KNOWLEDGE MANAGEMENT AND ITS APPLICATION TO LEAN CONSTRUCTION

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ABSTRACT

Knowledge Management (KM) has become one of the most significant terms in the IT industry. Knowledge management deals with creating, securing, capturing, coordinating, combining, retrieving, and distributing knowledge. Knowledge sharing between different projects is viewed as an essential source to gain the competitive advantage in the future. Lean construction comes from acknowledging the limitations of current project management and applying "lean production' to the construction industry. This paper presents an example of implementing of construction knowledge management to construction projects, exploring the relationship between knowledge management and lean construction. It shows that project control could encompass the cost and time consuming by adopting knowledge management concepts and tools in lean construction. The application of knowledge management to implement the lean construction in the construction phase is discussed in this paper through the presentation of a construction project-based knowledge management concept and system for general contractors. The results of real case approve that knowledge management is a useful tool for the application of lean construction in project life cycle by utilizing the latest web technology for knowledge management systems.

KEY WORDS

Lean Construction, Knowledge Management, Project Management.[1]

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LEAN PRODUCTION

Lean has been described as "doing more with less". Lean Production strives towards zero inventory and just-in-time logistics (Womack et al. 1990). The origins of Lean Production can be traced to the Toyota Production System (Alarcon 1997), with its focus on the reduction and elimination of waste (Ohno 1988). Fundamental principles of Lean Production include (e.g. Koskela 1992):

- Identify and deliver value to the customer by eliminating activities that do not add value.
- Organize production as a continuous flow.
- Perfecting the product and create reliable flow through stopping the line, pulling inventory, and distributing information and decision making.
- Pursue perfection by delivering an order of a product which meets customer requirements with nothing in inventory.

Lean demand high levels of product quality. It also require minimum total lead-times defined as the time taken from a customer raising a request for a product or service until it is delivered. Total lead-time has to be minimized to enable agility, as demand is highly volatile and thus difficult to forecast. If a supply chain has long end-to-end lead-time then it will not be able to respond quickly enough to exploit marketplace demand. Furthermore effective engineering of cycle time deduction always leads to significant bottom line improvements in manufacturing costs and productivity (Howell 1999).

LEAN CONSTRUCTION

Lean construction is a new way to manage work over the life of a project. It is not a productivity improvement program. Lean construction is a production management-based approach to project delivery; it is a new way to design and build capital facilities. The application of lean production management to manufacturing caused a revolution. Applied to project settings, particularly to construction projects, the concept of "lean" can have a similar impact. "Introduction to Lean Construction" links the objectives of the production system – maximize value and minimize waste – to specific techniques, and applies those techniques to form a project-based production system. Lean Construction is particularly useful on complex, uncertain, and quick projects.

It challenges the belief that there must always be a tradeoff between time, cost, and quality. When projects are managed with Lean Construction (see Figure1):

- The facility and its delivery process are designed together to better reveal and support customer purposes. Positive iteration within the process is supported and the negative iteration reduced.
- Work is structured throughout the process to maximize value and to reduce waste at the project delivery level.

- Efforts to manage and improve performance are aimed at improving total project performance because improvement is more important than reducing the cost or increasing the speed of any activity.
- "Control" is redefined from "monitoring results" to "making things happen." Performance of planning and control systems is measured and improved.
- Coordination is improved because the release of work from one specialist in design, supply, and assembly to the next is more reliable.

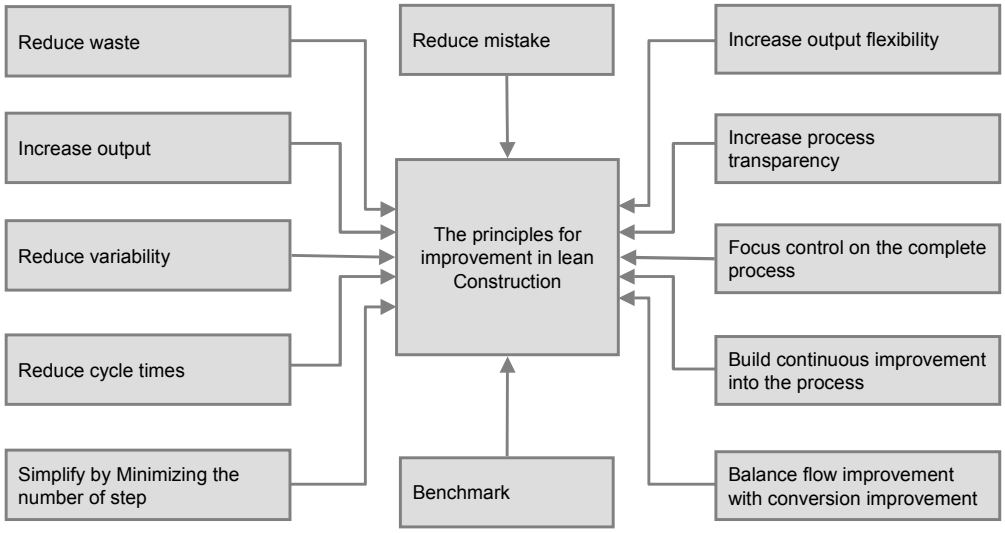

Figure 1: The principles for improvement in lean production (adapted from Alarcon 1997)

GOAL AND STRUCTURE

The goal of this paper is to present a concept and system of applying knowledge management in lean construction and describe an example of applying knowledge management in the construction phase, exploring the relationship between knowledge management and lean construction. It includes a review and evaluation of prior applications of knowledge management in lean construction. Then it approves the improvement in lean construction with knowledge management applying in the construction phase, illustrated with web-based knowledge management system and concluded with the relationship between knowledge management and lean construction.

APPLICATION OF KNOWLEDGE MANAGEMENT IN CONSTRUCTION

Knowledge is the true asset of a marketing-oriented organization, and its integration across departments and disciplines should be emphasized (Carneiro 2001). Many organizations are now engaged in Knowledge Management (KM) efforts in order to leverage knowledge both within their organization and externally to their shareholders and customers (Malhotra 2000, 2001).

These assets, the knowledge, can be classified as either tacit or explicit. Explicit knowledge is that which has been codified and expressed in formal language; it can be

represented, stored, shared and effectively applied (Nonaka and Takeuchi 1995). Tacit knowledge is knowledge that is difficult to express, represent, and communicate (Nonaka and Takeuchi 1995). The distinction of these two types of knowledge is relevant because each must be managed differently. Knowledge management in the construction phase mainly deals with the process of creating value from construction operation and organization to company knowledge. Valuable knowledge is available in different forms and media, the brilliant ideas of experts, in operation procedures, and in documents, databases, intranets, etc.; however, knowledge management in the construction phase of projects aims at effectively and systematically collecting and sharing the experience and knowledge of the project using web-based and intranet technologies.

The reuse of information and knowledge minimizes the learning processes from past projects, reduces the time and cost of problem-solving, improves the solution quality during the construction phase of a construction project. By sharing experience and knowledge, the same problems in the construction phase do not need to be solved over and over again. Reduced problem-solving leads to the following benefits: (1) the cost of problem solving is reduced; and (2) the probability of repeat problems is decreased. To enable the ultimate goal of efficient experience and knowledge reuse, several enabling activities should be considered; the experience and knowledge should be preserved and managed, i.e., they could be captured, modeled, stored, retrieved, adapted, evaluated, and maintained (Bergmann 2002).

The latest communications and information technologies are available to be used to improve collaboration, coordination, and information exchange among organizations and projects that work on construction projects (Soilbelman and Kim 2002). They can be described as a set of information exchange platforms that collect, retrieve, process, store, and distribute data to support planning, control, management, and decision-making among project organizations (Dzeng and Tommelein 1997). Knowledge reuse and update improves the performance of future activities and projects. Most of the data and information for construction projects are stored in paper-based documents; these consist of contracts, specifications, notes, discussions, and field reports. In order to facilitate information management and enable knowledge reuse, it is important to convert paper documents into electronic versions to be shared and applied in other and future projects. Information and knowledge of a project can then be identified as project components during project management and preserved in a web-based system that provides the platform for the exchange and storage of information and knowledge.

The relationship between knowledge management in construction and lean construction is shown in figure 2. From the view of construction project life cycle, tacit knowledge and explicit knowledge can be created based on knowledge and experience generated from the project. Especially true of explicit knowledge, it can be reused for other current and future projects to avoid repeating the same or similar mistakes. Also, reducing cycle time, reducing waste, and increasing output in the project are the main advantages with the application of knowledge management in lean construction. Also, the practice in the lean construction should apply the knowledge management in the whole construction life cycle because knowledge management can help engineers reduce waste, reduce cycle times, increase output, and make innovation based the past experience and know-how. With the application of knowledge management, the storage and management of project-oriented tacit and explicit

knowledge can reuse for others or future projects. Therefore, the advantage of knowledge management may meet the objective of lean construction. Furthermore, knowledge management is one of important and necessary tool for lean construction.

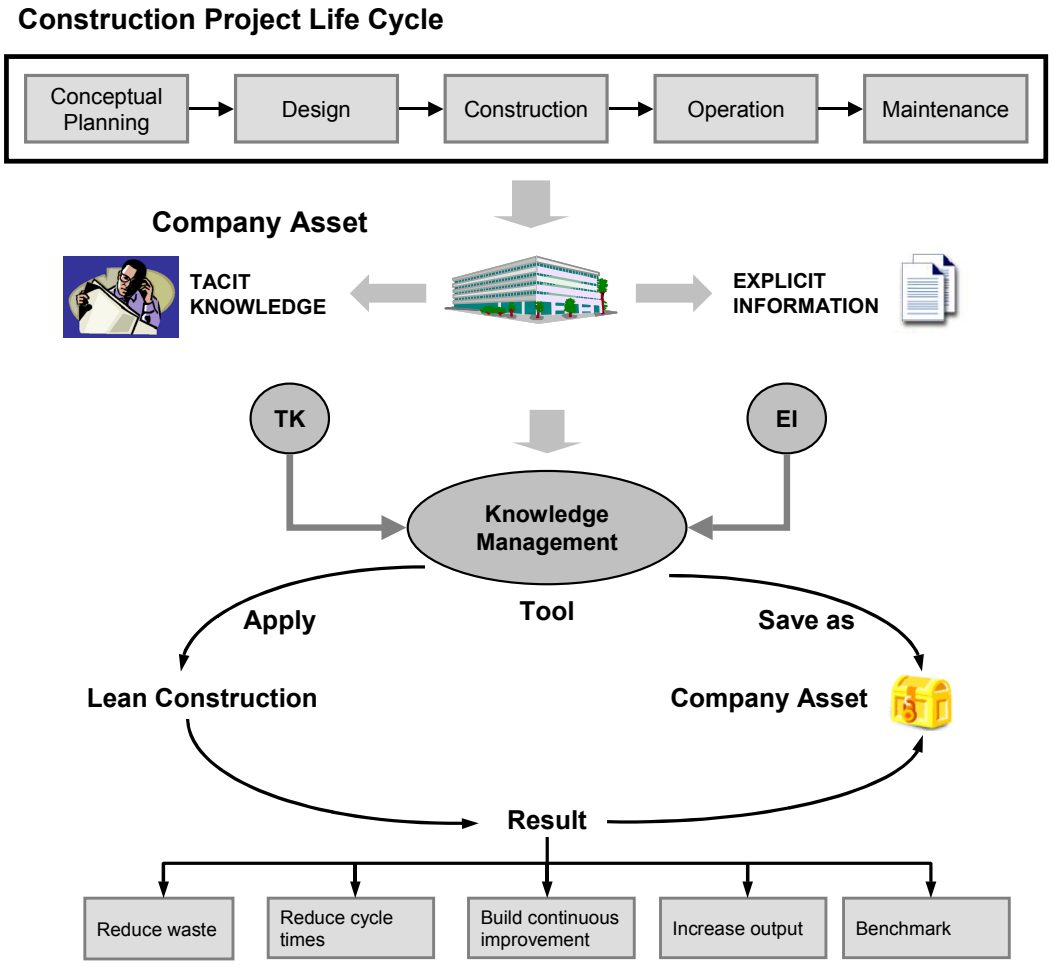

Figure 2: The relationship between Knowledge Management and Lean Construction.

KNOWLEDGE MANAGEMENT IN THE CONSTRUCTION PHASE

Construction projects are intricate, time-consuming undertakings. Usually, construction projects are typified by their complexity, diversity, and by the non-standardized nature of their production (Clough 2000). Professional competency in project management is attained by the combination of knowledge acquired during training, and skills developed through experience and the application of the acquired knowledge (Edum-Fotwe and McCaffer 2000). During the construction phase of projects, one of the improvements for construction management is to share experiences amongst engineers, which helps prevent mistakes that past projects have encountered already. Reusing experience also avoids problem-solving from scratch, i.e., already solved problems do not need to be solved over and over again. However, there are no suitable platforms to assist senior engineers or experts with sharing and collecting their know-how and experiences when general contractors execute the project.

This is a major loss for general contractors who do not preserve the know-how and experiences of senior engineers and experts. When these engineers and experts finish the projects or leave the company, they usually take the domain knowledge with them and leave little or nothing for the projects or the company. In the view of knowledge management, these know-how and experiences of construction engineers and experts are the most valuable because they not only need man power; they also require major cost and time to be accumulated. In construction projects, 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. During the construction phase of a project, most project-related problems, solution, experience, and know-how are in the heads of individual engineers and experts. Implicit knowledge usually is not documented or stored in a system database. To reuse the knowledge in other projects and also preserve it as corporation property, to capture the implicit knowledge and make it become available as explicit knowledge is important in the execution of knowledge management in the construction phase. Experience, problem solving, know-how, know-what, and innovation are created in the construction phase of all projects. By practicing knowledge management, tacit knowledge can be reused for other projects and speed the improvement of operations in the construction phase.

CONSTRUCTION KNOWLEDGE MANAGEMENT LIFE CYCLE

There are five phases in the construction knowledge management life cycle as shown in Figure 3. These include knowledge acquisition, knowledge extraction, knowledge storage, knowledge sharing, and knowledge update. Table 1 is the description for each phase in the construction knowledge management life cycle. Table1 summarizes the survey from the officials of Taiwan Area National Expressway Engineering Bureau.

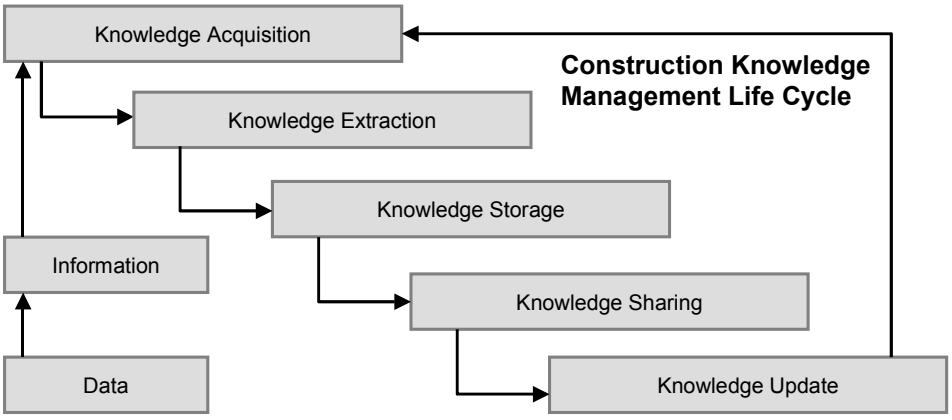

Figure 3: Five phases of construction knowledge management life cycle.

PROJECT-ORIENTED KNOWLEDGE MANAGEMENT

Similar to what is found in project management, knowledge management is based on the concept of activity in project planning and control. In order to explain the application of knowledge management used in construction projects, Figure 4 shows the overview and

conceptual framework of project-oriented knowledge management used in construction projects. The knowledge and information of activities in past projects may be reused and applied in other and future projects. To collect and manage the domain knowledge of all projects, the information and knowledge are divided and saved as "activity" units under the projects' categories. The main benefit of project-oriented knowledge management is ease-of-understanding and reuse of the information and knowledge.

Table 1: The descriptions of construction knowledge management life cycle.

KM Phase	Key Activites
KM Acquisition	The knowledge to be shared must be acquired. In view of the construction phase, most information and knowledge mainly come from the job site. Therefore, knowledge collection on a job site plays an important role in the first phase. In the main office, the content of knowledge collection is the same as those in the other industries. During knowledge acquisition, most work is done in the main office because all the information or tacit knowledge sent back from the job site can be transferred to explicit knowledge.
KM Extraction	Some knowledge that must be extracted for reuse and storage may be only in the heads of experts and engineers. It typically arises in the context of certain problem-solving situations. Mechanisms are required to collect such new experiences when they become available.
KM Storage	The collected knowledge could be stored for future reuse. During knowledge storage, all information and knowledge are centralized and stored in the knowledge bank (central database) to avoid redundant knowledge. In order to store all information and knowledge in the system, the data must be electronic and be in a standard format for each type of file such as a specific document format or vector drawing format.
KM Sharing	Knowledge sharing is the ultimate goal of knowledge management. After the development of knowledge management, only people who need related-knowledge concerning of the select projects can access and select appropriate knowledge for reuse. If necessary, they can adapt knowledge to a new project and solve the new problem by reusing the knowledge.
KM Update	Available knowledge and experience should be updated continuously. During problem solving, reused experience can be evaluated in the context of the new problem to be solved. The evaluation can be in terms of the appropriateness of the selected experience, or in terms of the accuracy and actuality of the retrieved experience. Such evaluation is important to continuously improve the process of experience reuse. Invalid knowledge must be identified and be removed or updated. Knowledge update can be triggered by a negative experience evaluation or can be performed precautionary.

When knowledge is saved in project units, the knowledge includes both tacit and explicit knowledge. In terms of explicit knowledge, activity-related information or knowledge usually include specification/contracts, reports, drawings, change orders, and data. Actually, each activity does not contain one-to-one information or knowledge because some are project-based type of 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 activity 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 activities in past projects. The tacit and explicit knowledge of activity-unit knowledge management is the same as the duration and relationship of activity-unit project management.

Figure 4 shows the overview of items and past related activities based on activity-unit knowledge management. The relationship of current and past activities is important for users to link related information and knowledge together. According to Figure 4, not only can the information and knowledge of the current project be applied, but also same or similar activities of past projects can be referred to as experiences are recorded. When experts or engineers enter related information and knowledge into the system, they need to add the relationships for the activities in the project. Of course, the system is designed to link the relationship between same or similar activities automatically or manually.

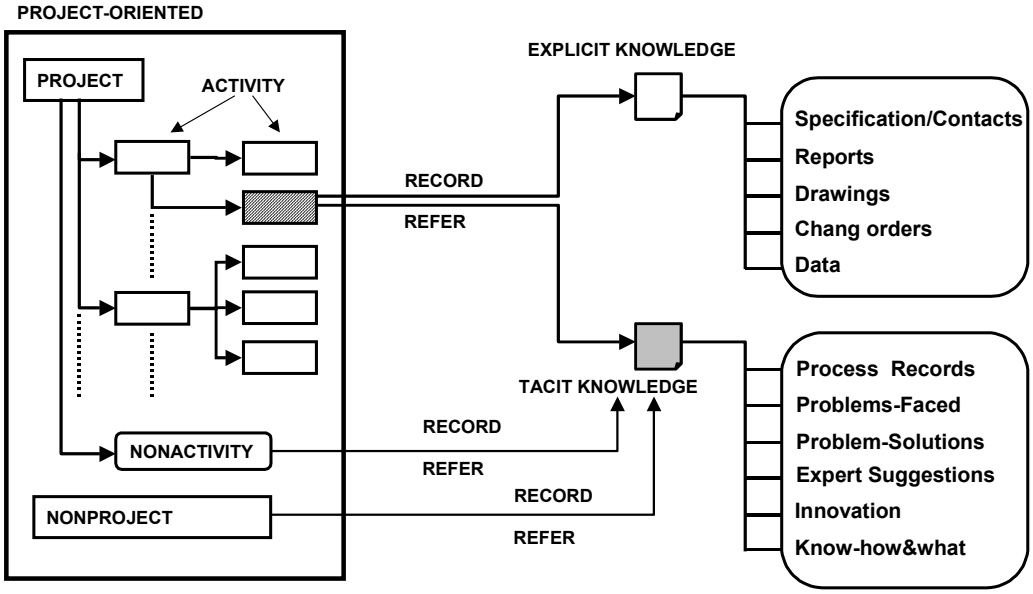

Figure 4: Project-Oriented Knowledge Management Concept framework.

Figure 4 shows the overview of information and knowledge which are not divided into activity units. The reason is that some of the information and knowledge belong to the whole project without clear classification of activity units. To let users access the information by the web-based portal, the basic electronic information concerning the project (i.e. specifications, contracts, reports, and drawings) may be saved as explicit knowledge. In terms of tacit knowledge, advanced electronic information and knowledge for the project (i.e. meeting records and e-courses) are saved in the system. The information and knowledge will be saved under the catalog of current projects. The benefit of non-active classification is the collection of related electronic information in the centralized system.

In order to enrich the knowledge bank for construction enterprises, explicit knowledge and tacit knowledge need to be transferred separately into the knowledge bank. The method of transfer includes two source types: the main office (or job office) and the construction site. On the construction sites, the main task for construction knowledge management is knowledge collection, which includes the recording of photos and videos of the construction process, making digital data collection, and noting the problem solution. The information is explicit knowledge hence does not require additional conversion. Also, the information must be collected in real-time on the construction site. The main tasks at the main office are knowledge acquisition and knowledge storage. The tasks at both the main office and

construction site must be completed to lead to the success of knowledge management in construction projects.

The main purpose of a knowledge bank is to provide a richer source of content concerning all the projects to gather project-related explicit information and tacit knowledge for involved engineers and experts. In order to enrich the knowledge bank in the system, the system is designed to encourage all engineers and experts to submit their domain knowledge and valuable experience to the knowledge bank. In general, companies include mostly numeric, structured data in their data warehouse. From this point of view, decision support systems are divided into two camps: data warehouses deal with structured data; knowledge management involves unstructured data (Ponniah 2002). It is necessary to integrate both structured (such as data and text) and unstructured information (such as image, video, audio, image, and drawing) in the knowledge bank for further decision-making and reference.

The main purpose of this paper presents a Construction Project-Oriented Knowledge Management (ConPOKM) system for general contractors as a knowledge-sharing platform. Construction Project-Oriented Knowledge Management maps the valued information and knowledge into project units for a project during the construction phase. The development of a prototype ConPOKM system employing the integration of web technology with a portal is delineated in a case study of the Taiwan Highway Project. The ConPOKM system is advanced at least in the following aspects: it enables gathering insights into the factors having impact on construction management activities, which in turn helps engineers share knowledge to access and improve operation performance. Junior engineers can interact with the computer so that they can understand the domain knowledge to prepare and participate in a construction project. In short, the ConPOKM system is able to assist engineers by providing accurate and rich information for knowledge reuse and reference. The integration of knowledge management and web-based technologies appear to be a promising way to improve construction operation management during the construction phase of a project.

CONCLUSION

The application of lean construction using knowledge management in the construction phase is discussed in this paper. Construction knowledge management is the collection of processes that govern the creation, dissemination, and utilization of tacit and explicit knowledge for construction projects. In order to make the lean Construction more effective, this paper describes the relationship between knowledge management and lean construction. Furthermore, the web-based knowledge management system, called Construction Project-Oriented Knowledge Management (CPOKM) system is presented to explain how the application of construction knowledge management can improve the efficiency in lean construction implementation. The result shows that construction projects control can encompass the cost and time saved by adopting knowledge management concepts and tools.

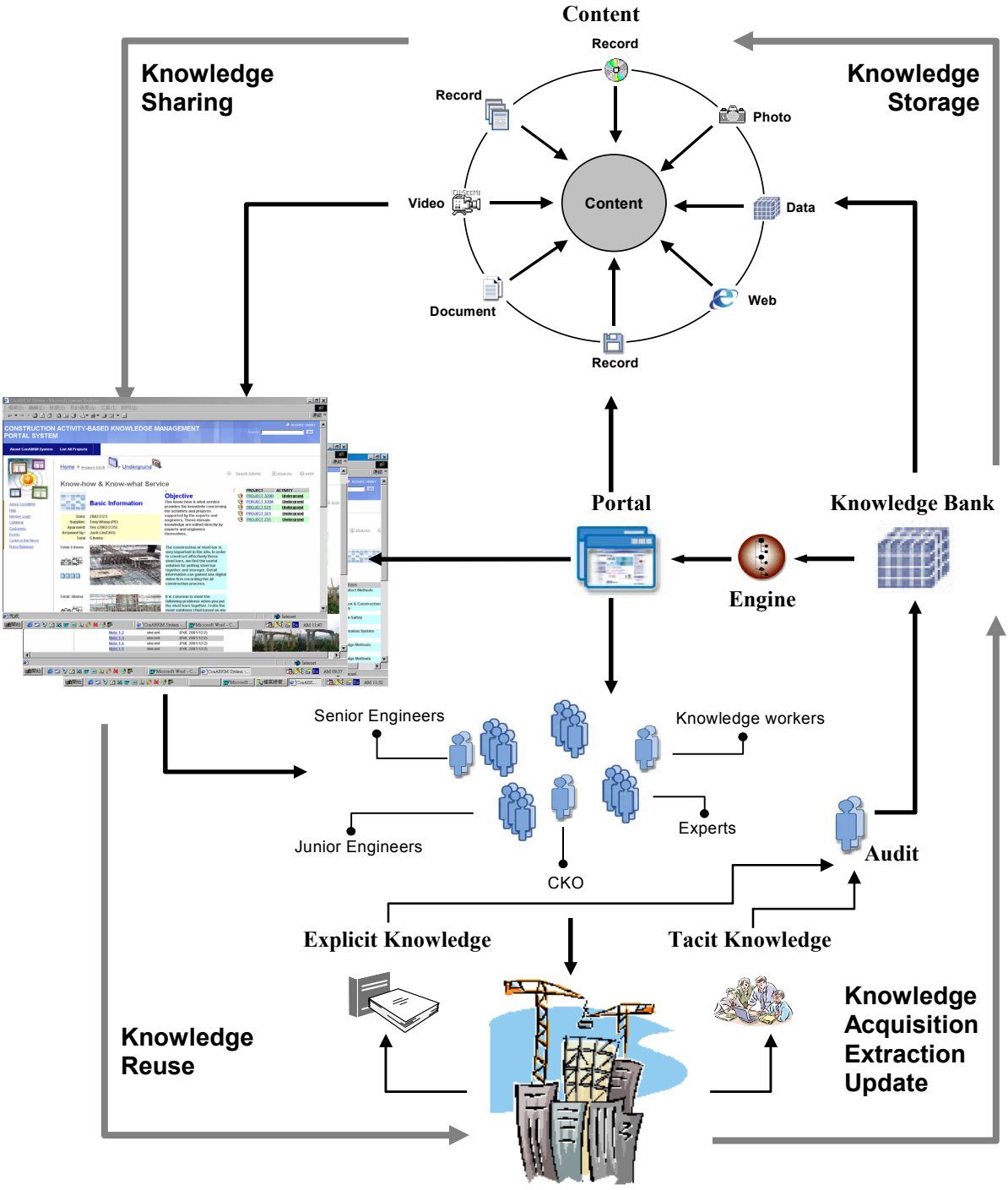

Figure 5: Overview of the ConPOKM System

The collection of explicit and tacit knowledge concerned about construction projects allow engineers and experts to reuse most project-related knowledge/information during the construction phase. The contents of the knowledge bank not only provide the specific problem-solutions, but also support all areas of domain knowledge and experiences from the

projects. Although efforts are required to update the explicit/tacit knowledge for various types of projects, the developed system will benefit lean construction by (1) providing an effective and efficient computerized environment to assist knowledge management tasks, and (2) facilitating the implementation of a web-based knowledge management system pertinent to these activities in the projects. With the evaluation of the case study of the Taiwan Second Highway project by experts and engineers, the suggestions and results show the ConPOKM system is an effective system in knowledge sharing for construction projects. Therefore, it should be considered conscientiously for lean construction implementing to execute the construction projects with knowledge management by utilizing the latest web technology.

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