lines with relatively independent knowledge profiles. To stay at the leading edge in so many different products, DuPont encourages a strong sense of independence and technical excellence among its

	Guided	Specialist	Dispersed points	Dispersed Clusters
Technical Concerns				
Size of KBSs	Small to medium	Large	Small	Medium to large
Complexity of KBSs	Simple or medium complexity	Complex	Simple	Complex
Technical skills in users	Not essential	Not essential	Critical	Useful
Central pool of technical experts	Essential	Critical	Not essential; some central coordination useful	Useful
Technical risks	Low	High	Low	Medium
Costs	Low (< $1m)	High (> $5m)	Low (< $1m)	Medium ($1m - $3m)
Time horizon for development	Short term (< 1 year)	Long term (2-3 years)	Short term (< 1 year)	Medium/long term (1 - 3 years)
Organizational Concerns				
Overall organizational risk	Low	Medium to high	Medium to high	High
Top management commitment	Low to medium	High	Low	Medium to high
Facilitators	• Few experts with core knowledge • Need to spread expert knowledge within corporation	• Acknowledged need for integrating knowledge • Appropriate levels of cooperation across corporation	• Many relatively independent knowledge assets (employees) • Educated and skilled staff	• Multiple lines of businesses with independent knowledge flows • History of team work within firm
Barriers	• Experts cannot be identified • Expert knowledge cannot be easily articulated	• Knowledge interdependencies too complex • Inadequate top management support	• Strong interdependencies across knowledge assets • Inadequate IT skills within employees	• Inability to identify the "right" clusters • Inadequate management support for clusters
Major value for organizational effectiveness	• Attainment of specific goals	• Integrating organizational knowledge flows	• Greater degree of adaptability	• Greater degree of adaptability • Selective integration of organizational knowledge flows

Fig. 9. Implications of different knowledge processing strategies.

employees. Thus a dispersed point strategy seems appropriate for the knowledge flows within DuPont.

If a company is new to the domain of KBS's, it is best to pursue a guided strategy because it minimizes risk and costs, and provides a good environment for experimenting with the technology. Though the dispersed points strategy is of low cost, it should be avoided if KBS technology is new to the company because end users can be easily misguided during the experimental stages, and their initial results can be misinterpreted by management. All other strategies require a larger degree of commitment and should be chosen only after the company has acquired a certain degree of familiarity with, and confidence in, KBS technology.

Resources such as people, capital, and information systems architectures also impact the choice of a knowledge processing strategy. If a company has a large base of computer literate end users (as in DuPont), decentralized strategies may be appropriate; but if there is a limited number of computer literate end users, centralized strategies may be better. Large capital investments are required for the specialist and dispersed cluster strategies. The guided and dispersed points strategies are relatively less resource intensive to implement. Centralized strategies are facilitated by the presence of an uniformly consistent information systems architecture. For example, Digital has fairly uniform data and communication standards throughout the company. Digital's centralized AI Technology Center ensures that developed KBS's fit into this information architecture. However, for a company such as DuPont, a decentralized development strategy seems more appropriate because there is no common information systems architecture with different computing platforms being used in a relatively uncoordinated manner.

The choice of knowledge processing strategies is also related to the strategic nature of the desired KBS applications. Guided and dispersed points strategies are well-suited for enhancing knowledge processing within specific value activities [34] (such as credit authorization for American Express). With some central coordination, these strategies can also lead to limited knowledge transfers across value activities. The specialist and dispersed clusters strategies are best suited for enhancing knowledge transfers across value activities and for reconfiguring knowledge flows across the organization (such as in Digital). The dispersed clusters and specialist strategies can lead to such an integrative coordination and give the organization a special competency[3] or capability [41] which is not easily duplicated by competing organizations.

Regardless of the chosen strategy (see Fig. 9 for a summary of the four strategies), it is important that there is some thought and consensus about it. All too often organizations have rushed into adopting advanced IT systems without thinking through the strategic implications of the technology. For example, during the late 1980's, several organizations started investing in expert systems technology without due attention to the competitive needs satisfied by expert systems and their relation to the organization's knowledge management needs. This often resulted in a wasteful expenditure of resources and a subsequent disillusionment with the technology [7], [17]. Note that the chosen knowledge processing strategy influences both the nature of desirable KBS applications and the distribution of responsibility for their development.

V. Conclusion

The management of organizational knowledge is a relatively new and challenging concept for most organizations. KBS's can have an important role in the management of organizational knowledge at all levels: individual, group, organizational, and knowledge links. With considerable progress in the underlying technologies, the major challenges in the implementation of KBS's have evolved from technical matters to organizational and strategic issues. This research has focused on the relationship between KBS's and the management of an organization's knowledge assets. Specifically, four different strategies (guided, specialist, dispersed points, and dispersed clusters) have been proposed and described in relation to the different levels of organizational knowledge and the locus of responsibility for the development of KBS's. The technical, managerial and strategic implications of each of the four strategies have also been discussed.

The research presented in this paper is by no means complete. There are several related concerns which are either beyond the scope of this research or serve as avenues for further research. These concerns are summarized below.

Noting the five phases of KBS development outlined in Section III-A, it is useful to reemphasize that this paper has focused on only the first phase, namely the choice of an appropriate knowledge processing strategy. A description of issues related to the four remaining phases has not been included in this paper [7], [10], [11], [36].

The successful implementation of all five phases of KBS development is a necessary but not sufficient condition for enhancing organizational effectiveness through the use of KBS's. However, a description of the reasons why a KBS, even after the successful implementation of all five phases, may not lead to enhanced organizational effectiveness has not been included in this research [7], [31], [42].

The choice of the appropriate knowledge processing strategy is a complex issue. While Section IV has outlined the impact of these strategies in broad strokes, there are several other factors which have not been included in the discussion. For example, cultural factors, both organizational and national, can have important impacts in favoring certain types of knowledge networks. For example, organizational (group) knowledge seems to be more dominant in Japanese corporations [13]. Thus it would make more sense to consider the specialist and/or dispersed clusters strategy within such firms. This relationship between culture and the desired knowledge processing strategy can serve as a fruitful avenue for further research.

The knowledge processing strategies described in the paper have considered only two levels of knowledge assets: individual and organizational. Research shows that both the group and knowledge link levels of knowledge are important. For example, groups play an important role in knowledge transfer and learning, specially in new product development [32]. Current research in operations management [12] also illustrates the importance of collaborative knowledge links with suppliers and partner organizations. Thus the strategies presented in this research could be honed further by including the group and knowledge link levels of knowledge assets.

Finally, knowledge is a rich, multifaceted concept. This research has essentially considered one classification (along the four levels) of knowledge. Different insights can be obtained by considering other aspects of knowledge. For example, Dutta [7] and Bohn and Jaikumar [2] have outlined different stages of knowledge ranging from ignorance to complete and total knowledge about a particular topic. Others [14] have identified different types of knowledge such as cognitive knowledge, skills-related knowledge, and knowledge embodied within products and services. Including these dimensions of knowledge can also provide an additional avenue for further research.

[3] A core competency has been defined [35] as the ability of an organization to "coodinate diverse production skills and integrate multiple streams of technologies."

References

[1] V. E. Barker and D. E. O'Connor, "Expert systems for configuration at digital, XCON and beyond," *Comm. ACM*, vol. 32, no. 3, pp. 298–318, Mar. 1989.

[2] R. Bohn and R. Jaikumar, "The structure of technological knowledge in manufacturing," Harvard Bus. School Working Paper, 1992.

[3] B. Braden, J. Kanter, and D. Kopcso, "Developing an expert systems strategy," *MIS Quart.*, pp. 459–466, Dec. 1989.

[4] K. S. Cameron, "A study of organizational effectiveness and its predictors," *Manage. Sci.*, vol. 32, no. 1, pp. 87–112, 1986.

[5] Daedalus, *Special Issue on Artificial Intelligence,* Winter 1988.

[6] G. B. Davis and M. H. Olson, *Management Information Systems: Conceptual Foundations, Structure and Development.* New York: McGraw-Hill, 1985.
[7] S. Dutta, *Knowledge Processing and Applied Artificial Intelligence.* London: Heinemann, Mar. 1993.
[8] ExperTax, case study no. 9-187-007, Harvard Bus. School, 1988.
[9] E. Feigenbaum, P. McCorduck, and H. P. Nii, *The Rise of the Expert Company.* New York: Times Books, 1988.
[10] P. Harmon and B. Sawyer, *Creating Expert Systems.* New York: Wiley, 1990.
[11] P. Harmon, R. Maus, and W. Morrissey, *Expert Systems: Tools and Applications.* New York: Wiley, 1988.
[12] R. Hayes, S. Wheelwright, and K. Clark, *Dynamic Manufacturing: Creating the Learning Organization.* New York: Free Press, 1988.
[13] G. Hedlund and I. Nonaka, "Models of knowledge management in the west and Japan," in *Implementing Strategic Processes, Change, Learning and Cooperation*, P. Lorange, B. G. Chakravarthy, J. Roos, and H. Van de Ven, Eds. London: Basil Blackwell, 1993, pp. 117–144.
[14] G. Hedlund, "A model of knowledge management and the N-form corporation," *Strategic Manage. J.,* vol. 15, pp. 73–90, 1994.
[15] G. P. Huber, "A theory of the effects of advanced information technologies on organizational design, intelligence, and decision making," *Acad. Manage. Rev.*, vol. 15, no. 1, pp. 47–71, 1990.
[16] H. K. Jain and A. R. Chaturvedi, "Expert system problem selection: A domain characteristics approach," *Info. Manage.*, vol. 17, pp. 245–253, 1989.
[17] T. P. Kehler, "AI or knowledge processing will be a boon to MIS," *Info. Week*, Jan. 26, 1987.
[18] B. Kogut and U. Zander, "Knowledge of the firm and the replication of technology," *Organizat. Sci.*, vol. 3, no. 3, pp. 383–397, 1992.
[19] A. Kupfer, "Now live experts on a floppy disk," *Fortune*, p. 49, Oct. 12, 1987.
[20] S. C. Laufmann, D. M. DeVaney, and M. A. Whiting, "A methodology for evaluating potential KBS applications," *IEEE Expert*, pp. 43–61, Dec. 1990.
[21] D. Leonard–Barton, "The case for integrative innovation: An expert system at Digital," *Sloan Manage. Rev.*, pp. 7–19, Fall 1987.
[22] M. C. Maletz, "KBS circles: A technology transfer initiative that leverages Xerox's 'leadership through quality program'," *MIS Quart.*, pp. 323–329, Sept. 1990.
[23] J. McCarthy, "Epistemological problems of artificial intelligence," in *Proc. 5th Int. Joint Conf. Artificial Intell.,* 1977, pp. 1038–1044.
[24] C. L. Meador and E. G. Mahler, "Choosing an expert systems game plan," *Datamation*, Aug. 1, 1990.
[25] B. Moulin, "Strategic planning for expert systems," *IEEE Expert*, pp. 69–75, Apr. 1990.
[26] E. Mumford and W. B. Macdonald, *XSELO's Progress: The Continuing Journey of an Expert System.* New York: Wiley, 1989.
[27] E. Mumford, "Managerial expert systems and organizational change: Some critical research issues," in *Critical Issues in Information Systems Research,* R. J. Boland, Jr. and R. Hirschheim, Eds. Chichester, U.K.: Wiley, 1987, pp. 135–155.
[28] A. Newell, "The knowledge level," *AI Mag.*, vol. 1, pp. 1–20, 1981.
[29] I. Nonaka, "Managing the firm as an information creation process," working paper, Hitotsubashi Univ., 1987.
[30] D. E. O'Leary and E. Turban, "The organizational impact of expert systems," in *Human Systems Management*, vol. 7, no. 1. Amsterdam: Elsevier, 1987, pp. 11–19.
[31] W. Orlikowski, "Learning from notes: Organizational issues in groupware implementation," Tech. Rep. #131, Ctr. for Coord. Sci., MIT, Cambridge, MA, 1992.
[32] G. P. Pisano, "Knowledge, integration, and the locus of learning: An empirical analysis of process development," *Strategic Manage. J.*, vol. 15, pp. 85–100, 1994.
[33] M. Polanyi, *Personal Knowledge: Toward a Post-Critical Philosophy.* New York: Harper, 1962.
[34] M. E. Porter, *Competitive Advantage: Creating and Sustaining Superior Performance.* New York: Free Press, 1985.
[35] C. K. Prahalad and G. Hamel, "The core competence of the corporation," *Harvard Bus. Rev.*, pp. 79–91, May/June 1990.
[36] D. S. Prerau, *Developing and Managing Expert Systems.* Reading, MA: Addison-Wesley, 1990.
[37] M. J. Prietula and H. A. Simon, "The experts in your midst," *Harvard Bus. Rev.*, pp. 120–124, Jan/Feb. 1989.
[38] R. E. Quinn and J. Rohrbaugh, "A spatial model of effectiveness criteria: Toward a competing values approach to organizational analysis," *Manage. Sci.,* vol. 29, no. 3, pp. 363–377, 1983.
[39] R. S. Sharma, D. W. Conrath, and D. M. Dilts, "A socio-technical model for deploying expert systems—Part I: The general theory," *IEEE Trans. Eng. Manage.*, vol. 38, pp. 14–23, Feb. 1991.
[40] J. Slagle and M. Wick, "A method for evaluating candidate expert system applications," *AI Mag.,* vol. 9, no. 4, pp. 44–53, 1988.
[41] G. Stalk, P. Evans, and L. E. Shulman, "Competing on capabilities: The new rules of corporate strategy," *Harvard Bus. Rev.*, pp. 57–69, Mar./Apr. 1992.
[42] E. W. Stein and V. Zwass, "Actualizing organizational memory with information systems," *Info. Sys. Res.*, vol. 6, no. 2, pp. 85–117, 1995.
[43] T. A. Steward, "Brainpower," *Fortune*, pp. 42–60, June 3, 1991.
[44] J. J. Sviokla, "An examination of the impact of expert systems on the firm: The case of XCON," *MIS Quart.*, pp. 127–140, June 1990.
[45] ——, "Business implications of knowledge based systems," *Data Base,* vol. 17, no. 4, pp. 5–19, pt. 1; vol. 18, no. 1, pp. 5–16, pt. 2, Summer/Fall 1986.
[46] E. Turban and J. Liebowitz, Eds., *Managing Expert Systems.* Harrisburg, PA: Idea, 1992.
[47] E. Turban, "Review of expert systems technology," *IEEE Trans. Eng. Manage.*, vol. 35, pp. 71–81, May 1988.
[48] J. P. Walsh and G. R. Ungson, "Organizational memory," *Acad. Manage. J.*, vol. 16, no. 1, pp. 57–91, 1991.
[49] B. Wernerfelt, "A resource-based view of the firm," *Strategic Manage. J.,* vol. 5, no. 2, pp. 171–181, 1984.

Soumitra Dutta (M'96) received the M.S. degree in business administration and the Ph.D. degree in computer science from the University of California at Berkeley.

He is presently an Associate Professor of Technology Management at the European Institute of Business Administration (INSEAD), Fontainebleau, France. He is also a Visiting Associate Professor at the Haas School of Business, University of California, Berkeley. His research interests focus on the role of technology in knowledge management and organizational change. He authored *Knowledge Processing and Applied Artificial Intelligence* (Butterworth–Heinemann, 1993).

Dr. Dutta is a member of ACM and INFORMS.