Communications of the IIMA

Volume 5 | Issue 4 Article 12

2005

An Effective Knowledge Management Environment Based on Knowledge Grid in Business Organizations

Hengshan Wang
University of Shanghai for Science and Technology

Liqun Ji
University of Shanghai for Science and Technology

An Effective Knowledge Management Environment Based on Knowledge Grid in Business Organizations

Hengshan Wang
College of Management, University of Shanghai for Science and Technology
Shanghai 200093, P. R. China
Phone: 86 21 6568 5971 *Email:* wanghs@usst.edu.cn

Liqun Ji
College of Management, University of Shanghai for Science and Technology
Shanghai 200093, P. R. China
Email: megjee@msn.com

ABSTRACT

Ongoing transition of most of business enterprises to knowledge-based ones is a watershed event in the evolution of the global knowledge economies. This transition marks a paradigmatic shift from energy-based economies with traditional factors of production to information-based economies based upon knowledge assets. Accordingly, the objective of this paper is to develop a theoretical and pragmatic architecture of knowledge management system based on Knowledge Grid for better implementing knowledge management (KM) in business organizations to facilitate their vision of sustainable growth and development. This paper objectively analyzes the environmental problems that most of those enterprises, especially those knowledge-based ones have to face up in such a distributed, increasingly changing environment. Also the critical situations of knowledge management in those business organizations are outlined. Then a new theory about knowledge management, namely, knowledge systems engineering in introduced, which paves the way for better understanding knowledge management and lays the groundwork for constructing a more valid architecture of knowledge management system. And a new architecture of knowledge management system based on knowledge grid is proposed to solve those problems mentioned above, which may provide not only a friendly user interface for end-users to easily access and manage many kinds of Web resources but also a platform for those business organizations to successfully implementing knowledge management.

Key words: core competences; knowledge; knowledge system; knowledge systems engineering; knowledge transferring model; knowledge grid framework

INTRODUCTION

The phrase knowledge management emerged in business areas in the 1980s, usually used by information technology managers. Over the last decades, business organizations have taken considerable interest in a concept called knowledge management and computer hardware and software providers have been eager to adopt the term and associate it with information technology solutions, because knowledge has become the most important factor determining their destinies – more than land, than tools ,than labor (Dorothy, 2000; Ruggles and Holtshouse, 2001; Biqiang, 2002; Zhongtuo, 2004).

But what is knowledge management really about? Key components: ideas, communicating, sharing, collaborating, retrieving and innovation. We start with knowledge, we accumulate more knowledge, we re-use knowledge and we produce more knowledge. It's a perpetual activity in business organizations.

Business organizations' ability to create new knowledge is regarded as a primary source of competitive advantage already today and increasingly so in the future, and finding ways to actively support the process of organizational knowledge creation is therefore an activity that should be prioritized. Knowledge management experts have been used techniques in the areas of social network analysis, systems analysis, processing mapping, focus group sessions, one-on-one interviews with key employees and other methods to reuse knowledge or create new knowledge. The works of scholars from a multitude of disciplines have suggested that access to a rich variety of information stimulates enterprises' survival and sustainable development (Nonaka and Takeuchi, 1995).

However, existing theories development directives and empirical studies of knowledge management are still at a nascent stage (Jeffery *et. Al.*, 2000; Malhotra, 2000), and there is significant debate and confusion as to the situations of knowledge management in many business organizations. And a more important and immediate issue that precedes such concerns is how to implement knowledge management effectively and efficiently in business organizations.

Further, there are a lot of troublesome problems that most of those enterprises have to face up in such a distributed, increasingly changing environment. The implementation of knowledge management in those business enterprises is hindered by the limitations of the business organizational network environment, though it has its strengths.

It is therefore anticipated that the process of devising a more valid architecture of knowledge management system will generate insights for developing better theoretical and pragmatic understanding about implementing knowledge management in business enterprises.
Informed by the new theory of knowledge systems engineering and researches on Knowledge Grid, this study also attempts to define the future trajectory of knowledge management and the major challenges for research in the coming years.

The structure of this paper is as follows. In the next section, the author will outline several problems that still exist in the environments of those business organizations. Also the critical situations of knowledge management in those enterprises are addressed. The following section introduces a new theory about knowledge management, namely, knowledge systems engineering. There are two key outcomes of the above theory. First, to clarify the meanings of knowledge system, knowledge systems engineering, this paves the way for better understanding knowledge management. Second, it lays the groundwork for further analyzing the necessities of improving knowledge management. Using that as a theoretical backdrop, the next section proposes a architecture of knowledge management system based on Knowledge Grid, we discuss its components as well as the relationships among them. The conclusions are summarized in the final section.

THE SITUATION OF BUSINESS ENTERPRISE

The Internet and World Wide Web, as enormous sources of such cross-disciplinary and mostly uncontrolled information, are milestones in the history of information sharing. Scientists are increasingly relying on them to support their research (Hendler, 2003).

Intranets built in those business enterprises also play important roles in communication and sharing information within or across those organizations. But Web pages' exponential growth and intrinsic characteristics on Internet/Intranets prevent people from effectively and efficiently sharing information. Much effort to solve this issue has achieved limited success (Adamic and Huberman, 2000; Kleinberg and Lawrence, 2001).

On the other hand, most of the knowledge management systems adopted in business organizations are based upon the architecture of client/server (C/S) or browser/ server (B/S). That means the Web server in a business organization has to process lots and lots of information in working time and the database server need to deal with more and more data accumulated during its performance. However, radical changes in the business environments and organizational structures have limited those systems' applications.
The rest of this section is about to analyze applications of knowledge management in business organizations from two aspects: the business organizational network environments and the situations of knowledge management.

An analysis of business enterprises' network environments

When organizations adopt Internet technology to set up intranets, they have what seems to be a good foundation for knowledge creation. Intranets were indeed also quickly hailed as the ultimate solution to many organizational issues (Scott, 1998). Although intranets have enthusiastically been implemented in many fields, there are many cases of poor utilization and information loss or distortion that block information and knowledge sharing and innovation (Lili, 2003; Liqun and Hengshan, 2004).

The common strengths of the network environments in those business organizations are as fellows.

Hyperlinked and distributed. In the network environments, end-users and developers are allowed to communicate, collaborate, and exchange information in a transparent way. The most significant feature of such an environment is that it provides a way to create hyperlinks to other resources. On the other hand, it's also a distributed environment both physically and in authority. Any object anywhere in the web environments may be easily addressed and thus likewise easily accessed at anytime, which enables single individuals as well as large organizations to distribute information equally easily (Turoff and Hiltz, 2003).

Adaptable. The network environment is based entirely on open and publicly accessible standards. The open standards, the in-place world-wide net, and the availability of open source and free-to-use software for both servers and clients make an intranet both a flexible and a relatively inexpensive implementation (Scott, 1998). The access mechanism of the HTTP protocol enables anybody—even end-users—to develop add-ons, which in turn guarantees adaptability and access to both proprietary formats and types not yet existing.

As a coin has two sides, there are two aspects contributed to the limitations of the network environments of those business enterprises.

Organizationally bounded. Most of business organizations have their own intranets, which are accessible only by users from their own organization, so the network environments based on intranets is organizationally bounded and shielded from the outside world by security devices such as firewalls. Such an environment may enables the organization to more freely share information not intended for competitors, however, with the development of the organization, it will make a great negative impact on knowledge management, because it only allows users belonging to the same organization to collaborate and share their individuals or organizational information, which will gradually hinders knowledge management from going further.

Non machine-understandable and intelligently clustered. Knowledge management, in short, means providing the right information to the right people at the right time, but web pages could not reflect machine-understandable semantics, so it has difficulty supporting intelligent services (Hendler, 2003). What's more, relevant knowledge distributed in those business organizations can be intelligently clustered and fused to provide on-demand knowledge services with underlying reasoning and explanations.

The critical problems in knowledge management in business organizations

Being inspired by the promise of automated solutions that could somehow manage knowledge, managers leapt to implement an astonishing variety of software applications associated with knowledge management hype. The late-90s killed the belief in the hype, more quickly than most implementations could be brought to maturity. Some of those implementations might actually have resulted in desired benefits but the will to persevere in such undertakings requires thoughtful approaches and sustainable plans that evolve over time. Now is a good time to talk about what knowledge management should really be about and how it relates to information technology (IT).

Knowledge management is often defined as the ability to get the right information to the right people at the right time. This definition confines to the existing knowledge only. More important is the production of new knowledge to fulfill increasing demands. Knowledge creation is the core competence of business organization (Delu, 2003; Jinghua and Xin, 2003), and IT projects as the best solutions for most of the practitioners of knowledge management have been widely used in attempting to promote their core competences to keep up with and excess their competitors in business area.

However, with the development of those business organizations, knowledge management has stepped into its second stage (Thomas and Davenport, 2000). It is being realized that the programmed nature of heuristics underlying such knowledge management systems, based on C/S or B/S architectures, may be inadequate for coping with the demands imposed by the new business environments, which are characterized not only by rapid pace of change, but also discontinuous nature of such change. As a result, there are still so many critical problems unresolved in those enterprises.

Information overload

The development of network and IT resulted in an enormous amount of Web knowledge resources. As we known, the Web has significant impacts on both academic and ordinary daily life by revolutionizing the way in which information is gathered, stored, processed, presented, shared, and used. It has provided us a large-scale, universal

and global information resource space. And the accumulation of knowledge resources in many business organizations, especially those knowledge-based ones, is increasing at an incredible speed (Malhotra, 2000). On the other hand, huge amounts of information available on the Web have become overwhelming, inaccurate, imprecise, incomplete and irrelevant, which only further confuse knowledge workers (Liqun and Hengshan, 2005).

What also remains a major problem to solve in knowledge management now, if companies adopt a more liberal information sharing policy, is the issue of information overload. This problem is often marginalized or ignored by technology evangelists who promote the use of IT in KM-related work (Scott, 1998). Though redundancy of information helps creativity, it also increases the risk of being flooded with useless information (Nonaka and Takeuchi, 1995).
Information convergence

Since most of the knowledge management systems adopted by many business organizations are independent without a uniform portal; they are devoid of channels to communication with other departments or organizations, consequently, it's impossible to share knowledge resources with other collaborators.

Network fragility

At present, most of the knowledge management systems are based on the frameworks of C/S or B/S. These kinds of networks have two main generic features:

First, they are dynamic, open systems that grow by the addition of vertices;

Second, preferential attachment is another feature, which favors attachment to vertices with high degree (can be called core nodes). Those core nodes contain a giant cluster compromised of most of other nodes, when core nodes are removed; all other nodes linked with them are removed too. So such so kind of network is fragile.

On the other hand, these knowledge management systems are not suitable for sharing and leveraging knowledge effectively and efficiently, when scales of those enterprises are expanding. What's more, they are not flexible for knowledge communication and reutilization between business organizations due to the network structures' limitations.

And there are still other problems should be taken into account if one want to deal with those critical problems mentioned above. They are as follows:

(1) How do we organize and manage those knowledge resources in a business organization? We can get the knowledge encoded into the Web documents and published onto the intranet or internet. However, the Web document is not a suitable container for knowledge, and the traditional Web server architecture can not suffice as the run time environment for knowledge.

(2) How could we discover and share those knowledge resources within or between knowledge-based companies?

(3) How could we dynamically utilize those knowledge resources to provide coordinated query answering services?

Coordinated sharing of resources would bring us much more in a cooperative environment.

According to Thomas Davenport and Laurence Prusak (Thomas and Davenport, 2000), phase one of the knowledge management movement is over, firms aiming for long-term advantage must now tie their knowledge management initiatives to core aspects of their business. As knowledge management is on to phrase two, it's urgent for business companies to build up a more robust environment for distributed management and coordinated gathering, using, sharing and creating of knowledge.

A NEW THEORY ABOUT KNOWLEDGE MANAGEMENT

A new theory about knowledge management, knowledge systems engineering is addressed here in greater depth to understand knowledge management. Before we give the definition of knowledge systems engineering (Zhongtuo, 2004), there have been prior efforts to clarify the related concept---knowledge system.

Definition 1. Knowledge system is to investigate the knowledge acquisition, manipulation, dissemination and creation in business organizations in the way of a unified and systematic view. It's a man-machine system and human factors play important roles.

Definition 2. The main components of the knowledge system include: human being, books, documents, patents and copyrights, computer information systems as well as working solutions, community of practice and webs of relationships. It also includes those embedded in the products and services. So the structure of knowledge system can be considered as a network system, which is composed of a set of networks. It's notable that nodes in such a system can be documents, models, individuals, teams, or even organizations. They are the focal points for activity or organizational processes. The links are various connecting and coordinating mechanisms, such as workflow procedures or knowledge flow procedures. People often think about the nodes as the place of knowledge storage and knowledge creation, but in fact, knowledge creation also happens on the links. Since the links represent the knowledge process, as information flows across the links, new knowledge is created both at the nodes and on the links, which can be then applied to meet the needs of the organization.
From the view of systems engineering, the function of the system determines the structure. The functions of knowledge system are:

- Effective capturing and organizing of knowledge;
- Efficient storage and protection of knowledge;
- Dissemination of right knowledge to right person at right time;
- Promoting innovation;
- Managing of knowledge assets;
- Creation and reshaping of organizational culture.

It indicates that all of the five aspects: knowledge gathering, knowledge storage, knowledge transferring, knowledge sharing and knowledge creation in knowledge management should be taken into account for building a new kind of knowledge network system.

On the other hand, we should lay a strong emphasis on two key issues, namely, knowledge creation and knowledge sharing so as to accelerate knowledge transferring and creation within or across business organizations. These two key issues relates to two knowledge cycles. The first one is knowledge creation cycle, in which there are four processes, namely, creation, codification, storing, and distribution. This cycle addresses a process from idea creation into more structured and reproducible knowledge, or from tacit knowledge to explicit one. The second one is knowledge sharing cycle, in which there are four steps: gathering, sharing, spreading, reusing. This cycle has the focal point on knowledge repository.

Recently, many business organizations' growth and performances are built upon information technologies (IT) based on the technology-centered perspective. And many such measures have also focused on structural inputs such as IT investments with lesser consideration for the social and human factors that also affects the quality of performance outcomes. Fortunately, there is growing awareness about the roles of social and human factors, simultaneously, developmental organizations are adopting a more holistic perspective of organizational growth that goes beyond just IT and includes human, social, cultural development and general well being.

Knowledge systems engineering, as an application-oriented discipline of organization and management of knowledge systems, integrates technology-centered and human-centered approaches, knowledge management and knowledge enabling, and can be accepted by the people with science-technology and humanity backgrounds. According to knowledge systems engineering, the architectures of knowledge system involves four aspects: organization architecture, personnel architecture, technological architecture, cultural architecture. Consequently, the architecture of a knowledge network system may be composed of four layers: interface layer, application layer, function layer, and repository layer.

A NEW KNOWLEDGE MANAGEMENT ENVIRONMENT FOR BUSINESS ORGANIZATIONS

Knowledge is the basis of realizing intelligent services (Lynda , 2005). As Vannevar Bush pointed out, sharing and inheriting knowledge can be challenging (Bush, 1945).

Knowledge management, as a framework for managing knowledge in organizations is one way of looking some of the components of knowledge management and relating them to other infrastructure activities. Like the seemingly

endless variants on how different human brains process the same information, organizations can operate in infinitely diverse ways when using the same or similar data sources. The variations depend, in large measure, on their employees' personal knowledge and behaviors interacting. With accumulation of more and more knowledge resources in business organizations, the traditional architectures of knowledge management systems as well as the network environments could not afford such heavy knowledge services, namely, knowledge gathering, knowledge storing, transferring, sharing and utilization (Hubert, 1996; Zhongtuo, 2004).

Knowledge grid

Grids has been a mature architecture for distributed computing in Internet and carries the promise to enable widespread sharing and coordinated using of networked resources (Foster and Kesselman, 1999). The global Grid (www.gridforum.org) promotes sharing, managing, coordinating, and controlling distributed computing resources, such as machines, networks, data, and any devices. The Grid's goal is to enable compatible devices to be plugged in anywhere on the Grid and be guaranteed the required services, just as the power grid does with electricity (Foster, 2000).

Grid technologies are currently evolving toward an Open Grid Services Architecture (OGSA), in which the Grid provides an extensible set of services that virtual organizations can aggregate in various ways (Zhihong *et. al.*, 2002; Ganmei *et. al.*, 2003; Guangwen *et. al.*, 2003). OGSA development is a natural extension of the activities defining the standards for Web Services. However, it is now a matter of some urgency to have an agreed architecture which encompasses both the W3C web services standard and provides retro-fitting to meet the needs of knowledge management systems have been or are used in most of business organizations.

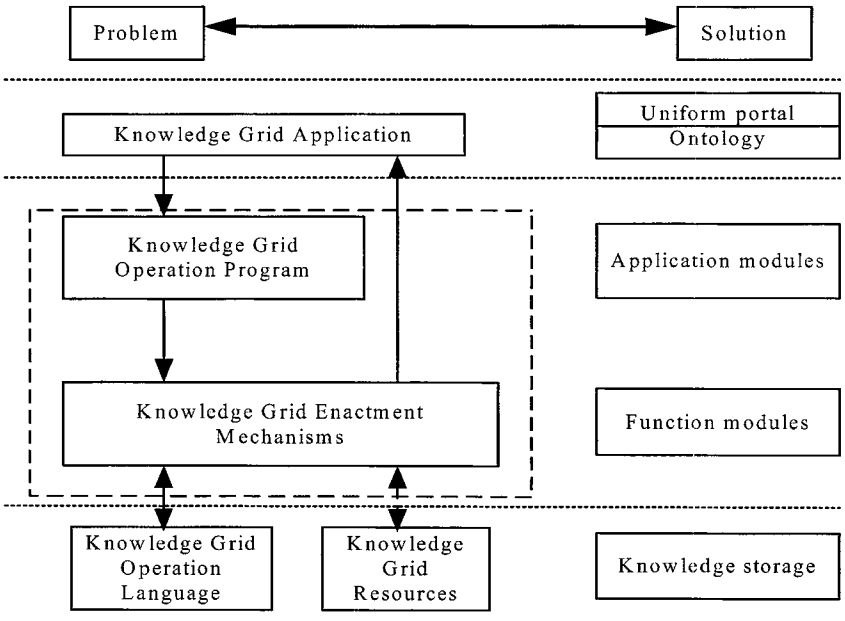
Knowledge Grid, according to Fran Berman, will be a mechanism that can synthesize knowledge from data through mining and reference methods and enable search engines to make references, answer questions, and draw conclusions from masses of data (Berman, 2001). In fact, Knowledge Grid is an intelligent, sustainable Internet application environment that enables people or virtual roles (mechanisms that facilitate interoperation among users, applications, and resources) to effectively capture, publish, share, and manage explicit knowledge resources. It also provides on-demand services to support innovation, cooperative teamwork, problem solving, and decision making. It incorporates epistemology and ontology to reflect human cognition characteristics; exploits social, ecological, and economic principles; and adopts the techniques and standards developed during work toward the intelligent Web.

The characteristics and architecture the Knowledge Grid are addressed in (Zhuge, 2004).Generally speaking, Knowledge Grid will go beyond traditional and improved information retrieval, filtering, and mining and question-answering techniques. It will also exploit research toward a new distributed Web environment, using it to build a more efficient and effective intelligent application platform.

The framework of knowledge management system based on knowledge grid

A new knowledge management system based on knowledge grid architecture for widespread gathering, sharing, managing and coordinated using knowledge resources, and providing more intelligent web services, which will build up solid theoretical and technological fundaments to realize a great stride in knowledge management in those business enterprises.

The architecture of the new knowledge management system based on Knowledge Grid is sketched out in Fig. 1, which consists essentially of a 3-layer model.



(Resource from: the Key Lab of Intelligent Information Processing, Institute of Computing Technology, Chinese Academy of Sciences, China)

Figure 1: Knowledge grid architecture.

The knowledge storage layer at the bottom corresponds almost exactly to the knowledge bases, in which knowledge is "stored" and from which knowledge may be "retrieved" – across different contexts– when needed in the very same condition as it has been produced, i.e. has been "transferred" (better transformed into information) into a database. It provides secure access to distributed data and knowledge resources for knowledge workers. Its function also involves parsing, searching, querying and extending knowledge bases. It supports the Knowledge Discovery service with distributed resources. In this case the most significant tasks for the Knowledge Grid support of knowledge management would be to acquire knowledge entities and to optimize the storage, navigation and distribution of these separable units of knowledge in databases.

The knowledge services layer above relies on two components:

(1) Knowledge Grid operation program, which mainly achieves application modules, such as knowledge indexing;

(2) Knowledge Grid enactment mechanisms, which realizes function modules as well as the controlling mechanisms. It provides knowledge workers with a homogeneous view over heterogeneous knowledge sources and software systems, together with appropriate software for knowledge discovery and reduction-statistics and simulation/modeling, so as to accomplish distributed knowledge services which involve communication and decision making activities.

The hypotheses or theories held in this layer are promulgated to the bottom layer to calibrate and control the instrumentation, so allowing smarter knowledge collection. Furthermore, knowledge is used in this layer to improve query precision and accuracy and to explain results to the end-user. So it is the core component in the whole Knowledge Grid architecture.
It's considered that ontologies are available on the Web and freely accessible. We assume that the advent of the semantic Web will bring the ontologies of many different domains as its components. Therefore, the topmost knowledge application layer, as the user interface for semantic query answering and the knowledge services, provides the end-users with a uniform portal. All users can work together regardless of their heterogeneous and decentralized hardware and software environments.

CONCLUSIONS

This paper analyzes the strengths and limitations of business organizational environment based on intranets, represents the main critical problems that those business organizations are facing up in the second section, which indicates that it's needed to pay more attentions to improving knowledge management in business organizations. Then this paper introduces a new theory about knowledge management, namely, knowledge systems engineering which may set the stage for building a new knowledge management environment. And a new architecture of knowledge management system based on Knowledge Grid is proposed and its main components as well as the interactions among them are addressed. Much remain in terms of ensuring not only what architecture of the new knowledge management system we build, but in developing clearer understanding of knowledge management itself, which may provide directions for future research and development for further improvements in knowledge management.

REFERENCES

Adamic, L. A., Huberman, B. A. (2000). Power-Law Distribution of the World Wide Web. *Science 287*, 2115

Berman, F. (2001). From TeraGrid to Knowledge Grid. *Comm. ACM 44(11)*, 27 - 28

Bush, V. (1945). As We May Think. *The Atlantic Monthly 176(1)*, 101 - 108

Delu, W. (2003). Knowledge Management'S IT Implementation---Plain Knowledge Management (in Chinese). Beijing: Publishing House of Electronics Industry

Dorothy, L. (2000). Wellspring of Knowledge---Building and Sustaining the Sources of Innovations (in Chinese). Beijing: Xinhua Publishing House

Foster, I., Kesselman, C. (1999). The Grid: Blueprint for a New Computing Infrastructure. San Francisco: Morgan Kauffman

Foster, I. (2000). Internet Computing and the Emerging Grid. *Nature*, Retrieved December 7, 2000, from www.nature.com/nature/webmatters/grid/grid.html

Ganwei, Y., Huaming, L., Feng, L. (2003). An Adaptive Metadata Publishing Policy in Information Grid (in Chinese). *Journal of Computer Research and Development 40(2)*, 1791 - 1795

Guangwen, Y., Yongwei, W., Jing, Z. (2003). A Global Uniform Hierachical Grid Resource Model (in Chinese). *Journal of Computer Research and Development 40(12)*, 1763 - 1769

Hendler, J. (2003). Science and the Semantic Web. *Science 299*, 520 - 521

Hubert, S. (1996). Tacit Knowledge: The Key to the Strategic Alignment of Intellectual Capital. *Strategy & Leadership 24(2)*, 10 - 14

Jeffery, K. G., Brinkkemper, J., Lindencrona, E., Solvberg, A. (2000). Information Systems Engineering. London: Springer-Verlag

Jinghua, X., Xin, J. (2003). Knowledge Management (in Chinese). Beijing: Mechanical Industry Press

Kleinberg, J., Lawrence, S. (2001). The Structure of the Web. *Science 294*, 1849 - 1850

Lili, S. (2003). Knowledge Management in Chinese Companies: A Review of Related Research (in Chinese). Tianjin Library Journal *(6)*, 48 - 52

Liqun, J., Hengshan, W. (2004). The Application of Knowledge Management Inmanufacturing Industry (in Chinese). *Studies in Science of Science 22(3)*, 303 - 307

Liqun, J., Hengshan, W. (2005). Analyzing the Management of Knowledge Workers (in Chinese). *Library and Information Service 49(1)*, 47 - 50

Lynda, M. (2005). KM as a Framework for Managing Knowledge Assets. *The Gilbane Report 12(9)*, 2 - 3

Malhotra, Y. (2000). Knowledge Management & New Organization Forms: A Framework for Business Model Innovation. *Information Resources Management Journal 13(1)*, 5 - 14

Malhotra, Y. (2000). Knowledge Management for E-Business Performance: Advancing Information Strategy to Internet Time. *In the Executive's Journal 16(4)*, 5 - 16

Nonaka, I., Takeuchi, H. (1995). The Knowledge-Creating Company: How Japanese Companies Create the Dynamics Of Innovation. London: Oxford University Press

Qiang, B. (2002). Web Information Resources Development and Utilization (in Chinese). Beijing: Science press

Ruggles. R., Holtshouse, D. (2001). The Knowledge Advantage: 14 Visionaries Define Marketplace Success in the New Economy. Beijing: Mechanical Industry Press

Scott, J. E. (1998). Organizational Knowledge and the Intranet. *Decision Support Systems 23(1)*, 3 - 17

Thomas, H., Davenport, L. (2000). Working Knowledge: How Organizations Manage What They Know (paperback edition). Watertown: Harvard Business School Publishing

Turoff , M., Hiltz, S. R., Benbunan-Fich, R. (2003). A Comparative Content Analysis of Face-To-Face vs. Asynchronous Group Decision Making. *Decision Support Systems 34(4)*, 457 - 469

Zhihong, D., Shiwei, T., Dongqing, Y. (2002). Semantic-Oriented Integration: The Role of Ontology in Web Information Integration (in Chinese). *Computer Applications 22(1)*, 15 - 17

Zhongtuo, W. (2004). Knowledge Network System: Not Only a Tool, But a Paradigm. in Proceedings of The First International Symposium on Knowledge Management for Strategic Creation of Technology, Japan Advanced Institute of Sceince and Technology, Ishikawa, Japan

Zhongtuo, W. (2004). Knowledge Systems Engineering (in Chinese). Beijing: Science press

Zhuge, H. (2004). China's E-Science Knowledge Grid Environment. *IEEE Intelligent Systems and Their Applications 19(1)*, 13 – 17

Acknowledgement

This paper is supported by the China 863 Research Program on Enterprises Knowledge Creation-Oriented Knowledge Engineering and Knowledge Management Technique under Grant Number 2002AA414310, and the Shanghai Science and Technology Bureau Research Program on Knowledge Management Technology Study under Grant Number 03JG05051.