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Decision Support Loop based on Knowledge Integration: A Cognitive Model Perspective

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Knowledge management has been increasingly recognized as important in business management context. Although knowledge management has been proposed as an enabler to reach competitive advantage, little research has considered applying knowledge to business decision-making activities, which may be the main task of enterprise management. The application of knowledge to decision-making has a more significant impact on organizational performance than mere knowledge management for operational level processing. For this purpose, the present study proposes a decision support loop based on the integration of knowledge by adopting a cognitive modeling approach. The proposed model is then discussed in the real context of an application case.

Keywords : Organizational knowledge, Decision-making Support, Cognitive model

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Ⅰ. Introduction

Knowledge Management (KM) can be defined as the uncovering and managing of various levels of knowledge from individuals and teams, and from the organization itself, in order to improve organizational performance. One of the prerequisites for successful KM is an appreciation of what Nonaka [1994] described as "tacit" knowledge. Effective KM requires such "tacit" knowledge to be transformed to "explicit" knowledge, and then organized accordingly. Integrating individual knowledge from diverse areas into organizational knowledge leads to not only new knowledge but also new understanding [Huber, 1991], which also helps decision-makers choose appropriate action to achieve organizational goals [Brown and Dugid, 1998; Stein, 1995].

Competitive advantage results from the application of the knowledge rather than from the knowledge itself [Alavi and Leidner, 2001]. However, most KM research have focused on identifying, storing, and diffusing knowledge for efficient and effective transaction-processing [Grover and Davenport, 2001]. There have been little research on the application of organizational knowledge or KM to business decision-making or strategic planningwhich is the core activity of business management. Business management-related knowledge covering cross-functional areas has a more significant impact on organizational performance than does individual or team-level knowledge covering individual tasks or functional processes.

The study proposes a linkage between knowledge management and support for business decision-making. The study is in three parts. First, it reviews previous research on KM for managerial problems, discusses the use of KM in organizations from the perspectives of top management, middle management, and employees, and reviews the characteristics of managerial problems in linking KM to decision support. Secondly, by adopting a cognitive modeling approach, the study proposes a decision-support loop obtained by integrating individual knowledge as it resides in mental models into an organizational model. The model incorporates a feedback loop among the four elements of the proposed loop: 1) individual knowledge; 2) organizational knowledge; 3) formulating the knowledge model; and 4) testing and decision support. Finally, the study discusses the proposed model based on its application to a real managerial problem.

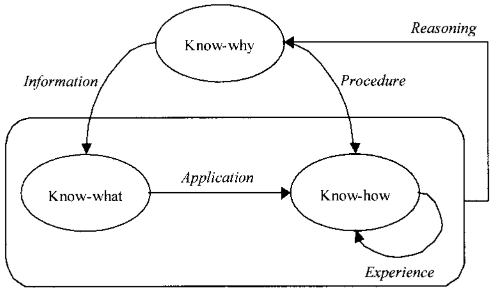
Ⅱ. Conceptual Background

2.1 Knowledge and Knowledge Management

Leonard and Sensiper [1998] defined knowledge as "information that is relevant, actionable, and based partially on experience." They suggested that knowledge is linked to meaningful behavior and that it has tacit elements born of experiences. "Tacit" knowledge is perceivable but difficult to model or transfer because it is unstructured, and because the essence of its nature is necessarily experiential and intuitive [Nonaka, 1994]. Such knowledge enables intuition, insights, and decisions based on "gut feel" [Leonard and Sensiper, 1998].

"Explicit" knowledge differs from tacit knowledge in that the former embodies structural characteristics that enable people to manipulate, organize, model, and transfer its essential elementssuch as its logical and sequential attributes. Anderson [1983] defined "declarative" and "procedural" knowledge, based on the structure of knowledge. He observed that declarative knowledge is expressed with a definition and implies "know-what". In contrast, "procedural" knowledge can be considered as "know-how" by which manipulation of knowledge or behavioral procedure is knowledge itself [Alavi and Leidner, 2001]. Consequently, the taxonomy of knowledge is dependent upon the ontological and epistemological stance taken in assessing it.

Based on previous research, the study proposes a knowledge taxonomy as illustrated in <Figure 1>. This taxonomy consists of three types of knowledge *know-what*, *know-how*, and *know-why*. Compared with the information aspect of *know-what* and the procedural aspect of *know-how*, *know-why* is characterized by a reasoning capability. *Know-what* can be applied to *know-how* which, in turn, can be refined by experiences [Brown and Dugid, 1998]. The experiences enable reasoning as to whether there is any way to do better. The reasoning capability, in turn, identifies any requirements to modify existing *know-what* or *know-how* Whereas *know-how* is critical to making knowledge actionable and operational [Brown and Dugid, 1998], *know-why* is essential to understanding the target situation, and to effective decision-making and improving "tacit" knowledge.



<Figure 1> Taxonomy of knowledge

KM means the systematic process of finding, gathering, integrating, and presenting information in a way that improves employees' comprehension in a specific area of interest. The current KM methods can be classified by knowledge-transfer mode from either tacit/explicit to explicit/tacit, based on Nonaka's [1994] suggestion: socialization, externalization, internalization, and combination.

Despite the fact that most KM methods focus on the attainment and management of knowledge at the operational level, it is often difficult, in practice, to ascertain the actual methods used in business decision-making. An examination of Table 1 illustrates this problem. <Table 1> depicts an organization with three layers of hierarchy-top management, middle management, and the operational level-each with its own characteristics. As indicated in the table, knowledge used by top management is related to decision-making or strategic planning, in which management has a larger proportion of tacit knowledge than explicit knowledge. This is knowledge with an organization-wide scope. In addition, knowledge for business management has a greater impact on organizational performance than individual or team-level knowledge. In the case of middle management, because this level of management requires knowledge related to operations of a department unit, middle managers possess both tacit and explicit knowledge in almost equal proportions. As a consequence, knowledge scope can be limited to a department unit or division level. In conducting individual tasks at the operational level, the use of explicit knowledge is proportionately greater than that of tacit knowledge.

The KM methods as applied to top management have been extremely limited by the nature of the tasks involved and the areas of application. It is often difficult to identify and integrate the knowledge required for solving managerial problems because of the nature of problems dealt with by management-which tend to be unstructured, irregular, and organization-wide. This organization-wide scope requires the gathering and integration of knowledge from diverse areas for business decision-making. Each division of a company has partial knowledge related to the particular matter under consideration by management. Since a great proportion of required knowledge resides in mental models, knowledge management for managerial problems becomes an even more complex matter. In addition, although a manager might possess similar knowledge as a result of previous experiences, it is difficult to validate that the previous knowledge is applicable to the new (albeit similar) situation now under consideration. Therefore, there is a need to integrate the partial knowledge which presently resides in mental models into organizational knowledge, before generating alternatives and testing these for their appropriateness in handling present managerial problems.

2.2 Managerial Problems

Managerial problems, the target of business decision-making, commonly entail two stages in their resolution-problem-formulation and problem-solving [Smith, 1989]. *Problem-formu-*

<Table 1> Characteristics of KM in organization

	Top Management	Middle Management	Employee
Applications of Knowledge	Decision-making, strategic planning	Departmental or divisional task, decision-making	Individual task
Knowledge distribution	Explicit knowledge < Tacit knowledge	Explicit knowledge Tacit knowledge	Explicit knowledge > Tacit knowledge
Knowledge scope	Overall organization	Department or division	Individual
Impact on organizational performance	Maximum	Medium	Minimum
KM Method	Meeting	Benchmarking	Education and training
		KMS, Community of Practice, Expert system, Meeting	

lation consists of identifying the problem, defining the problem, and structuring the problem. Problem definition is the explicit or implicit representation of the problem. The key issues in definition are how the problem should be represented, what elements should be included, and what relationships should be considered among the elements [Smith, 1989]. With respect to problem definition, there are two types of complexity involved-detail complexity and dynamic complexity [Senge, 1990]. Detail complexity, which focuses on static aspects of the problem, arises when there are many variables. Dynamic complexity arises when the same action has different effects in the short run and the long run, when an action has one set of consequences locally and a very different set of consequences in another part of the target, and when cause and effect are distant in space and time. Senge [1990] claimed that the real leverage in most management situation lies in understanding dynamic complexity, rather than detail complexity.

Once defined, a problem needs to be structured for solution. The structuring phase addresses how to go about solving the problem, which involves identifying the major tasks involved in working towards a solution, and identifying the likely means of discharging these tasks [Smith, 1989]. In considering dynamic complexity at the definition stage, the problem can be structured in terms of causal relationships-focusing on the changes of pattern or behavior of the target problem over time. The problem should have "emergent properties" arising from the interactions and relationships among the related elements [Checkland, 1981]. These emergent properties dynamically change over time. The interaction of elements inside the closed boundary determines the structure of the problem. To conceptualize a target problem, there is a need to analyze and model the elements and the relationships among them.

Problem-solving consists of diagnosis, generating alternatives, and testing these for their appropriateness in handling present managerial problems. The diagnosis stage identifies the causes of the problem. The stage of alternative-generation discovers (or designs) alternatives for a solution. Thereafter, testing or validation of the alternative solutions can be carried out. Most decision-making methods based on Management Science focus on events involving detail complexity, and aim to find an optimal solution by structuring the target problem with limited hard variables from the perspective of linear and static time. Some other methods [Kwahk and Kim, 1999; Forrester, 1961; Sterman, 2001; Zhang et al., 1994] aim to identify better solutions by understanding dynamic complexity, which enables problems to be structured in terms of causal relationships and feedback loops. It also allows an understanding of the behavioral mechanisms of the target situation over time that facilitates systems thinking. Systems thinking is a conceptual framework for seeing the whole and for seeing the interrelationships or the feedback loops among its elements [Senge, 1990]. In systems thinking, every influence can be both cause and effect. This means that changes intended to improve performance in one part of an organization may inflict other part(s) with negative results. Therefore, it needs to shift away the focus from one particular part to many parts that have an impact upon one another. The impact of systems thinking on decision-making is increased as knowledge is acquired at higher levels-from the event itself, to the behavior pattern, and finally to the problem structure [Kim, 1994].

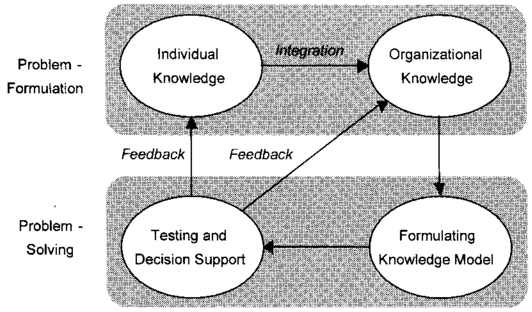
2.3 Managerial Problem-Solving with Cognitive Fit

Newell and Simon [1972] proposed information processing theory that humans seek ways to reduce their problem-solving efforts, since they are considered limited information processing systems. One of the ways to reduce their efforts is to facilitate the problem-solving processes that human problem solvers use to complete the task [Vessey and Galletta, 1991]. It is argued that this can be achieved by an approach known as cognitive fit theory. Cognitive fit theory has explored the influence of the nature of the task and the way it is represented on problem-solving performance, based on Newell and Simon's previous work. Cognitive fit theory posits that problem-solving with cognitive fit leads to effective and efficient problem-solving performance [Vessey, 1991]. The basic model of cognitive fit views problem-solving as the outcome of the relationship between the problem representation and the problem-solving task, which are characterized by the type of information emphasized. According to the cognitive fit theory, when the types of information emphasized in the problem-solving elements (problem representation and task) match, the problem solver can employ processes (and formulate a mental representation) that also emphasizes the same type of information. Cognitive fit exists because the cognitive processes used to act on the problem representation and the cognitive processes used to complete the task both match, resulting in superior problem-solving performance.

Cognitive fit theory can be applied to managerial problem-solving context. As mentioned in the previous section, managerial problems we are dealing with have the dynamic complexity characteristics. In terms of cognitive fit, this means that the understanding of the causal relationships and feedback loops derived from the dynamic complexity characteristics should be supported by both the problem representation and the problem-solving task in order to gain a better problemsolving performance. Cognitive fit seeks to identify specific task characteristics that can be supported by the problem representation and the task environment, thus effectively controlling decision-making processes. As a consequence, the study proposes a cognitive modeling or cognitive mapping approach (mental representation) which supports causal structure (problem representation) and systems thinking (problem solving task) for managerial problems. The idea of cognitive fit has gained empirical support in diverse domains, which suggests that it provides a general and powerful framework for investigating problemsolving performance [Vessey and Galletta, 1991].

Ⅲ. Linking KM to Decision Support

The study proposes a decision-support loop based on organizational knowledge, as illustrated in <Figure 2>. Based on an identified managerial problem, individual knowledge is gathered and then integrated into organizational knowledge, which captures and defines the problem. This constitutes the problem-formulation phase. As a process of the linkage between knowledge management and decision support, the organizational knowledge model is formulated and analyzed and then decision guidelines are generated based on the knowledge model. This constitutes the problem-solving phase. The entire process embraces dynamic complexity in an organization to obtain significant leverage in a real management situation as suggested by Senge [1990]. The reasoning process at the step of knowledge model formulation and testing and decision support reflects new knowledge derived from decision-making processes based on individual and organizational knowledge. The study adopts a cognitive modeling approach for the decision-support loop. This approach can be appropriate in the perspectives of cognitive fit that its problem representation revealing the cause-effec relationshipswell supports problem solving task such as decision-making process for managerial problems involving dynami complexity.



<Figure 2> Decision support loop

3.1 Individual Knowledge

Knowledge is useful only when it is related to target tasks or problems. If the knowledge is not helpful in a given situation, it can be said not to be knowledge in that situation, although it might be in other situation. Individual knowledge means individual and partial mental model knowledge related to the target problem. It can be either tacit or explicit, and it consists of the three types of knowledge illustrated in <Figure 1> Each department has a mental model regarding the departmental objective. An organization can be perceived as a complex network consisting of interrelated causal elements [Lenz and Engledow, 1986; Robey et al., 1995; Segne, 1990]. A prior cognitive model or belief structure will shape each department's interpretation of information and affect its decision-making or task-processing [Huber, 1991]. These cognitive models vary across organizational units, depending upon their different responsibilities and viewpoints. For example, the marketing team might have knowledge regarding the way in which delays in delivery affect sales volume, but not know how such delivery delay could be shortened. In contrast, the delivery team might know little about increasing sales, but might know a lot about how to shorten the delivery delay. In this way, each team has a partial mental model or individual team knowledge about the target issue. The cognitive modeling method can be applied to capture such individual knowledge. Cognitive modeling has been used to represent relationships that are perceived to exist among the attributes and/or concepts of a given environment [Fiol and Huff, 1992].

For individual knowledge modeling, the present study adopts the Causal-Loop Diagram (CLD) [Forrester, 1961; Sterman, 2001] - a form of cognitive modeling - and hypothesizes regarding the dynamic interactions among elements. It offers a systematic tool for uncovering counterintuitive dynamics that might be overlooked. Counterintuitive consequences are more likely when there are feedback loops which are not readily apparent. A representation of the feedback of related elements requires the addition of positive (+) and negative (-) polarities to the CLD diagram.

3.2 Organizational Knowledge

Integrating individual knowledge constitutes organizational knowledge, producing a network of knowledge across areas. Organizational knowledge is a specific knowledge model related to a target concern or problem. After integrating individual knowledge embracing the three knowledge types, organizational knowledge can also be modeled on a cognitive model. For example, individual knowledge from the marketing, sales, production, and delivery teams (regarding the enhancement of revenue) can all be integrated. This integrated organizational knowledge can explain many things to the various teams. The marketing, sales, production, and delivery teams can collaborate to know how sales are affected by delivery delay and how the teams can shorten delivery delay. That is, the organizational knowledge model regarding the target issue shows all the relationships among elements across all areas, and helps decision-makers to understand the problem clearly and choose appropriate actions to achieve organizational goals. As such, the organizational knowledge constitutes the core competency of management. Although each team or each individual creates an individual knowledge model, shared works among teams based on their individual knowledge generates an organizational knowledge model. The organizational knowledge model becomes a basis for understanding the dynamic complexity of the target situation. It enables decision-makers and subunits to understand the entire structure of the target business problem (e.g., to increase revenue), and helps them to estimate the behavior mechanism, thus facilitating the choice of appropriate action to achieve organizational goals.

3.3 Formulating Knowledge Model

For the decision support, the most important thing is to identify several decision options and validate which option is the best choice for the problem-solving. For this purpose, the organizational knowledge model must be translated into an analyzable form. Although CLD improves communication and comprehensiveness among its users, it does not seem to be enough to analyze the knowledge model. CLD can be formulated and analyzed in various ways. One alternative to analyze a cognitive model is to investigate causal paths. This aims at identifying the paths leading to either causes or effects for each causal factor. For this purpose, the organizational cognitive model should be analyzed in terms of the strength of the impact between causal factors. The cognitive model includes the indirect causal paths as well as the direct causal paths. The direct causal paths can be easily identified from CLD, while it is difficult to identity the indirect causal paths. Besides, the indirect causal paths are usually multiple. In this context, our concern is to identify the causal paths with the maximum causal impact among all causal paths regardless of the direct or indirect impact. In order to capture those causal paths, some studies proposed methods combining heuristic algorithms with the cognitive model, which include the following steps: 1) assigning causal strengths to cause-effect relationships; 2) transforming the cognitive model into the updatable matrix; and 3) applying the algorithm to the matrix to elicit causal impact paths and values [Kwahk and Kim, 1999; Zhang et al., 1994]. Appendix 1 summarizes a computation method which is helpful to analyze the organizational knowledge model in that it takes a position of considering both qualitative and quantitative aspects of the cognitive model.

The organizational knowledge represented in CLD will be analyzed in terms of the causal paths and strengths among the elements to gain a decision support by capturing core business activities. The causal impact paths and values among the causal factors are computed based on the method proposed by Kwahk and Kim [1999] (Appendix 1). The derived matrix includes the negative path and value as well as the positive path and value for each relationship among the causal factors. We first need to focus on the most effective causal factor in achieving the goal regardless of the sign of the impact. It can be an opportunity if it has a positive impact, but it can be a problem if it has a negative impact. Then, we need to identify the relevant feedback loop paths which make the positive impact stronger and the negative impact weaker. For the positive impact causal factor, this means making its own positive loop more positive and making its own negative loop less negative. For the negative impact causal factor, this means making its own positive loop less positive and making its own negative loop more negative.

3.4 Testing and Decision Support

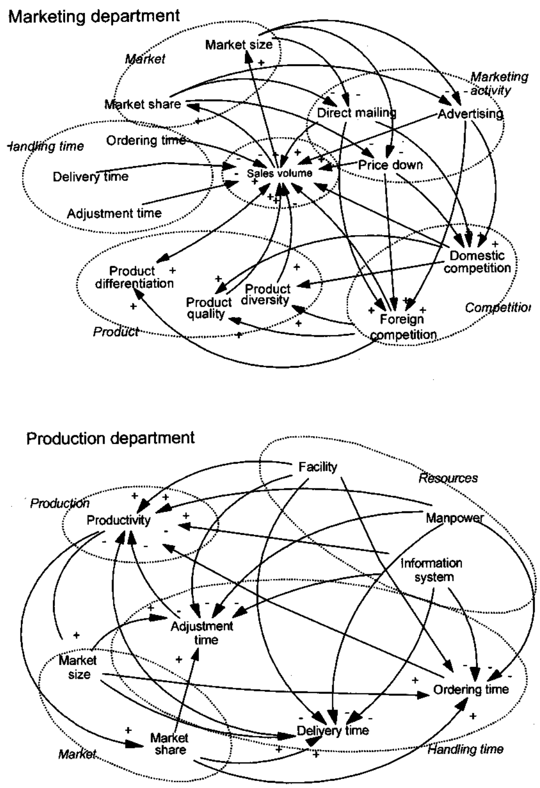
The analyzed knowledge model should suggest decision guidelines to the managerial problems. A decision guideline can be generated in the view of organizational goal, based on the organizational knowledge model and causal path analysis. An organizational goal is a desired future state of affairs that the organization attempts to realize [Etzioni 1964]. Goal plays a role of direction setting for people's activities and lead their thoughts and actions to a specific result [Hamner et al. 1983]. Therefore, we can identify decision guidelines by analyzing people's thoughts and actions toward their organizational goal - thus, identify the opportunity for addressing managerial problems. The output from reasoning process enables a decision to be made. There are many reasons (*know-why*) which update individual and organizational knowledge, and upon which the selected option can be chosen. That is, there is a feedback process from integrating knowledge and decision support to individual knowledge and mental models. This is a kind of organizational learning process. Although decision-makers cannot apply the same option and the same knowledge to similar problems in the future, they now understand the dynamic complexity of the target problem, the structure among the elements, and the behavior patterns. Decision-making by understanding dynamic complexity based on cognitive model enables the acquisition of real leverage in managerial problems [Senge, 1990; Sterman, 2001].

Ⅳ. Application Case

The study applied the proposed decision support loop to a beverage company with an annual sales volume of about 600 million dollars. The company was conducting a business process reengineering project which requires enterprise-wide cooperation and management coordination. Company management and the project team were grappling with the managerial issues of which cross-functional business processes should be redesigned while maintaining the organizational consensus. They decided to introduce a cognitive modeling approach to the decision-making context for addressing those managerial problems, based on organizational knowledge.

4.1 Individual Knowledge

Individual knowledge was gathered from marketing department and production department. In order to generate CLD for each department, we first had a brainstorming session and interviews with the participants from each department. Through the discussion and the interviews, the CLD diagrams were generated along with the relevant goals as illustrated in <Figure 3>.

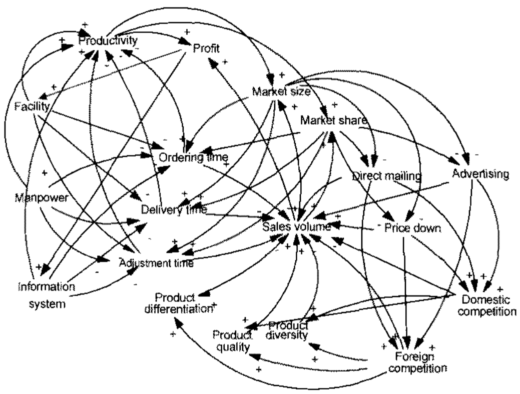


<Figure 3> Individual knowledge models

After discussion and interview, participants of each department established the goal. Marketing department set its goal as "increase of sales amount", while production department set its goal as "improvement of productivity". Then, we attempted to extract all the causal factors including state, activity, and emotion related concepts in each department. Brainstorming technique was used again. After all the causal factors were listed, they were clustered according to their functional similarity and behavioral homogeneity. Participants of marketing department identified fourteen causal factors and grouped them into six clusters. Similarly, participants of production department identified nine causal factors and grouped them into four clusters. Based on these clusters, the relationships between clusters are identified along with directions and signs. A CLD diagram is derived from the causal factor clustering list and the cluster relationship by replacing clusters with corresponding their causal factors and by making an appropriate connection among causal factors.

4.2 Organizational Knowledge

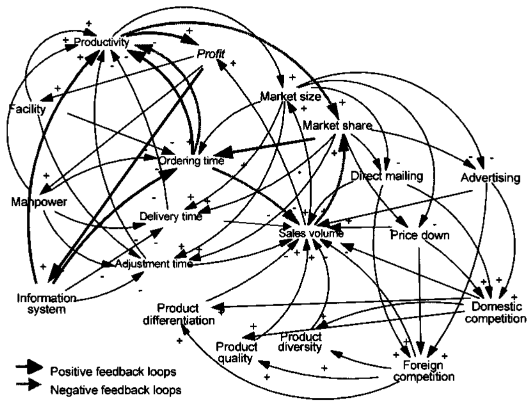
The knowledge related to the organizational goal is dispersed across the company, and is kept by top management, department managers, and department staffs. This knowledge must be identified and organized through "externalization" and "combination". Although some information or knowledge can be obtained from documents or databases, large portions of the full knowledge reside in mental models. Interviews were conducted with top managers and middle managers to identify partial knowledge, and this was then integrated into an organizational knowledge. Combining the two individual knowledge models generated the organizational knowledge model as in <Figure 4>. The synthesizing process revealed new organizational knowledge that was not known yet to the departments. Two departments became aware of how elements in one department could impact the other department beyond the departmental border. For example, efforts to increase "market share" by marketing department lead to increasing "ordering time" and "delivery time" resulting in diminishing "productivity" which is of interest to production department.



<Figure 4> Organizational knowledge model

4.3 Formulating Knowledge Model and Decision Support

The organizational knowledge represented in CLD was analyzed in terms of the causal paths and strengths among the elements to gain a decision support on which business processes should be considered for redesigning. The causal impact paths and values among the causal factors were computed based on the method in Appendix 1. In this application case, core business activities were identified from the causal impact paths and values matrix as illustrated in Appendix 2 (also in Figure 5). Considering the profit increase as a target goal, two most effective causal factors were identified from the causal impact paths and values matrix. One is the "productivity" which is the most positive causal factor, and can be considered as an opportunity for accomplishing the goal since productivity enhancement contributes most to increasing the corporate profit. The other is the "ordering time" which is the most negative causal factor, and can be viewed as a problem to the goal since the increase of ordering time prevents the profit from increasing through the decrease of sales volume. Our objective is to make the positive causal factor, "productivity", stronger and to make the negative casual factor, "ordering time", weaker. As seen in <Appendix 2> and <Figure 5>, the causal factors "productivity" and "ordering time" have the positive feedback loops of {Productivity - Profit - Information system - Productivity} and {Ordering time - Productivity - Profit - Information system - Ordering time}, respectively. In addition to that, the above two factors have the negative feedback loops of {Productivity - Market share - Ordering time - Productivity} and {Ordering time - Sales - Market share - Ordering time}, respectively. It seems clear that the paths {Productivity - Profit - Information system} and {Ordering time - Productivity} are the main drivers that accelerate the improvement of productivity and the decrease of ordering time. Thus, by designating the above two paths related activities as core busines



<Figure 5> Feedback loops related to the target goal

activities, we can focus on how to use information technologies in redesigning the productivity and ordering time related processes.

Based on the above organizational knowledge and consensus, we identified the order process as a candidate target process and attempted to redesign it. The current order process heavily depends on manual handling which results in the longer ordering time and less efficient production and delivery. By introducing a newly designed information system for the redesigned order process, they could reduce the total ordering time significantly. In the newly redesigned order process, every agency directly sends its orders to the factory through the network without intervention of the branches. Reduction of the branch's intervention in order taking is expected to result in the decreased ordering time, which leads to the efficiency of production and delivery and, in the long run, contributes to profit. In addition to discovering the best decision option, top management and other managers came to understand the elements involved, the interrelationships among them, and the behavior mechanism of the target business problem. They can now apply the accumulated knowledge to other situations through feedback from the result of testing and decision support to individual knowledge and organizational knowledge model.

After this project, the results and insights were presented to the top management and the two departments. Top management could understand what factors affect organizational profit and how the factors are interrelated across the two departments. Also, he could perceive why the proposed decision guidelines are effective. The two departments and the employees also could expand their department-constrained knowledge into cross-department knowledge. Thus, the proposed method facilitated understanding of the behavior mechanism regarding the target managerial problem by linking knowledge management to decision support.

V. Discussion

This study can be best discussed as an exercise in knowledge conceptualization. During the conceptualization process, the knowledge related to the target problem was identified (*know-what*) and structured (*know-how*) from the causal relationship perspective using CLD. The analysis enabled decision-makers: (i) to trace the basic causes of unexpected outcomes; (ii) to understand which decision factors had more significant impacts on performance; and (iii) to make trade-offs between decision alternatives (*know-why*). The reasoning process (*know-why*) had effects either on the value of decision factors (*know-what*) or the causal interrelationships (*know-how*). A feedback loop among the three knowledge types <as in Figure 1> was discovered.

The proposed approach can be discussed on the basis of the four modes of knowledge creation suggested by Nonaka [1994]. As illustrated in the application case, we identified partial knowledge from the cognitive models of individual departments, and integrated this partial knowledge into an explicit organizational knowledge model-"combination" and "externalization". The approach facilitated structuring a previously unstructured problem, which enabled decision-makers to understand the structure of target problem. In addition, decision-makers could learn the behavior mechanism of the target system by understanding and analyzing the knowledge model - "socialization" and "internalization". The knowledge derived from "internalization" - that is, the accumulated knowledge from their experiences-became a source for "externalization" or "combination". This showed a knowledge spiral [Nonaka, 1994]. Although Nonaka [1994] argued that organizational learning belongs to the "Internalization" mode, the proposed approach is not limited to this mode. The model also supports the other three modes. This implies that this approach is applicable to the area of organizational learning. Organizational learning aims to obtain knowledge, to store this in the organizational memory, and to revise it by experience-thus diffusing the accumulated organizational knowledge [Huber, 1991; Senge, 1990]. The proposed approach enables the obtaining of previous knowledge from individuals or an organizational knowledge model, the creation of new organizational knowledge, and the revision of it by reasoning and new experiences. Management and different teams can share the collective tacit/explicit knowledge to improve their understanding of the target situation-which enables them to be more cooperative in their dealings with each other. The organizational knowledge model thus plays a role in organizational memory.

It is possible to compare the proposed method which focuses on dynamic complexity with other methods which focus on detail complexity. As indicated in the application case, business problems are often too complex to allow recognition of the structure because of the many decision-making variables in mental models and the feedback loops among them. Without fully exploring the feedback loops in the model, it cannot be assumed that the solution will work well over time, although it might work well over a limited period of time [Forrester, 1961; Kim, 1994; Sterman, 2001].

This approach seems to be more appropriate to the decision-making context with highly constrained tasks involving resource allocation. Highly constrained tasks can be classified as mixed motive negotiation tasks in which participants have mixed-motives to compete and cooperate [McGrath, 1984; Rees and Barkhi, 2001]. In that case, it is important to understand the whole view of the system which should be shared among participants and how one part of decision can impact other parts over time. Systems thinking would enable individuals or subunits in an organization to make decisions consistent with the organizational goal, leading them to collaborate each other. Decision-making support should aid individuals or subunits in an organization to exchange information and make coordinated decisions [Barkhi, 2001-2002]. A cognitive modeling approach leading to systems thinking can aid the decision-makers to reach the organizational goal by linking organizational knowledge into decision support.

Ⅵ. Conclusion

The core contribution in the study is the linkage between knowledge management and decision-making support. For this purpose, the integration of individual knowledge into organizational knowledge was suggested, across subunits which took into account the dynamic complexity of the problem-formulation phase in addressing a business problem. Without integrating partial knowledge into an organized knowledge, it is difficult to understand managerial problem which is characterized as cross-department coverage and dynamic complexity, and make effective decisions. That is, more effective knowledge can be obtained by integrating partial knowledge, rather than by merely adding together individual knowledge. Expressing this mathematically, we can say that: effectiveness (knowledge1 + knowledge2) $\geq$ effectiveness (knowledge1) + effectiveness (knowledge2). As a problem-solving phase, the organizational knowledge was transformed into an analyzable model for decision support. Generation of alternatives and testing of those alternatives enables decision-makers to appreciate the behavior mechanism and the inherent structure of the target business problem. During the learning process, decision-makers can identify the relative impact of decision alternatives on the target problem. This approach also provides more mentally appropriate tools in terms of cognitive fit. It is argued that matching the type of information provided by tool to that in the task would lead to effective and efficient problem-solving performance

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〈부 록〉

<Appendix> Two-phase Cognitive Modeling Method [Kwahk and Kim, 1999]

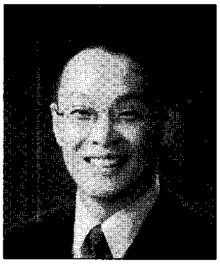
Phase	Task	Output	Means
Cognitive model generation	1. Specifying the goal	Goal statement	Brainstorming, Interview Document analysis Questionnaire Eigenvector algorithm
	2. Identifying causal concepts - List all the causal concept - Cluster the causal concepts	Causal concept list	
	3. Identifying causal connections - Identify the relationships between clusters - Identify the relationships between causal concepts	Cluster relationship diagram Causal concept relationship diagram	
	4. Determining causal values - Conduct pairwise comparison - Compute eigenvectors	Pairwise comparison matrix Causal values	
Causal path identification	1. Initializing cognitive matrix	Cognitive matrix	Matrix operation Causal path computation algorithm*
	2. Computing causal impact paths and values	Causal impact paths and values matrix	

Note) The algorithm produces an n x n matrix called causal impact path and value matrix consisting of Xij, where Xij is the set of {+pij, -pij, +vij, -vij}: +pij is a positive causal impact path from element i to j, -pij is a negative causal path, +vij is a maximum positive causal impact value corresponding to +pij, and -vij is a maximum negative causal impact value corresponding to -pij. The algorithm is applied iteratively while either maximum positive value (+vij) or maximum negative value (-vij) can be improved - in other words, until new dominant values cannot be identified.

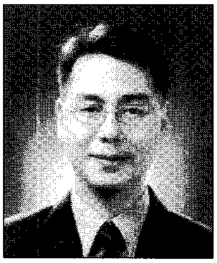
<Appendix 2> Analysis on core business activities

Causal factor		Feedback loops
The most positive impact factor: Productivity	Positive	Path = {Productivity - Profit - Information system - Productivity} Value = +0.52
	Negative	Path = {Productivity - Market share - Ordering time - Productivity} Value = −0.19
The most negative impact factor: Ordering time	Positive	Path = {Ordering time - Productivity - Profit - Information system - Ordering time} Value = +0.36
	Negative	Path = {Ordering time - Sales - Market share - Ordering time} Value = −0.32

◆ 저자소개 ◆



곽기영 (Kwahk, Kee-Young)
서울대학교 경영학과를 졸업하고 한국과학기술원(KAIST)에서 경영과학 석사 및 경영정보학 박사학위를 취득하였다. 삼성SDS에서 IT 및 비즈니스 컨설팅 업무를 수행하였으며 현재 계명대학교 경영대학에 재직중이다. Decision Support Systems, International Journal of Information Management, Expert Systems with Applications 등에 논문을 발표하였으며 현재 주요 관심 연구분야는 IT adoption, IT's role in organizational change, CRM, e-Business initiatives 등이다.



김희웅 (Kim, Hee-Woong)
한국과학기술원에서 경영공학 박사 학위를 취득하고 LG-EDS 컨설팅 부문에서 근무하였다. 관심 연구분야는 Online Trust, Post-adoption, Process Theory 등이다. 그 동안 Information & Management, Decision Support Systems, Journal of Information Technology Management, International Journal of Flexible Manufacturing Systems 등에 논문들을 발표하였다. 현재 National University of Singapore에 재직 중이다.

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