MANAGING EXPERIENCE AND KNOWLEDGE IN HIGH-TECH BUILDING PROJECT USING KNOWLEDGE MAP APPROACH

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ABSTRACT

Knowledge management involves creating, securing, capturing, coordinating, combining, retrieving and distributing knowledge. The knowledge can be reused and shared among the involved engineers and experts to improve the construction process and reduce the time and cost of solving problems. This paper proposes a new and practical methodology to capture and represent construction project knowledge by using network knowledge maps approach. Using Network Knowledge Maps (NKM), users can get an overview of available and missing knowledge in core project areas and take appropriate management in tacit and explicit knowledge. This study addresses application of knowledge management in the construction phase of construction projects and proposes a construction Map-based Knowledge Management (MBKM) concept and system for subcontractors. The MBKM system is then applied in selected cases study of a High-Tech factory building enterprise in Taiwan to verify our proposed methodology and demonstrate the effectiveness of sharing knowledge special in the construction phase. By effectively using information and web technologies during the construction phase of a project, knowledge can be captured and managed to benefit future projects. The combined results demonstrate that, an MBKM-like system can be an effective tool for construction knowledge managements in construction industries by utilizing the map-based knowledge management approach and web technology.

KEY WORDS

Knowledge Management; Knowledge Map; Web-based Application; Construction Projects

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INTRODUCTION

Knowledge management (KM) is the organization, creation, sharing and flow of knowledge within organizations. Knowledge management can be in the form of idea management systems that allow employee ideas and suggestions to be captured and shared online. The reuse of information and knowledge minimizes the need to refer explicitly to past projects; reduces the time and cost of solving problems, and improves the quality of solutions during the construction phase of a construction project. If experience and knowledge are shared, then the same problems in construction projects do not need to be repeatedly solved. Reduced problem-solving has the following advantages. (1) The cost of problem solving is reduced and (2) the probability of repeat problems is decreased. Several enabling activities should be considered to help to achieve the ultimate goal of efficient experience and knowledge reuse; experience and knowledge should be preserved and managed; that is, they should be captured, modeled, stored, retrieved, adapted, evaluated and maintained (Bergmann, 2002).

In AEC industry, enterprises have been good at collecting and storing explicit information in enterprise databases, but they are not always successful at tacit knowledge retrieval and sharing (Woo et al., 2004). A case study from the oil and gas sector is used to explore the KM activities of eight leading organizations and investigate the opportunities for construction organizations (Carrillo, 2004). A three-stage approach underpinned by an industry survey and case study findings is presented for developing a business case for KM and evaluation shows that the framework could significantly facilitate the implementation of a KM strategy in construction organizations (Robinson et al., 2004). Although those literatures have attentions and focus on the application of knowledge management in construction, the problem that is not available in those literatures is where the acquired knowledge is placed better to find easily for users and how the related knowledge is illustrated relationships. With the characteristic of construction project and map, the paper proposes the new concept Network Knowledge Maps (NKM) specific for construction projects uses. Users can get an overview of available and missing knowledge in core project areas and take appropriate management in tacit and explicit knowledge using network knowledge maps. Also, the construction Map-based Knowledge Management (MBKM) system is developed for contractors in the construction phase according to network knowledge maps concepts and approved in Taiwan case studies.

PROBLEM STATEMENT

Professional competency in project management is attained by combining knowledge acquired during training and skills developed through experience as well as the application of the acquired knowledge (Edum-Fotwe and McCaffer, 2000). Whatever successful and unsuccessful projects have been executed, a valuable record of each one should be kept to identify best and worst company practices. During the construction phase of projects, one of effective means in improving construction management is to share experiences among engineers, which helps to prevent mistakes that have already been encountered in past

projects. Problems that have already been solved do not need to be solved again. Furthermore, engineers and experts normally take domain knowledge with them and leave little or nothing that will benefit subsequent projects or the company when they complete projects or leave the company. From the perspective of knowledge management, this know-how and these experiences of construction engineers and experts are the most valuable because their accumulation depends not only on manpower but also on the spending of much money and time.

When knowledge management is considered and applied in construction industries, the general commerce packages currently focus on the document management and knowledge classification and some construction companies had applied the commerce package for knowledge management. However, those systems just can handle the explicit knowledge. The tacit knowledge and experience are still existed in the head of engineers and experts, if the commerce packages have been used in the construction companies. Also, the problem in the knowledge storage method is where the acquired knowledge is placed to find easily for users and how the knowledge is illustrated relationships. Therefore, the proposed approach and system are designed to solve the above problems in construction.

In the cast study, the subcontractor has special experience over ten years in building high-tech factor projects. However, high-tech building projects is to own greater risk than other construction projects because of the characteristic of high-tech building projects. The problem and challenge to the enterprise is how to reuse past knowledge and experiences to reduce the project duration and cost spends in current and further similar problems. The enterprise decides to apply the knowledge management integrated with knowledge map to solve the problem and improve the performance.

RESEARCH OBJECTIVES

Knowledge management in the construction phase mainly deals with the process of creating value from construction operation, organization to company knowledge. How to apply and reuse the past finished projects for future similar projects is the main issue of knowledge management in the construction phase of projects. According to a survey conducted for this research study, most engineers and experts agree that KM is necessary and expect that KM may benefit many advantages in the enterprise asset management. However, there are still existing problems in knowledge management although the construction enterprises use commerce knowledge management tools and software. One of the problems is those users don't fell so easy to find where the project-related knowledge locates and understand which collected knowledge is available. This situation represents a major problem for enterprises that most users didn't know what and which past project-related knowledge is stored in the enterprise. In order to solve the above problem, the paper proposed original approach – Network Knowledge Map for the engineers and experts to easily find the past project-related knowledge and experience.

The proposed knowledge map approach is new concept and approach to improve the performance of knowledge management in construction projects. Furthermore, the idea of knowledge map mainly comes from the practice of construction management in schedule. Most engineers used to utilize the network schedule applied in construction management. In the paper, a Map-based Knowledge Management (MBKM) system is developed specifically in the construction knowledge management according to the idea and prototype of network knowledge map. Integrated with network knowledge map, the MBKM system provide efficiently knowledge exchange and management service in construction projects for the reuse of domain knowledge and experience in future and other related projects. To be competitive, an enterprise may make innovative use of knowledge created and accumulate through past finished projects, and share and apply similar knowledge across the rest of other relative projects. Engineers and experts participating in projects act as knowledge workers facilitating the collection and management of knowledge between current and past projects. In order to improve the knowledge usage, knowledge map assist the user as a tool to quickly note key concept, identify important processes and tools, and gain insights into associated behaviors.

KNOWLEDGE MANAGEMENT IN CONSTRUCTION PROJECTS

Construction knowledge management is a discipline that promotes an integrated approach to the creation, capture, access, and use of a profession's domain knowledge on products, services and processes. Experience, problem-solving, know-how, know-what, and innovation are created in the construction phase of any project. By practicing knowledge management, tacit knowledge can be reused for other projects and speed the improvement of operations in the construction phase. According to Lin and Tserng (2003), there are five phases in the construction knowledge management life cycle. They are knowledge acquisition, knowledge extraction, knowledge storage, knowledge sharing, and knowledge update. Each phase is briefly outlined in the following descriptions. In the knowledge acquisition phase, most information and knowledge is acquired on the job site in the construction phase. Most work of knowledge acquisition is done in the office because all information and tacit knowledge sent back from the job site can be transferred to explicit knowledge. In the knowledge extraction phase, knowledge extraction is defined as a process by which the expert's thoughts and experience are captured. Some knowledge that must be extracted for reuse and storage may be only available from the memories of experts and engineers. In a broader view, knowledge extraction may also include capturing knowledge from other sources such as problem-solution descriptions, construction operation process digital record, virtual communication and collaboration. Furthermore, knowledge workers will assist with experts and engineers and deal with the digital process recording work if they are important or valuable to be kept as the company asset. In the knowledge storage phase, all information and knowledge are centralized and stored in the central database to prevent the collection of redundant. All information and knowledge can be stored in the system by ensuring that data are all electronic and in standard format for each type of file, such as a specific document format, or a drawing format. Knowledge sharing is the ultimate goal of

knowledge management. After the development of knowledge management, people who need to apply knowledge on a particular project can access relevant knowledge for reuse. In the knowledge update phase, available knowledge and experience should be continually updated. Reused experience can be evaluated in the context of a new problem to be solved. It can be evaluated in terms of the appropriateness of the selected experience, or in terms of the accuracy of the retrieved experience. Such evaluation is important to ensure the continued improvement of the process by which experience is reused. Invalid knowledge must be identified and be removed or updated.

METHODOLOGY – NETWORK KNOWLEDGE MAP

A knowledge map can be defined as a diagrammatic and graphic presentation of knowledge linking the relationships between knowledge and knowledge attribute. The knowledge map mainly deals with the assistance to find the needed knowledge easily and effectively. A knowledge map includes the sources, flows, constraints, and sinks (losses or stopping points) of knowledge within an organization (Liebowitz, 2005). Dynamic knowledge map can assist in the reuse of experts' tacit knowledge (Woo, 2004). In order to enhance knowledge management in construction, a research methodology has been proposed and applied in the case study. The proposed methodology called network knowledge map is specific approach for construction knowledge management and methodology. Although knowledge man is not new in the knowledge management, the proposed network knowledge maps is new concept and approach specific for construction project management. The components and procedures of knowledge map is designed based on the construction project management in practice and is different from others existing knowledge maps. The components and procedures of knowledge map are described in the following.

The components of network knowledge map

The network knowledge map proposed in the paper, network knowledge map consists of three components (see Figure 1):

1. Knowledge diagram: Graphical representation of knowledge, having node, sub-node and linkage:
   - Node: Rectangular object (denoting project or map-unit representation);
   - Sub-node: Ellipse object (denoting captured knowledge);
   - Linkage: Arrow between nodes implying relationships among knowledge; and
2. Knowledge attribute: Descriptive representation of knowledge feature
3. Knowledge packages: Additional files to illustrate Knowledge preparation.

The procedures of network knowledge maps usage

Procedures are proposed for building the network knowledge maps according to the knowledge management framework. The procedure consists of the following five phases: knowledge determination phase, knowledge extraction phase, knowledge attribute phase,

knowledge linking phase, and knowledge validation phase.

Knowledge Determination Phase

The scope of the knowledge map decides whether the knowledge map is constructed throughout a specific project. After deciding the scope, we determine the detail level of knowledge analysis. It is necessary and important to determine the proper level of detail to meet project-based knowledge demand effectively. When analyzing the source of knowledge within a project, map-unit is suggested as a unit to analyze the construction project knowledge. We analyze related knowledge based on a map-unit of the construction project. In other words, we consider which experience and know-how should and can be captured according the map-unit of the selected project. After the analysis process of this phase, the types of tacit and explicit knowledge specific to the map-unit will be considered. Furthermore, all capturing and documenting knowledge regards to the map-unit are saved in this map category.

Knowledge Extraction Phase

Knowledge is extracted through the project execution. There are two types of knowledge extracted from the projects. They are tacit knowledge and explicit knowledge. Tacit knowledge and explicit knowledge may exist in any project. After identifying knowledge through those activities of the project, we decide which knowledge needs to be extracted from the activities of the projects. Following suggested knowledge extraction techniques include interviewing with experts, group meeting discussion, and digital process record.

Knowledge Attribute Phase

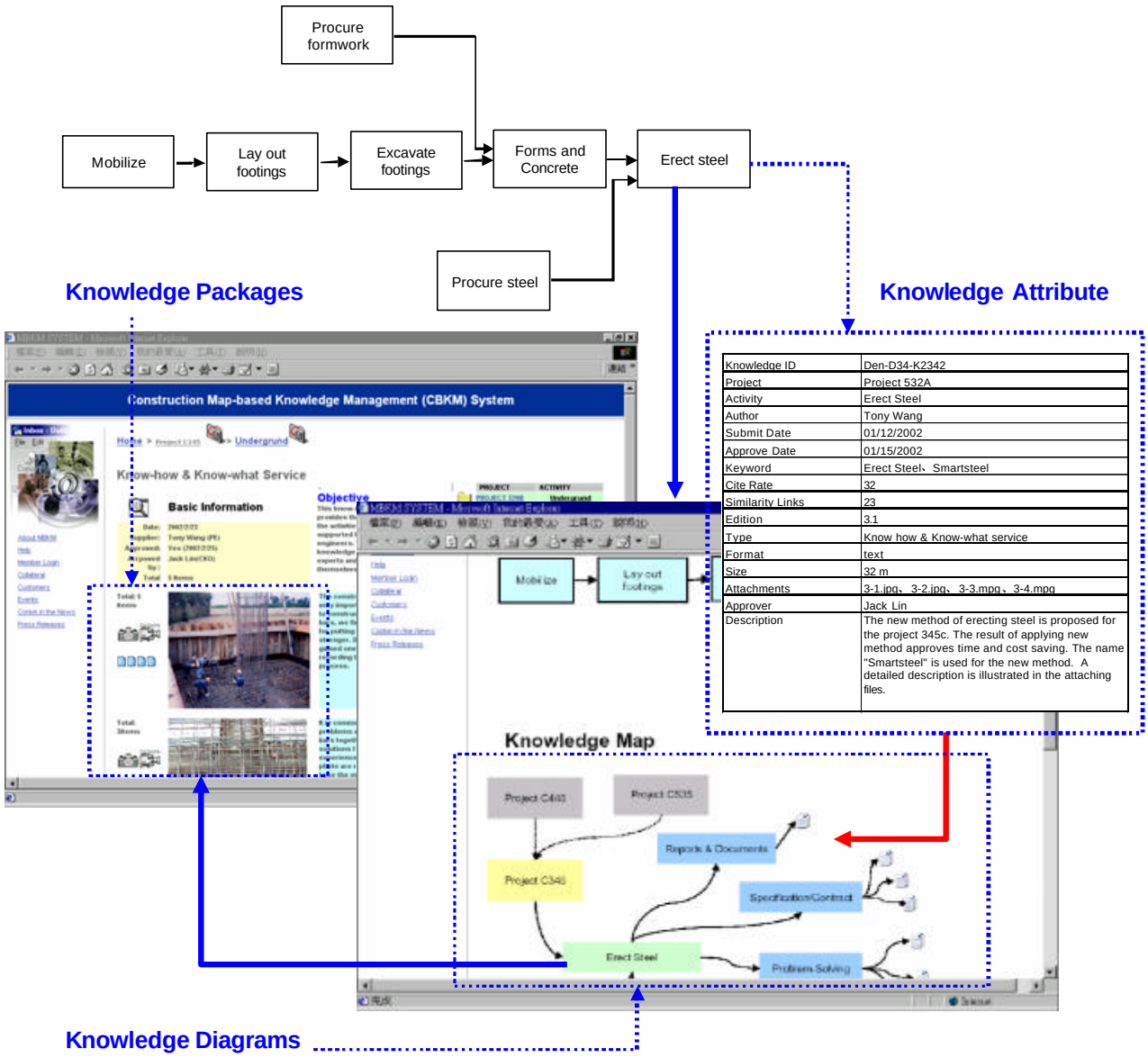
A knowledge attributes illustrate the basic description of extracted knowledge and derive relationships with project and similarity map-unit. The main purpose of knowledge attribute is provides the knowledge relationship and available knowledge information for knowledge workers and general users. Knowledge attributes include the keywords, description, project name, map-unit name, contributor, and attached files.

Knowledge Linking Phase

The knowledge link is identified after completing the knowledge attribute. The knowledge link is first indicated when the tacit or explicit knowledge is available and documenting, and is later confirmed. Three types of knowledge linking are proposed in the paper. One is map-unit link map-unit based on high similarity. Second is map-unit link knowledge based on relationship between map-unit and knowledge. The third is knowledge link knowledge based on knowledge high similarity. When the contributor creates a new link, the link needs to be examined and confirmed before knowledge map is published.

Knowledge Validation Phase

All knowledge map need to be validated before the map is published. All the validation process must be communicated with domain experts, knowledge worker, and knowledge map producer in the enterprise knowledge management division.



Knowledge ID	Den-D34-K2342
Project	Project 532A
Activity	Erect Steel
Author	Tony Wang
Submit Date	01/12/2002
Approve Date	01/15/2002
Keyword	Erect Steel、Smartsteel
Cite Rate	32
Similarity Links	23
Edition	3.1
Type	Know how & Know-what service
Format	text
Size	32 m
Attachments	3-1.jpg、3-2.jpg、3-3.mpg、3-4.mpg
Approver	Jack Lin
Description	The new method of erecting steel is proposed for the project 345c. The result of applying new method approves time and cost saving. The name "Smartsteel" is used for the new method. A detailed description is illustrated in the attaching files.

Figure 1: Knowledge Sharing and Reuse Using Network Knowledge Map

One of the main contributions is to propose a new and original approach – Network-based knowledge maps approach to improve the performance of knowledge sharing and reuse. Figure 2 presents an overview and conceptual framework of Network-based knowledge maps used in construction knowledge management. Knowledge and information associated with activities in previous projects may be reused and applied in future projects. Information and domain knowledge from all projects are divided and saved as map units in categories related to the projects for collection and management.

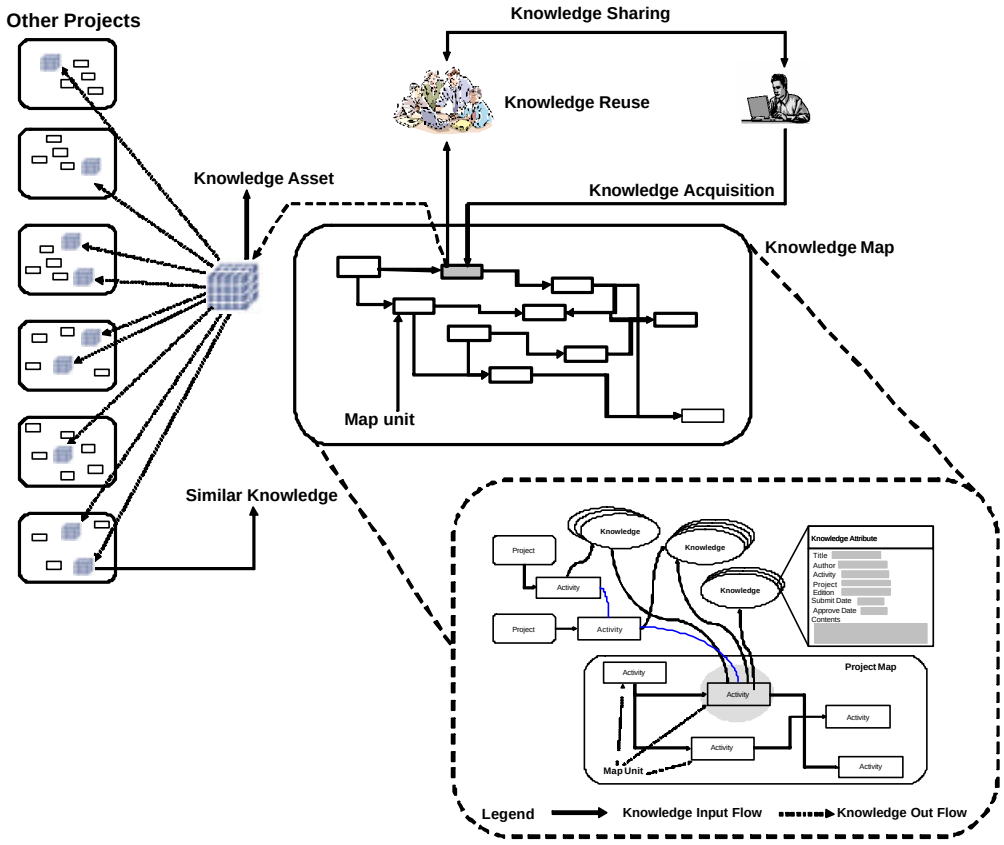


Figure 2: The application of network knowledge map with knowledge management.

When knowledge is saved in map units of project map, the knowledge includes both tacit and explicit knowledge. In terms of explicit knowledge, project-related information or knowledge usually include specification/contract, reports, drawing, change order and data. Actually, each project does not contain one-to-one information or knowledge because some of them belong to Map-based information. In contrast, tacit knowledge may include process records, problems-faced, problems-solved, expert suggestions, know-how, innovation, and experience notes. The information and knowledge is better saved as map units because the result makes it easier to be classified and searched by users. In addition, users may search and refer to related information and knowledge from related map units in past projects. The tacit and explicit knowledge of map-based knowledge management is the same as the duration and relationship of map-unit-based project management.

THE SYSTEM

This section describes in detail the MBKM system. The server of the MBKM system supports four distinct layers - interface, access, application and database layers; each has its own responsibilities. The interface layer defines administrative and end-user interfaces. The

Users can access information through web browsers such as Microsoft Internet Explorer or Netscape Navigator. Administrators can control and manage information via the web browser or using a separate server interface. The access layer provides system security and restricted access, firewall services and system administration functions. The application layer defines various applications for collecting and managing information. These applications offer indexing, full text search, collaborative work and document management functions. The database layer consists of a primary SQL Server 2003 database and a backup database (also based on SQL Server 2003).

CASE STUDY

In the following case study, the contractor with seven years of experience involving six High-Tech factory building projects decided to apply knowledge management to raise the enterprise competition. The contractor hoped to maintain knowledge and experience effectively from the senior engineers and experts specific in the construction phase, and so decided to hire two High-Tech construction knowledge workers, to help the senior engineers manage project execution knowledge and experience gained from ten previous finished projects. To reuse knowledge in future similar projects, the company decided to exploit knowledge management to pass on the valuable know-how to the engineers and manage it well to keep the knowledge inside the company. The contractor applied and practiced knowledge management using a network knowledge map. Figure 3 illustrates the system utilized in this case study.

Knowledge Acquisition Phase (Steps 1-5)

A knowledge worker collects and digitizes information/documentation from the current project and six finished projects. The senior engineer then edits the descriptions and notes and packages them as knowledge for submission.

Knowledge Extraction Phase (Steps 6-10)

A junior engineer and another knowledge worker record all the operating procedures by taking digital video and photographs in the executed project. The senior engineer discusses progress with the expert every two days to accelerate problem solving. All discussions were recorded and summarized as recommended by the senior engineer. Discussions with experts continue for six months, until the problem is solved. The domain knowledge includes the problem description (including documents, photographs, drawings and specifications), the solution (including related documents and photographs and video of processes) and expert suggestions (such as notes, discussions and meeting records). Finally, items of domain knowledge and experience are linked to map units.

Knowledge Storage Phase (Steps 11-15)

When the submitted knowledge set is approved, a knowledge worker in the knowledge management team attributes knowledge and places it in an appropriate position (according to project map unit) in the system. In other words, users can find and read related domain

knowledge directly by simply clicking on project map units. All knowledge maps have to be validated to perform well before the map is published. After approving and storing knowledge, the system transmits a message to the appropriate users automatically stating that the knowledge has been updated.

Knowledge Sharing Phase (Steps 16-20)

A new project is started after High-Tech building project was constructed ten month previously. Another junior engineer with no prior experience encounters a similar problem special in Fire alarm system and attempts to solve it by finding past knowledge/information. The junior engineer utilizes the knowledge map search to find an expert with domain knowledge concerning High-Tech building project and which knowledge are available according to the knowledge map in seven finished projects. The junior engineer identifies the relevant experts, and then retrieves and studies the knowledge packages (including digital video and documentation) from the knowledge maps. He begins to reuse knowledge from the previous seven finished projects, and applies the knowledge to his own new project.

Knowledge Update Phase (Steps 21-25)

The junior engineer solves his problem in collaboration with senior engineers using knowledge obtained from previous similar projects. Finally, the junior engineer notes and submits the new suggestion and experience in the project map units, linked with the original knowledge. Furthermore, the knowledge is updated with the additional feedback and solution. The updated knowledge set is then republished in the map units of the project after the approval process is completed, and the notice message is transmitted to the authorized members.

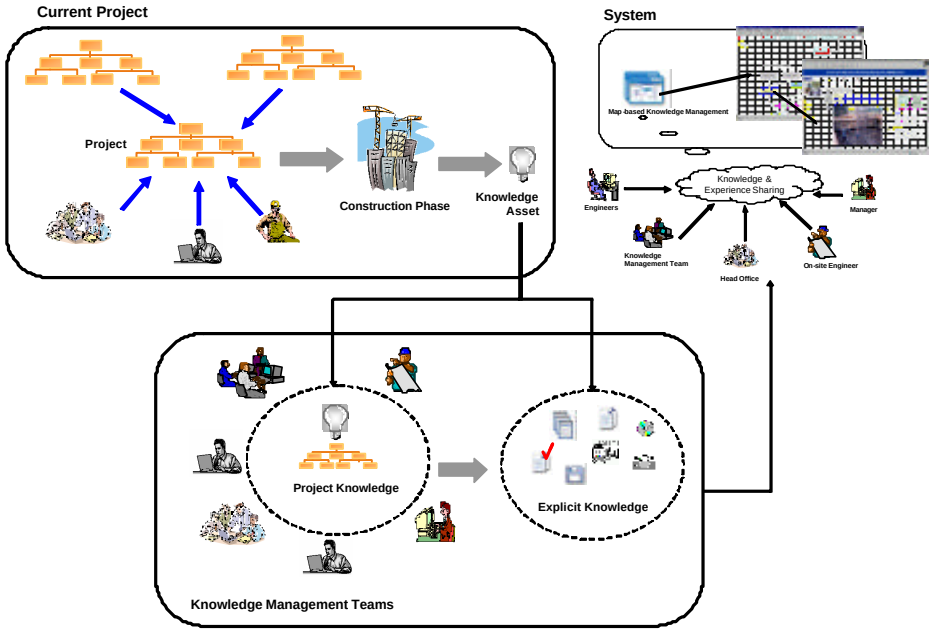


Figure 3: System architecture.

CONCLUSIONS

This study presents the application of knowledge management in the construction phase of construction projects using network knowledge map. The concept of map-based knowledge management (MBKM) is presented, and a system for use as a knowledge-sharing platform in construction projects is presented. The MBKM system provides insight into the factors that have an impact on construction management, and so helps engineers to share knowledge and improve the results of the entire construction project. The demonstration of the system in a case study of the new High-Tech factory building located in Taiwan indicates that the MBKM system effectively promotes the sharing of knowledge acquired from past projects and reuse for other similar projects effectively. However, the received feedbacks based on the use of the system are as follows; (1) the content of knowledge database needs big effort to acquire and manage past experience and knowledge in the knowledge management team; (2) it takes time and is very inconvenient for senior engineers to edit and record the knowledge without any assistance form knowledge workers, and (3) most senior engineers agree the MBKM system is a useful platform for them to edit and manage their knowledge and experience.

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