Assessment of Construction Risk Management Maturity Using Hybrid Fuzzy Analytical Hierarchy Process and Fuzzy Synthetic Approach: Iraq as Case Study

Hayder Razzaq Abed*[iD], Hatim A. Rashid[iD]

Civil Engineering Department, College of Engineering, Al-Nahrain University, Baghdad 10072, Iraq

Corresponding Author Email: st.hayder.razzaq@ced.nahrainuniv.edu.iq

ABSTRACT

Knowing and developing the construction organizations' maturity level in risk management is critical to ensure they achieve their strategic objectives. This paper aims to design a new construction organizations' risk-management maturity model (C.ORM3) using new hybrid techniques and a distinct validation strategy based on global and local experience, to assess risk management maturity level in developing countries. A multi-steps methodology was adopted in this research. The study adopted an excessive systematic literature reviews of 22 previous articles on RM maturity and four standards and guidelines for eliciting model components. These components include five attributes with 26 capabilities; 24 capabilities identified from literature review and 2 from experts. These capabilities are evaluated against five levels: immature, ad-hoc, standard, managed, and optimized. The authors adopted a new strategy for validating the model by three groups of global and local experts and verifying the proposed model in a realistic-world case study. This study is the first to use a hybrid method based on the Fuzzy Analytic Hierarchy Process (FAHP) and Fuzzy Synthetic Evaluation (FSE) techniques in evaluating RM maturity (RMM). Iraqi construction organizations validate the practicality of the model. The results showed that the overall RMM level of the Iraqi construction sector is 1.52, between immature and ad-hoc. The model has been converted into a computer template for ease of use by organizations. This study concluded that the suggested C.ORM3 helpful for construction organisations to evaluate their current state of RM and plan for future development.

1. INTRODUCTION

A risk is an event or set of circumstances that, if they occur, have the potential to have either a good or bad impact on the objectives of a project [1]. Risk management entails determining the uncertainty sources (risk identification), calculating the probability and consequences of uncertain conditions or events on a project (risk analysis), formulating response strategies, and subsequently monitoring and reporting throughout the entirety of a project, has become common among construction companies [2]. The maturity of organizations is needed in the knowledge of project management. This will coordinate and direct the implementation of the project by organizational strategy [3]. Risk-mature firms have a culture of openness, understanding, and sensitivity to operational risks and social and financial obligations to stakeholders, the public, and the environment [4]. Thus, a mature organization can achieve an acceptable risk level with minimal losses. The primary advantages of RM maturity (RMM) for project risk management and project management are (I) recognizing risk management's strengths and weaknesses in organizations and projects; (II) offering information that can be used as a benchmark; (III) comparing achievements against PM standards; (IV) identify possibilities for continuing growth; (V) enables an enterprise to enhance its performance indicators [5]. There is a strong relationship between RMM and project success, where it is necessary to

use a framework of RM3 in order to identify areas of improvement in projects or organizations and to measure progress in the development of risk management [6, 7].

In recent years, numerous risk maturity models for construction projects have been developed. In 1997, Hillson highlighted the need for a formalized and uniform maturity model to assist firms in developing and improving their risk management processes [8]. This was the first RM maturity model. Zou et al. [9] developed an RMM measuring tool on the Web for the construction industry consisting of five attributes assessed against four levels distributed on a scale from 0 to 1. Using the viewpoints of Chinese construction firms (CCFs), Zhao et al. [10] evaluated 66 best practices of enterprise risk management (ERM) and 16 essential ERM maturity factors that were adopted through reviewing previous studies and expert opinions. Bhosale et al. [11] assessed the present RM procedures of highway construction projects and contractors using the RMMM. The model consists of four levels for evaluating nine attributes. Abdulrahman et al. [12] created an RMMM for Abuja construction organizations participating in Joint Venture projects. This model has four attributes from previous studies measured by five levels. This model has four attributes from previous studies measured by five levels.

Despite the variety of available RMMs, all have two primary components. First, RMMs establish a collection of levels describing the evolution of a project. The second

component pertains to measured items: their attributes or capabilities [13]. In previous risk maturity models, many strategies were used for the purpose of verifying the validity of the model and its suitability for the purpose for which it was designed, as well as the diversity of maturity levels in these models and the difference of the examined criteria. most prior models adopted weak processes of validation [13, 14]. Table 1 illustrate validation strategies, maturity level and numbers of criteria used in each RM maturity model.

Table 1. Illustrate validation strategy, maturity level, and criteria for different maturity models

Model name	Validation strategy	Maturity level	Criteria
Risk Management Capability Maturity Model [15]	Literature review & case studies	5	4
RM3 for construction [16]	Literature review and five case studies	4	4
Risk management capability [17]	Literature review and survey	5	6
RMM of construction organization [18]	Literature review & 16 case studies	4	4
RMM for construction projects [19]	Literature reviews and questionnaire surveys by 346 participants	4	4
GRMM [13]	Literature reviews & two panels of local experts	Score system	7
CRMA [20]	Literature review & Delphi technique with 28 experts	-	5

The current study's authors believe that most of the previous models are not suitable for organizations in developing countries. The reason for this belief is that most RMMMs associated in construction organizations depend on four levels to find the maturity of RM, or they lack a detailed explanation of the characteristics of each level. According to Čech and Januška [21], the use of four levels of maturity is not suitable for organizations that do not have experience in risk management, such as in developing countries. Also, the lack of a detailed explanation of each level for each attribute will create ambiguity about the exact level of maturity, especially in companies that lack experience in risk management, as is the case in developing countries. Thus, the authors concluded that the existing models might be inappropriate and there is a need to develop a new model with more than four levels of assessment, with the need to provide a detailed explanation for each level to facilitate the assessment process accurately.

Reviewing the past literature for various RMMs, the authors identified some shortcomings in these models:

(1) Most previous models are unsuitable for organizations in developing countries with poor RM.
(2) Most of these models couldn't tackle all RM phases.
(3) Most of previous models used ineffective validation strategies [13, 14].
(4) Most of the earlier models did not explain the features of the attributes and capabilities' levels appropriately and understandably. This may sometimes lead to the unreliability of participants' choices.

(5) The relative weight of attributes and capabilities was based on participant opinions, which may not be accurate specially in organizations with weak risk management culture, such as those in developing countries.
(6) Most models only used the knowledge of local experts and simple algorithms that may give inaccurate results of the RMM.
(7) Previous models did not highlight the maturity of risk management for construction companies after the crisis, like COVID-19.

As a consequence of the above, the aim of this research is developing a novel model that overcomes the shortcomings of current ones by using new hybrid techniques and a distinct validation strategy based on global and local experience and real-world application to evaluate RMM of construction organizations in the developing countries.

This article has the following organization: A literature review is explained in section 2. The methodology of the research is explained in section 3. Section 4 discusses the field work. This section explains the components and techniques used in proposed model. Section 5 outlines the face validity with expert panels to confirm proposed model. Section 6 represents the results of executing the model through a real-world case study, and in section 7, the conclusions are given.

2. LITERATURE REVIEW

In several practical situations, crisp data cannot be utilized for modelling. In different circumstances, human decisions and judgments are often subjective, unclear, and ambiguous and thus cannot be quantified with precise values [22]. Zadeh [23] invented the theory of fuzzy set, which could be utilised to address the vagueness of human judgements and cognitions. Using partial set membership functions instead of crisp ones offers mathematical advantages for addressing ambiguities associated with human reasoning. Although there is a long history of fuzzy set theory in various fields, its use in construction management is relatively recent compared to other engineering fields [24]. The construction industry has unique features and a lack of historical data in specific areas; therefore, this technique is considered a robust modelling approach and well-suited for the construction industry [25, 26]. Many risk assessment techniques are used, such as FAHP, Bayesian network, and Grey System theory.

FAHP is typically utilized in multi-attribute analyses and structured hierarchical judgment cases and is superior to AHP in producing importance weight vectors for decision-making. [27]. FAHP is an enhanced approach based on conventional AHP that employs fuzzy values to evaluate uncertainties in converting the preferences of humans into a scoring approach while evaluating various selection criteria [28].

Fuzzy Synthetic Evaluation technique (FSE) is essential for assessing risks in ambiguous environments. The FSE is a subclass of the fuzzy set methods that may cope with ambiguous, opinionated, and imprecise evaluation issues [12]. It aims to offer a synthetic assessment of an item concerning a goal in a fuzzy-decision environment, including several criteria [17]. The benefit of FSE is that the influence of numerous related components may be assessed thoroughly based on their weight. It has been extensively used in environmental decision-making and evaluation procedures. The merging of FAHP and FSE is intended to reduce the ambiguity inherent in Likert-type variables and eliminate subjective assessments. However, little research has integrated

these techniques [29].

As a consequence, integrating FAHP and FSE is used in this proposed model. In this study, the authors will use the (FAHP) technique (Extent Analysis method, known as Chang approach) to calibrate the weight vector of the attributes and capabilities. These weights will then be used in the equations of the Fuzzy Synthetic Evaluation (FSE) technique, as the (FSE) technique will be used to measure and assess the maturity level for these attributes and capabilities. However, the aggregation of these techniques has not yet been used for the maturity assessment of risk management; hence, this work contributes to the existing literature on forecasting and assessing risk management maturity.

3. METHODOLOGY

The Construction Organization Risk Management Maturity Model (C.ORM3) conceptual framework is a set of steps to use this strategy implementation framework. This model consists of five stages:

(1) Stage one: In this stage, excessive systematic literature reviews to extract a set of possible attributes, capabilities, and maturity levels. The output of this stage is initial form of the survey.

(2) Stage two: Validating and confirming the outputs of the stage one through expert interviewes with 3 experts' panels. The output of this stage is final form of model's survey.

(3) Stage three: Calibrating the weight vector of attributes and capabilities of the proposed model by adopting pairwise comparisons collected from second panel of experts. FAHP technique will be utilized for calculating weights.

(4) Stage four: Applying the final form of survey in a real case study and calculate the level of RMM in construction organizations by integrating weights vector from FAHP with fuzzy synthetic evaluation technique (FSE).

(5) Stage five: Design a template for the proposed model.

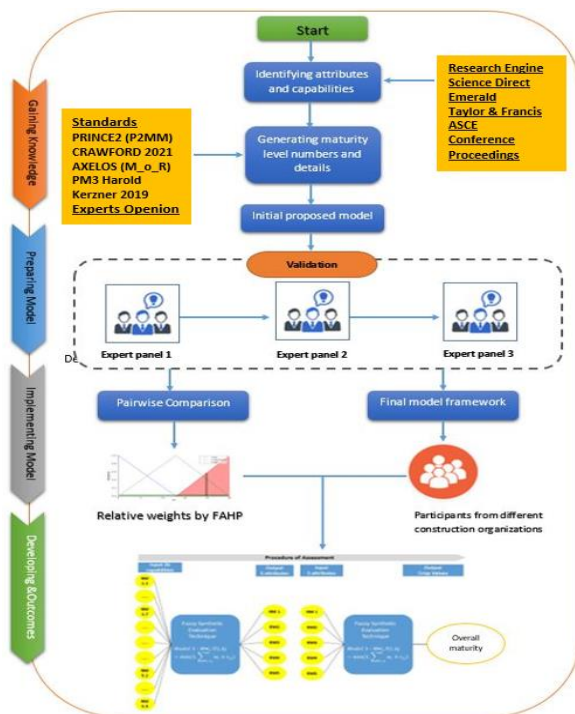Figure 1 below illustrates the conceptual framework of C.ORM3.

Figure 1. Conceptual framework of C.ORM3

The expert interview is a very successful method for acquiring data from participants, essential for understanding or investigating complex phenomena or situations. A successful interview is an art form of exploring the beliefs and perspectives of the participants and their topic expertise [30]. During preparing this framework, the authors will rely on three panels of experts. Those experts consisted of academics and specialists in the construction industry. Details of the experts are in **Appendix A**.

4. FIELD WORK

4.1 Attributes and capabilities

The attributes and capabilities constitute the model's core. They will determine the model's meaning and function [21]. Excessive systematic literature reviews of 22 models dealing with the RMM were undertaken to derive capabilities. These capabilities are the issues and concerns being questioned. First, the authors identified 24 capabilities and categorized them under five attributes. Table 2 describes the attributes and capabilities and their references.

Table 2. The attributes and capabilities of C.ORM3 and their references

Attributes	Capabilities	References
RM1 Risk management culture & knowledge	Attitude about RM	[12, 15-21, 31, 32]
	Risk management policy	[8, 10, 13, 15, 18, 32, 33]
	RM communication	[9, 10, 12, 15-17, 19, 21, 31, 33-35
	Commitment of senior management	[9, 10, 12, 13, 15, 16, 19-21, 32-35]
	Responsibility and authority	[9, 10, 15, 17, 20, 21, 31, 33]
	RM objectives	[12, 15, 19, 20]
RM2 Risk management processes	Capability of plan RM	[10, 13, 15, 18, 19, 21, 36-39]
	Capability of identifying risks	[9-12, 15-21, 33, 36-39]
	Capability of risk analysis	[9-12, 15-21, 33, 34, 36-39]
	Capability of risk response	[9-12, 15-21, 33, 36-39]
	Monitoring and controlling risks	[9-12, 15, 16, 18-21, 33, 36-39]
RM3 Risk management resources	Allocating the budget for RM	[9-11, 13, 15-19, 21, 33, 35]
	Dedicated team for RM	[9, 10, 12, 15, 16, 19, 33]
	Training	[10, 15, 16, 18-20, 33, 34]
	Allocating time of RM	[8, 13, 35]
RM4 Risk management practice	RM formalization	[9, 10, 12, 16, 19-21, 33, 35]
	Key stakeholders	[13, 15, 33, 35]
	RM documentation	[10, 14, 15, 16, 18, 19, 35]
	RM scope	[16, 18, 21, 33]
	Integrated RM with PM tasks	[10, 15, 16, 19, 21, 31-34]
RM5 continuous Improvement	Change management	[21, 33]
	Research in developing RM	[33]
	Reviewing performance	[10, 13, 15, 17, 20, 21, 31, 33]
	Risk audit	[9, 12, 13, 21, 33]

4.2 Proposed C.ORM3 levels

The authors believe that maturity levels are the most crucial aspect of the model, which demands precision and abundant information. Most prior models provide just a basic description of the maturity levels and lack detailed explanations of each risk management criterion in the models.

The number of maturity model levels ranged from four to six in the twenty-two risk maturity models used across several industries that were analyzed [40]. It has been argued that having six maturity levels provides too much granularity, making it difficult to describe the difference between one level and another. Similarly, it is difficult for users of the model to determine what level of maturity they have attained for a specific capability. On the other hand, using just four levels in the maturity model makes it impossible for organizations and projects to express suitable phases of incremental development and restricts the model's ability to evaluate an organization without risk management experience, as in many construction organizations in developing countries. Therefore, selecting five levels allows for a more precise distinction of the organization's maturity [21, 32]. In contrast, some research asserts that choosing five maturity levels may lead participants to select the "middle level" [9]. The authors of current study believe that selecting "middle level" is because earlier models lack a description of the levels, where they are restricted to single expressions such as "not applied," "high application," and "naive," etc., or others offer just a basic explanation of the level without delving into detailed descriptions relevant to each capability of the model. Thus, the participant may be left in a state of uncertainty about "which is the suitable level for each criterion?" and ultimately choose the middle level.

The authors had long discussions about maturity levels and scale points based on the above. It was decided that the proposed model would have five levels so that all construction organizations in both developing and advanced countries could use it. These levels are: (level 1: Immature); (level 2: Ad-hoc); (level 3: Standard); (level 4: Managed), (level 5: Optimized). Detailed descriptions of all levels in each question (capability) would be needed to ensure the right level was chosen and stop people from picking the "middle-level" option. After a two-month search, no standard, guideline, or model covered all the studied attributes and capabilities to provide these descriptions. Consequently, the authors integrated four significant modern standards and guidelines to elicit the required statements. Adjustments were made to formulating these statements to make it easier for participants. The modern standards and guidelines are:

(1) "**PRINCE 2 Maturity model (P2MM)**" standard, version 2.1 from Axelos. Based on PRINCE 2 publication [41]. This standard model consists of five levels and discusses many areas of project management, like risk management, financial management, stakeholder management, etc., published in 2010.

(2) "**Managing of Risk (M_o_R)**"**:** It is a guide that aims to develop a framework that helps organizations manage risks with high efficiency. This guide describes a maturity model (in **Appendix D**) consisting of five maturity levels, released in 2010 from AXELOS [42].

(3) "**Project Management Maturity Model (PM3)**" by Crawford 4th edition which reflects the logic of the PMBOK 6 standard [43]. This guide consists of five levels and measure the maturity of knowledge area in PMBOK 6.

(4) "**Using the Project Management Maturity Model: Strategic Planning for Project Management**" by Harold Kerzner 3rd edition [5]. It is a book prepared by one of the greatest management experts, "Harold Kerzner". The designed model consists of five levels to evaluate all organizations of all sizes.

4.3 Fuzzy Analytic Hierarchy Process (FAHP)

Fuzzy AHP is the most widely utilized multi-attribute decision_making methods under fuzzy conditions. The AHP tool, developed in the 1970s by Saaty, is an effective method for making decisions when there are several criteria to choose from. It was not possible to fully capture human thinking using the conventional AHP. Therefore, the authors used the FAHP to obtain accurate results. In this study, Chang's fuzzy AHP approach calculates the weights of the attributes and capabilities. The following actions comprise the fuzzy AHP [44]:

1. Build a pairwise comparison of the attributes and capabilities that will be sent to the second panel of experts so that they can assign relative importance based on the Table 3 below:

Table 3. Linguistic expressions for pairwise comparison [45]

Linguistic expression	Equivalent fuzzy number	Triangular fuzzy numbers	The reciprocal scale of fuzzy
Importance is equally	1	(1, 1, 1)	(1, 1, 1)
Importance range from equal to Moderate	2	(1, 2, 3)	(1/3, 1/2, 1)
Moderate	3	(2, 3, 4)	(1/4, 1/3, 1/2)
Moderately to strongly important	4	(3, 4, 5)	(1/5, 1/4, 1/3)
Strong importance	5	(4, 5, 6)	(1/6, 1/5, 1/4)
Strongly to very strongly importance	6	(5, 6, 7)	(1/7, 1/6, 1/5)
Very strongly important	7	(6, 7, 8)	(1/8, 1/7, 1/6)
Very strongly to extremely_important	8	(7, 8, 9)	(1/9, 1/8, 1/7)
Extreme important	9	(8, 9, 9)	(1/9, 1/9, 1/8)

2. Integrate the judgments of the experts using the geometric mean technique, as in the following formula:

$$A = (a, b, c); \; K = 1,2,3, \ldots \ldots, k$$
$$a_{ij} = \left(\prod_{i=1}^{n} a_{ij_k} \right)^{1/n}, \tag{1}$$

where, A: triangular fuzzy number; K: number of experts; a_{ij}: relative importance.

3. Compile the matrices of all pair-wise comparisons for experts and synthesize them to provide the list of overall priorities.

4. The authors will determine the consistency ratio (CR) using the Saaty approach. The CR value must be<0.10.

5. Finally, triangular fuzzy number weights of attributes and capabilities will be obtained as follows:

Let $M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, \ldots \ldots, M_{g_i}^m$ where m is the values of extent analysis, i= 1,2,3,…..,n, while $M_{g_i}^j$ is the (TFN), j= 1,2,3,….m. So, in the Eq. (2), the fuzzy synthetic extent magnitude with regard to "$i\ th$" object can illustrated:

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} ; \qquad (2)$$

To determine the magnitude of $(\sum_{j=1}^{m} M_{g_i}^j)$, a fuzzy addition operation is utilized of (m) extent analysis values:

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right); \qquad (3)$$

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i\right), \qquad (4)$$

Then, determine the reverse of the vector (4) as explained in the Eq. (5):

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{g_i}^j\right]^{-1} = \left(\frac{1}{\sum_{j=1}^{m} u_j}, \frac{1}{\sum_{j=1}^{m} m_j}, \frac{1}{\sum_{j=1}^{m} l_j}\right); \qquad (5)$$

I. After calculating S_i, the degree of possibility for a two fuzzy numbers $\{M_2=(l_2, m_2, u_2) \geq M_1=(l_1, m_1, u_1)\}$ will be computed as follows Eq. (6) below:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) = \lambda_{M_2}(d) =$$
$$\begin{cases} 1 & if\ m_2 \geq m_1 \\ 0 & if\ l_1 \geq u_2 \\ \frac{(l_1-u_2)}{(m_2-u_2)-(m_1-l_1)} & o.w \end{cases} ; \qquad (6)$$

(d) represents the highest point's ordinate of interaction between (μ_{M_1}) & (μ_{M_2}). Figure 2 explained that:
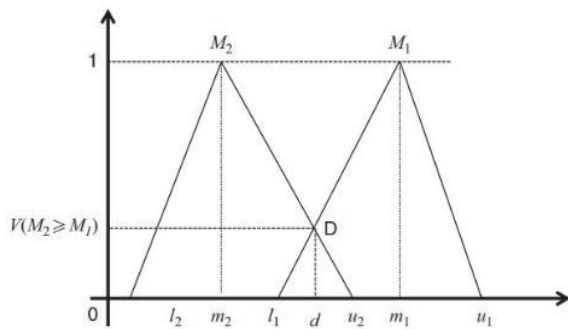

Figure 2. Illustrate highest point between M1 & M2 [44]

The possibility degree that a convex-fuzzy number is greater than k convex-fuzzy numbers can be explained as follows:

$$M_i(i = 1,2,3, \ldots \ldots \ldots, k)$$
$$V(M \geq M_{1,}M_{2,}M_{3,} \ldots, M_K) = V[(M \geq M_1)and \times$$
$$(M \geq M_2) \ldots . \& (M \geq M_k)] \qquad (7)$$
$$\min V(M \geq M_K)$$

The weight vector will be computed by Eq. (9) based on the assumption of Eq. (8) as follows:

$$d'(A_i) = \min\{V(S_i \geq S_k)\}, \qquad (8)$$

where, k= 1,2,3,…..,n; but $k \neq i$.

$$W'\{d'(A_1), d'(A_2), \ldots \ldots, d'(A_n)\}^T; \qquad (9)$$

where, A_i(i=1,2,3,……,n.).

Final step represents calculating normalized weight vector:

$$W = \{d(A_1), \ldots, d(A_3), \ldots \ldots, d(A_n)\}^T \qquad (10)$$

W: represent Crisp magnitude of parameters.

4.4 Fuzzy Synthetic Evaluation Technique (FSE)

The authors will use this technique to assess the level of RMM possessed by construction organizations. This technique consists of three elements [46, 47]:
1. A set of factors. in our study, it represents the attributes and capabilities of the proposed model. Let us named {f_1, f_2,…, f_n}.
2. A family of grade alternatives N= {n_1, n_2,.....,n_n}; where n_1= immature; n_2= ad-hoc; n_3= standard; n_4= managed; n_5= optimized.
3. There exists, for each item $u \notin U$, (this expression explains that fuzzy sub-set u does not belong for fuzzy set U), an evaluate matrix R = $(r_{ij})_{mxn}$. In a fuzzy circumstance, r_{ij} represents the measurement that the the criterion f_j meets alternative n_j. The membership function of fuzzy set of alternative n_j with regard to criteria f_j presents it. Using the previous parts, the evaluation result for a given $u \notin U$ can be calculated.
- Using Eq. (11), we can figure out the M.F. for each capability based on the information we got from respondents:

$$(MF) =$$
$$\frac{X1}{Immature}, \frac{X2}{Ad-hoc}, \frac{X3}{Standard}, \frac{X4}{Managed}, \frac{X5}{Optimized} \qquad (11)$$

where, MF denotes the membership function, and X represents the percentage of total respondents who chose a specific risk management maturity level.
- Four approaches are widely used by the FSE to integrate outputs. The Trapezoidal Membership Function (TMF) of attributes and overall maturity level was determined using Model 3. The third one uses the composition of the vector of weight W calculated by the FAHP technique and the assessment matrix R(D=W×R) as in Eq. (12):

$$Model\ 3\ M(\bullet, \oplus), bj = \min(1, \sum_{i=1}^{m}(w_i \times r_{ij})); \qquad (12)$$

where, bj: member function of attributes or overall maturity level.; $\oplus$ represent the summation of weights and MF; W_i: is relative weight of capabilities & attributes i=(1, 2,..,m); M: number of capabilities or attributes.

Finally, after obtaining the membership function of all attributes as well as overall maturity level, finding de-fuzzification of TMF to compute a crisp number according to Eq. (13):

$$C = \sum_{i=1}^{n}(W_i \times R_k) \times L; \qquad (13)$$

where, C: crisp number of attributes or overall maturity level.; R_k: degree of TMF of capabilities or attributes; L: linguistic variable (1=immature; 2=ad-hoc; 3=standard; 4=managed; 5=optimized).

5. EXPERT INTERVIEWS (FACE VALIDITY)

After gathering the proposed model's components, the authors produced the model's preliminary form. As outlined in the following section, substantial attempts were made to validate the number of maturity levels and detailed descriptions of the proposed model through expert interviews with three panels of global and local experts:

1. The first group of experts consist of six global and local experts. Three international experts have excellent expertise in maturity models. The initial form of the model was evaluated by all experts. The model was evaluated, its relevance to the study's nature was tested, and whether these questions reflect the principles of the research. This process took more than two months to complete since it consisted of either face-to-face or internet interviews. The expert's comments were gathered for analysis and to make necessary adjustments. Based on the feedback, the experts advised adding new capabilities [**RM culture after crisis (like COVID-19); Automation in RM**]. They suggested adding the first capability to the attribute "RM Culture & Knowledge", and the other added to "Continuous Improvement", as well as many alterations were made to some of the sentences of the detailed descriptions of model levels and replaced with more straightforward language to be intelligible to the participants. After completing all the essential revisions, experts reviewed and accepted the model.

2. The modified form by the first group of experts was submitted to the second group of experts, consists of 24 local experts who participate in the construction industry. The group provided a few remarks on the model, mainly about the clarity and simplicity of its language, and also advocated creating an Arabic form of the model. No proposals were made to add new capabilities or detailed descriptions of levels. The second mission of these experts is related to finding the degree of importance of attributes and capabilities.

3. The third expert panel, made up of two statisticians, is tasked with finding out whether the model design for statistical analysis is appropriate. They confirmed that the model is statistically valid. In the end, the final form is valid and has been authorized. The model's final form is described in **Appendix B**.

6. RESULTS AND DISCUSSIONS

6.1 Development relative weights of attributes and capabilities

By using Eqns. (1-10) in the following manner, the authors will utilize a numerical example to demonstrate how to apply the FAHP technique to the four capabilities that make up "RM Resources":

1. Integrating experts' judgments by using geometric mean and the final result of fuzzy comparison as in Table 4:
2. Consistency ratio (CR) of experts' judgments is CR<10%.
3. Calculating the Synthetic extent value (S_i) of capabilities:
$\sum RM_{3.1}$ = (1+1.155+1+1), (1+2.176+2+1.414), (1+3.185+3+1.732)=(**4.155,6.59, 8.917**). $\sum RM_{3.2}$ = (**2.151, 2.608, 3.866**).; $\sum RM_{3.3}$ =(**3.333, 4.231, 5.303**).; $\sum RM_{3.4}$= (**3.337, 4.548, 6**).
By collecting each column of above vectors, the result is

(**12.976, 17.978, 24.086**). The reverse of calculated vector is (**0.04151794, 0.055624042, 0.077062884**). Now:

$$S_i \ for \ RM_{3.1}= (0.1725, 0.3666, 0.6872);$$
$$S_i \ for \ RM_{3.2}= (0.0893, 0.145063, 0.29789);$$
$$S_i \ for \ RM_{3.3}= (0.13839, 0.23537, 0.40867);$$
$$S_i \ for \ RM_{3.4}= (0.1386, 0.25298, 0.46238).$$

Table 4. Final comparison of RM resources from experts' opinions

	$RM_{3.1}$			$RM_{3.2}$			$RM_{3.3}$			$RM_{3.4}$		
$RM_{3.1}$	1	1	1	1.155	2.176	3.185	1	2	3	1	1.414	1.732
$RM_{3.2}$	0.3139	0.4595	0.865	1	1	1	0.503	0.648	1	0.333	0.5	1
$RM_{3.3}$	0.3333	0.5	1	1	1.542	1.987	1	1	1	1	1.189	1.316
$RM_{3.4}$	0.5773	0.7071	1	1	2	3	0.759	0.841	1	1	1	1

4. Comparing each degree of possibility $V(S_i \geq S_k)$

$$V(S_{RM_{3.1}} \geq S_{RM_{3.2}})=1; V(S_{RM_{3.1}} \geq S_{RM_{3.3}})=1;$$
$$V(S_{RM_{3.1}} \geq S_{RM_{3.4}})=1; V(S_{RM_{3.2}} \geq S_{RM_{3.1}})=0.3614;$$
$$V(S_{RM_{3.2}} \geq S_{RM_{3.3}})=0.638; V(S_{RM_{3.2}} \geq S_{RM_{3.4}})=0.596;$$
$$V(S_{RM_{3.3}} \geq S_{RM_{3.1}})=0.643; V(S_{RM_{3.3}} \geq S_{RM_{3.2}})=1;$$
$$V(S_{RM_{3.3}} \geq S_{RM_{3.4}})= 0.938; V(S_{RM_{3.4}} \geq S_{RM_{3.1}})=0.7184;$$
$$V(S_{RM_{3.4}} \geq S_{RM_{3.2}})=1; V(S_{RM_{3.4}} \geq S_{RM_{3.3}})=1$$

5. Identifying the min ($V(S_i \geq S_k)$), where, min value of $V(S_i \geq S_k)$ for $RM_{3.1}$= **1;** min value of $V(S_i \geq S_k)$ for $RM_{3.2}$ = **0.3614;** min value of $V(S_i \geq S_k)$ for $RM_{3.3}$ = **0.643;** min value of $V(S_i \geq S_k)$ for $RM_{3.4}$= **0.7184**.

6. Finally, the weights of capabilities of RM Resources can be obtained:

$$W_{RM_{3.1}} = \left(\frac{1}{1+0.3614+0.643+0.7184}\right) = 0.367;$$
$$W_{RM_{3.2}} = \left(\frac{0.3614}{1+0.3614+0.643+0.7184}\right) = 0.133 ;$$
$$W_{RM_{3.3}} = \left(\frac{0.643}{1+0.3614+0.643+0.7184}\right) = 0.236;$$
$$W_{RM_{3.4}} = \left(\frac{0.7184}{1+0.3614+0.643+0.7184}\right) = 0.264$$

The same procedure will be used to calculate weights for all attributes and capabilities of the model, as explained in Table 5.

6.2 Implementing model

In this section, the model will be applied with the participation of a group of engineers working in various public and private organizations to confirm the model's validity, and to stand on the level of maturity of Iraqi construction organizations in risk management. Figure 3 in (**Appendix C**) demonstrates model implementation.

6.2.1 Data collection and statistical analysis
1. **Sample size:** It is statistically determined utilizing Kish's formula as explain in (Eq. 14) [48], and the Cochran formula for continuous data (Eq. 15) [49, 50] in the following manner:

$$N_s' = \frac{p \times q}{(v)^2}; \qquad (14)$$

where, N_s': sample size of an unlimited population; P: estimated percentage of the target population q: 1-p; v: acceptable standard of error for the sample population. p & q are set to 0.5 to achieve the ultimate sample size. The standard percent of the error is specified as 5 percent to get a confidence level at 95%. Considering the above conditions, the minimum sample size necessary is=100. According to the Cochran formula:

$$N_s = \frac{t^2 \times s^2}{e^2}; \qquad (15)$$

where, N_s: required sample size; t: the value of confidence level; s: standard deviation; e^2: margin of error. For continuous data, the acceptable error is 3% [51]. In the proposed model, a five-point scale is adopted; thus, the value of (e) is calculated by multiplying the acceptable error by the points of the scale (0.03x5=0.15). The estimation of standard deviation (s) is calculated by dividing the 5-point scale by the six standard deviations (3 on each side of the mean) that capture nearly all (roughly 98%) of the scale's available values. Therefore, the (s) will be (5/6). At a confidence level of 95%, the value of (t) is 1.96. So, the sample size is $\cong$119. From the above two equations, the sample size's minimum value will equal 119. Interviews are used to disseminate the questionnaire. A (169) respondents from publics and private organizations took part.

2. **Data outlier:** The respondents' responses were screened for outliers. The issue is that a slight outlier is always sufficient to skew data findings. The identification of outliers is the prominent use of the Mahalanobis distance in multivariate statistics [52]. The Mahalanobis distance is the squared distance between the vector of an observed point and the vector of the means (μ) for the closer points [53]. By using SPSS, it was determined that the probability of Mahalanobis distance is much less than (P < 0.001) for ten replies; hence, those responses were omitted [54]. Only 159 answers were utilized for further analysis after data screening. Most of those respondents have more than 10 years of experience.

3. **Data normality:** SPSS's Kolmogorov–Smirnov normality test (K-S) was used to determine the data's normality. The K-S values for capabilities varied from 0.255 to 0.515, whilst the K-S values for attributes ranged from 0.189 to 0. 355, and all significant values were less than 0.05. The data thus varied from normality, and nonparametric tests for data analysis should be used.

4. **Reliability analysis:** The authors adopted the Guttman Split-Half Reliability coefficient and Cronbach's alpha coefficient. The value of the Guttman Split-Half coefficient ranged from 0.814 to 0.966, Cronbach coefficient ranged from 0.813 to 0.901. That means excellent stability and internal consistency of the model.

6.2.2 Generating Membership Functions (M.F) for the model

A total of 26 capabilities have been identified for evaluating the RMM level of construction organizations. By assessing organizations, the M.F. will be generated. It should be noticed that there are three levels of M.F. as follows:

1. **For capabilities and attributes:** For instance, the results of a survey regarding the capability" Allocating budget for RM (RM$_{3.1}$)" revealed that 39% of respondents viewed

the maturity level of this capability as immature, 45% as ad-hoc, 16% as standard, 0% as managed, and 0% as optimized; therefore, the M.F.:

$$RM_{1.1} = \frac{0.39}{Immature} + \frac{0.45}{Ad-hoc} + \frac{0.16}{Standard} + \frac{0.00}{Managed} + \frac{0.00}{Optimized}$$

It can be written as (0.39,0.45,0.16,0.00,0.00). Likewise, the M.F. of other capabilities can be generated in the same manner. Table 5 illustrate the MF of all capabilities.

After that, the M.F. of the five attributes will be calculated by Eq. (12). For instance, take 'RM resources', which has (Allocating budget for RM; Dedicated team for RM; Training; Allocating time of RM), the membership function of this attribute determined as follows:

$$[0.367 \quad 0.133 \quad 0.236 \quad 0.264] \begin{bmatrix} 0.39 & 0.45 & 0.16 & 0 & 0 \\ 0.36 & 0.64 & 0 & 0 & 0 \\ 0.43 & 0.53 & 0.04 & 0 & 0 \\ 0.69 & 0.31 & & 0 & 0 \end{bmatrix}$$
$$= \mathbf{(0.47, 0.46, 0.07, 0, 0)}$$

Likewise, the M.F. of other attributes can be generated similarly. Table 5 illustrates the MF of all attributes.

2. **For Overall Maturity Level (OML):** The M.F. of OML can be generated from Eq. (12) by multiplying weights of attributes by membership functions of these attributes as follows:

$$[0.257 \quad 0.229 \quad 0.244 \quad 0.14 \quad 0.13] \begin{bmatrix} 0.515 & 0.375 & 0.111 & 0 & 0 \\ 0.671 & 0.31 & 0.019 & 0 & 0 \\ 0.475 & 0.457 & 0.068 & 0 & 0 \\ 0.541 & 0.391 & 0.053 & 0.015 & 0 \\ 0.557 & 0.371 & 0.0719 & 0 & 0 \end{bmatrix}$$
$$= \mathbf{(0.55,0.382,0.066,0.002,0)}$$

Table 5 illustrates the M.F. of the overall maturity level of the Iraqi construction industry:

6.2.3 De-fuzzification of the membership functions of model

The de-fuzzification procedure is necessary in order to discover crisp values (maturity levels) for components in accordance with the Eq. (13). For instance, the crisp value of 'Attitude about RM' (RM1.1) is:

$$C = \sum_{i=1}^{n}(W_i \times R_k) \times L =$$
$$(0.352*1+0.616*2+0.03*3+0*4+0*5)=1.67$$

Likewise, the crisp value of all capabilities, attributes and overall maturity level can be calculated similarly. Table 5 illustrates the crisp numbers of all.

The results showed that the overall RMM of the Iraqi construction sector is (1.52), falls between immature and ad-hoc levels, which explains the construction industry's risk management weakness These results fully demonstrate the model's validity since the results are consistent with previous studies [55, 56] confirming the weak application of RM in the Iraqi construction sector. Thus, strict laws from the relevant authorities are needed to compel organizations to develop integrated and proactive strategies and frameworks for implementing risk management. This model can be the first and most important step to implementing these strategies because any organization needs to identify its strengths and weaknesses and then strengthen the areas where they are weakest. In addition, this model can be used as a tool by contracting agencies in evaluating organizations before the project's assignment.

Table 5. Maturity levels of capabilities, attributes and overall maturity level

No.	Attributes & capabilities (A&C)	W_i FAHP	M.F. of capabilities & attributes	M.F. of OML	Crisp values A&C	Crisp value of OML
RM1	**RM culture & knowledge**	**0.257**	**(0.515,0.375,0.1108,0,0)**		1.596	
RM1.1	Attitude about RM	0.177	(0.352, 0.616, 0.03, 0 ,0)		1.67	
RM1.2	Risk management policy	0.178	(0.522, 0.34, 0.14 ,0, 0)		1.616	
RM1.3	RM communication	0.113	(0.597, 0.333, 0.07, 0, 0)		1.47	
RM1.4	Commitment of senior management	0.187	(0.434, 0.497, 0.07, 0, 0)		1.635	
RM1.5	Responsibility and authority	0.104	(0.478, 0.314, 0.21, 0, 0)		1.73	
RM1.6	RM objectives	0.154	(0.547, 0.233, 0.22, 0, 0)		1.67	
RM1.7	RM culture after crisis	0.087	(0.881, 0.069, 0.05, 0, 0)		1.17	
RM 2	**RM processes**	**0.229**	**(0.671, 0.31, 0.019, 0 0)**		1.348	
RM2.1	Capability of plan RM	0.258	(0.761, 0.189, 0.05, 0, 0)		1.29	
RM2.2	Capability of identifying risks	0.253	(0.686, 0.314, 0, 0, 0)		1.314	
RM2.3	Capability of risk analysis	0.19	(0.667, 0.302, 0.03, 0, 0)		1.365	
RM2.4	Capability of risk response	0.206	(0.572, 0.428, 0,0,0)		1.428	
RM2.5	Monitoring and controlling risks	0.093	(0.61, 0.39, 0, 0, 0)	(0.55, 0.382, 0.0662, 0.002, 0)	1.39	**1.52**
RM 3	**RM resources**	**0.244**	**(0.475, 0.457, 0.0681,0, 0)**		1.593	
RM3.1	Allocating the budget for RM	0.367	(0.396, 0.447, 0.16, 0, 0)		1.76	
RM3.2	Dedicated team for RM	0.133	(0.358, 0.642, 0, 0, 0)		1.64	
RM3.3	Training	0.236	(0.428, 0.528, 0.04, 0, 0)		1.616	
RM3.4	Allocating time of RM	0.264	(0.686, 0.314, 0, 0, 0)		1.314	
RM 4	**RM practices**	**0.14**	**(0.541,0.391, 0.053, 0.015, 0)**		1.54	
RM4.1	RM formalization	0.155	(0.509, 0.491, 0, 0, 0)		1.49	
RM4.2	Key stakeholders	0.232	(0.572, 0.365, 0.06, 0, 0)		1.49	
RM4.3	RM documentation	0.24	(0.478, 0.447, 0.08, 0, 0)		1.597	
RM4.4	RM scope	0.103	(0.597, 0.403, 0, 0, 0)		1.403	
RM4.5	Integrated RM with PM tasks	0.27	(0.566, 0.302, 0.08, 0.057, 0)		1.623	
RM 5	**Continuous improvement**	**0.13**	**(0.557, 0.371, 0.072, 0, 0)**		1.515	
RM5.1	Change management	0.29	(0.358, 0.497, 0.14, 0, 0)		1.786	
RM5.2	Automation in RM	0.258	(0.723, 0.277, 0, 0, 0)		1.27	
RM5.3	Research in developing RM	0.226	(0.541, 0.352, 0.11, 0,0)		1.56	
RM5.4	Reviewing performance	0.115	(0.472, 0.478, 0.05, 0, 0)		1.58	
RM5.5	Risk audit	0.111	(0.811, 0.189, 0, 0, 0)		1.2	

7. CONCLUSION

Risk management is one area of knowledge that is poorly applied, especially in developing countries. Great efforts are required to address this weakness and design modern strategies to develop this area. Based on a thorough review and in-depth investigations of previous research and practice in risk management maturity around the world, the authors developed a Construction Organization Risk Management Maturity Model (C.ORM3) suited for construction organizations in developing countries that can help better understand the current state of their RM practice. This study has contributed to addressing most of the shortcomings of previous models. A five stages are adopted to build methodology of this study. This model contains five attributes with 26 capabilities extracted through a systematic literature reviews of 22 articles and experts' opinions. Furthermore, four standards and guidelines are analyzed to elicit different maturity levels for the model. These criteria will be evaluated against five levels: 1- immature, 2-ad-hoc, 3- standard, 4-managed, and 5-optimized. A new strategy for model validation was implemented based on three groups of international and domestic experts and a real-world model's implementation. To reduce the ambiguity that may accompany some of the respondents' choices when judging maturity levels, the authors apply high-precision algorithms represented by FAHP and Fuzzy Synthetic Evaluation techniques. The aggregation of these techniques has not yet been used for the RMM. The practicality of the

model is validated by Iraqi construction organizations. The results showed that the overall RMM level of the Iraqi construction sector is 1.52, between the immature and ad-hoc levels. A digital version of the model has been created to enable its use by construction organizations. This work adds to the body of knowledge about risk management by providing a novel fuzzy assessment model for RM maturity for construction organizations.

There were certain limitations to this study, which should be highlighted. The outcome solely pertains to the RM in the construction sector. Therefore, the authors recommend that future studies apply a similar approach to designing maturity models for other industries. In addition, the model implemented just in Iraqi construction organizations.

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NOMENCLATURE

RM	Risk management
RMMM	Risk management maturity model
FAHP	Fuzzy analytical hierarchy process
FSE	Fuzzy synthetic evaluation
C.ORM3	Construction organization risk management maturity model
M.F.	Membership function
C.R.	consistency ratio
TFN	triangular fuzzy number
TMF	Trapezoidal membership function

Greek symbols

v	acceptable standard of error for the sample population
s	standard deviation

Subscripts

a_{ij}	Relative importance
S_i	Fuzzy synthetic extent
W	Crisp magnitude of parameters
$\oplus$	the summation of weights and MF
C	crisp number of attributes or overall maturity level
R_k	degree of TMF of capabilities or attributes
N_s'	sample size of an unlimited population
P	estimated percentage of the target population
N_s	required sample size
t	the value of confidence level
e^2	margin of error

APPENDIX

Appendix A

Table A1. Illustrate experts' panels

Experts	No.	Expertise & field of activity	Work experience (years)	Education	Country
		First panel of experts			
E	1	Senior Manager Program Management; Specialist in OPM & maturity models	More than 21	B.Sc.	USA
E	1	Chief Specialist projects and program management/ EPMO; PMI-RMP	More than 30	Ph.D.	Egypt
E	1	Head of Department; Prof. in project management	More than 21	Ph.D.	Egypt
E	1	Prof. in construction management	More than 21	Ph.D.	Iraq
E	1	Specialist in risk and safety management	More than 10	Ph.D.	Iraq
E	1	Specialist. in construction management	More than 20	Ph.D.	Iraq
		Second panel of experts			
E	2	Specialists in construction projects in Public & Private sector	More than 25	Ph.D.	Iraq
E	8	Specialists in construction projects	More than 12	M.Sc.	Iraq
E	1	Specialists in mechanical engineering	26	M.Sc.	Iraq
E	12	Specialists in construction projects	More than 10	B.Sc.	Iraq
E	1	Specialists in construction projects	24	Higher Diploma	Iraq
		Third panel of experts			
E	1	Statistician	More than 15	Ph.D.	Iran/Iraq
E	1	Statistician	More than 10	M.Sc.	Iran/Iraq

Appendix B

Table B1. The survey of construction organisation risk management maturity model

Details of Construction Organization Risk Management Maturity Model	
RM Culture & Knowledge	
	What is the organization's attitude (maturity level) about risk management (RM) in construction projects?
Attitude toward RM	1. Immature [Need for RM not necessary to achieve project success] 2. Ad-hoc [Need for RM is only for large-scale projects; Inconsistent approach] 3. Standard [Formal awareness of RM exists, but benefits are not continually earned] 4. Managed [RM works very effectively on projects; Aggregation of Risk and Opportunity Management] 5. Optimized [RM can be highly involved in optimizing business performance, it is an integral part of the corporate culture]
	Does the organization have a risk management policy that explains how and why RM will be implemented in its projects?
RM Policy	1. Immature [No risk management policy] 2. Ad-hoc [Informal risk management policy] 3. Standard [Formal risk management policy]

	4. Managed [Complete risk management policy with many supplementary documents containing parent/child relationships.]
	5. Optimized [Optimized risk management policy that is updated periodically to comply with new legislation, financial management and internal controls]
RM Communication	**Does the organization have an internal and external risk communication plan for its projects?**
	1. Immature [Undefined risk communication plan]
	2. Ad-hoc [Risk communication plan is limited, and focuses on websites or email only for large projects]
	3. Standard [Centrally controlled and structured risk communication plan for most projects.]
	4. Managed [Strong risk communication plan that integrated with the organization's communication plan]
	5. Optimized [Continuous development of the risk communication plan to be more optimal and beneficial to the organization]
Commitment of senior management	**Does senior management support risk management practices in projects?**
	1. Immature [No support or participation by senior management in RM]
	2. Ad-hoc [Inconsistent engagement of senior management in risk management]
	3. Standard [Senior management is constantly engaged and provides informed support]
	4. Managed [Senior management will be firmly committed and engaged in RM]
	5. Optimization [Continuous improvement by senior management of risk management processes to meet business changes and external conditions]
Responsibility and authority	**Does the organization define the roles and responsibilities among individuals to manage the risks of its projects?**
	1. Immature [Roles and responsibilities are not defined]
	2. Ad-hoc [unclear responsibilities]
	3. Standard [Centrally and formally defining roles and responsibilities]
	4. Managed [Strong definition, with succession plans for the main roles]
	5. Optimization [Risk management responsibilities are included in job description]
RM Objectives	**What are the objectives that the organization is trying to obtain from risk management in its projects?**
	1. Immature [Inconsistency and ambiguity in business objectives]
	2. Ad-hoc [Cost and time objectives]
	3. Standard [Formal objectives, cost, time and quality]
	4. Managed [Health and safety; Quality; As well as cost and time]
	5. Optimized [Long-term goals like the reputation of the organization, as well as health and safety, quality, cost and time]
RM Culture after crisis	**To what extent is the organization taking corrective actions to manage risk in its projects after crises such as the COVID-19 pandemic?**
	1. Immature [Tendency to stay in previously existing plans]
	2. Ad-hoc [Inconsistent corrective plans for RM after crises]
	3. Standard [Formal corrective and developed plans for RM after crises]
	4. Managed [Strong corrective actions (Crisis management in place)]
	5. Optimized [Continuous and proactive improvement of Crisis management plans]
RM PROCESSES	
Capability of plan RM	**What is the maturity level of the organization to prepare a risk management plan for its projects?**
	1. Immature [There is no risk management plan prepared]
	2. Ad-hoc [A risk management plan has been developed for visible and large projects]
	3. Standard [Formal risk management plan for most projects]
	4. Managed [A RM plan is compulsory for all projects, and the details of the plan depend on the type and size of the project and organizational environment]
	5. Optimized [RM plans are constantly improved and permeate the entire business]
Capability of identify risk	**Has the organization adopted tools and techniques (like a checklist, root cause analysis, brainstorming or any other tools) and applied a risk register in identifying risk?**
	1. Immature [No risk identification process as a standard activity]
	2. Ad-hoc [Risk identification processes are documented, but only for specific projects]
	3. Standard [Standard process, repeatable and documented process; expanded with techniques like checklist]]
	4. Managed [A systematic and integrated process with time and cost management; The project and organization are in mind when identifying risks]]
	5. Optimized [Risk identification processes are constantly improved and permeate the entire business]
Capability of risk analysis	**Is the organization adopting guided practices (PMBOK 6th, Prince2) for qualitative and quantitative analysis for assessing the impact of project risks?**
	1. Immature [No systematic RM processes]
	2. Ad-hoc [Inconsistent approach to risk assessment]
	3. Standards [Qualitative analysis is applied to most projects; prioritizing risks based on multi factors]
	4. Managed [Qualitative and quantitative analysis for all projects (on an organizational basis)]
	5. Optimized [RM processes are constantly improved; state-of-the-art methods and tools]
Capability of risk response	**Does the organization implement mitigation strategies or adopt contingency plans to respond to risks?**
	1. Immature [No official risk response plan]
	2. Ad-hoc [Risk response processes are informally defined; only for large projects]
	3. Standards [Standard processes used by most projects, including templates for RM plans and mitigation strategies]
	4. Managed [Developed risk response plans are fully integrated with time management, cost, finance and accounting systems]
	5. Optimized [Risk response plans constantly improved; The reserves used in the project are tracked]

	Does the organization have standard methods and procedures for monitoring and controlling risks during the implementation of projects?
Monitoring and controlling risk	1. Immature [No official processes] 2. Ad-hoc [informally defined; an extraordinary personnel approach is applied to monitor and control risks; tracking risk of large projects] 3. Standard [Formal process to manage and control risks; Risks are routinely and effectively tracked for most projects] 4. Managed [Strong risk monitor and control system that integrated with time and cost management; And with the organization's control systems] 5. Optimized [Continuous improvement of monitoring and controlling processes, and permeate the entire business]

RM RESOURCES

	Does the organization allocate a contingency budget to manage project risks?
Allocating budget of RM	1. Immature [No contingency budget dedicated for RM] 2. Ad-hoc [Contingency budgets are allotted only for near-term risks and large-scale projects] 3. Standard [Formal allocation of contingency budget for most projects] 4. Managed [Comprehensive allocation of contingency budgets for all projects] 5. Optimized [Continuous improvement via applying contemporary technology to anticipate contingency budgets with high accuracy and expenditure tracking]

	Does the organization prepare a dedicated risk management team for its projects?
Dedicated team for RM	1. Immature [No team dedicated to RM] 2. Ad-hoc [External consultant just for strategic projects] 3. Standard [Formal RM team dedicated to most projects] 4. Managed [Robust and knowledgeable risk management team for all projects] 5. Optimized [A proactive risk management unit with a highly-skilled team]

	Has the organization provided risk management training for personal development?
Training	1. Immature [Providing uncoordinated training] 2. Ad-hoc [It is possible that general basic training has been provided for key employees] 3. Standard [Well-established training program in place to develop individuals' skills in specific roles] 4. Managed [Strong training with a focus on performance improvement and character development] 5. Optimized [Continuous improvement of staff skills by external advanced training; The training program is provided to all heads of business units]

	Does the organization allocate contingency time to manage risk while scheduling a project?
Allocating time of RM	1. Immature [No dedicated contingency time for RM] 2. Ad-hoc [Contingency time is allotted for utmost necessary in large projects] 3. Standard [Formal assigning of contingency time for risk management in the majority of projects] 4. Managed [Pay importance to allocate contingency time for all projects via leveraging lessons learned from other leader companies] 5. Optimized [Continuous improvement via the use of modern technologies to accurately forecast contingency time based on its own lessons learned and past experiences].

RM Practice

	What level of maturity do the organization's risk management practices have?
RM formalization	1 Immature [There are no RM practices even though the organisation realises the importance of RM] 2 Ad-hoc [Local risk management measures are limited to large and important projects only] 3 Standard [Formal RM practices that are consistently applied to most projects] 4 Managed [Strong risk management practice in all projects, drawing on the experience of leading organisations; the benefits of RM are well understood] 5 Optimized [Continuous improvement in RM practices; RM is considered the main criterion in all decision-making processes in the organisation]

	How would you describe the involvement of key stakeholders in managing project risks?
Key stakeholders	1. Immature [Key stakeholders lack experience in risk management] 2. Ad-hoc [Basic and inconsistent participation of the key stakeholders] 3. Standard [Key stakeholders formally participate in RM in most projects] 4. Managed [Key stakeholders are strongly involved in business decisions for all projects] 5. Optimized [At all levels of the organization, key stakeholders are actively involved in the delivery of continuous improvement in risk management.]

	Does the organization have a documentation system for the risks encountered during the implementation of the project?
RM documentation	1. Immature [No documentation system keeps information of typical risks faced and related experiences.] 2. Ad-hoc [Inconsistent documentation system, which is utilized generally only for large projects.] 3. Standard [Centralized documentation and reporting system for most projects] 4. Managed [Integration of the risk documentation system with other project document management systems for all projects] 5. Optimized [A procedure is in place to constantly enhance risk documentation and database maintenance; Post-project evaluations are performed]

	What is the scope of RM practice in the organization?
RM scope	1. Immature [There is no implementation of risk management practices] 2. Ad-hoc [Risk management scope covering risks for large important projects only)] 3. Standard [Scope of RM practice covers the risks of most projects in the organization]

|	
	4. Managed [[Comprehensive risk management practice scope that covers risks and opportunities for all projects]]
	5. Optimized [the integrated scope of risk management practices covering risks and opportunities for all projects as well as functions of the organization]
Integrated RM with PM tasks	**To what extent is risk management integrated with other project management tasks?**
	1. Immature [Risk management not coordinated with other project management tasks.]
	2. Ad-hoc [Risk Management integrates with project management tasks for high-visibility projects only]
	3. Standard [Centralized integration between RM and project management tasks for most projects]
	4. Managed [Strong integration of risk management processes with all other project management tasks for all projects in the organization]
	5. Optimized [Continuously enhancing the integration of risk management across all projects and organizational processes and systems.]
Continuous Improvement	
Change management	**What is the organization's maturity level in adopting change management?**
	1. Immature [Resistant to change]
	2. Ad-hoc [Change management happens in a limited number of organizational areas]
	3. Standard [There are several change management initiatives implemented within the organization]
	4. Managed [Organization-wide change management programs are adopted on all projects with the full backing of the leadership team]
	5. Optimized [Continuous improvement efforts for change management; change management is a standard component of organizational functioning.].
Automation in RM	**Does the organization have risk management automation tools and technologies to manage risk programmatically?**
	1. Immature [No risk management automation tools or techniques].
	2. Ad-hoc [limited application of risk management automation tools]
	3. Standard [formal application of risk management automation tools]
	4. Managed [Strong application of risk management automation tools]
	5. Optimized [Excellent application with continuous improvement of risk management automation tools and techniques]
Research in developing RM	**Does the organization support scientific research in developing risk management practices in its projects?**
	1. Immature [No support research for developing RM]
	2. Ad-hoc [Research may depend on individual efforts if exist]
	3. Standard [Formal support for risk management development research]
	4. Managed [Strong support to efforts for risk management development research]
	5. Optimized [The official research and development unit that deals with the continuous development of institutional performance]
Reviewing performance	**Does the organization conduct performance reviews for its projects?**
	1. Immature [No performance review (no measures in place])
	2. Ad-hoc [Local reviewing (inadequate measures of success)]
	3. Standard [Regular reviews are an opportunity to eliminate potential weaknesses]
	4. Managed [Focusing reviews on opportunities; Using metrics and quantitative techniques to review performance]
	5. Optimized [A robust framework that addresses performance management issues; Proactive and routine performance review for improvement through consistent feedback]
Risk audit	**Does the organization audit how well RM processes, people involved and planned and carried out risk responses work?**
	1. Immature [No risk audit]
	2. Ad-hoc [Partial auditing for essential and large projects only]
	3. Standard [Audit report exist for most projects]
	4. Managed [Strong auditing on risk status for all projects]
	5. Optimized [Proactive and continuous Internal and external auditing for risk status]

Appendix C
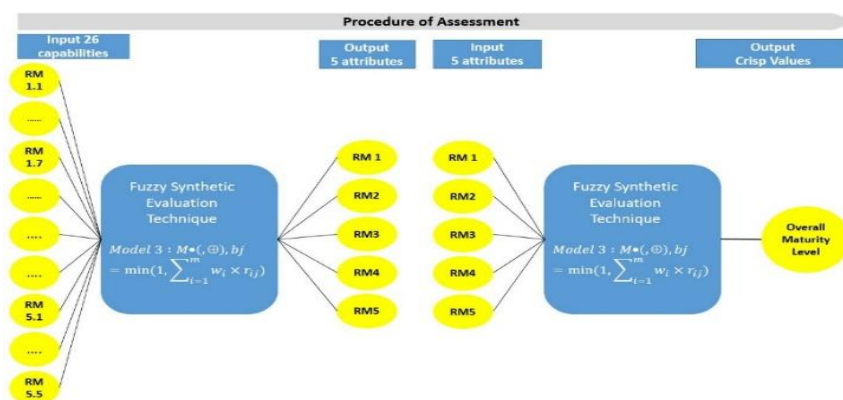
Figure 3. Process of implementing model