DEVELOPMENT OF KM MODEL TO SIMPLIFY KNOWLEDGE MANAGEMENT IMPLEMENTATION IN CONSTRUCTION PROJECTS

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To improve competitiveness, construction companies have to reduce cost and time of completion of projects while improving the quality of projects. Knowledge management (KM) is becoming increasingly important for the construction industry. Lessons learnt from the construction industry have proved that by reusing and sharing knowledge among engineers and experts can enhance construction projects successfully and decrease cost and time of completion, and help in solving problems associated with the projects. Many KM models currently used in the construction industry may have some problems in many circumstances, which cannot be used efficiently and effectively. This paper presents a new KM model that combines many of the recent research outputs from construction domain and other disciplines. The proposed model presents the essential KM activities and features broken down into more manageable parts that are easy to understand and use, which simplifies the understanding of the sources of knowledge, the inputs and outputs, the flow of knowledge and the identification of other variables such as the cultural effects on the organizational knowledge. A case study collected from the industry is used to demonstrate how the proposed KM model can be used to improve the industry KM performance.

Keywords: knowledge management model, knowledge management system.

INTRODUCTION

Knowledge management (KM) is now considered as one of the most important parts of any organizations and it is a complement to the organizations' business activities. Many construction companies found that they received many benefits by adopting KM systems in their construction work. For example, in order to complete the projects with reduced cost and time while improving quality, by reusing and sharing previous experience and knowledge employees can select the solutions for their problems without spending extra time and resources on reinventing solutions that have already been invented elsewhere in the organizations. Many construction companies have claimed to have millions of dollars savings from the adoption of KM techniques in their organizations.

Knowledge can be defined as the facts, information, skills, and understanding that one has gained, especially through learning or experience. Alavi and Leidner (2001) defined a KM system as "IT-based systems developed to support and enhance the organizational processes of knowledge creation, storage/retrieval, transfer, and application." Because knowledge combines information with experiences, it shows

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methods and procedures used by others previously to solve similar problems, and provides the ability to learn from their experiences and maintains the new experiences to be used in future (Tiwana, 1999; Davenport and Prusak, 1998; Baker *et al.*, 1997). With the rapid development of the construction industry, the industry faces the challenge of how to construct a well-linked KM system that allows a learner to acquire knowledge. Many techniques have been developed to simplify the use of KM systems in construction industry such as knowledge maps (Wetherill *et al.*, 2002) and construction activity-based KM models (Tserng and Lin, 2004; Lin *et al.*, 2006), which help to create relationships among isolated knowledge and represents via a hierarchy structure of knowledge representation type that is most valuable. KM systems refer to a class of information systems applied to managing organizational knowledge, which helps organizations to find, select, organize, disseminate and transfer important information and expertise necessary for activities such as problem solving, dynamic learning, strategic planning and decision making. In the construction industry, the major difficulty in implementing KM is formulation and implementation of a strategy (Robinson *et al.*, 2004). Although previous studies attempted to select or to develop an appropriate strategy for the construction industry, managerial courage is required to face this challenge and achieve changes.

Knowledge may be classified into explicit and tacit knowledge. Explicit knowledge is easy to be captured, retrieved and used because it can be expressed in words and numbers. Tacit knowledge is personal and exists in the individuals' heads in the form of experiences and know-how. However, tacit knowledge can be captured, mobilized and turned into explicit knowledge it would then be accessible to others in the organization and enable the organization to progress rather than have its members having to relearn from the same stage all the time (Gore and Gore, 1999). There are many existing KM packages, but they only deal with explicit knowledge. Tacit knowledge, however, is important in a KM system because it is an important type of knowledge for the organizations (Tiwana, 1999; Davenport and Prusak, 1998; Baker *et al.*, 1997; Gore and Gore, 1999, Robinson *et al.*, 2004).

Wetherill *et al.* (2002) introduced a KM model in the E-Cognos project, which promoted KM within collaborative construction environments. The proposed approach is a cyclic approach and consists of eight phases. The model addresses the knowledge requirement of end-users and supports their exist practices while taking into account the contractual, legal, intellectual property rights, security and confidentiality constraints. In this KM model, the knowledge is divided into three categories: the domain knowledge, organizational knowledge and the project knowledge. However, this model ignores a number of important issues such as knowledge acquisition, classification, storing, reusing and updating, in particular, the identification of the two types of knowledge, i.e. explicit and tacit knowledge, which require different methods, tools and processes to capture and manage. Furthermore, it is also necessary to identify the important factors that affect construction activities such as culture and management strategy.

Tserng and Lin (2004) researched into the application of KM to construction projects and proposed a construction activity-based KM model for contractors. The main advantage of this model is that it simplifies the way to collect and reuse knowledge in construction projects. This model represents activities and processes that are necessary for a successful implementation and use of KM system. On the basis of activity-based KM model, Lin *et al.* (2006) introduced a method to capture and present knowledge for the construction projects by using network knowledge maps. It

can clarify vague knowledge, enabling users and learners to easily find desired knowledge. Although this KM model shows the importance of classifying knowledge into explicit and tacit knowledge and emphasizes both of these two types of knowledge must be managed differently, there is a lack of a statement of the environmental factors that affect the application of KM in construction such as employees' culture and management strategies, and it is unavailable to application of parallel activities.

Most recently, Maqsood *et al.* (2007) applied Soft System Methodology (SSM) to a case study to show how knowledge-pull from external knowledge source could systemize knowledge exchange as a KM initiative. Seven sequential steps of the developed SSM model aim to explore problematic situations that arise in human activities by learning from the different perceptions that exist in the minds of the different people who are involved in these situations. However, the research only focused on human knowledge exchange.

A C-SanD project carried out by Shelbourn *et al.* (2006) at Loughborough University aimed to promote knowledge creation in construction sectors for subsequent sharing and re-use. The work focuses on the promotion of sustainable development in the construction industry especially in the areas such as the minimization of waste, material recycling and energy conservation in the design, construction and operation of buildings. The research developed a "Sustainability Management Activity Zone" (SMAZ) as an activity zone within the generic design and construction process protocol (GDCPP) that was created by the University of Salford in 1998. The process protocol is a process map that provides a framework for the management of processes on any given construction project through eight activity zones such as development, project, resources, design, production, facilities, health and safety, statutory and legal, and process management.

There are many other KM models in the literature. Although some KM models have been developed which help construction organizations to embrace KM, but, however, most of available approaches for KM modelling development are not targeted to explicit and tacit knowledge, which leads to difficulty during KM implementation and application. This study proposes a KM model that is suitable for extracting knowledge from various sources to provide a simple and practical method for KM implementation for contractors and construction projects.

PROPOSED NEW KM MODEL

A new KM model has been proposed as shown in Figure 1, which consists of initiatives, roles and influential factors when applying KM in construction projects. This model takes into consideration the importance of integrating project information and knowledge in the organization. By integrating information it avoids re-recording information that already exists in the organization, this can minimize the existence of many pieces of information that contradict each other. The new KM model can be divided into four components: knowledge resources, influencing factors, human resources activities, and knowledge system architecture that will be described in the following sections.

Knowledge Resources

Knowledge resources such as documents from ongoing projects, data from past projects, knowledge from literatures, interviews with experts and senior engineers, and questionnaire surveys can be the main source of knowledge to be used in the

processes of analysis, design and implementation of KM system. Therefore, the proposed KM model starts with information collection, organization and review of knowledge. The information will be used in the design and implementation of KM system.

After the KM implementation, the types of knowledge such as explicit and tacit knowledge should be identified to ensure that the knowledge is available and important to the organization. It should be noted that these two types of knowledge require different methods and procedures in processing and management. Explicit knowledge can usually be found in the enterprise documents, for example manuals, specifications, contracts and reports or organization's database. As tacit knowledge is the personal knowledge that is exists in the mind of engineers and experts in the form of experiences and know-how, which is difficult to be stored and formalized. An effective method to collect such tacit knowledge is through direct contacts. But sometimes this type of knowledge can be captured and stored in a form similar to explicit knowledge to be reused and shared by others. Tacit knowledge contains many shapes such as descriptions of problems, solutions, experience notes, procedures, and innovations. However, tacit knowledge is difficult to be captured simply by normal tables, but rather they can be captured and stored in forms similar to articles including those attached descriptions, pictures and videos. This method has been proven more convenient in the collection of tacit knowledge.

Influential Factors

The influential factors can be identified into five categories of management, culture, technology, infrastructure and measurement. The support from the management of an organization is important in managing knowledge. If managers encourage and support using and implementing KM initiatives, this will help the KM team duty toward developing and improving the KM system. Otherwise, it is more difficult to convince managers to implement and develop a desired level of KM system. There are many cultural factors that may affect the KM initiatives including people values, norms and behaviours. The most common cultural frictions and the proposed solutions are shown in Table 1 (Davenport and Prusak, 1998).

Continuous construction change and growth in technology also affects the KM systems. The KM systems should be designed to satisfy such changes and improvements of construction that emerge in the information domain, and also the outdated knowledge should be removed from the systems. Infrastructure includes support systems and staff in an organization to support the creation and use of knowledge. An advanced support system and experienced employees will be convenient in the implementation of knowledge management initiatives. It is the support staff's responsibility to provide in-house education and a KM network between employees, and educate employees on the benefits of sharing knowledge, e.g. with the help of information technology. Studying and understanding how the KM initiatives affect the business processes must be attained. Therefore, measurement and evaluation of business process and the effect of KM initiatives have to be applied. This will help the organization to improve knowledge initiatives further and develop effective KM tools.

KM Activities

The proposed model presents the essential KM activities and each activity can be further broken down into sub-activities which are described as follows.

- *KM Team Activities*

KM activities required by the KM team depend on information collected from resources such as experts' and engineers' interviews, employees' questionnaires, past projects' documents, literature reviews etc. Members in KM team also have responsibility to collect tacit and explicit knowledge during the life-cycle of construction projects. Analysis, design and implementation of KM system are a cyclic process. The aim of analysis phase is to understand and recognize the vision from top management in the organization, and then identifying values, norms and behaviours of the employees. It should be noted that the identification also includes identification of business processes so that the necessary types of knowledge can be understood. As stated earlier in this paper, explicit knowledge is easy to be captured, processed and accessed. The most effective way to collect tacit knowledge is to review the information flows between its component parts so that the full potential of the information system can be exploited.

In the design phase, the KM team should determine the effective methods and tools to capture, create, categorize, disseminate, search and share knowledge. An effective action plan and the guideline will help the KM team to understand the business problems and objectives of the construction projects, which provide the steps and details of implementation and evaluation of the KM system and show the relationship among KM initiatives. When a prototype KM system has been produced, it should be tested and evaluated before it is applied in a wide range of projects. The KM team should improve the KM system according to the feedbacks and recommendations produced in the testing and evaluating.

The purpose of implementation phase (deployment) is to apply the proposed KM system in practice. The KM team will identify the roles of individuals and encourage them to use the KM system in construction work and share necessary knowledge with others by promoting teamwork. The performance of the organization by using KM system needs to be monitored. This will help the KM team to track the KM process, and monitor environmental and influential factors as discussed earlier in this paper to improve the system. Many methods and techniques can be used to achieve the evaluation of the KM system including balanced scorecard, excellence model, cause-and-effect map, evaluation roadmap, cost and benefit checklists, priority matrix (EFQM, 1999). One effective method is to evaluate the system itself, which the system will be validated by testing cases to see whether the system can operated correctly according to the design specifications. This can be done by questionnaire survey and interviews.

The aims of the knowledge acquisition and storage phase are to collect knowledge and establish the knowledge bases in the implemented knowledge system, which can be reused and shared by the employees of the organization. The development of knowledge bases involves various knowledge acquisition techniques to generate a body of information such as historical data analysis, cost benefit analysis and domain human expert experience and engineering knowledge analysis. Knowledge review and digitizing of paper-based knowledge also have to be carried out by the KM team so that the desired knowledge can be identified and stored in the system.

- *Knowledge Workers Activities*

Knowledge worker is the employee within the construction project whose responsibility is to collect, classify and store knowledge during the construction life-cycle. His work depends on collecting and processing tacit knowledge more than

explicit knowledge that is mostly collected and processed by data workers. His activities are similar to those as described in the acquisition and storage phase such as collection, review, adaptation, edition, classification of knowledge, and the development of knowledge bases.

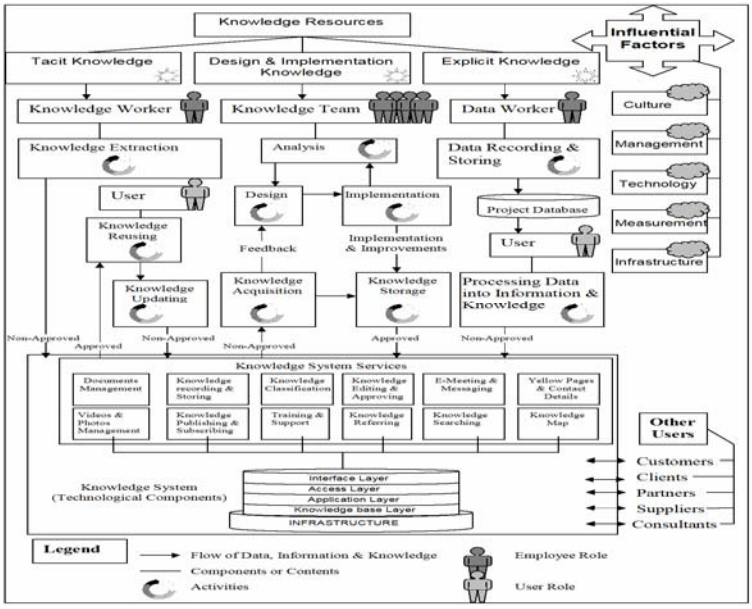

Figure 1: The proposed new KM model for construction

Table 1: The most common cultural frictions and the solutions

Friction	Possible Solutions
Lack of trust.	Build relationships and trust through face-to-face meetings.
Different cultures, vocabularies, and frames of reference.	Create common ground through education, discussion, publications, teaming, and job rotation.
Lack of time and meeting places; narrow of idea of productive work.	Establish times and places for knowledge transfers: fairs, talk room, and conference reports.
Status and rewards go to knowledge owners.	Evaluate performance and provide incentives based on sharing.
Lack of absorptive capacity in recipients.	Educate employees for flexibility; provide time for learning; hire for openness to ideas.
Belief that knowledge is prerogative of particular groups, not-invented-here syndrome.	Encourage non-hierarchical approach to knowledge; quality of ideas more important than status of source.
Intolerance for mistakes or need for help.	Accept and reward creative errors and collaboration; no loss of status from not knowing everything.

- *Data worker Activities*

The proposed KM model contains two main components, i.e., a database and a knowledge base. The database consists of many parts such as the equipment management, accounting, material inventory, customer management, human resource management and project operational data. The data workers should collect, analyse, edit and organize data and record them in tables that could be classified into fact tables and dimensional tables (Rujirayanyong and Shi, 2006). The information will form an important part of the KM system in the organization.

- *Knowledge User Activities*

Knowledge users include engineers, experts, managers, members of the knowledge team, and in some circumstances they could be from other companies who are allowed to access to the KM system and allowed to add their experiences, ideas, and innovations to the system. A user can share and reuse the knowledge stored in the knowledge bases with others where contains useful information and solutions to solve

the identified problems associated with the projects. However, the users also have the responsibility to update the knowledge in the knowledge bases. For example, They can add details, comments and descriptions, and remove non-required knowledge and make changes where required as a non-approved knowledge, and then the KM team will modify and improve the knowledge bases according to the information provided by the users.

Knowledge System components

The proposed KM model consists of four-layer components: knowledge base, application, access and interface. Knowledge base contains both tacit and explicit knowledge that can be captured, categorized, retrieved and updated. Application layer includes software programmes that provide services for the users such as indexing, searching, document management and collaborative work. Access layer provides system security and access restriction. Interface layer is the layer where end-user can access the knowledge base and use applications to retrieve, present, share and edit existing knowledge or add new knowledge to the knowledge bases. Building up such a four-layer KM system depends on the technical and organizational infrastructure. Technical infrastructure includes hardware tools such as internet search tools, networked desktop computing and communications, and software tools such as word processing and presentation softwares. Organizational infrastructure includes organizational groups whose members have the skills to use the technical infrastructure (Tserng and Lin, 2004). Table 2 shows the major services to the end-users by the proposed KM system.

Table 2: The descriptions of services provided by the KM system

Service	Description
Document Management	The purpose of this service is to facilitate saving and recording the information of documents and reports of projects in digital forms.
Video, Photo and Drawing Management	The purpose of this service is to facilitate saving videos, photos and drawings, and also to facilitate attaching them to digital records to simplify understanding of contents.
Knowledge Recording and Storing	The purpose of this service is to provide knowledge workers and other users the ability to record and save new knowledge of problem solving and innovations in digital format.
Knowledge Publishing and Subscribing	This service provides the ability for the KM team to publish the knowledge that will be shared by the users, and provide the ability to subscribe new users and determine their authority level.
Knowledge Classification	This service provides the ability for the KM team/knowledge workers to categorize knowledge to facilitate future retrieve of knowledge.
Training and Support	The purpose of this service is to provide e-learning to all participants in the construction projects. It also provides help and support to all users of the KM system.
Knowledge Editing and Approving	This service provides the ability for the KM team to review and modify the contents of knowledge packages and then approve them to by available for other users.
Knowledge Referring	This service provides the ability for the KM team/knowledge workers to refer and connect the knowledge package to the related experts.
E-Meeting and Messaging	The purpose of this service is to facilitate the contact of people through video conferencing and e-mails. It also provides the ability to record and save the contents in the KM system.
Knowledge Searching	The purpose of this service is to provide the ability for users to search for knowledge by using one or a combination of keywords, expert name, domain, activity name or project name etc.
Yellow Pages and Contact Details	This service provides the contact information of experts and other employees with information about their professions and experiences.
Knowledge Maps	This service provides another way for knowledge searching and also provides an overview of available and missing knowledge in the KM system.

CASE STUDY

A case study collected from the UK construction industry has been carried out to evaluate and validate the proposed KM system. The information of projects used in the evaluation is based on medium and large size construction projects that need experiences in different domains such as highways, bridges, soil excavations and buildings. Each project has many problems due to the complex and diverse situations and the solutions of these problems could not be easily found in the similar previous projects. This causes remarkable delays of many projects. According to the results of information analysis from project databases more than 50% of the new projects are completed behind the expected dates of completion. Engineers and managers have found that many problems associated with projects could be avoided and the ideal solutions could be found for these problems by using KM system. According to the project databases the percentage of delays of new projects has been reduced to less than 30%. Interviews with 2 project managers, 4 senior engineers and 3 knowledge workers have been conducted on the construction sites to discuss and collect their opinions about KM issues, which provide important findings and details in evaluation and improvement of the proposed KM system. The interviews used open-ended questions such as what benefits are provided by the KM system; what problems can the system help to solve; what benefits can be provided by the KM system evaluation; how easily a required piece of knowledge can be found; how important is the knowledge sharing to the problem solving; how useful to the system users are the support services and the knowledge map, what are problems or difficulties in adopting and using the proposed KM model etc. The suggestions and recommendations have been recorded. Findings are summarized as follows:

- The new KM system provides accurate and timely knowledge that facilitates the process of decision making. The KM system provides a great opportunity to learn experiences from previous projects. Although the system is not designed to make decisions for users, it provides knowledge in assistance of decision making.
- The system helps to raise the company competition, enhance work quality and reduce costs and time required in projects by providing problem solutions and reducing the probability of mistakes.
- The system provides a useful tool for training junior engineers.
- The new system helps to solve problems of losing knowledge and experiences of engineers and experts when they leave the organization, and helps the company to keep their knowledge and experience within knowledge bases.
- Feedbacks from the evaluation of the KM system provide very useful information for the improvement of the management system.
- The new system is found to be used easily for users to find problem solutions and required information.
- Knowledge sharing is found to be important and useful in construction projects where there are many interrelated components working together in a complex manner.
- The KM team and knowledge workers found that the proposed system is a useful tool in supporting to their employees, which is easy to maintain and update the knowledge in the knowledge base.
- A knowledge map is a powerful tool that provides an overview of existing and missing knowledge and facilitates problem solutions through finding appropriate knowledge/experts.

- Although the KM model is found to be comprehensive, it is found that it is not easy to follow without reading the instruction carefully. This provides a demand for further development and modification of the proposed KM model by dividing the model into a number of parts to make it easier to understand and follow so that the proposed KM model can be used in practice more efficiently and effectively.
- The proposed KM model should be improved to satisfy the needs of the industry, because it sometimes requires considerable changes to be implemented including those changes of culture, strategy, processes and technology in the organizations.

Evaluation of the proposed KM system has been carried out with balanced scorecard method to evaluate and assess the business processes, and the verification and validation test to obtain the feedback from users regarding the operation of the system. The results of questionnaires provide feedback from selected users about the system capability, ease of use, comprehensiveness, reliability, and applicability etc. by using five levels of rating scale, where 1 means strongly disagree and 5 means strongly agree. The participant users include 4 senior engineers with 15 years of experience, 2 senior engineers with 10 years of experience, 2 project managers with 5 years of experience, 2 junior engineers, and 2 knowledge workers. The weighted average score is 4.54, which indicates that the users favourably agree that the proposed KM method is feasible and applicable. The evaluation has also been carried out on the impact of KM system on business performance in terms of its effectiveness and efficiency. Measures of effectiveness relate to the degree or the probability that target performance measures are achieved, whilst measures of efficiency reflect the ratio of expected benefit or utility per unit of investment.

CONCLUSIONS

Knowledge of construction management has received considerable attention in the construction industry. This paper presents the development of a new KM model and its application to a case study. The new model simplifies the process of implementation, the use and enhance of KM system in the construction. This model overcomes and solves the problems that exist in other construction KM models, and emphasizes the important roles of the KM team and users. The advantages of the new model can be summarized as follows:

- Tacit and explicit knowledge which are formulated in its knowledge base.
- A clear process of data collection and transformation.
- A clear factor monitoring mechanism.
- A combination of the activities required in design, implementation and use of KM system with feedback system to enhance the KM system.
- The ability of implementation parallel activities.
- The new model provides a good level of details that make implementing and using KM systems easier.
- Emphasis of roles and activities of the KM team and knowledge workers in the process of KM.
- More suitable KM system architecture and its components.
- A clear relation between the different parts and the knowledge flow.

Although the adoption and application of KM models facilitate and encourage KM initiatives, they cannot guarantee that people of the organization are willing to share

their knowledge with other users or to participate in using knowledge and/or creating new knowledge. This requires the organization to modify the processes and activities of the employees to embed the KM activities and to adopt a performance appraisal method that appreciate tasks such as knowledge sharing, reusing and updating. The most elaborate KM system for construction projects may be quite complex due to changes in knowledge over time. A comprehensive knowledge map must be developed for subsequent studies. Some recommendations based on this study provide a platform for further development and modification of the KM model so that the proposed KM model can be used in practice more efficiently and effectively.

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