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Building a Knowledge Brokering System using social network analysis: A case study of the Korean financial industry

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ABSTRACT

The importance of knowledge is increasing in our global and knowledge-based society. As a part of knowledge management, successful knowledge transfer can improve an organization's competitive advantages and increase an organization's valuable knowledge assets. However, knowledge transfer is complex and a lot of factors exist that affect successful knowledge transfer such as context, social networks, and IT/IS. This paper aims at the role of the knowledge broker which is to be a link between knowledge seekers and knowledge experts. In this context, this research implemented a Knowledge Brokering System – called *K-broker* system – as a prototype system to improve knowledge transfer in an organization based on an analysis of users' social network. The *K-broker* system can provide a 'single view' screen for identifying knowledge experts and has no bottlenecks in contrast with a human knowledge broker and can provide a permanent communication channel between knowledge seekers and knowledge experts.

1. Introduction

The famous phrase 'Knowledge is Power' stated originally by Francis Bacon, could be interpreted to means that knowledge based firms can gain a competitive advantage in a globally competing and knowledge-based society. Many examples of knowledge management literature have emphasized that knowledge is the foundation of innovation (Davenport & Prusak, 1998;Drucker, 1993) and has become an important organizational resource of firms (Alavi & Leidner, 2001). Also knowledge resources are critical for the successful development and maintenance of a competitive advantage by creating value for the firm's stakeholders (Carlile & Rebentisch, 2003; Khamseh & Jolly, 2008). Knowledge is certainly one of the best resources and is the only sustainable competitive advantage (Khamseh & Jolly, 2008).

Knowledge management (KM) is a strategy for creating, accessing and supporting knowledge resources (Agrawal & Henderson, 2002), and consists of four sets of 'knowledge processes': (1) creation, (2) storage/retrieval, (3) transfer, and (4) application (Alavi & Leidner, 2001). As an important and essential part of knowledge management, successful knowledge transfer can improve an organization's competitive advantages and increase the value of an organization's knowledge assets (Argote & Ingram, 2000; Cranefield & Yoong, 2007). Therefore, we should focus on successful knowledge transfer and especially tacit knowledge as it is more complicated and difficult to transfer in organizations.

There have been various definitions of the knowledge transfer suggested by researchers. Knowledge transfer in organizations is the process in which one unit (e.g., group, department or division) is affected by the experience of another according to Argote and Ingram (2000). Major and Cordey-Hayes (2000) saw the transfer of knowledge as a conveyance of knowledge from one place, person, ownership, etc., to another. Szulanski (2000) also defined knowledge transfer as a process in which an organization recreates and maintains a complex, casually ambiguous set of routines in a new setting. According to King (2006), knowledge transfer is the focused, unidirectional communication of knowledge between individuals, groups or organizations such that the recipient of knowledge (a) has a cognitive understanding, (b) has the ability to apply the knowledge, or (c) applies the knowledge. Another definition of knowledge transfer is the process by which knowledge receivers acquire knowledge from providers so that it could

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accumulate and renew a productive capability (Liao & Hu, 2007). And lastly, Leiter, Day, Harvie, and Shaughnessy (2007) defined knowledge transfer, as the process of sharing new knowledge among members in an organization, and explained that it is a process within the broad scope of organizational learning that also includes the codification and retention of existing knowledge and practices.

In this paper, knowledge transfer can be redefined as a process that has a direction and intention to retain and recreate the valuable knowledge assets of an individual or organization.

The importance of knowledge has been widely emphasized and knowledge transfer is also an important area of knowledge management. Knowledge transfer has been said to be the basis for competitive advantages in firms (Argote & Ingram, 2000), and is said to be an essential source of a firm's sustainable competitive advantage (Osterloh & Frey, 2000). Transferring knowledge is a key dimension of a learning organization and learning occurs when knowledge in one part of an organization is transferred effectively to other departments and then used to solve problems there or to provide new and creative insights. So, effective knowledge transfer is one of the most important knowledge management activities for organizations (Goh, 2002).

Without successful knowledge transfer, all problem-solving methods or operational skills have to be reinvented again when knowledge is needed (King, 2006). If global and multinational corporations do not have successful knowledge transfer from their parent company, it is difficult for subsidiaries to build up their knowledge base, improve their capabilities, accelerate management localization, and survive intense competition to generate good returns for their parents (Wang, Tong, & Koh, 2004). Wakefield (2005) argued that knowledge transfer is crucial for the development of effective KMS (Knowledge Management System).

In spite of the fact that the importance of knowledge transfer has been emphasized continuously, some difficulties still exist in successful knowledge transfer. Szulanski (2000) suggested three factors that negatively affect knowledge transfer processes; the arduous relationship between source and recipient, stickiness, and organizational context. An arduous relationship may increase the efforts needed to resolve transfer-related problems, and recipients must be able to discard old practices and sustain new ones, and organizational context can affect the willingness and ability of organizational subunits to complete transfer-related tasks.

Ko, Kirsch, and King (2005) argued that communication-related factors influence the transfer of knowledge between consultants and clients both directly and indirectly in information system implementation processes. Low source credibility inhibits communication and learning and the recipient's communication decoding competence influences knowledge transfer.

Argote and Ingram (2000) insisted that the member to member or social network plays an important role in knowledge transfer. People play the most critical role in the success of technology transfer and the social network can link organizational units to new sources of knowledge and help to interpret new knowledge.

For the development of a successful knowledge transfer, this paper could make use of the concept of 'knowledge broker' (Hargadon, 1998). According to Hargadon, a knowledge broker is an intermediary (an organization or a person), which provides links, knowledge sources, and in some cases knowledge itself (i.e. technical know-how, market insight, etc.) to an organization in its network. Also a knowledge broker is critical for supporting the innovative behaviors of individuals within organizations and provides opportunities for individual and organizational capacity development (Dobbins et al., 2009).

By using the concept of a 'knowledge broker', this paper can provide the framework necessary for the successful transfer of tacit knowledge. There has been some previous research on the role of a knowledge broker, but they have limitations and were inadequate for practical application. An intelligent agent-based knowledge broker for an enterprise-wide healthcare knowledge procurement system framework (Hashmi, Abidi, & Cheah, 2002) focused mainly on explicit knowledge retrieval and procurement and Loew, Bleimann, and Walsh (2004) suggested that a knowledge broker network based on communication between humans but with their framework users may then have too many steps to take to reach experts. In research by Johri (2008), knowledge brokering involves a multitude of things and the boundaries are also numerous and there is a dynamic nature to the process where the needs of the role and the context in which the role is performed keeps changing, but the boundary spanning knowledge brokering model failed to take into account the dynamicity of the role of a knowledge broker. Boden and Avram (2009) concentrated on the particular roles the knowledge brokers play in distributed development practices in the context of two small companies. Because of the small size of the teams, knowledge brokers could be bottlenecks and be overloaded, and permanently open communication channels are needed.

In summary, this paper suggests implementing a system (not a human being) which can link knowledge seekers and experts and remove the bottlenecks and overloads for the successful context-specific and tacit knowledge transfer. As a tool to reflect social networks among members in an organization, this paper focuses on social network analysis.

The objectives of this paper are as follows:

First, the implementation of a Knowledge Brokering System using social network analysis.

Second, enlarging the competitive advantages of firms by using effective knowledge transfer with a Knowledge Brokering System.

The rest of this paper is organized as follows. In Section 2, previous research on knowledge transfer is mentioned and a knowledge broker and social network analysis is introduced. In Section 3, a framework, subsystems and functions of Knowledge Brokering System that developed this study is described. Implementation of a prototype of Knowledge Brokering System, K-broker and how it works are described in Section 4. Finally, the concluding remarks and further works are presented in Section 5.

2. Related works

2.1. Tacit knowledge

The concept of 'tacit knowledge' was introduced by Polanyi (1996). He describes tacit knowledge as follows: 'I shall reconsider human knowledge by starting from the fact that we can know more than we can tell'. And Nonaka and Takeuchi (1995) distinguished between tacit and explicit knowledge (shown in Table 1).

Tacit knowledge is essentially the opposite of explicit (codified) knowledge. Explicit knowledge exists in print or in an electronic form and is available either freely or free of charge after a small registration fee (Bush, 2008).

The characteristics of tacit knowledge can be classified as follows:

Table 1
Distinction between tacit and explicit knowledge.

Tacit knowledge	Explicit knowledge
Subjective	Objective
Knowledge of experience (body)	Knowledge of rationality (mind)
Simultaneous knowledge (here and now)	Sequential knowledge (there and then)
Analog knowledge (practice)	Digital knowledge (theory)

First, tacit knowledge is difficult to write down and to formalize (Nonaka, 1991). Tacit knowledge is not easily shared and codified. Tacit knowledge consists of habits and culture that we do not always recognize in ourselves. In many knowledge management literatures, tacit knowledge refers to knowledge which is only known by an individual and is difficult to communicate to the rest of an organization. People who possess tacit knowledge cannot describe the decision rules that underlie their performance: 'the aim of a skillful performance is achieved by the observance of a set of rules which are not known as such to the person following them' (Polanyi, 1996).

The second characteristic of tacit knowledge is that it is personal knowledge (Nonaka, 1991; Sternberg, 1994). Sternberg (1994) and Nonaka (1991) argue that tacit knowledge has a cognitive dimension and consists of mental models that individuals follow in certain situations. Tacit knowledge becomes so embedded in the individual that it seems entirely natural (Ravetz, 1971).

Yet a characteristic of tacit knowledge is that it is practical (Sternberg, 1994) and that it describes a process. Tacit knowledge cannot be easily codified and can only be transmitted via training or gained through personal experience. Tacit knowledge has been described as "know-how" (Nonaka, 1991) – as opposed to "know-what" (facts), "know-why" (science), or "know-who" (networking). Nonaka (1991) argues that know-how may be used as a synonym for tacit knowledge because 'tacit knowledge consists partly of technical skills – the kind of informal, hard-to-pin down skills captured in "know-how"'.

The final characteristic of tacit knowledge is that it is context specific (Nonaka, 1991; Sternberg, 1994). Tacit knowledge 'is knowledge typically acquired on the job or in the situation where it is used' (Sternberg, 1994), and is 'deeply rooted in action and in an individual's commitment to a specific context – a craft or a profession, a particular technology or product market, or the activities of a work group or team' (Nonaka, 1991).

According to the characteristics of tacit knowledge explained above, tacit knowledge is slow and costly to transmit, but is a crucial source of sustainable competitive advantage because it is difficult for competitors to imitate it (Teece, 1998). Tacit knowledge is hard to codify so it cannot be transferred easily (Osterloh & Frey, 2000), and if a greater about of knowledge is tacit in an organization the transfer of knowledge can often become less (Khamseh & Jolly, 2008).

2.2. Knowledge transfer factors

Knowledge transfer occurs in various situations; between individuals, from individuals to explicit sources, from individuals to groups, between groups, across groups, and from a group to the organization (Alavi & Leidner, 2001). A lot of research exists on identifying and verifying the factors that affect knowledge transfer in various scenarios: knowledge characteristics, individual, organizational, inter-organizational, international and university-industry. Those factors can impact on successful knowledge transfer and can work as facilitators or barriers (Hall, Sapsed, & Williams, 2000).

From the list of knowledge transfer factors, we should consider the following three factors as being vital for the successful transfer of tacit knowledge; context, social networks, and Information Technology/Information System (IT/IS).

As described in the previous section, tacit knowledge is practical and context-specific (Nonaka, 1991; Sternberg, 1994), therefore the transfer of tacit knowledge should be also context-specific. Knowledge can be embedded in almost everywhere such as people, tools, routines, products, and systems (Argote & Ingram, 2000; Cummings & Teng, 2003).

Knowledge context, organizational context, relational context and social context can influence the process of knowledge transfer (Cummings & Teng, 2003; Riusala & Suutari, 2004) and it is necessary to be aware of the context factors for the successful management of knowledge transfer (Kasper & Muhlbacher, 2008). Also Hutzschenreuter and Listner (2007) described the reasons for the failure of knowledge transfer projects and gave attention to knowledge transfer context factors like 'sender- and receiver-related contextual factors' and 'knowledge-related contextual factors' for successful knowledge transfer. Lin, Geng, and Whinston (2005) addressed five factors that constitute the basis of the expectations that the sender and the receiver has for the value of the knowledge transfer in their 'Sender–receiver' framework. One of the factors is the context in which the knowledge is put to use. According to Yakhlef (2007), knowledge transfer does not only take place within a social context, but that context itself is part of the content of knowledge.

The second factor is social networks. As people play the most critical role in the success of technology transfer, the social network also plays an important role in knowledge transfer and can link organizational units to new sources of knowledge and aid the interpretation of the new knowledge (Argote & Ingram, 2000). In their research on the impact of network structures on knowledge transfer, Fritsch and Kauffeld-Monz (2008) found strong ties to be particularly important with regards to the exchange of knowledge and information and it is important to learn more about the ways in which knowledge and information in networks is transferred between the actors and how the strong ties are formed.

Also, Tang, Mu, and MacLachlan (2008) proposed that the knowledge transfer speed and the empowerment of individuals play dominant roles in the process of knowledge transfer. The higher the knowledge transfer speed and the more powerful the influence of the individuals who own new knowledge, the quicker other members in the network will absorb the new knowledge.

To enhance knowledge transfer in multinational corporations, social interaction is a key mechanism for leveraging the knowledge because it enables the development of cognitive and relational dimensions of social capital (Gooderham, 2007). Plentiful ways of social interaction are especially important for the transfer of tacit knowledge.

Formal knowledge transfer methods, such as instructor-led training and computer-based training, can be used to pass on preliminary job task knowledge, and informal knowledge transfer via the social network of employees can be used to transfer more of the detailed job task and role knowledge (Lahti, Darr, & Krebs, 2002).

The third factor to be considered for the successful transfer of tacit knowledge is Information Technology/Information System (IT/IS). IT/IS can increase knowledge transfer by extending the individual's reach beyond formal communication lines (Karlsen & Gottschalk, 2004), and IT/IS can be used as a means to catalog individuals in the organization that hold critical tacit knowledge, and then enable communication between those who need the knowledge and those who have it (Bloodgood & Salisbury, 2001; Syed-Ikhsan & Rowland, 2004).

IT/IS can enhance the transfer of tacit knowledge (Changchit, 2003) and can increase the sharing of information and information about sources of knowledge, as well as knowledge about sources of information, and the development of technologies that can provide the information richness of face-to-face contact will remove co-location as a requirement for the effective transfer of tacit knowledge, thereby increasing the efficiency and flexibility of knowledge transfer (Roberts, 2000).

IT/IS can improve the efficiency of knowledge transfer by increasing the speed of communication and decreasing costs due to time and distance (Albino, Garavelli, & Gorgoglione, 2004). Zhang (2007) showed a positive relationship between IT/IS support for knowledge transfer and labor productivity in their research for an empirical assessment of the performance impacts of IT/IS support for knowledge transfer, and proposed that firms need to consciously develop unique organizational resources that can make IT/IS less susceptible to imitation by their competitors.

2.3. Knowledge broker

Hargadon (1998) defined a 'knowledge broker' as an intermediary (an organization or a person), which provides links, knowledge sources, and in some cases knowledge itself (i.e. technical know-how, market insight, etc.) to organizations in its network. Knowledge brokers are those individuals or organizations that profit by transferring ideas from where they are known to where they represent innovative new possibilities. They transfer those ideas in the form of new products or processes to industries that had little or no previous knowledge of them. Knowledge brokers engage in a few simple, but tightly interdependent, activities that enable them to consistently innovative. They hold strategic positions spanning multiple industries and exploit that position to consistently create new products or processes by recognizing and transferring ideas from where they are known to where they are unknown. They do so by gaining access to a wide range of industries, learning the diverse knowledge that resides within these different industries, linking past knowledge to solutions for current problems, and finally implementing new solutions in the form of new products or processes. Table 2 describes the activities underlying innovation by knowledge brokers:

Hellström, Malmquist, and Mikaelsson (2001) also defined a 'knowledge broker' as a catalyst whose responsibility would be to connect those with knowledge and experience with those who needed it for particular purposes. The role of the knowledge broker had to be clear, visible, and acknowledged throughout the organization, both within and between units. The role of the knowledge broker should be set to:

- Facilitate knowledge flashes and learning situations.
- Identify knowledgeable persons with particular expertise, their respective competence areas, and list them.
- Facilitate contacts between knowledge need and related expertise.
- Strive to connect people across organizational boundaries.
- Be perceived to be available by potential users.
- Follow up knowledge flashes and learning situations.

This means that the knowledge broker's main role can be said to be the connection of people who needed some specific piece of knowledge (knowledge what) with those who possessed it (knowledge that).

Cillo (2005) also addressed the idea that the knowledge broker's role is to help transfer complex knowledge between different parties that are not directly related and rarely interact.

Burnett, Brookes-Rooney, and Keogh (2002) suggested that the facilitators for knowledge brokering could be from the lessons learned from SPN (Stretch Performance Network) research; the knowledge of the individuals, the needs of the organizations, the systems which will allow for the fruitful development of the project undertaken, and the human relationships between partnerships. Because much of the knowledge in an organization is tacit and resides within individuals, an organization should focus on how to capture and transfer their employees' tacit knowledge. So effective knowledge transfer processes or frameworks should be established which would be robust and flexible, and an organization can then deal with the complexity of partnership requirements.

In relation to the research for facilitating learning and knowledge transfer through supplier development, Giannakis (2008) suggested that knowledge brokers can be a key to knowledge transfer between organizational units and knowledge brokers can be used to assess and then transfer 'good practices' and ensure that they are transmitted to the correct and required source.

Also a knowledge broker plays a critical role for supporting the innovative behaviors of individuals within organizations and provides opportunities for individuals and organizational capacity development (Dobbins et al., 2009). A knowledge broker provides a link between research producers and end users by developing a mutual understanding of goals and cultures, collaborates with end users to identify issues and problems for which solutions are required, and facilitates the identification, access, assessment, interpretation, and translation of research evidence into local policy and practice. They addressed the knowledge broker's role in their study including relationship development, ongoing support, customized approaches and opportunities for individual and organizational capacity development.

2.4. Social network analysis

2.4.1. Definition and objectives

Social network analysis (SNA) is an approach and set of techniques used to study the exchange of resources among actors (i.e., individuals, groups, organizations) (Haythornwaite, 1996). SNA is a sociological paradigm to analyze the structural patterns of social relationships and focuses on patterns of relationships between actors and examines the availability of resources and the exchange of resources between these actors (Scott, 1991). SNA provides a rich and systematic means of assessing informal networks by mapping and analyzing relationships among people, teams, departments or even entire organizations (Cross, Parker, Prusak, & Borgatti, 2001). SNA is a powerful tool with increasing applications in social sciences and has been applied in areas as

Table 2
Activities underlying innovation by knowledge brokers.

Activity	Implications
Access	• Exposes organizations to a wide range of industries and the valuable knowledge residing in each • Puts organizations in a position to broker valuable knowledge from industries where it is known to where it is not
Learning	• Brings knowledge of an industry's existing problems and solutions into the organization for use at a later time • Creates an inventory of potentially valuable ideas with "requisite variety" typically broader than any held by firms working within a single industry
Linking	• Enables development teams facing a problem in one industry to recognize its similarity to other problems – and their solutions – in different industries • Combines ideas from within an industry with other ideas from outside to create innovative product and process concepts
Implementation	• Turns innovative concepts from outside industries into real products or processes by combining them with existing ideas from within the industry • Leads to learning-by-doing that further builds the organization's knowledge base for use in later projects

diverse as psychology, health, business organization and electronic communications by examining the informal connections between units. Recently, interest has grown in the analysis of leadership networks to sustain and strengthen relationships within and across groups, organizations and related systems.

In the context of knowledge management, SNA can be helpful to evaluate the availability and distribution of critical knowledge and facilitates the following (Müller-Prothmann, 2007):

- Strategic development of organizational knowledge.
- Identification of personal expertise and knowledge.
- Transfer and sustainable conservation of tacit knowledge.
- Development of core competencies.
- Identification and support communities of practice.
- Creation and discovery of opportunities to improve communication process and efficiency.

SNA can help to get useful information from network structures and roles using simple patterns of relationships (who knows whom) based on social data collection methods (e.g. questionnaire, email analysis, document analysis) with a lowest effort in terms of costs (time and money).

2.4.2. Knowledge management with SNA

A lot of research has been carried out on studying knowledge management with social network analysis to better understand the flow of knowledge, knowledge networks and knowledge mapping in an organization. Liebowitz (2005) introduced the integrated use of AHP (Analytical Hierarchy Process) with SNA to produce interval/ratio measures for use in an organization's knowledge map. In the research, SNA could be used to develop value graphs for use in a knowledge map to describe the different types of lessons received. Knowledge maps could also become more meaningful in describing the strength of relationships for organizational business process improvement. In their research on the synergy between social network analysis and knowledge mapping, Chan and Liebowitz (2006) stressed the importance of informal networks in organizations and showed that SNA is a very powerful tool in developing knowledge maps and in knowledge flows for an organization.

In research on the network analysis of knowledge construction in asynchronous learning networks (ALN), Aviv, Erlich, Ravid, and Geva (2003) analyzed network structures using the SNA of response relations among participants during online discussions. In the knowledge construction process, certain roles need to be taken on to ensure that the group function is uninterrupted and that no one is left behind. Roles affect the distribution of power among ALN participants. SNA could identify cohesion, roles and the power structure of the ALN.

In the area of knowledge network research, Hu and Racherla (2008) analyzed and mapped networks of collaboration among researchers in the field of hospitality business research and to demonstrate a means to identify key researchers by characterizing them as research hubs using SNA. Also Zhong and Wang (2008) performed knowledge network analysis within organizations based the SNA approach and concluded that social network relationships among members within organizations have a strong effect on knowledge diffusion and the efficiency of knowledge transfer.

2.4.3. Knowledge Brokering System using SNA

As described in the previous section, SNA plays an important role in the knowledge management field for identifying critical members and examining the relationships among members. In conjunction with SNA, the Knowledge Brokering System (KBS) can identify the individuals, teams, and units that who play central roles in an organization to promote and improve knowledge transfer processes.

The KBS can link knowledge seekers and experts by strengthening the efficiency and effectiveness of existing, formal communication channels. For the successful transfer of context-specific and tacit knowledge, the KBS can raise awareness of and reflection on the importance of informal networks and suggest ways to enhance organizational learning and performance.

The KBS can gain timely access to specific expertise and help to transfer implicit knowledge including the identification and support of communities of practice with SNA-based data. The system can visualize the social network from the users' point of view and experts' information in detail and facilitate tacit knowledge transfer without a bottleneck and members' overloads in contrast to a human knowledge broker. For a detail explanation of Knowledge Brokering System, Section 3 shows.

2.4.4. SNA measures

When implementing a Knowledge Brokering System, we should take account of the following important SNA measures; *tie strength, degree centrality, closeness centrality, and betweenness centrality*.

Tie strength is important in assessing the overall degree of connectivity of members in an environment and the likelihood that information will flow from one member to another (Haythornwaite, 1996). Individuals who are closely tied to others have more intimate ties and are more motivated to provide information to others. The stronger the tie between members, the more personal the relationships become. Tie strength can be measured by the number of relationships between actors.

Degree centrality refers to the number of relationships maintained by each member in a network (Haythornwaite, 1996). It can show which member or members have influence or power in a network. The degree centrality can be an indicator of expertise and can be a measure that helps to purposefully support individual members in a knowledge network (Müller-Prothmann, 2007). Members who have more ties to other members may have a position of advantages. Because they have many ties, they may have alternative ways to satisfy needs, and hence are less dependent on other individuals. Because they have many ties, they may have access to, and be able to call on more of the resources of the network as a whole. Because they have many ties, they are often third parties and deal makers in exchanges among others, and are able to benefit from this brokerage. So, a very simple, but often very effective measure of a member's centrality and power potential is their degree (Hanneman & Riddle, 2005).

The third measure is closeness centrality. Closeness centrality shows the integration or isolation of network members (Müller-Prothmann, 2007) and measures how many steps a member is from others in the network (Haythornwaite, 1996). It can be measured as the sum of distances between members. A high closeness centrality indicates a greater autonomy of an individual person, since he or she is able to reach other members easily and a low closeness centrality indicates a higher individual member dependency on other members. Closeness centrality approaches emphasize the distance of an actor from all others in the network by focusing on the geodesic distance from each member to all others. One could consider either the directed or undirected geodesic distances among members (Hanneman & Riddle, 2005).

Finally, betweenness centrality refers to the extent to which a member sits between others in the network (Haythornwaite, 1996). So, betweenness centrality can indicate the extent to which he or she plays the role of intermediary, and help to identify a member as a knowledge broker and gatekeeper within a network (Müller-Prothmann, 2007). Betweenness centrality views a member as being in a favored position based on the extent that the member falls on the geodesic paths between other pairs of members in the network (Hanneman & Riddle, 2005).

3. Knowledge Brokering System

3.1. Flows of a Knowledge Brokering System

Fig. 1 shows the flows of Knowledge Brokering System (KBS) briefly as follows: (1) knowledge seekers can log in to the KBS in order to search for specific knowledge experts, (2) KBS visualizes the link and connection relationships between knowledge seekers and knowledge experts using user's SNA-based information, (3) from knowledge experts to knowledge seekers, context-specific tacit knowledge can be transferred and this flow may be invisible, and (4) knowledge seekers can evaluate the degree of expertise, satisfaction, etc. for knowledge experts.

Fig. 2 describes the conceptual framework of KBS. KBS can provide a permanent channel between knowledge seekers and knowledge experts in an organization. Also, it can be accessed at any time throughout the entire organization.

3.2. Architecture of a Knowledge Brokering System

The KBS mainly consists of three subsystems: User Interface Module, Knowledge Brokering Module, and Management Module (see Fig. 3).

- User Interface Module: This module consists of three user control components – Access Control, Preference Control and Feedback Control. The Access Control manages user registration, log in/out, access history, etc., and the Preference Control provides brokering preference options and filtering functions. The Feedback Control provides the function of evaluation for the experts' response and knowledge transfer activities.
- Knowledge Brokering Module: This module consists of four components – SNA Manager, Refiner, Evaluation Manager and Visualization Manager. The SNA Manager calculates SNA measure indexes, selects SNA data using user's information, and updates SNA data using user's evaluation information. The Refiner mainly refines SNA data based on the user's preference information such as the brokering and filtering options. The Evaluation Manager updates evaluation information based on the user's feedback results and adds SNA measure indexes for the user and the selected expert. The Visualization Manager provides path information from user to experts based on refined expert information and provides detailed information about the selected expert, and visualizes a link and relationship information.
- Management Module: Management module consists of three components – K-domain Manager, User Info Manager, and SNA data Manager. The main function of the Management Module is the management of KBS-related databases such as the Knowledge-domain DB, the User-info DB, and the SNA data DB. Only authorized users can access these databases. The K-domain Manager manages business-related knowledge domains and topics and the User Info Manager manages user-related information. The SNA data Manager manages SNA-related information like tie strength, degree centrality, closeness centrality, etc.

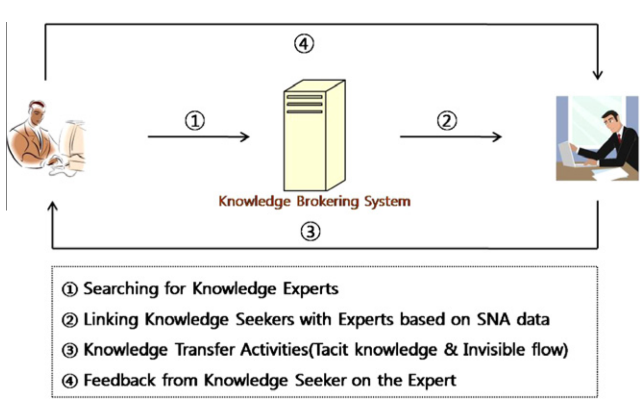


Fig. 1. The flows of a Knowledge Brokering System.

3.3. Subsystems of KBS

This section describes the subsystems of a Knowledge Brokering System in more detail.

3.3.1. User Interface Module

A User Interface Module, consisting of three user control components, mainly provides user-related functions such as Access Control, Preference Control, and Feedback Control.

The Access Control carries out user registration activities such as ID, password and user profile information, log in/out details and access history management, etc. Its functions should be implemented in a user friendly manners as with the following characteristics; easy to access, easy to understand and easy to use.

The Preference Control provides an overview of knowledge topics and domain selection, brokering preference options and filtering functions. Fig. 4 shows the example of tree structure of the user's preference and constraints selection.

The Feedback Control area allows for the evaluation of the experts' response and knowledge transfer activities using questionnaires such as degree of satisfaction, degree of expertise, degree of understanding and quick turnaround time assessment. As the most widely used scale in survey researches, the Likert-5 point scale is used in scoring the evaluation. Fig. 5 shows the expert evaluation questionnaires.

3.3.2. Knowledge Brokering Module

Knowledge Brokering Module consists of four components; SNA Manager, Refiner, Evaluation Manager and Visualization Manager.

To find expert using Knowledge Brokering System, it needs to select most appropriate expert in a knowledge domain. Using expertise index which is developed in this study can find such expert of each knowledge domain. To calculate the expertise index, the SNA Manager calculates SNA measure indexes using the log-in user's information as follows:

(1) We assume that the weight of each index can be calculated in advance by KM manager in an organization using the AHP (Analytical Hierarchy Process) method (Saaty, 1980).
(2) Calculations for tie strength, degree centrality, closeness centrality and betweenness centrality use original SNA data.
(3) Before summation of each index value, it is standardized from 0 to 1 to remove potential errors from having different scales.
(4) Sum each index value with multiplication by each weighted value.

The original SNA data can be gathered by tracing the KMS log history and the expertise index can be used for the selection of experts after refining user's preference based on processing by Refiner. Fig. 6 summarizes the SNA data DB process.

The expertise index (*Vexpt*) is calculated by the multiplying the weight values and standardized index values according to the following equation:

$$Vexpt = \sum (Wi \times Si),$$

where Wi = weight of index i, Si = standardized value of index i.

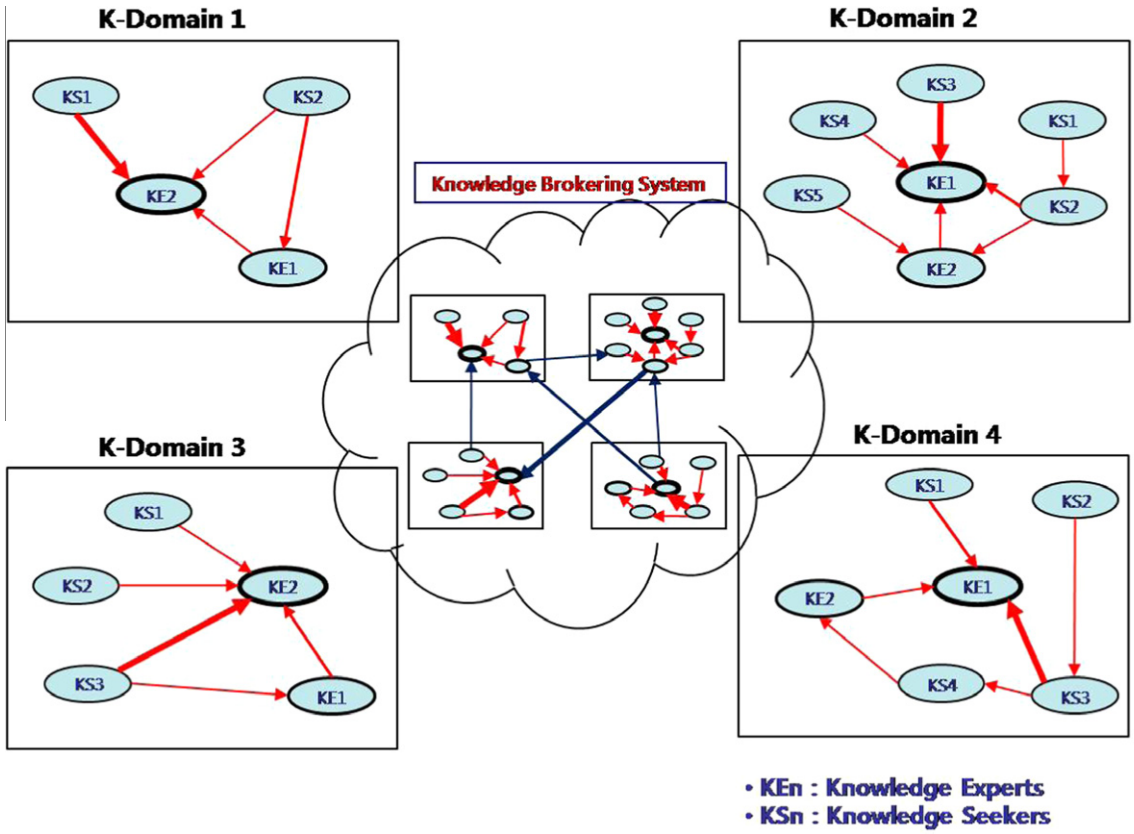


Fig. 2. Conceptual framework of a Knowledge Brokering System.

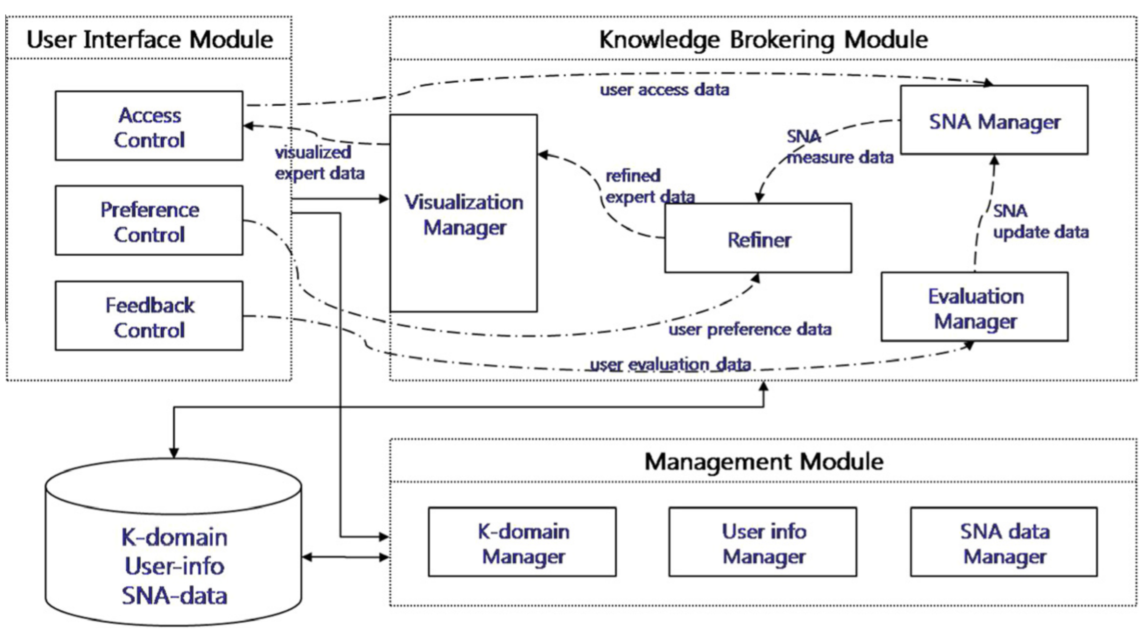


Fig. 3. The architecture of a Knowledge Brokering System.

Wi = {*Wr*, *Wt*, *Wd*, *Wc*, *Wb*}, calculated by the AHP method:

- *Wr* = weight value of the registered documents item.
- *Wt* = weight value of the tie strength value.
- *Wd* = Weight value of the degree centrality value.
- *Wc* = Weight value of the closeness centrality value.
- *Wb* = Weight value of the betweenness centrality value.

Si = {*Sr*, *St*, *Sd*, *Sc*, *Sb*}

- *Sr* = (Ri − Rmin)/(Rmax − Rmin): standardized the number of registered documents.
- *St* = (Ti − Tmin)/(Tmax − Tmin): standardized tie strength value.
- *Sd* = (Di − Dmin)/(Dmax − Dmin): standardized degree centrality value.

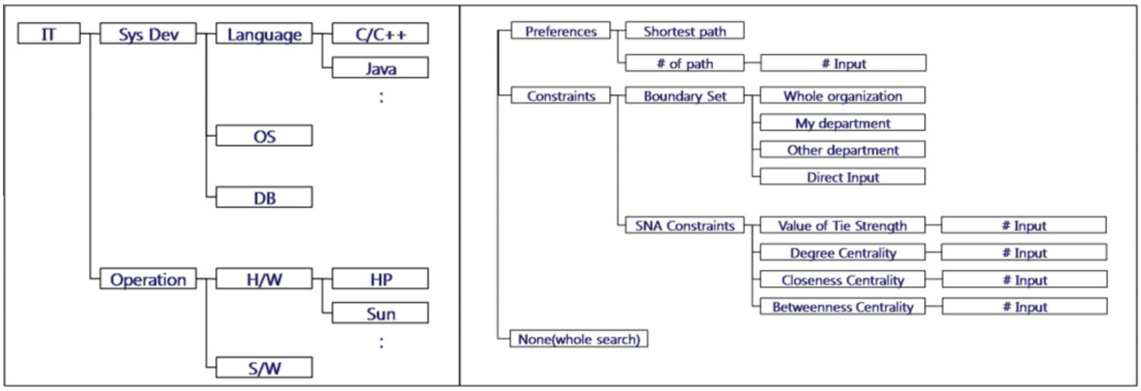


Fig. 4. User preference control.

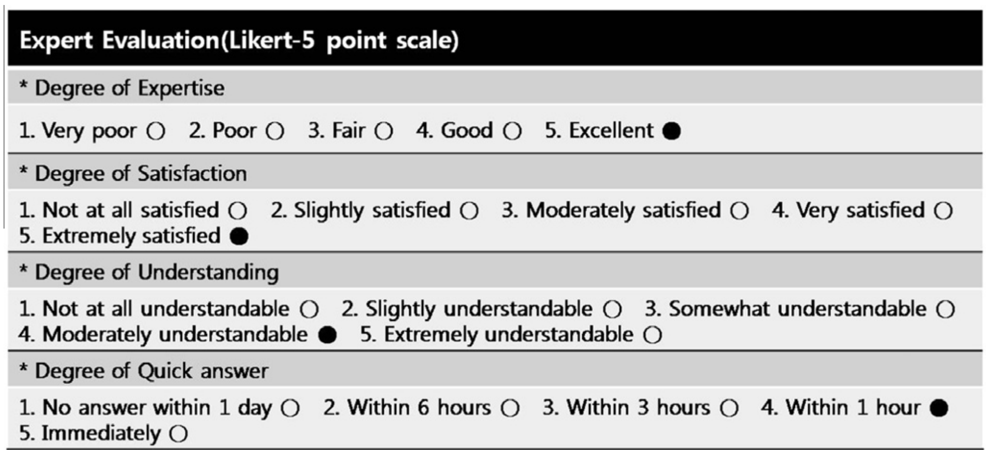
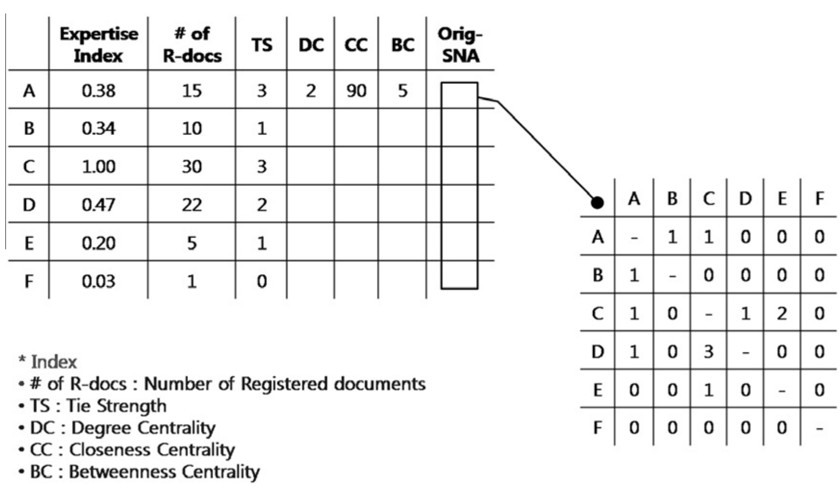


Fig. 5. Expert evaluation.



	Expertise Index	# of R-docs	TS	DC	CC	BC	Orig-SNA
A	0.38	15	3	2	90	5	
B	0.34	10	1				
C	1.00	30	3				
D	0.47	22	2				
E	0.20	5	1				
F	0.03	1	0				

	A	B	C	D	E	F
A	-	1	1	0	0	0
B	1	-	0	0	0	0
C	1	0	-	1	2	0
D	1	0	3	-	0	0
E	0	0	1	0	-	0
F	0	0	0	0	0	-

* Index
• # of R-docs : Number of Registered documents
• TS : Tie Strength
• DC : Degree Centrality
• CC : Closeness Centrality
• BC : Betweenness Centrality

Fig. 6. Processing of SNA Manager.

- Sc = (Ci − Cmin)/(Cmax − Cmin): standardized closeness centrality value.
- Sb = (Bi − Bmin)/(Bmax − Bmin): standardized betweenness centrality value.

The SNA Manager also updates SNA data table with the user's feedback information from the Evaluation Manager. The relationship information between the user and the selected expert is added to the SNA data DB, and then the SNA measure indexes should be recalculated by the SNA Manager.

The Refiner mainly refines the SNA data based on the user's preference information such as the brokering and constraints options. The user's preference option can be the selection of the shortest path to the desired expert or a constraint on the number of paths from a user to the experts. In finding experts, users may want to search the whole organization or they may want to limit

Table 3
Example of refining preference as 'Java'.

	Name	Dept.	Role	...	K-domain
A	Kim	Finance	Manager		Fin-Acc-001
B	Lee	Marketing	Clerk		–
C	Hong	IT-Dev.	Manager		IT-Dev-001
D					
E					
F					

Table 4
Example of refining constraints using 'tie strength ⩾ 3'.

	Expertise index	The number of registered documents	TS	DC	CC	BC
A	0.38	15	3	2	90	5
B	0.34	10	1			
C	1.00	30	3			
D	0.47	22	2			
E		5	1			
F		1	0			

the search to only look within departments for example. Other than the boundary set, users can set SNA constraints such as the value of tie strength index, degree of centrality, closeness centrality, etc. Alternatively users can set no preference nor constraints options at all.

In the example shown below, the Refiner selects experts according to a user's knowledge domain preference option which is entered as 'Java' from the User Info database. Table 3 shows the output from refining the knowledge domain by preference when searching for 'Java' experts.

An example of the Refiner's function using constraints can be seen in Table 4 by setting a constraint for the SNA index to 'tie strength ⩾ 3'. In this example, A and C can be selected as temporary experts based on the user's constraints.

The Evaluation Manager's functions to update the evaluation information based on user's feedback results and to add the SNA measure indexes about the user and the selected expert. After this the knowledge transfer activities between the user and the selected expert through various communication methods such as face-to-face meetings, phone call, e-mail, etc., and these knowledge transfer flows are not visible. In the Knowledge Brokering System, when a user accesses the system after the knowledge transfer activities are complete, the User Feedback Control in the User Interface Module can gather evaluation data from the user, and the Evaluation Manager performs the rest of the updates using related SNA measure indexes.

Fig. 7 shows an example of processing by the Evaluation Manager.

The Visualization Manager provides path information from the user to the experts based on the refined expert information as processed by the Refiner and provides detailed information about the selected expert along with a visualized link and relationship information. From the user's perspective, KBS visualizes the paths including the primary path and the alternatives. Fig. 8 shows an example of the screen of a Knowledge Brokering System.

3.3.3. Management Module

The Management Module consists of three components – the K-domain Manager, the User Info Manager and the SNA data Manager. The main function of the Management Module is a management of KBS-related databases such as the Knowledge-domain DB, the User-info DB and the SNA-data DB. Because these databases are critical and essential elements of the Knowledge Brokering System, only authorized users can access and manipulate this information in a secure and careful manner.

The K-domain Manager manages business-related knowledge domains and topics from the organization's perspective. To be compatible with the organizational management information system, the management of knowledge domains and topics in the Knowledge Brokering System should be consistent with the existing Knowledge Management System (KMS) in an organization.

Table 5 describes an example of a knowledge domain managed by the Knowledge Brokering System.

The User Info Manager manages user-related information including the name, department, role in the team, and codified knowledge-domain information. In the User Info DB, evaluation information exists about the expert's knowledge transfer activities and it can be used as a reference by the manager later. Table 6 shows an example of a User Info DB.

The SNA data Manager manages SNA-related information like the expertise index, the number of registered documents, and the SNA measure indexes (tie strength, degree centrality, closeness centrality and betweenness centrality) along with the original SNA data that contains the relationships between members. Table 7 describes an example of an SNA data DB.

4. Case study – *K-broker*

Company K is an institution that provides its member banks and customers with various convenient payment services by building and operating payment systems which are the core infrastructure

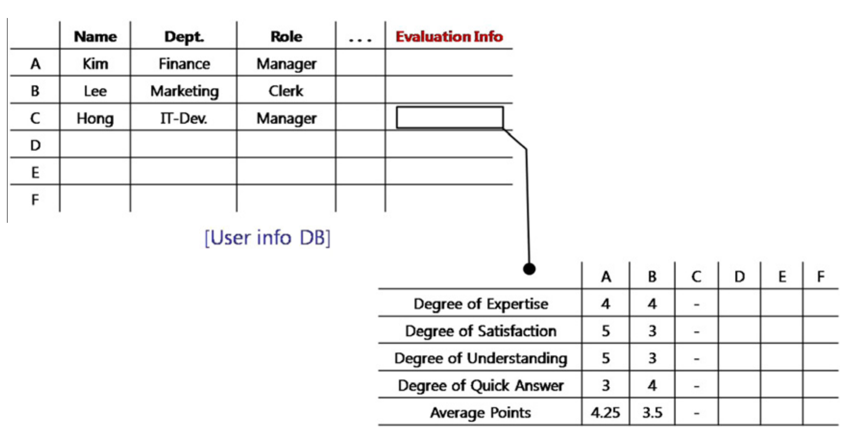


Fig. 7. Processing by the Evaluation Manager

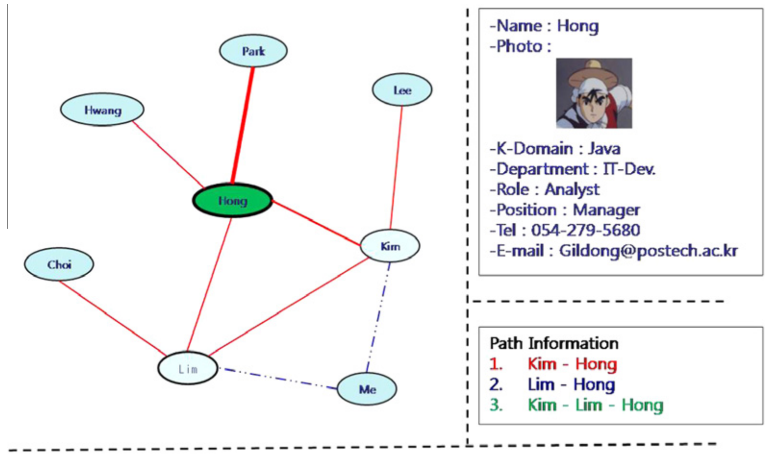


Fig. 8. Example 'single view' screen of KBS.

Table 5
Example of a knowledge domain DB.

Knowledge domain name	Code	Related topic/keywords	...	Experts
Java	IT-Dev-001	WWW, Internet, Program Language, ...		Hong, Hwang, ...
C/C++	IT-Dev-002	Program Language, System Program, ...		Lee, Lim, ...
Delphi	IT-Dev-003	4GL, UI Program, Program Language, ...		
⋮				
Accounting	Fin-Acc-001	Tax, Audit, ...		Park, Kim, Choi, ...

Table 6
Example of a User Info DB.

Name	Dept.	Role	...	K-domain	...	Evaluation info
Kim	Finance	Manager		Fin-Acc-001		
Lee	Marketing	Clerk		–		
Hong	IT-Dev.	Manager		IT-Dev-001		

Table 8
Weight values for calculation of expertise index.

Index	Weight
Number of registered documents	0.433
Tie strength	0.166
Degree centrality	0.166
Closeness centrality	0.166
Betweenness centrality	0.067

of the Korean financial industry (KFTC, 2009). Company K was established in 1986, and it has about 700 employees. A Knowledge Management in company K was launched in 2001 and its Knowledge Management System was implemented in 2002. In 2004, they converted their KMS into a portal service system. They collect and share knowledge with employees that is directly linked to the organization's growth strategy, encouraging all employees to expand upon what they know and simultaneously create a high value-added service. Also, based on a system that encourages creative thinking and a proactive attitude, they collect and reflect upon creative proposals and ideas from their employees from all segments of their business in order to improve on performance. They register about 57 new knowledge on average per employee in a year.

To validate the functions of the Knowledge Brokering System – named as the *K-broker* system, we investigated one project team in company K. The project team consists of 10 members and the team's aim is to implement a new system for global payment services.

4.1. Set up

Before analyzing the operational results of the *K-broker* system, we performed the following procedures: (1) input of information into the database i.e. User Info, K-domain, and SNA data including the user registration (2) make a decision about the weight value for calculating the expertise index using *expert choice*, software that perform AHP method, and (3) gather the SNA-related data.

Firstly, the profile information for members was accessed via the project team manager and it was approved by the KMS team manager and then we put the data into the *K-broker* databases. Also we linked the knowledge domain in KMS with *K-broker* to

Table 7
Example of an SNA data DB.

Name	Expertise index	The number of registered documents	Tie Strength	Degree centrality	Closeness centrality	Betweenness centrality	Original SNA data
Kim	0.38	15	3	2	90	5	
Lee	0.34	10	1				
Hong	1.00	30	3				

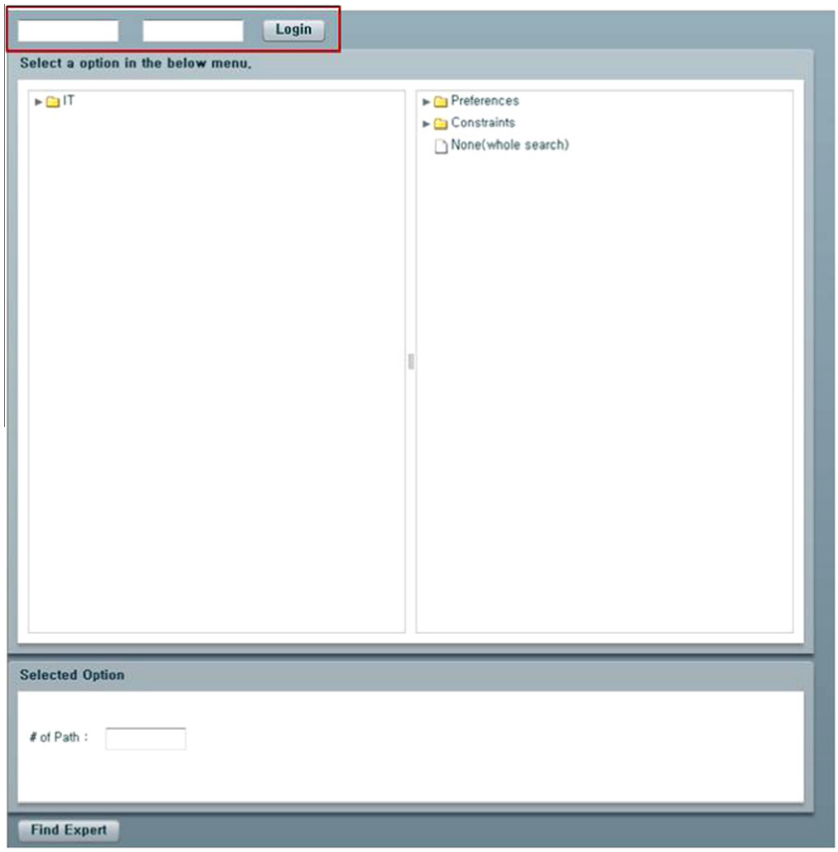


Fig. 9. Log-in screen of *K-broker* (before).

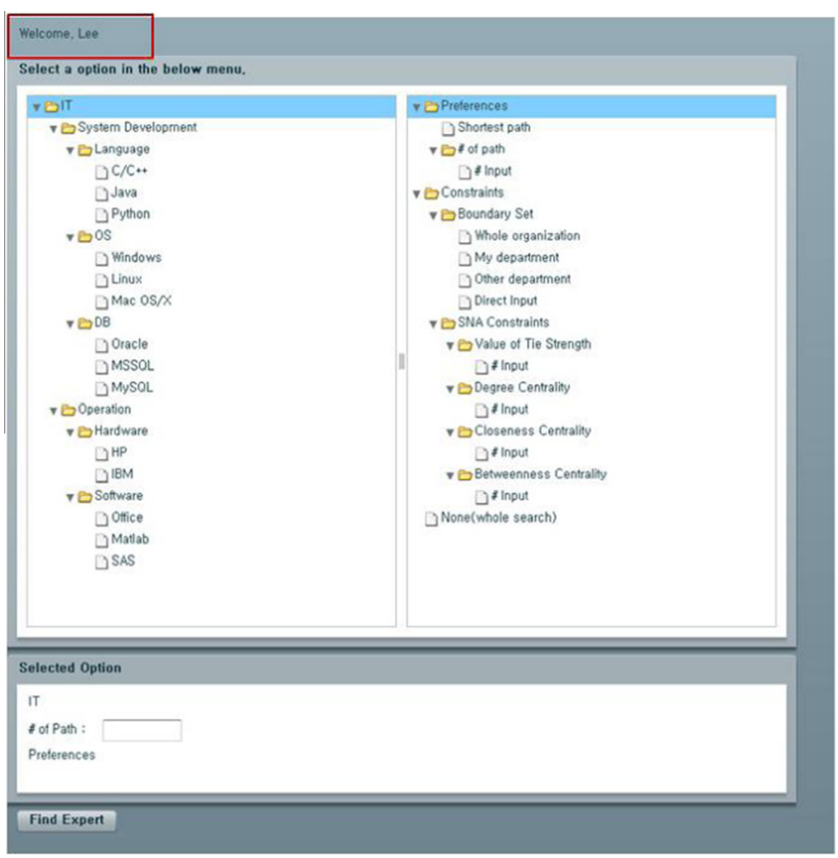


Fig. 10. Log-in screen of *K-broker* (after).

ensure compatibility with the existing organizational management information system.

Secondly, the research team and the KMS manager discussed the weight value of the indexes, and got the results shown in Table 8.

Finally, to gather the SNA data of the project team, we traced the Knowledge Management System so we could get information about the documents registered by the members, and the inquiry statistics by analyzing the history log of KMS. We collected the SNA data for about one month and inserted that information into the databases of the *K-broker* system.

4.2. Operations

The project team's final goal was the implementation of a system for global payment services.

Knowledge for both system development and global payment business-related knowledge was needed concurrently. So, we will

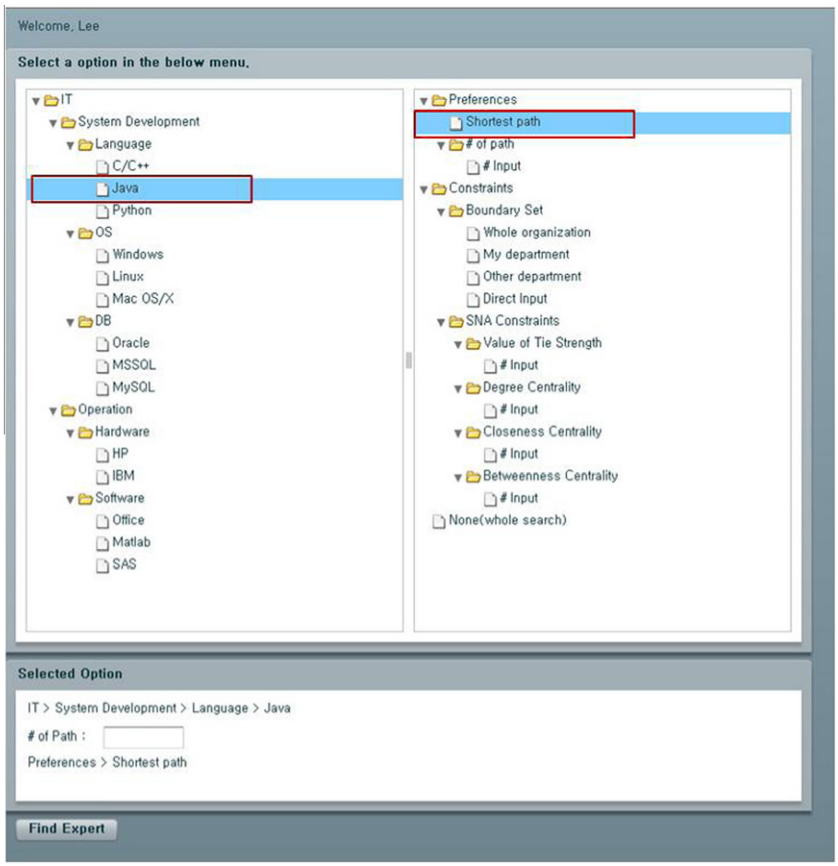


Fig. 11. Selection of knowledge domain and preference.

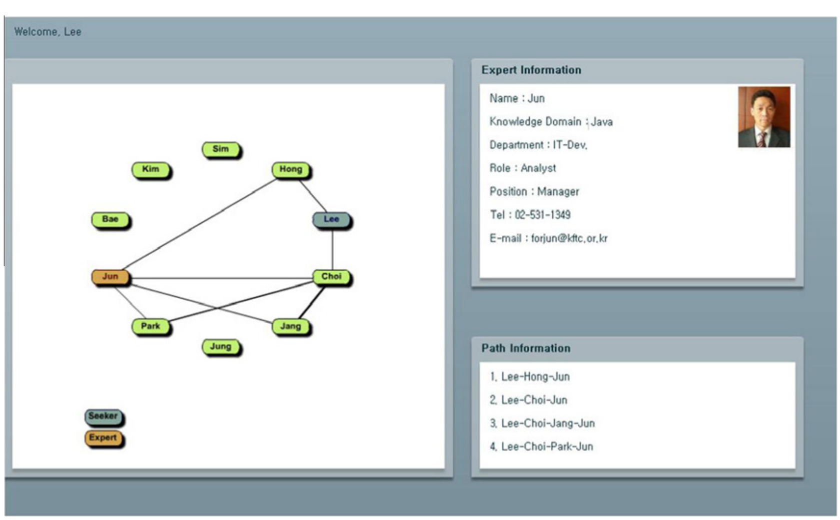


Fig. 12. Identifying expert in ''Java'.

describe scenarios for identifying experts in IT-related knowledge and business-related knowledge situations.

In the first scenarios, one member of the project team named 'Lee' had a problem with 'Java' programming in relation to the development of a new payment system. He wanted to find a solution which required problem solving experience or know-how as soon as possible, but he was a newbie of the team and did not know the project team members well. So, he entered the *K-broker* system and tried to find an expert in 'Java' programming based on his social networks.

Figs. 9 and 10 show the log-in screen of the *K-broker* system.

After logging-in the *K-broker* system, 'Lee' set the knowledge domain to identify a 'Java' programming expert by selecting the IT > System Development > Language > Java tab and setting his preference for the 'shortest path'.

Fig. 11 shows how to set the knowledge domain and user preference.

After the logging-in, the *K-broker* system showed the primary (the most recommendable) path and alternative paths based on Lee's social networks and the relationship between the project

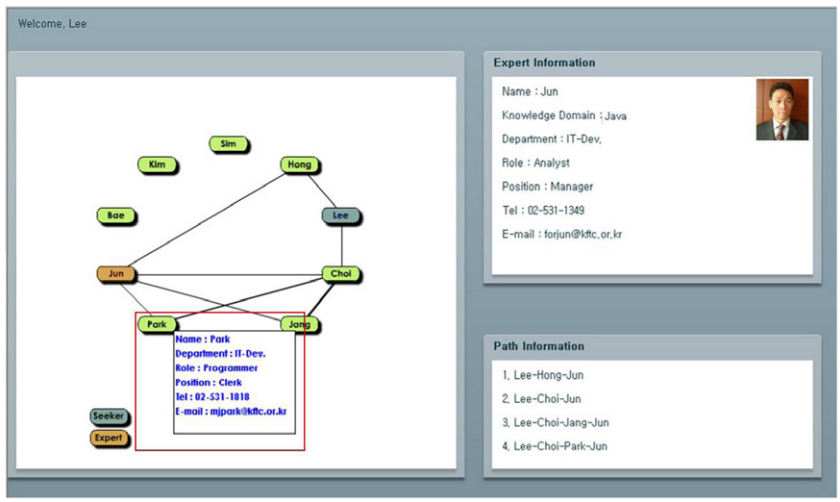


Fig. 13. Detailed information on the expert path.

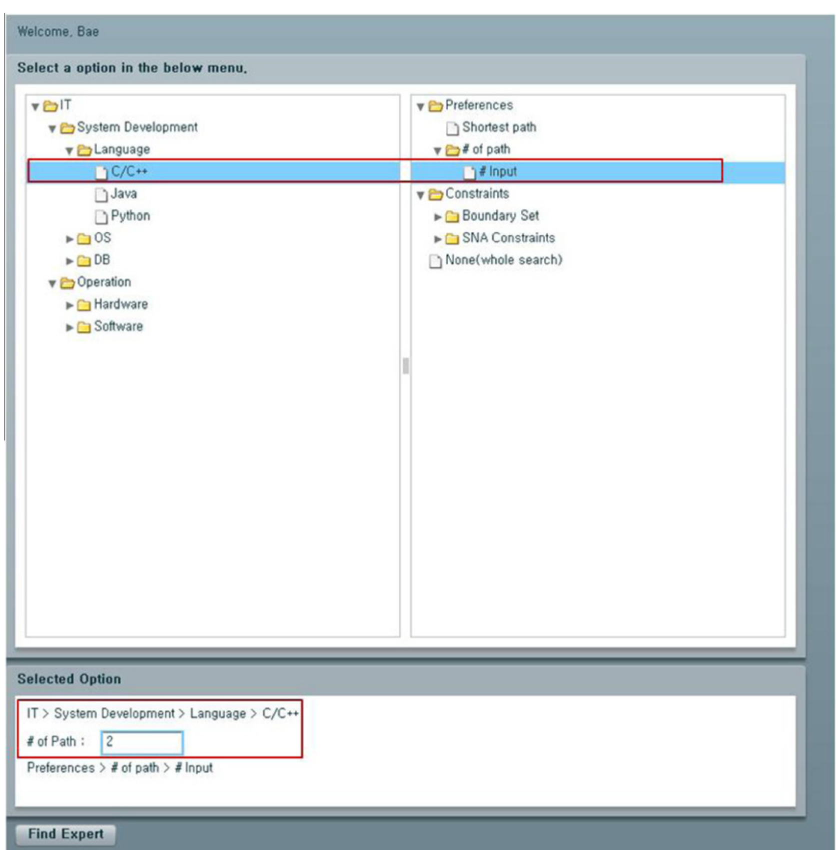


Fig. 14. Selection information showing C/C++ and two paths.

team members. Fig. 12 shows the identification result for the 'Java'search with detailed information on the expert.

The *K-broker* system can also provide information about the intermediary members, so users can contact them for more effective knowledge transfer if needed. Fig. 13 describes the information of the intermediary members who can be contacted with to reach the selected expert.

To link for 'C/C++' experts, the user 'Bae' entered the *K-broker* system and set the knowledge domain to IT > System Development > Language > Java and set the number of paths to '2 paths'. Fig. 14 describes the selection information for the 'C/C++' expert and 2 paths option.

Fig. 15 describes the result of the identification of the 'C/C++' expert from the user 'Bae' to the expert 'Sim' using just two paths. The *K-broker* system also could provide detailed information about the expert and the intermediary members of the project teams.

In the final expert identification scenario, the user 'Bae' searched for an expert in 'Accounting' for business-related knowledge transfer. Through a similar procedure to that described in the previous paragraphs, 'Bae' could link the expert 'Choi' based on social network information. Fig. 16 shows the path information provided by the *K-broker* system.

When completing the knowledge transfer activities between the user and the selected experts, various communication methods were used (e.g. face-to-face meetings, phone calls, e-mails), but these knowledge transfer activities are not visible from the *K-broker* system's perspective. So, when users re-enter the system after the knowledge transfer activities, the *K-broker* system gathers evaluation data from the user, and perform an update process for the SNA measure indexes. Fig. 17 shows the user evaluation screen for the expert's knowledge transfer activities.

4.3. Validation

There exist similar systems with Knowledge Brokering System that have functions to support in finding, communicating with experts on knowledge management. The Expert Recommender System suggests people who have some expertise to encourage exchanging ideas or finding solutions to problems (Huysman & Wulf, 2006). And the Expert Recommender System (ERS) works based mainly on the experts' documents and publications. The Expert Finding System (EFS), also called Expertise Location System, enables users to discover subject matter experts in order to hire or acquire their knowledge (Maybury, 2006). Knowledge map

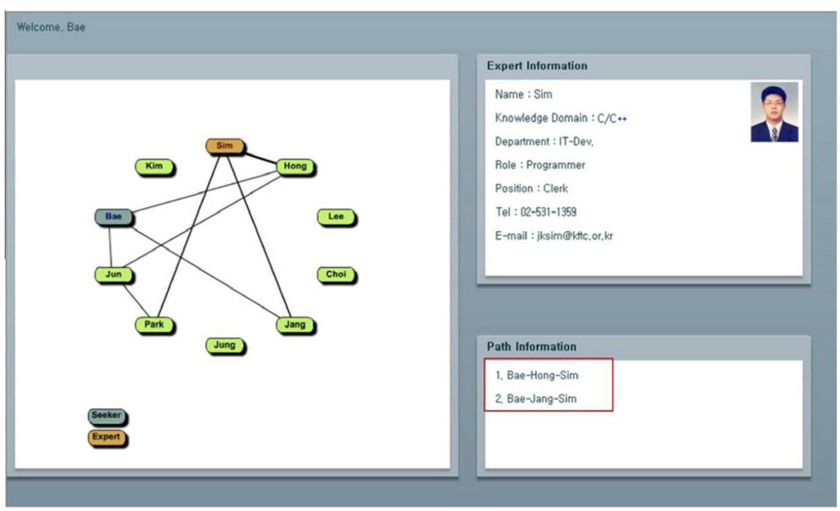


Fig. 15. Path information using C/C++ and two paths.

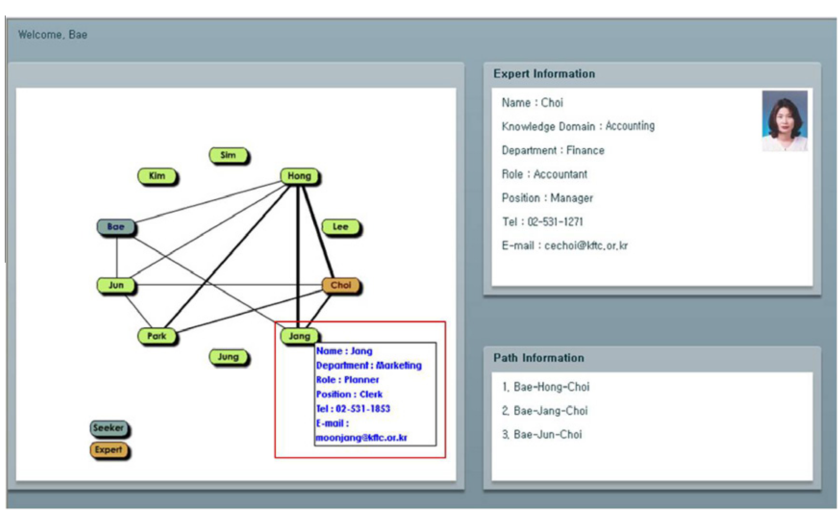


Fig. 16. Path information for 'Accounting' expert.

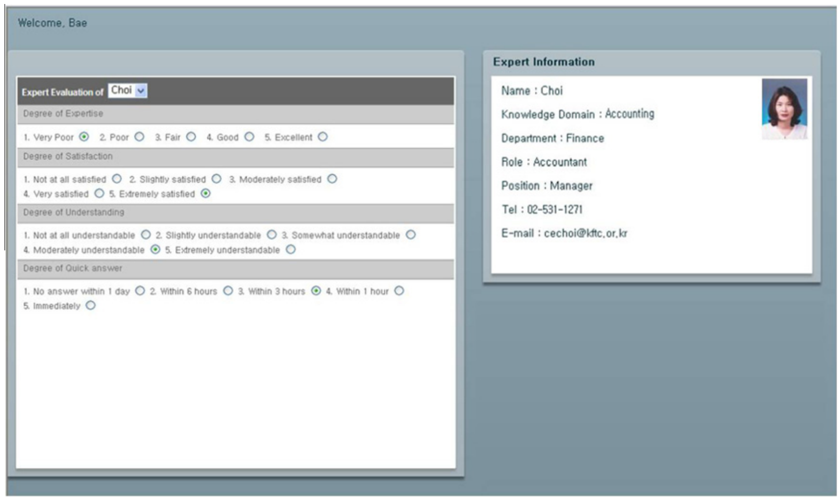


Fig. 17. User evaluation for the expert's knowledge transfer activities.

Table 9
Comparison between the similar systems.

	Authors	Intermediary information	Expertise evaluation	Single view	Automatic update
ERS	MacDonald and Ackerman (2000)	X	X	X	△
	Reichling, Veith, and Wulf (2007)	△	○	△	○
EFS	Crowder, Hughes, and Hall (2002)	X	X	△	△
	Lin, Ehrlich, Griffiths-Fisher, and Desforges (2008)	○	X	△	△
Knowledge Map	Kim et al. (2003) and Liu et al. (2008)	△	X	△	△
KBS	This study	○	○	○	○

○: Full, △: Partial, X: None.

provides visualization and navigation between knowledge. (Kim, Hwang, & Suh, 2003; Liu, Ke, Lee, & Lee, 2008).

The comparison between the similar systems and the *K-broker* system is presented in Table 9.

The Expert Finding System focuses on documents and ranking of the expertise. On the other hand, the Knowledge Brokering System (KBS) provides links between users who search tacit knowledge and experts who have that knowledge, and provides paths to reach those experts by focusing on problem solving and transfer of tacit knowledge based on registered documents and social network information between members.

The previous prototypes of ERS and EFS lack in providing the intermediary information for reaching a specific knowledge expert and 'single view' screen for the selected knowledge expert. However, KBS can describe the intermediary information in the link path including information about the members who exist between knowledge seekers and knowledge experts, and also provide a 'single view' screen to catch the overall information that can show the detailed information and social networks among members.

Knowledge map provides relationship between knowledge. Knowledge map focuses on not person who has knowledge but knowledge itself. however, Knowledge Brokering System focuses the relationship between members in the organization. Knowledge Map is not able to provide how to find knowledge.

Also, KBS can provide the expertise evaluation and automatic update of the relationship information between users and experts according to their knowledge transfer activities.

5. Conclusion and further works

As a strategic asset in an organization, tacit knowledge is difficult to imitate and substitute, but it is also difficult to transfer between members in an organization (Bou-Llusar & Segarra-Ciprés, 2006). Knowledge in the organization is complex because knowledge transfer is based on individual interpretation, cognition and behavior that can be formed by contextual rules and resources. For a more effective transfer of knowledge, it must be compatible with the existing social context (Guzman & Wilson, 2005).

Tacit knowledge is disseminated through an organization via socialization activities and experience, and needs to be transferred through practice. According to Nonaka and Takeuchi (1995), 'sharing tacit knowledge between individuals through communication is an analog process that requires a kind of "simultaneous processing" of the complexities of issues shared by the individuals'. Therefore knowledge transfer is in itself a complex process between knowledge seekers and knowledge experts.

In the context of social networks, informal relationships among employees are often a far better reflection of the way work is carried out in an organization than the relationships established by positions within the formal structure (Cross, Parker, & Borgatti, 2002).

For successful tacit knowledge transfer, we focused on the role of a knowledge broker as a connector between knowledge seekers and knowledge experts. There may exist a lack of competence or a misunderstanding between the seekers and the experts when the brokering is done via a human knowledge broker, therefore this study proposed the implementation of the Knowledge Brokering System, *K-broker*. The *K-broker* system can get rid of the possible problem of the distorted knowledge brokering between the seekers and the experts by providing 'direct contact'. Also the *K-broker* can provide a 'single view' screen interface for identifying a specific knowledge expert based on the user's social network and relationships. Because the *K-broker* is an information system, it can provide a permanent communication channel and be more robust and flexible enough for a large organization. However, the *K-broker* system