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International Journal of Project Management 32 (2014) 452 – 460

International Journal of Project Management

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Assessing risk management capability of contractors in subway projects in mainland China

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Received 5 March 2013; received in revised form 5 July 2013; accepted 13 August 2013

Abstract

Contractor's risk management capability (RMC) reflects the sophistication of contractor's understanding of risk portfolio and how to manage those risks. This paper aims to develop a RMC assessment model for subway project contractors and to assess the current overall RMC of subway project contractors in mainland China. To achieve the objectives, a questionnaire survey was conducted and data were collected from 58 respondents. The empirical research findings showed that the overall RMC of subway project contractors can be regarded as between "low" and "medium". In addition, currently in subway projects' area, contactor's risk analysis capability is relatively more mature than other capabilities. However, contractors' risk management attitude is relatively less mature than other capabilities. Assessing the current RMC of subway project contractors can be used to identify the priority or weakest areas needed for improvement.
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Keywords: Risk management capability; Subway project; Contractor; Fuzzy synthetic evaluation; Mainland China

1. Introduction

Subways are constructed in major cities across mainland China to overcome the transportation problems in the urbanization process. Up to July 2007, statistical data provided by China's Ministry of Construction showed that 10 cities had constructed subway or light rail transit systems and had been successful in their operation. Moreover, urban rail transit construction programs in Beijing, Shanghai, Tianjin, Chongqing, Guangzhou, Shenzhen, Nanjing, Hangzhou, Wuhan, Chengdu, Harbin, Changchun, Shenyang, Xi'an, Suzhou and Changsha have been approved by the China State Council. By 2020, the total length of urban rail transit lines in the above cities is estimated to be about 2500 km (NDRC, 2007).

Urban rail transit can be divided into subway, light rail transit, tramway, suburban railway and so on according to traffic scope and vehicle type. The International Tunnelling Association (ITA, 2004) defined subway as an urban rail transit traffic system whose gross rail load on axle is relatively heavier and whose conveying capacity in a single direction is more than 30,000 persons per hour. Generally underground parts take about 70% of subway construction while the ground and elevated parts take about 30%. In China, most urban railway transit systems are subways (Xue et al., 2001). Thus, subway projects are the ones we focus on here.

At any stage of a life cycle, a project is plagued with various risks due to the complex and dynamic nature (Zhao et al., 2010). According to the Project Management Institute (PMI, 2008), project risk is an uncertain event that, if it occurs, impacts at least one project objective (e.g. quality, cost, and time) and risk management (RM) is fundamental to accomplish project objectives, and it is not only trying to keep away bad results but also acting as a guide to maximize positive results (Ghosh and Jintanapakanont, 2004; Monetti et al., 2006).

Subway projects are very risky due to the complex and unpredictable underground conditions, and if these risks are

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http://dx.doi.org/10.1016/j.ijproman.2013.08.007

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not identified, assessed and responded to properly, may cause problems in design, construction and operation (Zhu et al., 2008). Thus it is very important to conduct RM in subway projects and implementing RM in subway projects may bring a number of benefits (Nakano et al., 2007).

Risks are usually undertaken by all project participants, and the contractors that deal with construction work are more likely to confront risk accidents which may have a negative impact on all other project objectives such as cost overruns, delays, poor quality, loss of productivity and loss of morale (El-Sayegh, 2008). Thus, RM should be also emphasized and implemented by contractors to assure the achievement of project objectives.

Risk management capability (RMC) reflects the sophistication of an organization's understanding of its risk portfolio and how to manage those risks (Zou et al., 2010). Contractors with diverse RMC can reduce risk in different levels (Hopkins and Nightingale, 2006). Besides, assessing the current RMC of construction organizations can be used to identify the priority or weakest areas needed for improvement and actions can be taken to increase the performance (Hopkinson, 2011).

More specifically, the objectives of this paper are: (1) to identify appropriate indices to assess the RMC of subway project contractors; (2) to develop appropriate weightings for each index; (3) to develop a RMC assessment model for subway project contractors and (4) to assess the current overall RMC of subway project contractors in mainland China. Thus, the findings of this study provide practitioners with a clear understanding of the status quo of their RMC. It also forms a solid base for industrial practitioners to measure, evaluate and improve the current performance of their RMC. Besides, as few studies have focused on RMC in subway project contractors, this study contributes to the body of knowledge relating to the RMC of subway project contractors.

Following the introduction to this study, the second section provides the background information relating to the RM in mainland China, RMC and RMC assessment. In the third section, RMC indices are identified. Then research methodologies are presented in the fourth section. Then, using factor analysis, mean scoring ranking technique, and fuzzy synthetic evaluation as quantitative tools for data analysis, a RMC assessment model for subway project contractors is developed and the current overall RMC of subway project contractors in mainland China is assessed, and the results are discussed in the fifth section. Finally, the sixth section draws conclusions of this study and recommends further research.

2. Background

2.1. Risk management in subway projects in mainland China

In mainland China, research on RM in subway projects began with how to relieve the impact of risks by means of insurance (Chen, 2004). Research was extended to risk assessment in terms of market, resource, financing and engineering (Chen, 2004). Later, the development of RM for subway projects in mainland China followed the way experienced by other countries. Risks were focused on cost, geological uncertainty, pit excavation, shield tunneling and safety (Zou et al., 2010). After analyzing recent accidents in mainland China, people's competency and safety behavior were found to be big issues which in many cases contributed to the accidents (Zou et al., 2010). In summary, current RM in subway projects in mainland China mainly focuses on geological, technical and safety risk identification and assessment, while little effort has been committed to research on assessing RMC.

2.2. Risk management capability

Wang et al. (2004) indicated that RM is a formal and orderly process of systematically identifying, analyzing and responding to risks throughout the lifecycle of a project to obtain the optimum degree of risk elimination, mitigation and/or control. According to PMI (2004), to be successful, the organization should be committed to addressing the management of risk proactively and consistently throughout the project, in addition, establishing the maturity level of RMC in an organization is very important especially for construction organizations due to the high risk nature of their business.

Akkirajul et al. (2010) argued that enterprise RMC means the process, data, tools and the culture in the organization that enables one to manage risks. And it is necessary for organizations to have a clear view on their current approach to risk in order to define goals, specify processes, and manage progress in raising their RMC (Risk Management Research and Development Program Collaboration, 2002). The mature RMC can contribute to minimizing costs and improving profitability (Anagnostopoulos et al., 2005).

As Loosemore et al. (2006) indicated, many organizations operate at different levels of maturity for different types of risks. For example, an organization's RM culture may be as low as level 1 but achieved level 3 in RM processes. This means that while organizations may have developed sophisticated RM systems, they have not fully imbedded it within its organizational behavior and practices. Furthermore, Hopkinson (2011) indicated that assessing RMC can help identify the strengths and weaknesses of the organization and can also identify areas needing improvement. In short, assessing the current RMC of subway project contractors can be used to identify the priority or weakest areas needed for improvement and actions can be taken to increase the performance.

2.3. Risk management capability assessment

Specific to RMC assessment, several researches have been conducted by researchers and organizations such as Ren and Yeo (2004), HVR Consulting (2006), Risk and Insurance Management Inc. (RIMI) (2006), Loosemore et al. (2006), Zou et al. (2010), Risk Management Research Development Program Collaboration (RMRDPC) (2002), and International Association for Contract and Commercial Management (IACCM) (2003), all of whom have successfully developed RM maturity models. Some developments of maturity models originated from a generic risk maturity model proposed by Hillson, 1997.

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Loosemore et al. (2006) indicated that establishing RMC of an organization should be the starting point when embarking on a review of current RM practices, systems, and culture. Monetti et al. (2006) also indicated that to understand the RMC maturity level of a construction organization, a useful starting point is to review current RM processes and cultures. In addition, a formalized and standardized RM process has been widely seen as a critical attribute to measure the RMC in previous studies (e.g. Hillson, 1997; Hopkinson, 2011; Ren and Yeo, 2004; Zou et al., 2010).

Zou et al. (2010) describe the development process of a Web-based risk management maturity model (RM3), including its contents, its validation and testing, as well as its applications. The RM3 developed has five attributes namely, management, risk culture, ability to identify risk, ability to analyze risk, and application of standardized risk management process/system. And these attributes are measured against four levels: initial, repeated, managed, and optimized. In addition, the author found that the proposed RM3 was suitable and useful, and by using the RM3, the author found that the Australian construction industry's overall RM maturity level was relatively low where 32% rated at level 2 and 52% rated at level 3.

However, little effort has been committed to research on assessing RMC of contractors in subway projects in mainland China. This paper attempts to fill this knowledge gap.

3. Identifying RMC index

The indices to assess RMC of subway project contractors in this paper were derived from various literatures as described above. The indices in the existing models and literature were reviewed and assessed (Hillson, 1997; Hopkinson, 2011; IACCM, 2003; Loosemore et al., 2006; Monetti et al., 2006; Ren and Yeo, 2004; RIMI, 2006; RMRDPC, 2002; Zou et al., 2010). Based on the comparison, the most suitable 21 RMC indices were determined to evaluate an organization's RMC (Table 1). By combining these 21 indices, it will show the overall RMC of contractors in subway project.

4. Research methodology

4.1. Overall research framework

The methodology employed in this research study was adapted from Chan et al.'s and Xu et al.'s research (Chan et al., 2004; Xu et al., 2010a, 2010b). It is based on a comprehensive literature review with questionnaire survey for data collection, factor analysis, mean scoring ranking technique, and fuzzy synthetic evaluation as quantitative tools for data analysis.

4.2. Questionnaire survey

As described above a comprehensive literature review was conducted to establish a foundation for this study and to support the development of a survey questionnaire. A pilot study was conducted with a couple of project managers in subway projects to validate the questionnaire. The questionnaire consisted of four main sections. The first section included questions meant to profile the respondents and their companies. In the second section, the respondents were asked to provide the number of subway projects that their companies had been engaged in and the location of projects during the past five years as well as the amount of projects was stratified according to project cost. In the third section, the respondents were asked to rate the importance of 21 RMC indices for contractors in subway projects using a five-point Likert scale (1 = least important and 5 = most important). In the fourth section, the respondents were asked to rate the states of RMC maturity level of their own companies based on 21 RMC indices also using a five-point Likert scale (1 = least mature and 5 = most mature).

A total of 200 survey questionnaires were sent out to contractors. The contractors in the sample were selected from Special Grade and Grade 1 contractors in mainland China. According to the principles defined in regulation on qualification management for construction contractors, Special Grade and Grade 1 contractors are dominant in subway projects (Shen et al., 2004). A review of the selected contractors showed that they covered most provinces apart from Tibet, Inner Mongolia and Qinghai. These regions are relatively less developed in terms of construction and thus have fewer Special Grade and Grade 1 contractors. A total of 58 complete questionnaires were returned, representing a response rate of 29%, which was in accordance with the norm of 20–30% with most questionnaire surveys in the construction industry (Akintoye, 2000). The low response rate could be due to the sensitivity and confidentiality of information which companies were unwilling to divulge. Table 2 presents the profile of the data collected from the questionnaire.

According to Table 2, among the respondents, 10.34% of them were senior managers while 32.76% were project managers and 56.90% were engineers. In addition, 24 (41.38%) out of the 58 respondents have more than 15 years of experience and 66.76% have more than 10 years of experience in the construction industry, which would ensure that the responses collected were accurate and trustworthy. Furthermore, in terms of the contractors, 33 (56.90%) out of the 58 contractors are Special Grade, and 25 (43.10%) are Grade 1 contractors. Also 84.48% of them have more than 10 years of experience in the subway projects, which could affirm the reliability and quality of data.

Furthermore, Table 2 summarizes the number of subway projects in which the companies had participated in the past five years. Among the 242 subway projects surveyed, 9.09% were less than 100 million RMB, 44.63% were equal or more than 100 million RMB but less than 1 billion RMB, 40.91% were equal or more than 1 billion RMB but less than 10 billion RMB, and 5.37% were equal or more than 10 billion RMB. In addition, when it comes to the project location, there are 16 cities in mainland China where subway projects are constructed and these respondents carried out their subway projects in all these cities.

4.3. Factor analysis

The basic assumption of factor analysis (FA) is that underlying dimensions or factors can be used to explain complex

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Table 1
Factor loading of the RMC indices for subway project contractors in mainland China.

No.	Critical index	Factor loading	Percentage of variance explained	Cumulative percentage of variance explained
Factor 1: RM attitude			13.211	13.211
1	Initiative to take part in risk activities	0.852		
2	Leaders support and encourage RM	0.722		
3	Resources dedicated to projects in accordance to the severity of risk events identified	0.654		
Factor 2: RM culture			12.645	25.856
4	Every member is responsible for managing risk	0.851		
5	Risk events are openly communicated within the team	0.847		
6	Team members are familiar with RM concepts and methods	0.697		
7	RM is widely practiced in every level of the team	0.585		
Factor 3: Risk identification capability			9.923	35.779
8	Potential risks could be identified for new projects	0.734		
9	A systematic analysis method is used	0.722		
10	Actual risks found are compared against initial identified risks	0.596		
Factor 4: Risk analysis capability			9.679	45.458
11	Every member grasps risk analysis skills	0.775		
12	A systematic analysis method is used	0.702		
13	The probability and severity of all risks could be assessed	0.665		
Factor 5: Risk response capability			11.118	56.576
14	Risk impacts could be reduced at most extent	0.842		
15	A systematic response method is used	0.699		
16	Every member grasps effective risk response method	0.604		
17	Appropriate measures are taken for reducing different risks	0.549		
Factor 6: Development and application of standardized RM process			9.776	66.352
18	Risks are consistently identified, analyzed, and responded throughout the project life cycle	0.806		
19	RM process is standardized	0.776		
20	RM process is woven into daily business processes of the organization	0.773		
21	RM process is often reviewed to ensure its applicability	0.588		

phenomena. In general, the model for the ith standardized variable is written as Eq. (1) (Norusis, 2008):

$$X_i = A_{i1} F_1 + A_{i2} F_2 + \cdots \in + A_{ik} F_k + U_i \quad (1)$$

where

F represents the common factor;
U represents the unique factor; and
A represents the coefficient used to combine the k factors.

In addition, the general expression for the estimate of the jth factor is shown in Eq. (2) (Norusis, 2008):

$$F_j = \sum_{i=1}^{p} W_{ji} X_i = W_{j1} X_1 + W_{j2} X_{i2} + \cdots + W_{jp} X_p \quad (2)$$

where

W represents factor score coefficients; and
p represents number of variables.

In this study the FA technique was used to identify the underlying RMC indices of subway project contractors in China. The appropriateness of the factor model was evaluated before using FA in this research. The sampling adequacy using Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity can be used to test out the appropriateness (Geourge and Mallery, 1999; Ghosh and Jintanapakanont, 2004; Xu et al., 2010a, 2010b). Furthermore, to ensure the reliability of each index, Cronbach's coefficient was used to test the internal consistency among the items included in each index and a minimum of 0.7 is sufficient (Norusis, 2008).

4.4. Mean scoring ranking technique

Chan and Kumaraswamy (1996) adopted the mean scoring (MS) method to establish the relative importance of causes of delay in building construction projects in Hong Kong as suggested by the clients, consultants, and contractors. The data collected from the current questionnaire survey were also analyzed using the same technique. The five-point Likert scale (1 = least important and 5 = most important) as described previously was used to calculate the MS for each index, which was then used to determine its relative ranking in descending order of importance. These rankings made it possible to triangulate the relative importance of the RMC indices. The MS for each RMC index was computed by the following formula (Eq. (3)):

$$M = \frac{\sum_{i=1}^{s} s_i f_i}{\sum_{i=1}^{s} f_i} \quad (3)$$

where:

s_i represents weight assigned to ith response, s_i = 1, 2, 3, 4 and 5 for i = 1, 2, 3, 4 and 5,respectively;

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Table 2
Profile of respondents and companies.

Characteristic			N	%
Respondents	Job title	Senior manager	6	10.34
		Project manager	19	32.76
		Engineer	33	56.90
	Years of experience	0–4	2	3.45
		5–9	13	22.41
		10–14	19	32.76
		≥15	24	41.38
Companies	Grade	Special Grade	33	56.90
		Grade 1	25	43.10
	Years of experience in subway projects	0–9	9	15.52
		10–19	19	32.76
		20–29	25	43.10
		≥30	5	8.62
Project (N = 242)	Project cost (RMB)	<100 million	22	9.09
		≥100 million but <1 billion	108	44.63
		≥1 billion but <10 billion	99	40.91
		≥10 billion	13	5.37
	Project location	Beijing	55	22.73
		Shanghai	39	16.12
		Chongqing	11	4.55
		Tianjin	15	6.20
		Guangzhou	33	13.64
		Shenzhen	29	11.98
		Nanjing	31	12.81
		Hangzhou	9	3.72
		Wuhan	3	1.24
		Chengdu	2	0.83
		Harbin	1	0.41
		Changchun	1	0.41
		Shenyang	2	0.83
		Xi'an	4	1.65
		Changsha	2	0.83
		Suzhou	5	2.07

f_i represents frequency of the ith response; and
i represents response category index = 1, 2, 3, 4 and 5 from the least important to the most important, respectively.

4.5. Fuzzy synthetic evaluation

Fuzzy synthetic evaluation is a method to assess multiple criteria decision making. Its purpose is to provide a synthetic evaluation of an object relative to an objective in a fuzzy decision environment with a number of factors (Hsu and Yang, 1997). A multicriteria evaluation model requires three basic elements (Xu et al., 2010a, 2010b):

1. A family of basic criteria/indices $f = \{f_1, f_2, \ldots, f_m\}$;
2. A set of alternatives $E = \{e_1, e_2, \ldots, e_n\}$; and
3. For every object $u \notin U$, there is an evaluation matrix $R = (r_{ij})_{m*n}$. In the fuzzy environment, r_{ij} is the degree to which alternative e_j satisfies the criterion f_j. It is presented by the fuzzy membership function of alternative e_j with respect to the criterion f_j. With the preceding three elements, for a given $u \notin U$, its evaluation result can be derived.

In this study, fuzzy synthetic evaluation is used to calculate the current overall RMC of subway project contractors in mainland China. RMC assessment involves a large number of indices and sub-indices. During the evaluation process, all the indices and sub-indices have to be scrutinized in order to ensure effectiveness. Hence, it would be more desirable if a synthetic evaluation method could be adopted to solve this multi-attribute and multi-level problem. As an application of fuzzy set theory, fuzzy synthetic evaluation has been adopted in many fields. Lu et al. (1999) adopted fuzzy synthetic evaluation for the analysis of reservoir water quality. Hsu and Yang (1997) developed a fuzzy synthetic decision system for use in human resources management. From these previous research studies, it can be seen that fuzzy synthetic evaluation has merits in handling complicated evaluation with multi-attributes and multi-levels. Thus, it is appropriate to adopt the fuzzy synthetic evaluation method to develop a fuzzy assessment model in this research study.

5. Results and discussions

5.1. Factor analysis

Factor analysis was performed on the 21 indices. To ensure suitability for conducting factor analysis, Kaiser–Meyer–Olkin (KMO) test and Bartlett's test of sphericity were used (Ghosh, and Jintanapakanont, 2004; Xu et al., 2010a, 2010b). The KMO test measures the adequacy of a sample in terms of the distribution of values for the execution of factor analysis (Geourge and Mallery, 1999; Ghosh and Jintanapakanont, 2004; Xu et al., 2010a, 2010b) and the acceptable values should be greater than 0.5 (Norusis, 2008). To reinforce the appropriateness of factor analysis, Bartlett's test of sphericity was also carried out. Bartlett's test of sphericity determines if the correlation matrix is an identity matrix. If there exists an identity matrix, factor analysis is meaningless (Field, 2000; Pett et al., 2003). The result of the KMO test was 0.703 and the value of Bartlett's test of sphericity was 991.321 with an associated significance level of 0.000. Both tests indicated the suitability of the variables for factor analysis.

Factor loadings are the correlations of the variables with the factor. High factor loading implies that the factors and variables are critical (Kline, 1996). Principal factor extraction with varimax rotation was performed through SPSS software package for the 21 indices derived from the sample of 58 responses. Six new indices were extracted after 5 iterations, which accounted for 66.35% of the variance in responses (Table 1). Therefore, the previous 21 indices are regarded as sub-indices. New indices resulting from factor analysis are given the labels of (as shown in Table 1): (1) RM attitude; (2) RM culture; (3) risk identification capability; (4) risk analysis capability; (5) risk response capability; and (6) development and application of standardized RM process. It is believed that the six indices derived are most important indices to assess the RMC of subway project contractors in mainland China. In this paper all factor loadings were found to be above 0.5 (Table 1). To ensure the reliability of each index, Cronbach's coefficient was used to test the internal consistency among the

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items included in each index and a minimum of 0.7 is sufficient (Norusis, 2008), and the values for all indices ranged from 0.749 to 0.852. These values were at an acceptable level, making all indices reliable. In general, the loadings and the interpretation of the factors extracted were reasonably consistent.

5.2. Developing appropriate weightings for the RMC indices for contractors in subway projects

The mean ratings of a particular index are calculated (Table 3) by the summation of individual ratings (provided by the respondents) of a particular index divided by the total number of respondents who provided the ratings by using Eq. (3) as described previously above.

Then a series of weighted indices were developed based on the mean ratings of these data. The weightings for each of the index were computed by using Eq. (4) (Yeung et al., 2007):

$$\begin{aligned} &X = (X_1, X_2, \ldots X_m) \\ &X_j(M_1, \ldots M_m) = \frac{M_j}{\sum_{j=1}^{m} M_j} \\ &j = 1, 2, \ldots, m \\ &X_j \in [0, 1] X_1 + X_2 + \cdots X_m = 1 \\ &j = 1, 2, \ldots, m \end{aligned} \tag{4}$$

where:

X_j represents the weighting of a particular index;
M_j represents the mean ratings of a particular index;
ΣM_j represents the summation of mean ratings of all the indices.

Table 3 shows the indices together with their corresponding weightings for assessing contractor's RMC in subway projects.

5.3. Determination of the membership function for the state of each RMC index

As mentioned earlier, a total of 21 RMC sub-indices were identified for assessing the overall RMC level of subway project contractors in mainland China. Suppose that the set of basic criteria in fuzzy RM model to be $f = \{f_1, f_2, \ldots, f_{21}\}$; and the grades for selection for the states of RMC level are defined as $E = \{1; 2; 3; 4; 5\}$where 1 = very low; 2 = low; 3 = medium; 4 = high; and 5 = very high. For each contractor's current RMC level, the membership function can be formed by the results of questionnaire survey. For example, the survey results on the initiative to take part in risk activities indicated that 22% of the respondents opined the maturity of this capability as very low, 33% as low, 24% as medium, 16% as high and 5% as very high. Therefore the membership function of this capability maturity level is given by Eq. (5):

$$\begin{aligned} B_1 &= \frac{0.22}{\text{very low}} + \frac{0.33}{\text{low}} + \frac{0.24}{\text{medium}} + \frac{0.16}{\text{high}} + \frac{0.05}{\text{very high}} \\ &= \frac{0.22}{1} + \frac{0.33}{2} + \frac{0.24}{3} + \frac{0.16}{4} + \frac{0.05}{5}. \end{aligned} \tag{5}$$

It can also be written as (0.22, 0.33, 0.24, 0.16, 0.05). Similarly, the membership functions of all RMC sub-indices' maturity level for contractors in subway projects can be written in the same way (Table 4).

Table 3
The mean ratings and weightings of RMC indices for subway project contractors in mainland China.

Risk management capability index		Mean	Total mean	Weighting	Total weight in g
RM attitude	Initiative to take part in risk activities	2.88	8.95	0.32	0.11
	Leaders support and encourage RM	2.96		0.33	
	Resources dedicated to projects in accordance to the severity of risk events identified	3.11		0.35	
RM culture	Every member is responsible for managing risk	2.43	11.69	0.21	0.14
	Risk events are openly communicated within the team	2.17		0.19	
	Team members are familiar with RM concepts and methods	3.77		0.32	
	RM is widely practiced in every level of the team.	3.32		0.28	
Risk identification capability	Potential risks could be identified for new projects	3.99	12.38	0.32	0.15
	A systematic identification method is used	4.17		0.34	
	Actual risks found are compared against initial identified risks	4.22		0.34	
Risk analysis capability	Every member grasps risk analysis skills	4.15	13.52	0.31	0.16
	A systematic analysis method is used	4.66		0.34	
	The probability and severity of all risks could be assessed	4.71		0.35	
Risk response capability	Risk impacts could be reduced at most extent	4.34	18.7	0.23	0.22
	A systematic response method is used	4.72		0.25	
	Every member grasps effective risk response method	4.81		0.26	
	Appropriate measures are taken for reducing different risks	4.83		0.26	
Development and application of standardized RM process	Risks are consistently identified, analyzed, and responded throughout the project life cycle	4.85	18.16	0.27	0.22
	RM process is standardized	4.76		0.26	
	RM process is woven into daily business processes of the organization	3.97		0.22	
	RM process is often reviewed to ensure its applicability	4.58		0.25	

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Table 4
The membership function of all states of RMC indices for subway project contractors in mainland China.

RM capability index		Weighting	Membership function of level 3	Membership function of level 2
RM attitude	Initiative to take part in risk activities	0.32	(0.22, 0.33, 0.24, 0.16, 0.05)	(0.20, 0.35, 0.29, 0.10, 0.06)
	Leaders support and encourage risk management	0.33	(0.12, 0.33, 0.38, 0.09, 0.09)	
	Resources dedicated to projects in accordance to the severity of risk events identified	0.35	(0.26, 0.40, 0.26, 0.05, 0.03)	
RM culture	Every member is responsible for managing risk	0.21	(0.03, 0.40, 0.31, 0.16, 0.10)	(0.08, 0.30, 0.37, 0.19, 0.07)
	Risk events are openly communicated within the team	0.19	(0.02, 0.14, 0.43, 0.34, 0.07)	
	Team members are familiar with risk management concepts and methods	0.32	(0.09, 0.26, 0.41, 0.19, 0.05)	
	RM is widely practiced in every level of the team.	0.28	(0.16, 0.38, 0.31, 0.10, 0.05)	
Risk identification capability	Potential risks could be identified for new projects	0.32	(0.00, 0.26, 0.45, 0.22, 0.07)	(0.05, 0.29, 0.33, 0.25, 0.09)
	A systematic identification method is used	0.34	(0.03, 0.19, 0.28, 0.40, 0.10)	
	Actual risks found are compared against initial identified risks	0.34	(0.12, 0.41, 0.26, 0.12, 0.09)	
Risk analysis capability	Every member grasps risk analysis skills	0.31	(0.03, 0.16, 0.48, 0.28, 0.05)	(0.01, 0.13, 0.44, 0.28, 0.14)
	A systematic analysis method is used	0.34	(0.00, 0.14, 0.48, 0.26, 0.12)	
	The probability and severity of all risks could be assessed	0.35	(0.00, 0.10, 0.36, 0.29, 0.24)	
Risk response capability	Risk impacts could be reduced at most extent	0.23	(0.26, 0.36, 0.24, 0.10, 0.03)	(0.12, 0.27, 0.33, 0.17, 0.11)
	A systematic response method is used	0.25	(0.05, 0.29, 0.41, 0.16, 0.09)	
	Every member grasps effective risk response method	0.26	(0.14, 0.29, 0.29, 0.17, 0.10)	
	Appropriate measures are taken for reducing different risks	0.26	(0.03, 0.14, 0.36, 0.26, 0.21)	
Development and application of standardized RM process	Risks are consistently identified, analyzed, and responded throughout the project life cycle	0.27	(0.05, 0.19, 0.50, 0.16, 0.10)	(0.08, 0.23, 0.38, 0.19, 0.11)
	RM process is standardized	0.26	(0.02, 0.14, 0.29, 0.36, 0.19)	
	RM process is woven into daily business processes of the organization	0.22	(0.16, 0.28, 0.38, 0.12, 0.07)	
	RM process is often reviewed to ensure its applicability	0.25	(0.12, 0.34, 0.36, 0.10, 0.07)	

5.4. Developing a fuzzy synthetic evaluation model for RMC of contractors in subway projects

After developing appropriate weightings for the 21 RMC sub-indices and 6 RMC indices for contractors in subway projects, and following the establishment of fuzzy membership functions for each RMC sub-indices, a model (Model 1) was built to assess the overall RMC maturity level of contractors in subway projects in mainland China.

$$\text{Model 1}: \mathrm{M}(\bullet, \oplus), \quad \mathrm{a_j} = \min\left(1, \sum_{i=1}^{m} X_i * r_{ij}\right) \qquad \forall \mathrm{a_j} \in \mathrm{A}$$

where:

X_j represents the weighting of a particular RMC index; and
r_{ij} represents the membership function of a particular state of RMC index.

This model is suitable when many criteria are considered and the difference in the weighting of each criterion is not great (Xu et al., 2010a, 2010b). It should be noted that there are three levels of membership function. Level 3 refers to each of 21 RMC sub-indices (membership function of each RMC sub-index). Level 2 refers to each of 6 RMC indices (membership function of each RMC index). Level 1 refers to the overall RMC (membership function of overall RMC). In addition, it should be noted that the membership functions of all the states of RMC indices for subway project contractors are derived from the Model 1 mentioned above. Take RM attitude for example, its membership function is as follows:

$$\begin{aligned}(0.32\ 0.33\ 0.35)&\begin{bmatrix}0.22\ 0.33\ 0.24\ 0.16\ 0.05\\ 0.12\ 0.33\ 0.38\ 0.09\ 0.09\\ 0.26\ 0.40\ 0.26\ 0.05\ 0.03\end{bmatrix}\\ &= (0.32*0.22+0.33*0.12\\ &\quad +0.35*0.26, 0.32*0.33+0.33*0.33\\ &\quad +0.35*0.40, 0.32*0.24+0.33*0.38\\ &\quad +0.35*0.26, 0.32*0.16+0.33*0.09\\ &\quad +0.35*0.05, 0.32*0.05+0.33*0.09\\ &\quad +0.35*0.03)\\ &= (0.20, 0.35, 0.29, 0.10, 0.06).\end{aligned}$$

Similarly, the results of fuzzy synthetic evaluation are shown in Tables 4 and 5.After deriving the membership function of level 1, the overall RMC level can be calculated using Eq. (6):

$$\mathrm{RMCL} = \sum\nolimits_{k=1}^{5} (\mathrm{X} * \mathrm{R_k}) * \mathrm{L} \tag{6}$$

where

RMCL represents the RMC maturity level;
X represents the weighting of each RMC index;
R represents the membership function of each state of RMC index; and
L represents the linguistic variable where 1 = very low; 2 = low; 3 = medium; 4 = high; and 5 = very high.

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Table 5
The membership function of overall RMC level for subway project contractors in mainland China.

RM capability index	Weighting	Membership function of level 2	Membership function of level 1
RM attitude	0.32	(0.20, 0.35, 0.29, 0.10, 0.06)	(0.09, 0.26, 0.36, 0.20, 0.10)
RM culture	0.21	(0.08, 0.30, 0.37, 0.19, 0.07)	
Risk identification capability	0.32	(0.05, 0.29, 0.33, 0.25, 0.09)	
Risk analysis capability	0.31	(0.01, 0.13, 0.44, 0.28, 0.14)	
Risk response capability	0.23	(0.12, 0.27, 0.33, 0.17, 0.11)	
Development and application of standardized RM process	0.27	(0.08, 0.23, 0.38, 0.19, 0.11)	

Therefore, the overall RMC level of subway project contractors in mainland China is:

$$0.09 * 1 + 0.26 * 2 + 0.36 * 3 + 0.20 * 4 + 0.10 * 5 = 2.99.$$

To have an in-depth analysis, the level of a particular RMC index state can also be calculated using the same method. Take the RM attitude for example, the capability level of RM attitude is:

$$0.20 * 1 + 0.35 * 2 + 0.29 * 3 + 0.10 * 4 + 0.06 * 5 = 2.47.$$

Similarly, the results of RMC level are shown in Table 6.

The empirical research findings (Table 6) showed that the overall RMC levels of contractors in subway projects in mainland China was 2.99, which can be regarded as between "low" and "medium"; the results are similar to the Australian construction organizations' RMC level (Zou et al., 2010). Therefore, the overall RMC level of contractors in subway projects in mainland China is far from maturity. It needs to be emphasized and improved. In addition, currently in subway projects' area, contractors operate at different levels of maturity for different particular RMC which is in accordance to the results indicated by Loosemore et al. (2006). Contactor's risk analysis capability is relatively more mature than other capabilities and it is regarded as between "medium" and "high". This means that the subway project contractors of mainland China may have paid more attention on risk analysis skills and developed sophisticated risk analysis method. Besides, the second mature capability is risk identification capability; it is also between "medium" and "high". In addition, development and application of standardized RM process is the third mature one, the capability level is between "low" and "medium". Moreover, RM culture and risk response capability are relatively the fourth and the fifth mature risk management capability. All their levels are between "low" and "medium". Furthermore, it is found that the weakest capability is RM attitude for which improvements are prioritized, the capability level is between "low" and "medium"; it is therefore necessary to pay more attention to improve people's initiative to take part in risk activities and dedicate sufficient resources to projects in accordance to the severity of risk events identified.

Table 6
Results of RMC level for subway project contractors in mainland China.

RMC	Level
RM attitude	2.47
RM culture	2.90
Risk identification capability	3.07
Risk analysis capability	3.41
Risk response capability	2.88
Development and application of standardized RM process	2.99
Overall RM capability	2.99

6. Conclusion

This research study has adopted a novel approach to develop a practical RMC assessment model for subway project contractors based on data obtained from mainland China. By doing so, it provides an opportunity for contractors helping identify the RM strengths and weaknesses of the organization, and can also identify areas needing improvement to increase the performance. This research found 6 indices to test different aspects of contractor's RMC, including: RM attitude; RM culture; risk identification capability; risk analysis capability; risk response capability and development and application of standardized RM process. The research findings showed that the overall RMC levels of contractors in subway projects in mainland China can be regarded as between "low" and "medium". And among the 6 different aspects, the top two RMC levels of subway project contractors were: (1) contactor's risk analysis capability; and (2) contactor's risk identification capability. Both of them are between "repeatable" and "managed". These findings also revealed that RM attitude is the least mature RMC aspect that place critical barriers for subway project contractors to succeed in RM.

This research has developed a comprehensive, objective, reliable, and practical evaluation model for assessing the RMC level of subway project contractors in mainland China using questionnaire survey technique and a fuzzy synthetic evaluation approach. The development of RMC index not only enhances the understanding of contractors and in implementing a successful RM, but it also forms a solid base for industrial practitioners to measure, evaluate, and improve the current performance of their RMC. However, there are some limitations. First, as the sample size in this study was small, caution should be warranted when the analysis results are interpreted and generalized. Also, the importance of 21 RMC sub-indices for contractors in subway projects and the states of RMC maturity level of their own companies based on 21 RMC sub-indices were assessed by the respondents based on their experience and perception. Thus, the data inevitably involved subjectivity. Actually, this is a common problem for most studies using questionnaire survey to collect data, and most assessment relating to RM was based on the

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experience and subjective judgment (Raz and Michael, 2001; Wiguna and Scott, 2006).

Future studies would be conducted to assess the RMC of contractors in other projects or in other countries and to investigate the relationship between the RMC and improvement in performance (e.g. quality, cost, schedule, safety, productivity and customer satisfaction) Also, it is interesting to study on how to improve RMC.

Acknowledgments

The work described in this paper was supported by the China Scholarship Council (No. 201206090095), the Fundamental Research Funds for the Central Universities and graduates' Science and Innovation Foundation of Jiangsu Province (No. CXZZ12_0125). We gratefully acknowledge and thank those who have responded to and contributed their valuable input to complete the survey questionnaires and we also thank those who have given suggestions. The anonymous reviewers and the editor of this paper are also acknowledged for their constructive comments and suggestions.

References

Akintoye, A., 2000. Analysis of factors influencing project cost estimating practice. Constr. Manag. Econ. 18 (1), 77–89.

Akkirajul, R., Nayak, N., Torok, R., Kaenell, J., 2010. A practitioner's tool for enterprise risk management capability assessment. Service Operations and Logistics and Informatics (SOLI), 2010 IEEE International Conference, pp. 369–374.

Anagnostopoulos, K.P., Milonas, A., Roumboutsos, A., 2005. Construction sector risk considerations on PPP projects in Greece. In: Pantouvakis, J., et al. (Ed.), Proc., 3rd Int. Conf. on Construction in the 21st Century "Advancing Engineering, Management and Technology". National Technical Univ. of Athens and Florida International Univ., Athens, Greece.

Chan, D.W.M., Kumaraswamy, M.M., 1996. An evaluation of construction time performance in the building industry. Build. Environ. 31 (6), 569–578.

Chan, A.P.C., Chan, D.W.M., Chiang, Y.H., Tang, B.S., Chan, E.H.W., Ho, K.S.K., 2004. Exploring critical success factors for partnering in construction projects. J. Constr. Eng. Manag. 130 (2), 188–198.

Chen, L., 2004. Risk Analysis and Assessment During Construction of Soft Soil Shield Tunnel in Urban Area (in Chinese). (Doctoral thesis) Tongji University, Shanghai.

HVR Consulting, 2006. Project Risk Maturity Model Scope. HVR Consulting, Alton, UK.

El-Sayegh, S.M., 2008. Risk assessment and allocation in the UAE construction industry. Int. J. Proj. Manag. 26 (4), 431–438.

Field, A., 2000. Discovering Statistics Using SPSS for Windows: Advance Techniques for the Beginner. Sage Publication, Great Britain.

Geourge, D., Mallery, P., 1999. SPSS for Windows Step by Step: A Simple Guide and Reference. Allyn and Bacon, USA.

Ghosh, S., Jintanapakanont, J., 2004. Identifying and assessing the critical risk factors in an underground rail project in Thailand: a factor analysis approach. Int. J. Proj. Manag. 22, 633–643.

Hillson, D.A., 1997. Towards a risk maturity model. Int. J. Proj. Manag. Bus. Risk Manag. 1 (1), 35–45.

Hopkins, M.M., Nightingale, P., 2006. Strategic risk management using complementary assets: organizational capabilities and the commercialization of human genetic testing in the UK. Res. Policy 35 (3), 355–374.

Hopkinson, M., 2011. The Project Risk Maturity Model: Measuring and Improving Risk Management Capability. Gower, Burlington, VT.

Hsu, T.H., Yang, T.S., 1997. The application of fuzzy synthetic decision to the human resource management. Fu Jen Manag. Rev. 4 (2), 85–100.

International Association for Contract, Commercial Management (IACCM), 2003. Organizational maturity in business risk management. The IACCM Business Risk Management Maturity Model (BRM3). May 20, 2008.

ITA, 2004. Guidelines for tunnelling risk management: International Tunnelling Association, Working Group No. 2. Tunn. Undergr. Space Technol. 19 (3), 217–237.

Kline, P., 1996. An Easy Guide to Factor Analysis. Routledge, Great Britain.

Loosemore, M., Raftery, J., Reilly, C., Higgon, D., 2006. Risk Management in Projects, 2nd ed. Taylor and Francis, New York.

Lu, R.S., Lo, S.L., Hu, J.Y., 1999. Analysis of reservoir water quality using fuzzy synthetic evaluation. Stoch. Env. Res. Risk A. 13 (5), 327–336.

Monetti, E., Rosa, S.A., Rocha, R.M., 2006. The practice of project risk management in government projects: a case study in Sao Paulo City. Construction in Developing Economics: New Issues and Challenges.Santiago, Chile (18–20 January 2006).

Nakano, A., Sahabdeen, M., Kulindran, A., Seah, T., 2007. Excavation management for slurry TBMs tunnelling under residential houses at C853 (CCL3) project. Proceedings of Underground Singapore 2007, Singapore, pp. 38–45.

National Development, Reform Commission (NDRC), 2007. Middle and Long Term Development on Comprehensive Communication Network ((in Chinese) 15 November, 2007).

Norusis, M.J., 2008. SPSS 16.0 Statistical Procedures Companion, second edition. Prentice Hall.

Pett, M.A., Lackey, N.R., Sullivan, J.J., 2003. Making Sense of Factor Analysis: The Use of Factor Analysis for Instrument Development in Health Care Research. Sage Publication, Thousand Oaks, Calif.

PMI, 2004. A Guide to the Project Management Body of Knowledge. Project Management Institute, Newtown Square, PA.

PMI, 2008. A Guide to the Project Management Body of Knowledge. Project Management Institute, Newtown Square, PA.

Raz, T., Michael, E., 2001. Use and benefits of tools for project risk management. Int. J. Proj. Manag. 19 (1), 9–17.

Ren, Y.T., Yeo, K.T., 2004. Risk management capability maturity model for complex product system (CoPS) projects. Proceedings of International Engineering Management Conference, pp. 801–871.

Risk and Insurance Management Inc. (RIMI), 2006. RIMS Risk Maturity Model (RMM) for Enterprise Risk Management (June 13, 2007).

Risk Management Research Development Program Collaboration (RMRDPC), 2002. Risk Management Maturity Level Development (May 14, 2007).

Shen, L.Y., Li, Q.M., Drew, D., Shen, Q.P., 2004. Awarding construction contracts on multicriteria basis in China. J. Constr. Eng. Manag. 130 (3), 385–393.

Wang, S.Q., Dulaimi, M.F., Aruria, M.Y., 2004. Risk management framework for construction projects in developing countries. Constr. Manag. Econ. 22 (3), 237–252.

Wiguna, I.P.A., Scott, S., 2006. Relating risk to project performance in Indonesian building contracts. Constr. Manag. Econ. 24 (11), 1125–1135.

Xu, Y., Chan, A.P.C., Yeung, J.F.Y., 2010a. Developing a fuzzy risk allocation model for PPP projects in China. J. Constr. Eng. Manag. 136 (8), 894–903.

Xu, Y., Yeung, J.F.Y., Chan, A.P.C., Chan, D.W.M., Wang, S., Ke, Y., 2010b. Developing a risk assessment model for PPP projects in China: a fuzzy synthetic evaluation approach. Autom. Constr. 19, 929–943.

Xue, X., Schmid, F., Smith, R.A., 2001. An introduction to China's rail transport. Part 2: urban rail transit systems, highway transport and the reform of China's railways. Proc. Inst. Mech. Eng. Part F J. Rail Rapid Transit 216, 165–174.

Yeung, J.F.Y., Chan, A.P.C., Chan, D.W.M., 2007. Development of a partnering performance index (PPI) for construction projects in Hong Kong: a Delphi study. Constr. Manag. Econ. 25 (12), 1219–1237.

Zhao, Z.Y., Lv, Q.L., Zuo, J., Zillante, G., 2010. Prediction system for change management in construction project. J. Constr. Eng. Manag. 136 (6), 659–669.

Zhu, S.L., Wang, W.B., Liu, W.N., Lu, M.L., 2008. Risk management in subway construction. Urban Rapid Rail Transit 1 (21), 56–60.

Zou, P.X.W., Chen, Y., Chan, T., 2010. Understanding and improving your risk management capability: assessment model for construction organizations. J. Constr. Eng. Manag. 136 (8), 854–863.