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An enterprise risk management knowledge-based decision support system for construction firms

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Abstract

Purpose – The purpose of this paper is to develop a knowledge-based decision support system for enterprise risk management (KBDSS-ERM) for Chinese construction firms (CCFs) to facilitate their ERM implementation. The specific objectives of the KBDSS-ERM are: first, assess the ERM maturity in a CCF; second, visualize the ERM maturity assessment results; third, provide action plans for improving the ERM implementation along the maturity continuum; and finally, generate a printable ERM maturity assessment report.

Design/methodology/approach – Microsoft Visual Studio 2010 was used to develop the KBDSS-ERM. Based on literature review and structured interviews, 191 action plans for improving ERM implementation were identified and included in the knowledge base. A fuzzy ERM maturity model, including 16 maturity criteria and 66 best practices, was embedded into the KBDSS-ERM. A total of ten experts from ten different CCFs, who were not involved in the survey or the development of the action plans, were invited to validate the KBDSS-ERM.

Findings – The validation results indicated that the results of the KBDSS-ERM were consistent with the expert judgments, and that the KBDSS-ERM had the accuracy ranging from 92.9 to 83.7 percent in assessing the maturity criteria and the overall ERM maturity of CCFs. In addition, the experts recognized the KBDSS-ERM as being a robust, convenient and useful tool for ERM implementation in CCFs.

Research limitations/implications – First, the maturity criteria and ERM best practices that were identified in this study may not be exhaustive even though close attention was paid in the research methodology adopted to circumvent this risk. Additionally, as the applicability of the best practices and the importance of the maturity criteria were checked in the context of CCFs, one should be cautious when the KBDSS-ERM is being applied in other construction firms outside of the CCFs domain.

Practical implications – Using the KBDSS-ERM, the management can clearly understand its ERM implementation as well as the strengths and weaknesses, and obtain the action plans recommended by the KBDSS-ERM. Thus, with the information from the KBDSS-ERM, the management would make better decisions relating to ERM. In addition, while using the KBDSS-ERM, the staffs need to read the ERM best practices, which allows them to learn the ERM fundamentals and produce practical or innovative ideas relating to ERM. Thus, the KBDSS-ERM would contribute to the organizational learning of companies.

Originality/value – The primary contribution is the provision of 191 specific action plans that could be followed to enhance ERM practice. These action plans are arguably the first to be presented for the construction industry and therefore add to existing knowledge of ERM, now embedded in the KBDSS. In addition, the KBDSS-ERM is also the first computerized ERM tool developed specifically for construction firms. Although the KBDSS-ERM is primarily designed for CCFs, the implications of this study are not limited to CCFs because researchers and practitioners could adopt the research method of this study to develop KBDSSs for other construction firms.

Keywords Knowledge, Maturity, Enterprise risk management, Fuzzy set theory, Construction firms, Decision support system

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Introduction

Recent years have witnessed a paradigm shift in the way companies view risk management (Zhao *et al.*, 2014a). Enterprise risk management (ERM) has been seen as the fundamental paradigm in the trend moving toward holistic risk management (Gordon *et al.*, 2009; Hoyt and Liebenberg, 2011). The Committee of Sponsoring Organizations of the Treadway Commission (COSO, 2004) defined ERM as "a process, effected by an entity's board of directors, management and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within its risk appetite, to provide reasonable assurance regarding the achievement of entity objectives" (p. 2). This definition is adopted for the current study. Driven by the legal compliance and corporate governance requirements as well as the credit rating agencies' requirements, an increasing number of organizations in various industries have initiated/implemented their ERM programs (Zhao *et al.*, 2015).

The construction industry inevitably involves complex and diverse risks (Deng *et al.*, 2014; Hwang *et al.*, 2014; Shi *et al.*, 2015; Zhao *et al.*, 2014b), and thus construction firms have been seen as prime candidates for implementing ERM (Druml, 2009). Because the architecture, engineering and construction industry is a knowledge intensive industry (Rezgui *et al.*, 2010), the knowledge on ERM in construction firms should be shared and used in decision making relating to ERM.

The objective of this study is to develop a knowledge-based decision support system for ERM (KBDSS-ERM) for Chinese construction firms (CCFs) to facilitate their ERM implementation. Specifically, the KBDSS-ERM allows the users to assess the ERM maturity of their firms and provides action plans for improving ERM implementation based on the assessment results. The rationale of the ERM maturity assessment lies in that such assessment helps a company to gain an understanding of its current ERM implementation, as well as the strong and weak aspects of ERM implementation. With such an understanding as well as the action plans selected by the KBDSS-ERM, the management of the CCFs can make better informed decisions relating to ERM.

In this study, CCFs are investigated because they have ventured into over 180 countries according to the National Bureau of Statistics of China (NBSC, 2015). Thus, their management and operation have a wider range of implications and tend to influence the international construction market. Despite a number of studies focussing on ERM in various industries, few have focussed on ERM in construction firms. In addition, there lacks a tool for construction firms to assess their ERM implementation and receive suggestions for improvement. Thus, this study can significantly contribute to the body of knowledge relating to ERM.

Background

ERM maturity model (ERMMM)

In this study, an ERM maturity assessment model serves as an approach to assessing the sophistication of ERM implementation. In the Phase I of the on-going research project, Zhao *et al.* (2013) developed a fuzzy ERMMM consisting of 16 important ERM maturity criteria and presented 66 applicable best practices under these criteria (see, Table I).

The input data of the ERMMM are the implementation level of each best practice, while the output data are the criteria scores and the ERM maturity index (ERMMI), namely, the overall maturity score. A linguistic variable, i.e. the implementation level of each best practice, is defined with the following linguistic values: very low, low, medium, high and very high. These values were transformed into triangular fuzzy numbers (TFNs), respectively.

Code	ERM maturity criteria	Weights (%)
M01	Commitment of the board and senior management	7.21
M02	ERM ownership	6.59
M03	Risk appetite and tolerance	5.56
M04	Risk-aware culture	6.06
M05	Sufficient resources	6.36
M06	Risk identification, analysis and response	6.79
M07	Iterative and dynamic ERM process steps	6.29
M08	Leveraging risks as opportunities	5.72
M09	Risk communication	6.18
M10	A common risk language	5.40
M11	A risk management information system (RMIS)	5.97
M12	Training programs	6.22
M13	Formalized key risk indicators (KRIs)	6.16
M14	Integration of ERM into business processes	6.47
M15	Objective setting	6.75
M16	Monitoring, review and improvement of ERM framework	6.29

Source: Adapted from Zhao *et al.* (2013)

Table I. ERM maturity criteria

When k people participate in the ERM maturity assessment, the implementation level of each best practice can be calculated as follows:

$$\tilde{L}_{ip} = (l_{ip1}, l_{ip2}, l_{ip3}) = (1/k) \times \sum_{j=1}^{k} \tilde{L}_{ipj} \quad (1)$$

where $\tilde{L}_{ip}$ is the TFN of the implementation level of the best practice p under criterion i; l_{ip1}, l_{ip2} and l_{ip3} represent the lower bound, the strongest membership degree and the upper bound of $\tilde{L}_{ip}$, respectively; and $\tilde{L}_{ipj}$ is the TFN of the implementation level of the best practice p under criterion i collected from the individual j.

To transform the TFNs into crisp values, The ERMMM adopts the centroid defuzzification method, which intends to find the center of gravity of the fuzzy set (Negnevitsky, 2006). As the fuzzy set in this study is a triangle, the crisp number of $\tilde{L}_{ip}$ can be calculated as follows:

$$L_{ip} = (1/3) \times (l_{ip1} + l_{ip2} + l_{ip3}) \quad (2)$$

where L_{ip} is the crisp number of $\tilde{L}_{ip}$. The implementation level of criterion i is measured by the average implementation level of all the best practices under criterion i:

$$L_i = (1/u) \times \sum_{p=1}^{u} L_{ip} \quad (3)$$

where L_i is the crisp number (i.e. maturity score) of the implementation level of criterion i; and u, the number of the best practices under criterion i. Therefore, the ERMMI can be calculated:

$$\text{ERMMI} = \sum_{i=1}^{16} (W_i \times L_i) = \sum_{i=1}^{16} \left((W_i/u) \times \sum_{p=1}^{u} L_{ip} \right) \quad (4)$$

where W_i is the weight of criterion i, as presented in Table I. The ERMMI in the interval of [0, 1] to fall into the regions of two adjacent linguistic terms. The ERMMI can be translated to the term whose membership value is higher. In this study, the ERMMM is embedded into the KBDSS-ERM.

KBDSS

A KBDSS is "a computer information system that provides information and methodological knowledge using analytical decision models, and providing access to data and knowledge bases to support decision makers in making decisions effectively in complex and ill-structured problem domains" (Zopounidis *et al.*, 1997, p. 263). Technically, KBDSSs originated from an integration of an expert system (ES) with a decision support system (DSS).

A DSS is an interactive, computer-based information system that utilizes decision rules and models, coupled with a comprehensive database (Turban and Watkins, 1986). A basic objective of a DSS is to provide the necessary information in order to help decision makers better understand the complex situations and make good decisions (Wang, 2005; Zopounidis *et al.*, 1997). In comparison, an ES is a computer program that includes a knowledge base containing experts' knowledge for a particular problem domain, and a reasoning mechanism for generating inferences over the knowledge base (Turban and Watkins, 1986). As a form of an ES, a knowledge-based system holds the subject knowledge as a set of facts and rules that may be interrogated and manipulated to provide an inferred solution or explanation for a given problem (Ülengin and Topcu, 2000), and aims to replicates the problem solving expertise of human specialists in a specific area of application (Cooke *et al.*, 2008). Klein and Methlie (1990) combined the frameworks of DSSs and ESs to produce the KBDSS frameworks. Hence, KBDSSs can overcome the drawbacks of DSSs and ESs without missing their strengths (Zopounidis *et al.*, 1997), provide smarter support to decision makers, and enable them to improve the decision quality (Bonczek *et al.*, 1981).

KBDSSs have been applied in various domains. These include cost estimation and pricing decisions in versatile manufacturing firms (Kingsman and de Souza, 1997), quantitative constructability analysis (Yu and Skibniewski, 1999), selection of water crossing infrastructure alternatives (Ülengin and Topcu, 2000), building project procurement (Kumaraswamy and Dissanayaka, 2001), management in flexible manufacturing systems (Özbayrak and Bell, 2003), enterprise mergers and acquisitions (Wen *et al.*, 2005), measurement of the performance of real estate investment (Wang, 2005), variation orders management (Arain and Low, 2006), construction equipment selection and cost estimation (Eldrandaly and Eldin, 2006), measurement of enterprise performance (Wen *et al.*, 2008), tender call evaluation (Alexopoulos *et al.*, 2009), road safety analysis (Dell'Acqua *et al.*, 2011; Jo *et al.*, 2011), and building envelop assessment (Singhaputtangkul *et al.*, 2013). In addition, SPRING (2010) Singapore, which is an agency under the Ministry of Trade and Industry of Singapore, developed a KBDSS, known as the Integrated Management of Productivity Activities Assessment Tool to help businesses identify the strengths and weaknesses in their productivity, measure their productivity levels and provide action plans for improving their productivity.

KBDSSs have also been applied in risk management in a variety of fields. Ferns (1995) developed a KBDSS called Lifenet in the social service domain for the risk assessment of adolescent suicide. Uricchio *et al.* (2004) presented a KBDSS to assess Italian groundwater pollution risks. Padma and Balasubramanie (2009) proposed a KBDSS to acquire and quantify the work-related risks on musculoskeletal disorder.

Baloi and Price (2003) pointed out that probability theory, FST and certainty factor theory had been widely used to deal with uncertainties in KBDSSs, and found increasing applications of the FST for modeling uncertainties in KBDSSs in the construction industry.

Although much attention has been paid to the KBDSSs for risk management, the issue of improving ERM practices through a KBDSS has not been much explored in the literature. Thus, this study expands the literature by developing a KBDSS-ERM for assessing ERM maturity and improving ERM implementation in CCFs.

Research method

The functions of the KBDSS-ERM include not only assessing the ERM maturity in users' firms, but also providing a series of specific action plans that can help users improve their ERM implementation. Based on the literature review, this study developed a preliminary set of action plans for improving ERM implementation. In addition, structured interviews were conducted because these can reduce the interviewer's bias and readily collect easily interpretable responses (Mitchell and Jolley, 2007; Zuo *et al.*, 2013). During the interviews, the preliminary set of action plans was presented to the interviewees in the same sequence. The interviewees were requested to comment on the action plans and to add new action plans as appropriate. Six interviewees were selected from the survey sample in the Phase I of the on-going research project, based on their willingness to be interviewed. This approach has been deemed as appropriate when the respondents are not randomly drawn from the population, but are selected based on whether they voluntarily participate in the survey (Jiang, 2014; Jiang *et al.*, 2015; Wilkins, 2011; Zuo *et al.*, 2012). As shown in Table II, all the interviewees had over ten years' experience in the construction industry, and four of them worked in overseas subsidiaries of CCFs. Two of them held positions in the senior management, project management and department management, respectively. Furthermore, a total of ten experts from ten different CCFs, who were not involved in the survey or the development of the action plans, were contacted for the validation of the KBDSS-ERM.

KBDSS-ERM

Objectives of the KBDSS-ERM

The KBDSS-ERM developed in this study can serve as an assessment tool for individual management staff in CCFs. The specific objectives of the KBDSS-ERM are: first, assess the ERM maturity in a CCF; second, visualize the ERM maturity assessment results; third, provide action plans for improving the ERM implementation along the maturity continuum; and finally, generate a printable ERM maturity assessment report.

Interviewees	Designation	Experience (years)	Location
1	Project manager	13	Singapore
2	Deputy director	16	Singapore
3	Contract manager	10	Saudi Arabia
4	Project manager	11	China
5	Vice president	18	China
6	International business director	12	Angola

Table II. Profile of interviewees

By using the KBDSS-ERM individually, the management staff can gain an overview of the ERM maturity as well as the action plans for improving their ERM implementation. This allows them to identify the aspects of the ERM implementation that have the priority for improvement, according to the information available and the real-world circumstances faced by the firm. In addition, when assessing the ERM maturity, the management staff would think about the status quo of their ERM implementation, and gain more innovative ideas relating to ERM. Thus, the ERM maturity assessment conducted individually can still contribute to the group decision making relating to ERM. Furthermore, it should be noted that the assessment results and action plans provided by the KBDSS play a supportive rather than a dominative role in the decision making relating to ERM. The KBDSS is not designed to make decisions for users, but rather it provides pertinent information in an efficient and easy-to-access format that enables users to make more informed decisions (Arain and Low, 2006).

Architecture of the KBDSS-ERM

Microsoft Visual Studio 2010, which supports various programming languages, was used to develop the KBDSS-ERM. Among the programming languages, Visual Basic 2010 was adopted because it allows programmers to easily build complex Windows and is as powerful as Visual C++ and C# (Shelly and Hoisington, 2010). In addition, Microsoft Visual Basic 2010 can produce the KBDSS in the exe format. Thus, the users do not need to install additional software programs prior to using the KBDSS-ERM.

The KBDSS-ERM consists of three main components: a knowledge base, a graphical user interface (GUI), and a decision support engine (DSE), as described in Figure 1. The knowledge base and DSE represent the knowledge-based and decision support aspects of the KBDSS-ERM, respectively. The GUI allows the users to input data and obtain the output results.

Knowledge base. The knowledge base is a repository of the knowledge and experience of experts. In addition to the 16 ERM maturity criteria and the 66 best practices in the ERMMM, the action plans for improving ERM practices are stored in the knowledge base. These action plans were acquired through the interviews with six

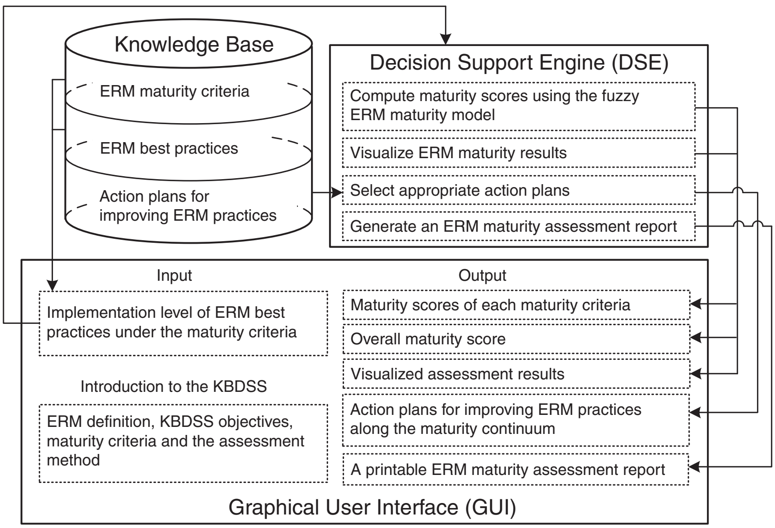

Figure 1.
The KBDSS-ERM architecture

practitioners as well as the literature review (Barton *et al.*, 2002; Cendrowski and Mair, 2009; Duckert, 2011; Fraser and Simkins, 2010; Hopkinson, 2011; Narvaez, 2011; Segal, 2011; Zou *et al.*, 2010).

Each best practice was assigned three action plans, which intend to help a firm improve the implementation of this best practice from a very low or low to a medium level, from a medium to a high level and from a high to a very high level, respectively. The rationale behind assigning three action plans to each best practice is that it makes no sense to provide an action plan to help a firm improve from a very low level to a low level. The preliminary set of action plans for the 66 best practices was presented to the interviewees to solicit insightful comments and additional action plans. Based on the comments and inputs of the interviewees, the action plans were revised and updated. The finalized set consisted of 191 action plans for improving the implementation of the 66 best practices and was included in the knowledge base. A sample of the action plans is presented in Table AI.

It should be noted that not all the best practices had three action plans because it was difficult to distinguish between the two adjacent implementation levels of some best practices. In this case, two of the three action plans for the best practices were duplicated. In addition, an interviewee indicated that some best practices did not need to have three action plans in a real-world situation. The reason was that it would be meaningless to develop action plans for these best practices to improve the implementation from a low to a medium level. Thus, these best practices had only two action plans.

GUI. The GUI allows users to interact with the KBDSS-ERM using graphical icons and visual indicators. Before a user proceeds to the ERM maturity assessment, the introduction interface presents a brief introduction to the KBDSS-ERM. In the assessment process, the assessment interfaces display ERM maturity criteria and best practices, and allow the user to input the implementation levels of the 66 best practices under the 16 criteria using the five-point scale (1 = very low, 2 = low, 3 = medium, 4 = high and 5 = very high), as shown in Figure 2. After ERM maturity assessment and action plan selection, the GUI displays the maturity criterion scores, the overall maturity score (i.e. ERMMI) and the selected action plans. In addition, the criterion scores and the ERMMI are interpreted using the same set of linguistic terms. As Figure 2 indicates, the GUI presents a histogram of the assessment results. In the histogram, the color of each bar represents the linguistic term of each maturity criterion, and the length is in proportion to each criterion score. Moreover, the criterion scores can be compared with the ERMMI. The scores below and above the ERMMI are highlighted in pink and light green, respectively. Thus, it is easy and convenient for the user to understand the implementation status of the maturity criteria and to find the weaker aspects that are represented by the shorter bars in the histogram.

DSE. The DSE transforms the input implementation level of ERM best practices into TFNs, adopts the centroid method to produce the crisp implementation scores ranging from 0 to 1, and calculates the ERM maturity criterion scores and the ERMMI, using Equations (1)-(4). Meanwhile, it sends commands to visualize the assessment results. In addition, according to the crisp implementation scores of the best practices, the DSE selects the action plans from the knowledge base for the user. Three rules coded in the If-Then conditional statements are adopted to select the appropriate action plans (see, Table III).

The action plans presented for the user are divided into two groups. One group intends to improve the implementation of the best practices scored below the ERMMI, and the other is aimed at those scored over the ERMMI. Thus, the management would

Figure 2.
The KBDSS-ERM screenshots

strengthen the implementation of the practices scored below the ERMMI, or focus on the ones scored above the ERMMI, or undertake both sets of practices. Furthermore, an ERM maturity assessment report (see, Figure 2), which includes the maturity scores, the visualization of the scores and the action plans, can be generated and printed, enabling the users to easily review the assessment results.

Validation

A total of ten experts from ten different CCFs, who were not involved in the survey or the development of the action plans, were contacted for the validation of the KBDSS-ERM (see, Table IV). Their experience in the construction industry ranged from 11 to 31 years. Five of them held positions in the senior management, three were department managers and two were project managers. The sample size of ten experts was adequate for the validation with references to previous studies: Arain and Low (2006) validated a KBDSS for managing variation orders by four professionals and one case; Liu and Ling (2005) verified a fuzzy system for mark-up estimations by one expert using three cases; and Imriyas (2009) validated an ES for insurance premium rating by five experts and one case.

During the validation process, these experts were first asked to rate the implementation levels of the 16 ERM maturity criteria as well as the overall ERM maturity of their firms according to their experience and judgments. To improve the accuracy of the rating, the scores were assigned in the form of percentage. Thus, there were at least two decimal places in the fractional part of the scores. Then, the experts applied the KBDSS-ERM to assess their ERM maturity and returned the ERM maturity assessment reports. The scores assigned by the experts (S_E) were compared with those calculated by the KBDSS-ERM (S_K). The comparison intended to test the validity of the ERMMM in the KBDSS-ERM. In addition, they were requested to comment on the KBDSS-ERM in terms of usefulness of the action plans to decision making, as well as the user-friendliness of the KBDSS-ERM. Specifically, the validity of the ERMMM was

Table III. Rules of selecting action plans in the DSE

Rules	If (condition)	Then (execution)
Rule 1	$L_{ip} < 0.375$	Select the action plan for improving the practice to a medium level
Rule 2	$0.375 \leqslant L_{ip} < 0.625$	Select the action plan for improving the practice to a high level
Rule 3	$L_{ip} > 0.625$	Select the action plan for improving the practice to a very high level

Note: L_{ip} is the score of the *p*th best practice under criterion *i*

Table IV. Profile of the validation experts

Expert	Experience (years)	Designation
E1	20	President
E2	18	Vice president
E3	11	Manager of contract department
E4	12	Manager of international marketing department
E5	31	Director
E6	16	Project manager
E7	11	Project manager
E8	17	Vice president
E9	21	Managing director
E10	15	Manager of procurement department

determined by calculating the percentage error (PE), mean PE (MPE), and mean absolute PE (MAPE). This approach was proposed by Upton and Cook (2006), and has been adopted by Liu and Ling (2005), Lim *et al.* (2012) and Ling *et al.* (2012). The equations are shown as follows:

$$\text{PE} = \left((S_E - S_K)/S_E\right) \times 100\% \tag{5}$$

$$\text{MPE} = \sum \left(\text{PE}_i/n\right) \tag{6}$$

$$\text{MAPE} = \sum \left(|\text{PE}_i|/n\right) \tag{7}$$

where n is the number of experts. The MPE is used to check whether the ERMMM result has a tendency to be over or below the respective expert judgment, while the MAPE indicates the magnitude of model errors (Liu and Ling, 2005). A lower MAPE indicates a lower magnitude of errors and higher accuracy of the ERMMM.

The validation results are presented in Table V. The MPE values ranged from −7.2 to 14.7 percent. The MPE signs suggested that the ERMMM was likely to underestimate the implementation levels of four maturity criteria and ERMMI, and to overestimate the implementation levels of 12 maturity criteria. Only one maturity criterion obtained a MPE value higher than 10 percent, indicating that the results of the ERMMM were still consistent with the expert judgments. In addition, the MAPE values ranged from 7.1 to 16.3 percent, suggesting the ERMMM had the accuracy ranging from 92.9 to 83.7 percent in assessing the maturity criteria and the ERMMI.

Fayek and Oduba (2005) quoted that a fuzzy system could be seen as successful if the discrepancy between the defuzzified and actual values was less than 33 percent of the actual value. Lee (2007) reported a fuzzy ES that showed the accuracy between 84.68 and 66.50 percent. Ling *et al.* (2012) developed the mathematical models to predict the corporate competitiveness, with the MAPE values of 14.4 and 22.2 percent. Compared with these previous studies, the ERMMM in the KBDSS-ERM can be seen as robust and valid.

In addition, the experts commented on the usefulness of the action plans to decision making. All the ten experts (i.e. annotated as E1-E10 hereafter) agreed that the action plans presented in the KBDSS-ERM were useful and helpful for making decisions relating to ERM implementation. Specifically, E1, E6 and E9 opined that these action plans comprehensively described what a company should do to obtain a mature ERM

Table V. Validation results of the ERMMM

Code	MPE (%)	MAPE (%)	Code	MPE (%)	MAPE (%)
M01	−5.7	13.5	M09	7.6	7.6
M02	−7.1	7.1	M10	2.0	11.2
M03	7.3	12.1	M11	4.0	15.4
M04	5.8	9.5	M12	0.2	12.1
M05	10.0	10.0	M13	9.2	16.3
M06	3.4	8.8	M14	−7.2	14.8
M07	5.4	13.0	M15	6.8	10.3
M08	−3.2	15.7	M16	14.7	15.9
			ERMMI	7.6	10.4

program, and included some new ideas about risk management, while E4 expressed that the action plans may serve as guidelines for the firm to implement ERM in the international market. However, E3 and E8 pointed out that the parent company should practice ERM according to the action plans, and share some resources with its subsidiaries. E3 added that it was impossible to implement ERM in subsidiaries without the support from the parent company. E5 also expressed that the small firms would not need such complicated action plans. But E5 admitted that these action plans can help the management make decisions relating to risk management. Therefore, the usefulness of the action plans to decision making can be seen as valid. Moreover, all the ten experts agreed that the KBDSS-ERM was user-friendly. Specifically, all the experts expressed that the clear interface layout made it easy for the user to assess the ERM maturity and understand how to effectively conduct risk management, and E4 and E8 emphasized that it was convenient to print out an assessment report, which allowed the users to take away the results and action plans for implementation.

Advantages of the KBDSS-ERM

The KBDSS-ERM allows the users to assess the ERM maturity and selects action plans for improving ERM implementation based on the assessment results. The specific advantages of this KBDSS-ERM are as follows:

(1) the KBDSS-ERM adopts the FST to deal with the ambiguous and imprecise human judgments that are inevitably involved in the ERM maturity assessment;

(2) the KBDSS-ERM is user-friendly and provides an easy-to-use computerized platform for the users to assess ERM maturity, thus ensuring the accuracy of the perceptibly complicated mathematical calculations;

(3) the KBDSS-ERM contains a series of action plans for improving ERM implementation, which can effectively support the decision making relating to ERM; and

(4) the KBDSS-ERM visualizes the assessment results and makes it easy and convenient for the users to understand the strengths and weaknesses of their ERM implementation.

Conclusions and recommendations

This study presents a KBDSS-ERM for CCFs, which includes the knowledge collected from the questionnaire survey and interviews and was developed using Microsoft Visual Studio 2010. The KBDSS-ERM can assess the ERM maturity in a CCF, visualize the ERM maturity assessment results, provide action plans for improving the ERM implementation along the maturity continuum, and generate a printable ERM maturity assessment report. The KBDSS-ERM was validated by practitioners, and recognized as being a robust, convenient and useful tool for ERM implementation in CCFs.

Despite the fulfillment of the objectives, there are some limitations to the conclusions that may be drawn from the results. First, the maturity criteria and ERM best practices that were identified in this study may not be exhaustive even though close attention was paid in the research methodology adopted to circumvent this risk. Additionally, as the applicability of the best practices and the importance of the maturity criteria were checked in the context of CCFs, one should be cautious when the ERMMM is being applied in other construction firms outside of the CCFs domain.

The primary contribution is the provision of 191 specific action plans that could be followed to enhance ERM practice. These action plans are arguably the first to be presented for the construction industry and therefore add to existing knowledge of ERM now embedded within the KBDSS. In addition, the KBDSS-ERM is also the first computerized ERM tool developed specifically for construction firms. Using the KBDSS-ERM, the management can clearly understand its ERM implementation as well as the strengths and weaknesses, and obtain the action plans recommended by the KBDSS-ERM. Thus, with the information from the KBDSS-ERM, the management would make better decisions relating to ERM. For example, the management could decide which areas of ERM are worthwhile to have more investments and the resource investment priorities. It is worth reiterating that the KBDSS-ERM provides pertinent information to support the decision-making process rather than makes decisions for users. In addition, the KBDSS-ERM can serve as a tool for training the relevant staff. While using the KBDSS-ERM, the staffs need to read the ERM best practices, which allow them to learn the ERM fundamentals and produce practical or innovative ideas relating to ERM. Thus, the KBDSS-ERM would contribute to the organizational learning of companies. Although the KBDSS-ERM is primarily designed for CCFs, the implications of this study are not limited to CCFs because researchers and practitioners could adopt the research method in this study to develop KBDSSs for other construction firms.

Further research would develop a benchmarking system for ERM and establish a database containing the maturity scores collected from a large number of construction firms with various characteristics. The benchmarking system could be embedded into the KBDSS-ERM, which allows the users to compare their ERM implementation with the average implementation level of all the firms and those with certain firm characteristics, respectively. Thus, such a KBDSS can better support the decision-making process.

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(The Appendix follows overleaf.)

Appendix

Table AI. Action plans for the criterion "M01 commitment of the board and senior management"

Code	Action plans for improving ERM implementation Low→Medium	Medium→High	High→Very high
B01.1	Prepare a written ERM policy that at least covers the aim, principles and process of ERM, commitment, and relevant responsibilities and accountabilities Ensure that the ERM policy is approved by the board and senior management and understood by most of the risk owners	Include most of the critical aspects of ERM implementation (e.g. the aim, principles and process of ERM, commitment, responsibilities and accountabilities, risk appetite, risk communication, timing for monitoring and review of policies, etc.) into the written ERM policy Ensure that the ERM policy with the top approval is understood by all the risk owners and made known to all the staff	Ensure that the written ERM policy with the top approval covers all the critical aspects of ERM implementation (e.g. the aim, principles and process of ERM, commitment, responsibilities and accountabilities, risk appetite, risk communication, timing for monitoring and review of policies, etc.) Ensure that the written ERM policy is understood by all the risk owners and made known to all the staff
B01.2	Develop an ERM plan and tailor it to the corporate objectives and context Make the ERM plan understood by most of the risk owners	Ensure that the ERM plan is consistently tailored to the corporate objectives and context Ensure that the ERM plan is understood by all the risk owners and known to all the staff	
B01.3	Try to make decisions and implement ERM according to the ERM policy and plan	Ensure that most of the decision-making and ERM practices are fully consistent with the ERM policy and plan	Ensure that all the decision-making and ERM practices are fully consistent with the ERM policy and plan
B01.4	Involve the board and senior management in the risk oversight and the development of the ERM policy and plan	Ensure the active participation of the board and senior management in all the critical aspects of ERM implementation	
B01.5	Ensure the visible commitment to ERM from the board and senior management, making people perceive ERM as a priority for the leadership	Ensure the visible and continual commitment to ERM from the board and senior management	

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