A study of ontology-based risk management framework of construction projects through project life cycle

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ABSTRACT

The process knowledge assets make a substantial contribution to the risk management (RM) for contractors in the construction phase. To effectively reuse these assets, knowledge extraction becomes a significant research area. This paper was designed to explore an approach to conduct knowledge extraction by establishing project risk ontology. Specifically, the study proposed the ontology-based risk management (ORM) framework to enhance the RM performance by improving the RM workflow and knowledge reuse. The ORM framework facilitated the identification, analysis, and response of project risks. This study validated the ORM framework through a case demonstration. Through the implementation and application, the results demonstrated that the ORM framework was able to apply to the RM workflow for contractors, and more importantly, it greatly increased the effectiveness of project RM.

1. Introduction

The characteristics of the construction industry include product uniqueness, on-site production, and ad hoc project teams with high turnover rate [34,52]. Subsequently, it has been difficult for the construction industry to coordinate, store, and reuse knowledge that is obtained between the organization and its individuals. Therefore, the construction industry needs to acquire, store and reuse knowledge in order to increase project performance. Previous studies had suggested the organization should conduct knowledge management through methods of project reports or lessons learned [15,29,42].

In addition to the aforementioned approach, Process-Oriented Knowledge Management (POKM) emphasizes that, through the combination of knowledge management and workflow process, the organization could increase project performance and purposely accumulate knowledge for future usage [40,24]. Recently, construction studies have explored knowledge management from the process-oriented perspective and studied the effectiveness of the POKM application in: safety management [5,12], design management [4,30], and facility management [44]. The results revealed that these studies primarily applied information technology (IT) tools to integrate the

workflow and knowledge management. Knowledge management was mainly conducted to capture explicit and tacit knowledge related to the workflow to help the user acquire and reuse knowledge with the standard operation procedure within the workflow.

In a previous research paper by the writers [54], the case study verified the POKM model could apply to the contractor's risk management (RM) workflow and therefore enhance the RM performance. Simultaneously, the project risk knowledge base could be built. Following the building of the knowledge base, an inquiry into how to extract and reuse the knowledge base effectively emerged as another important research issue. This study proposed ontology as the solution to investigate this issue. More importantly, the study would concentrate in the project risk knowledge base to study and verify the knowledge extraction model effectively. The study proposed an approach combining expert interview and information retrieval (IR) algorithms to extract the knowledge and develop the project risk ontology. Subsequently, the ontology-based risk management (ORM) framework is developed.

Based on literature review, the construction industry's project environment was usually exposed to a higher degree of risk and faced a significant amount of uncertainties [2,7]. Under such conditions, those decisions made by engineers and project managers were generally under uncertainty [3]. Consequently, project performance for the construction project was subject to risk factors and most projects failed to deal with the risk [18,22]. In particular, during the construction phase of project life cycle, the contractor not only faced risks produced from limited experiences in construction and project execution itself,

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but was also burdened with risks incurred from the owner or design company [19]. RM, consequently, played a significant role for the contractor. The risk manager is required to possess knowledge in order to conduct risk management [18,26,33,16]. An important concern regarding RM performance is how to reuse the knowledge base effectively. Accordingly, the ORM framework aims to enhance the RM performance through knowledge extraction and reuse.

In this study, the proposed ORM approach was found helpful for the selected contractor when conducting the project risk management. For the project manager (PM), this approach could be of assistance in risk identification, analysis and response. In addition to increasing RM effectiveness, the study verified that the project risk ontology could be developed through acquiring tacit knowledge and extracting explicit knowledge from the organization. To summarize, in this study the ORM approach could support the contractor by increasing effectiveness of RM workflow on the basis of implementing knowledge management.

2. Literature review

2.1. Knowledge management research

Peter F. Drucker [31], the late master of management science, attempted to clarify that knowledge had become the key asset to an organization in modern society. Later, the report from the Organization for Economic Co-operation and Development (OECD) [28] — knowledge, as embodied in human beings (as 'human capital') and in technology, had always been central to economic development — more specifically indicated knowledge was essential to Knowledge-based Economy. Therefore, knowledge asset had become a crucial factor for organizational competitiveness [5,15], and was regarded as highly important [29].

The crucial component of knowledge management (KM) is managing knowledge flow that the organization needed [39,17]. Through the application of the KM technique and IT tool, the procedures of knowledge processing could be strengthened to help knowledge flow support the workflow operation in the organization [15,25]. Conversely, Process-Oriented Knowledge Management (POKM) was conducted using the analysis of workflow activities and knowledge requirements, to integrate the appropriate knowledge management with the workflow. Thus, the POKM approach could facilitate the knowledge flow in each organization workflow and improve working performance because of knowledge reuse [40,24,48].

For KM, knowledge processing procedures could be categorized into five steps: knowledge capturing, knowledge editing & validating, knowledge storing, knowledge sharing, and knowledge creating [53,42]. However, knowledge management not only refers to knowledge-based management only, but it also covered the management of knowledge-creating processes, the management of person-to-person knowledge exchange within the organization [49,17]. With reference to Carrillo and Chinowsky's classification [29], the two KM types could be divided into 1) the information technology centric (IT), and 2) the human resource centric (HRM). The HRM and IT types of KM can be regarded as two management models that correlate with tacit and explicit knowledge. For example, explicit knowledge correlates with the knowledge extraction of the enormous and complex project database, i.e., IT type. This presented a research issue about how to reuse the knowledge effectively. To address this concern, previous researchers proposed several verified model to extract the construction knowledge [10], [11], [51]. Thus, these studies foreground the importance of knowledge extraction to the effective reuse of the knowledge.

The available reused knowledge usually encompasses explicit and tacit knowledge [15]. The tacit knowledge captured becomes a problem of knowledge reuse [20,47]. To solve such a problem, many studies suggested that explicit and tacit knowledge management should be conducted by combining the POKM approach and IT system

development during the workflow [5,12,44]. This solution adopted the systematic process support to retrieve information and knowledge, and to record the users' decisions and tacit knowledge effectively during the working process. In summary, these studies have proposed the verified models to support the capturing of the tacit knowledge by embedding the KM mechanism into the workflow.

2.2. Information retrieval and ontology application in construction industry

Information retrieval can be defined as a technology relating to the representation, storage, and organization of, and access to information items. [8]. To simplify it, the goal of IR in the technical aspect is to assist the users in quickly locating relevant and critical knowledge with much more ease. As the construction industry is characterized by its enormous, complex project data, how effective the knowledge dissemination and information sharing functions within the organization are can provide high level value for the organization [4]. This field of technology is, therefore, recognized as an important aspect in the construction industry applications.

Ontology is a formal, explicit specification of a shared conceptualization [46]. Specifically, ontology could be referred to the explicit formal specification of the concepts in a specific domain and the relations among them. Therefore, the two main elements of ontology are concepts and relations. Ontology could be relevant in the research field of artificial intelligence, representation of knowledge, semantic web, system integration and problem solving techniques [1]. In the construction management academia, ontology had been applied to knowledge representation, decision making, and information integration [1,52,23,43].

The development of ontology requires a great deal of time, cost, and expertise [23]. Previous efforts have focused only on a specific topic [36,37,44,1]. Conversely, the most notable industry-wide efforts that have been validated include the Industry Foundation Class (IFC) and the e-Cognos project [36,37,52]. Most of the validated ontology application models, however, have focused on a specific domain.

In previous studies, Kosovac et al. [6] assisted engineers with IR by constructing a thesaurus. Lin and Soibelman [23] utilized a specific ontology along with the algorithms for query expansion to enable users to retrieve and rank the information effectively. Moreover, semantic algorithms of the IR model were applied in the development of several verifiable knowledge management systems (KMS) to support architecture design and the organization of project documents [30,9]. In 2006, Rezgui [52] presented an application that combined the semantic algorithms and the construction industry ontology to construct the automatic knowledge-feeding system based on the result of knowledge extraction. In summary, the previous studies proposed several successful models which verified that IR algorithms could support, retrieve and reuse of knowledge. Furthermore, the IR algorithms could be applied with ontology.

2.3. Construction risk management

Tah and Carr's studies [18] indicated that RM procedure was widely accepted as the chief role to affect RM. A good procedure design enabled a systematic and consistent approach to implement RM; hence, many studies were dedicated to research the RM procedure [7,18,27]. Moreover, since risk management was important to project performance, it had also been built into "A guide to the Project Management Body of Knowledge (PMBOK guide)" framework proposed by [32]. Through case studies, it was also proved that the approach and tool mentioned in the PMBOK guide were influential to project performance [22].

Another important RM research objective was to develop risk management approaches through experience and knowledge application. Hence, many studies discussed conducting risk management on knowledge reuse bases [18,35,45,27,16]. In these studies, fuzzy model,