

MODEL OF PROACTIVE PROBLEM-SOLVING FOR CONSTRUCTION KNOWLEDGE MANAGEMENT

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ABSTRACT

Construction is an experience-based discipline, knowledge or experience accumulated from previous projects plays very important role in successful performance of new works. More and more construction organizations have adopted commercial Knowledge Management Systems (KMSs) for developing their own Knowledge Management (KM) functionalities. The existing KMS's are mostly developed based on Communities of Practice (COPs) for knowledge sharing and exchange. Such approach founds on the reactive problem-solving (RPS) method. That is, the problem raised by the questioner in the COP has to passively "wait" for the members to respond (or react). Previous research indicates that such RPS approach may suffer in poor time and cost effectiveness. This paper proposes a proactive problem-solving (PPS) approach called Model of Proactive Problem-Solving (MPPS) for KMS. Unlike RPS, the PPS proactively solves the problem based on lessons-learned from previous projects. Should the solution is not available; the MPPS dispatches the problem to the most appropriate domain experts so that the problem can be tackled timely and efficiently. The MPPS is described in details, and an example construction KMS that adopts the proposed MPPS is demonstrated. It is found that the proposed MPPS has significant potentials to improve the performance of KMS for construction organizations.

KEYWORDS

Knowledge Management, Problem-Solving, Knowledge Map, Lessons-Learned, Proactive

1. INTRODUCTION

Problem solving is the center of the daily operations for construction organizations [1]. Since Construction Engineering is an experience-based discipline, knowledge accumulated from previous projects is the key to solve similar problems in the future projects [2]. Current practice of knowledge management system (KMS) has established

operational framework and platform for construction knowledge management. However, most existing KMSs were based on so-called "reactive mode" of KM. That is, the problem raised by the questioner has to wait (passively) responses from members of the Community of Practice (COP) of the KMS. Previous research has indicated that such approach can be a bottleneck to the performance of the KMS due to poor time and cost

effectiveness of the reactive problem-solving (RPS) model [2].

It is very desirable to improve the drawbacks of the traditional RPS for the KMS of construction organizations, such as the contractors and A/E firms, where timeliness of problem-solving is crucial to the survival of the firm. In other words, a proactive problem-solving (PPS) approach is expected not to passively “wait” responses from the members of COP; but rather proactively “tackle” the posed problem with the most appropriate solution from lessons-learned before. While the solution is not available from historic lessons, it is expected to “proactively” seek the domain expert who holds the most related implicit knowledge for the problem to solve the problem manually.

In order to establish such approach, several functionalities of a KMS should be developed including: (1) a knowledge classifications scheme (or a Knowledge Map) that appropriately represents the knowledge asset of the organization and accurately describes problem encountered; (2) a representation scheme for description of the expertise of the domain experts (or an Expert Map), which properly reflects knowledge (expertise) that the domain expert accumulated previously; (3) a set of text mining algorithms for searching of the most relevant lessons learned in previous project; (4) a problem dispatching scheme for associating the posed problem with the most appropriate domain expert; and (5) a repository of lessons learned from previous projects and the required functions of lesson learning.

In this paper, a conceptual model of proactive problem-solving, namely Model of Proactive Problem-Solving (MPPS), is proposed to provide the above-mentioned functionalities and overcome the disadvantages of traditional RPS. The proposed MPPS provides a systematic framework for building a more intelligent knowledge management system (KMS) in four aspects: (1) it acquires knowledge systematically and continuously from daily knowledge management activities of a KMS; (2) it constructs a more efficient structure for the knowledge (domain expertise) and human resource (domain experts) management of a KMS; (3) it solves problems proactively unlike the traditional passive/reactive RPS approaches; (4) it combines

the merits of traditional KMS and automatic answering system (AAS) that make the best use of the knowledge of the organization.

The rest of the paper is presented in the following manner: in the second section, related previous researches are reviewed to provide backgrounds for the proposed MPPS; then, the theoretical framework for MPPS is proposed; in the fourth section, a preliminary implementation of the proposed MPPS in the KMS of a local leading consulting firm is presented to demonstrate the applicability of the proposed MPPS; finally, assessments of the preliminary MPPS implementation are summarized and conclusions are drawn based on research findings.

2. REVIEW OF RELATED WORKS

The term “Proactive Problem-Solving” is not found in the literature. However, building blocks of MPPS described in the problem statement can be related to some existing works that found the base of MPPS.

2.1 Problem-Solving in Construction

Li and Love [1] developed a framework of problem-solving for construction engineering and management. Their research found that construction problems pose several characteristics that should be tackled in order to solve them quickly, correctly, and cost-effectively, such as ill-structure nature, inadequate vocabulary, little generalization and conceptualization, temporary multi-organization, uniqueness of problems, and hardness in reaching the optimal solution. Two areas of problem solving researches tackle the above-mentioned issues: the cognitive science and decision support system. In addition to these two areas, Yu et al. [2] propose a new approach called Knowledge Management integrated Problem-Solver (KMiPS) to solve emergent construction problems. Their works proved that the KMiPS achieved both quantitative and qualitative benefits better than traditional problem-solving approaches.

2.2 Knowledge Classification and Knowledge Map

Kim et al. [3] proposed a practical method for capturing and representing knowledge that is

critical in knowledge management. The method employs a knowledge map as a tool to represent knowledge of a firm. The procedure consists of six steps: (1) defining organizational knowledge; (2) analyzing process map; (3) extracting knowledge; (4) profiling knowledge; (5) linking knowledge; and (6) validating map knowledge. Effective knowledge maps help identify intellectual capital, socialize new members, enhance organizational learning, and anticipate impending threats and/or opportunities [4]. Caldas et al. [5] proposed an automatic document classification method based on text mining algorithms. Their work successfully classified 4,000 documents automatically with the Construction Document Classification System (CDCS) they developed.

2.3 Automatic Answering System (AAS)

Automatic Answering System (AAS) serve as a domain expert who can answer the question posed by questioner instantly. Various types of AAS's have been developed in construction industry. The Advanced Construction Technology System (ACTS) was developed in University of Michigan at Ann Arbor by Ioannou et al. [6]. ACTS provides a technology information system for construction planners and managers to select the most appropriate state-of-the-art construction technologies during the project planning stage. More than 400 technologies are recorded with 25 attributes such as general description, cost benefit, construction constraints, special application, operation environment, test criteria, etc. The Architecture and Engineering Performance Information Center (AEPIC) was developed by Loss at the University of Maryland [7]. The AEPIC provides information of failures so that the mistakes won't be made again. The On-Line Reference Library (OLRL) was developed by Bechtel Inc. to provide the engineers with real-time reference manuals of SPECS. The Civil Engineering Information System (CEIS) of Kajima Corp. is similar to ACTS and OLRL, which stores more than 300,000 documents [8]. Even though the abovementioned construction information systems provide some features of AAS, most of them are database system equipped with search functions. None of them completely fit the requirements of an AAS, such as automatic problem characterizing,

intelligent information retrieval, problem dispatching, and solution repository. Moreover, they are information system rather than problem-solving system.

2.4 Lessons-Learned System

There have been many existing lessons-learned systems reported in literature, which provides references for developing MPPS. The Hypermedia Constructability System (HCS), Indiana Department of Transportation (INDOT) was developed in collaboration between INDOT and Purdue University [9]. The HCS stores historic lessons-learned in multi-media format so that construction engineers can learn from previous lesson more effectively. The Constructability Lessons Learned Database (CLLD) & Integrated Knowledge-Intensive System (IKIS) were developed by Kartam and Flood [8][10] to provide a repository for previously learned lessons. The major difference between CLLD & IKIS and the abovementioned lessons-learned systems is that the latter verifies historic lesson-learned by the domain experts before storing in the database. The Construction Industry Institute (CII) developed a Lessons-Learned Wizard (LLW) with the package of constructability program [11]. The LLW is a computer aided information system that helps the engineers to record and retrieve the lessons learned from historic projects.

3. PROPOSED MODEL OF PROACTIVE PROBLEM -SOLVING (MPPS)

The proposed MPPS consists of four major components: (1) Knowledge/Expert Map (K/EM)—providing classification scheme for knowledge and expertise of the domain experts; (2) Automatic Problem Answering (APA) module—solving the posed problem automatically based on the historic problem-solving cases and lessons-learned; (3) Automatic Problem Dispatching (APD) module—dispatching the posed problem to the most appropriate domain expert when the problem cannot be solved by APA; (4) Lesson-Learned Wizard (LLW) - accumulating historic lessons-learned based on the classification scheme of K/EM.

3.1 Knowledge/Expert Map (K/EM)

The proposed MPPS is kernelled at the knowledge and the expert holding the knowledge. In MPPS, the domain knowledge is modeled by Knowledge Map; while the domain experts are represented by Expert Map. The Knowledge Map and Expert Map (K/EM) provide the ontology for modeling the knowledge repository of the construction firm. A Multi-dimensional Knowledge Ontology (MKO) scheme is adopted for the following reasons: (1) effective and efficient classification of knowledge documents (e.g., proposals, plans, work journals, final reports, etc.) and problem-solving lessons-learned; (2) correct and accurate description of problem; (3) provides a basis of Expert Map. The MKO scheme represents a knowledge document (KD) or a lesson-learned (LL) with a vector of codes including: (1) lifecycle code—describing the time reference of the knowledge, such as all life cycle, feasibility analysis, comprehensive planning, basic design, detail design, construction/installation, testing, operation/maintenance, recycle, change, etc.; (2) service/product code—describing the service/product related to the knowledge, such as bidding proposal, execution plan, QA plan, procurement plan, SPEC, alternative report, inspection report, calculation report, drawing, etc.; (3) profession code—the profession classification of the knowledge, such as administration, HR, civil (excavation, refill, site preparation, piping, etc.), structural (RC, PC, SS, underground construction, retaining structure, etc.), architecture (urban planning, building design, interior design, landscape, model, finishing, etc.), geotech (site investigation, pile, foundation, drainage, rock, stability, etc.), survey, highway, transportation, logistics, airport, hydraulics, harbor, material testing, etc; (4) sub-class keywords—for more specific description of the knowledge. An example vector (13, 20, 35, 5) can be interpreted as “the basic design criterion for segmental precast bridge construction”.

The Knowledge Capacity Matrix (KCM) is proposed for representing the expertise of the domain experts. The KCM describes a domain expert with a row vector containing three dimensions: (1) seniority—recording the professional seniority (in years) of the expert; (2)

intensity—recording the intensity of work (work hours/ seniority years) of a specific domain (described by MKO), which reflects the strength of expertise of the expert in a specific domain; (3) enthusiasm—recording the historic performance of the expert in participation of KM activities automatically provided by the KMS of the firm.

3.2 Automatic Problem Answering (APA) Module

The Automatic Problem Answering module (APA) is an automatic problem-solving system (APS) that searches the solution database to provide the most appropriate answer to the problem. Several requirements are expected for an ideal APS [12]: (1) it must tolerate simple errors; (2) it must embody a degree of “common sense”; (3) it must have a relatively large and complete vocabulary for the subject matter to be treated; (4) it must accept a wide range of grammatical constructions; (5) it must be able to deal sensibly with partly understood input; and (6) it must be capable of providing the information and computations requested by the user. Previous research has developed APS for internet service [13] and tutoring assistant [14]. The APA module is planned as shown in Figure 1 based on the APS of Wu et al. [14].

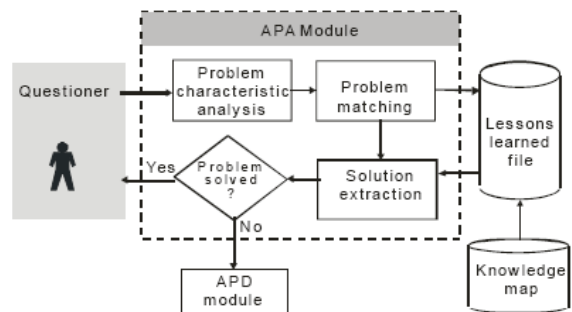


Figure 1 Conceptual Design of APA Module

In Figure 1, problem is posed by the questioner. The characteristics of problem are analyzed by APA. Then, APA searches the historic lesson-learned file (LLF) to find the most relevant lessons of the historic lessons. Finally, the solution is extracted from the relevant lessons based on a similarity measurement algorithm proposed by Wu et al. [14] as described below:

$$S_i = (N - R_i) \times 0.2 + S(F_i) \times 0.5 + S(A_i) \times 0.2 + S(T_i) \times 0.1 \dots \dots \quad (1)$$

where, $S(X) = \frac{|KQ \cap KX|}{|KQ|} \cdot 0.8 + \frac{\sum_{j=1}^n L_j}{LX} \cdot 0.2 \dots \quad (2)$

- $S(X)$: similarity measurement of the semantic fragment X to the problem;
- N : number of supplement materials considered;
- R_i : page rank of the supplement materials that contain fragment i ;
- F_i : content of the semantic fragment i ;
- A_i : abstract of the supplement materials that contain fragment i ;
- T_i : title of the supplement materials that contain fragment i ;
- $KQ = \{K_1, K_2, \dots, K_m\}$: keyword set of the problem;
- $KX = \{K_1, K_2, \dots, K_m\}$: keyword set of the fragment X ;
- LX : sum of word length of the fragment X ;
- L_j : total word length of occurrences of K_j in X .

If the solution is found (according to a predetermined similarity threshold), it is replied to the questioner. However, if the solution is not found, the problem is unsolved and diverted to APD module.

3.3 Automatic Problem Dispatching (APD) Module

Figure 2 shows the conceptual planning of the APD module. In figure 2, the unsolved problem is posed to KMS as an emergent problem and diverted to APD module at the same time. In APD module, the problem characteristics analyzed in APA module is used to find the most appropriate domain experts based on the Expert Map described previously. Then, the problem is dispatched to the most related domain experts for possible solution. Finally, the experts respond to the problem in a special COP called SOS of the KMS.

3.4 Lessons-Learned Wizard (LLW)

The LLF required in APA module is constructed by a Lessons-Learned Wizard (LLW) proposed by the Construction Industry Institute (CII) [11].The

LLW captures lessons-learned right after a problem is solved in the KMS. The LLW is integrated with an internet questionnaire surveying system that allows the questioner to evaluate the solution he/she obtains.

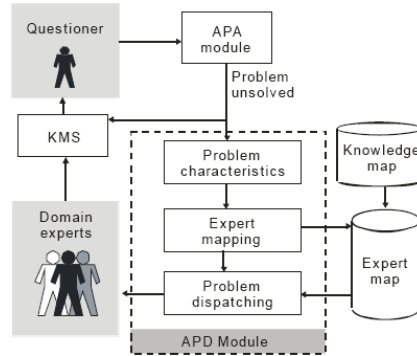


Figure 2 Conceptual Planning of APD Module

The LLF associated with the problem contains the following information: (1) the topic of the problem—titling the problem; (2) the description of the problem—detailed description of the problem; (3) the questioner—the name of questioner; (4) the solution—detailed description of the solution; (5) the responder—the name of the responder who provided the most related solution; (6) appendices—the supplementary materials for the solution; (7) benefits assessments - assessments of all benefits resulted by the solution including time, cost, quality, technical improvement, regulation impacts, etc. The LLFs are classified by the MKO scheme of Knowledge Map.

3.5 Integrated Model of Proactive Problem Solving (MPPS)

The integrated framework of MPPS is depicted in Figure 3. In the integrated framework, MPPS solves construction problems in two modes: (1) Automatic problem answering mode (APA mode)—the problem solving process is shown in Figure 3 as bold solid arrows, where the solution is searched automatically from historic lessons-learned based on problem characteristics; (2) Automatic problem dispatching (APD) mode—the problem solving process is shown in Figure 3 as dashed arrows, where the unsolved problems (by APA mode) is automatically

costs spent in problem solving are man-hours of the staffs participating in problem solving. According to 439 case study data, the average problem-solving man-hour cost is reduced from TWD 4,075 (USD 123.5) per problem to nearly zero in MPPS.

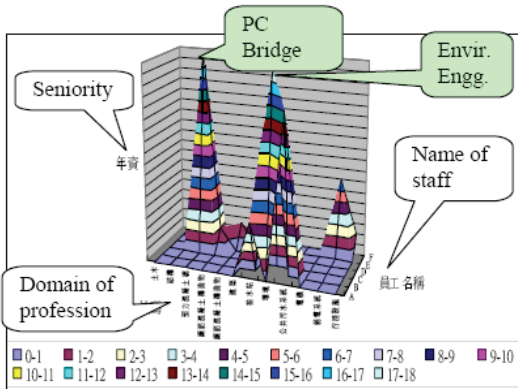


Figure 4 Example of Preliminary Expert Map

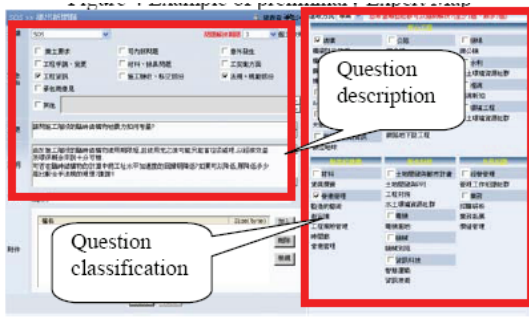


Figure 5 Preliminary APA Module-Questioning

The correctness of MPPS is assessed by verifying the solutions generated by APA module with those provided by the domain experts. This is currently conducted by the research team. The preliminary result is not satisfactory due to the high rate of incorrect solution. The research team is solving the problem by providing APA with specialized corpus for domain problems.

The extendibility of MPPS is another important issue concerning the future implementation of MPPS to other elements of the KMS as the preliminary implementation was focused on problem-solving. Since the KMS is cored with problem solving, the proactive problem-solving

mechanism developed in MPPS provides a problem-solving engine that can enhance the efficiency of all KM activities including problem socialization, knowledge generation and sharing, solution finding, and other KM issues. The extendibility of MPPS is also confirmed.

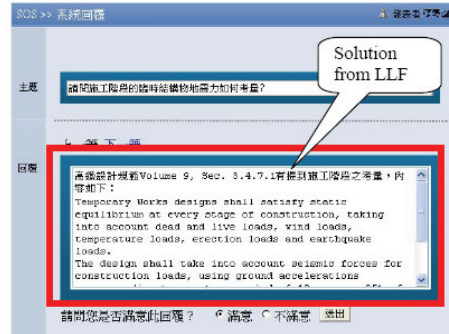


Figure 6 Preliminary APA Module—Answering

6. CONCLUSIONS AND FUTURE WORKS

This paper presents the preliminary result on the development of the model of proactive problem-solving (MPPS). All elements of MPPS are described in details. The preliminary implementation of the proposed MPPS in the KMS of a local leading A/E consulting firm, CECI, is demonstrated. Assessments of the preliminary implementation are discussed to show the applicability and potentials of the proposed MPPS. The proposed MPPS provides a new paradigm for problem-solving, which completely reforms the traditional passive/reactive mode of problem-solving approaches. It is concluded that the proposed MPPS is very powerful in improving the timeliness and cost effectiveness of the traditional KMS. It is beneficial to construction firms who are facing emergent problems in daily operations.

Even though preliminary results show promising benefits of the proposed MPPS, future verifications are required to validate the implementation of MPPS including: (1) quantitative evaluation of time and cost effectiveness; (2) verification of correctness of solutions inferred by MPPS for all

types of domain problems; (3) integrated computer system for MPPS need to be developed and verified to ensure the implementation of the proposed MPPS.

7. ACKNOWLEDGMENT

The founding of this research project was partially supported by the National Science Council, Taiwan, under project No. NSC 95-2221-E-216-049. Sincere appreciations are given to the sponsor by the authors. The valuable case study information presented in this paper was provided by CECI, Taipei. The authors would like to express sincere appreciations to Dr. Liu, S. J., Manager, Mr. Chen, G. L., and other staffs of the Department of Business and Research and Department of Information Systems, China Engineering Consultants, Inc., Taipei, Taiwan.

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