**Construction Risk Management in Iraq During the COVID-19 Pandemic: Challenges to Implementation and Efficacy of Practices**

M. K. S. Al-Mhdawi1; Mario Brito2; B. S. Onggo3; Abroon Qazi4;Alan O'Connor5; Mostafa Namian6

**ABSTRACT**

The main challenges and barriers facing the effective implementation of risk management (RM) practices in the construction industry have increased the ceiling of challenges associated with the implementation of construction projects during the COVID-19 era. The aim of this paper is to assess the level of significance of risk management implementation challenges and barriers (RMICB) and the level of efficacy of construction RM practices during COVID-19 by considering the case of Iraq. A multistage research methodology was adopted, including semi-structured interviews with construction experts to identify the main RMICB and RM practices indicators; surveys to assess the identified RMICB and RM practices indicators; Analytical Hierarchy Process-based and Fuzzy-based models to quantify RMICB level of significance, and RM practices level of efficacy. Based on the adopted methodology, the authors identified a total of 34 RMICB grouped under four categories, namely analytical approach-related, behavior-related, management-related, and team-related RMICB. Moreover, the assessment of the current construction RM practices during the COVID-19 era indicated a low level of RM practices efficacy. This study significantly contributes to the body of knowledge by helping construction practitioners and researchers to better understand the RMICB that are hindering effective implementation of RM strategies for construction projects during the COVID-19 era. Furthermore, it provides valuable information to decision-makers regarding the current construction RM practices efficacy during extreme conditions.

**Keywords:** COVID-19, risk management, challenges and barriers, risk management practices, Iraq.

**Introduction**

The construction industry operates in a dynamic and complex environment characterized by the complex relationships among owners, contractors, suppliers, designers, government authorities, and the public and private stakeholders (Zhao et al. 2015). Hence, the construction industry is subjected to numerous risks and challenges that could impair the achievement of the project's set objectives. In fact, research has shown that both construction practitioners and research scholars are unanimous in their beliefs that construction projects are more susceptible to risk than other industries (Shojaei and Haeri 2019). Risk, according to ISO 31000, is the “*effect of uncertainty on objectives*” and the effect can be a deviation from what is expected. The process of optimizing the probability of risk occurrence, mitigating its adverse effects, and exploiting its opportunities is known as Risk Management (RM). The effective application of RM can deliver the following benefits (Shad and Lai 2015): it enables effective management that maximizes the effectiveness and efficiency of work while minimizing stress and waste; it fills strategic gaps by shaping and updating risk culture at all levels within the organization; it decreases the instability of construction activities; it discourages the acceptance of financially unsound projects; it preserves the credibility and reputation of the organization; it facilitates sharing potential problems with a wider audience, allowing for better mitigation plans; it enhances communication among the project’s team; it provides a structured framework for systematically guiding the process of managing unwanted events that would otherwise be overlooked; it improves decision-making processes and the efficiency of data collection; and it strengthens corporate governance. Despite its reported benefits, the perceived benefits by construction practitioners are not as substantial as expected (Al-Mhdawi 2022). This perception has discouraged upper management from adopting a unified RM methodology and allocating funds to support RM operations. Consequently, the industry is characterized by poor risk management practices (Ferede et al. 2020) and it has encountered by many challenges and barriers that hinder its effectiveness, such as skills shortages and lack of RM knowledge and training (Boadu et al. 2020). The COVID-19 pandemic has heightened the level of challenges facing the construction industry worldwide and generated new set of risks. Examples of such risks include significant reduction in productivity, increased materials costs, delayed payments, supply chain distribution, contractual, legal, and insurance implications, unavailability of needed materials, equipment, and tools, challenges in accessing jobsites, health and safety implications, lack of human resources and workforce restrictions, and psychological challenges caused by the loss of employment and the absence of social security systems ([Agyekum](https://www.emerald.com/insight/search?q=Kofi%20Agyekum) et al. 2021; Assaad and El-adaway 2021; AL-Mhdawi et al. 2023a; Al-Mhdawi et al. 2022a; Al-Mhdawi et al. 2022b). Many factors can attribute to the high severity level of such risks, the most important of which is the poor construction RM practices during the COVID-19 era (Al-Mhdawi et al. 2022a). To this end, it is imperative to investigate and assess the current challenges, barriers, and practices that hinder the effective application of RM in the construction industry during extreme conditions such as the COVID-19 pandemic.

At this point, a question arises as to how to investigate and assess the current challenges and barriers facing the effective implementation of RM, and how to measure the efficacy of RM practices. Previous research studies have mainly investigated either the impact of the COVID-19 pandemic and its emerging risks on construction projects as a whole (see e.g., Khalfan and Ismail 2020; Agyekum et al. 2021; Al-Mhdawi et al. 2022a; Al-Mhdawi et al. 2023b) or on specific construction operations or themes such as risk management (Al-Mhdawi et al. 2022b), supply chain operations (Araya 2021), legal implications (Salami et al. et al. 2021), health and safety (Amoah and Simpeh 2020; Chigara and Moyo, 2021; Nabil et al. 2022), and response strategies guidelines (Assaad and El-adaway 2021; Kim et al. 2021). For instance, Alsharef et al (2021) provided a reflection on the early adverse effects and opportunities of the COVID-19 pandemic on the United States construction industry. Agyekum et al. (2021) examined the impact of COVID-19 on Ghana's construction industry and evaluated the extent to which construction companies contribute to mitigating the virus's adverse impact. Moreover, Khalfan and Ismail (2020) conducted exploratory research to assess the progression of Bahraini construction projects during the COVID-19 pandemic. Moreover, Salami, et al., et al. (2021) examined how construction companies in the United Kingdom mitigate the risk of litigation resulting from potential COVID-19 contract breaches. A further study, conducted by Assaad and El-adaway (2021), outlined best practices for addressing the pandemic within the United States construction industry. In the same vein, Kim et al. (2021) investigated the feasibility of the response guidelines for the COVID-19 pandemic for construction projects in Korea. Another example is the work of Stiles et al. (2021) who investigated the impact of COVID‐19 on health and safety in the construction industry in the United Kingdom and highlighted the importance of integrating a unified health and safety system within a general construction risk management framework. Chigara and Moyo (2021) investigated the key factors influencing the delivery of optimal health and safety during the COVID-19 pandemic in Zimbabwe. The results indicated that the delivery of optimum health and safety services during the COVID-19 pandemic was influenced by job security and funding-related, production-related, access to information and health services-related, on-site facilities and welfare-related, risk assessment and mitigation-related, change and innovation-related, cost-related, COVID-19 risk perception-related, monitoring and enforcement-related factors. Furthermore, Umar (2022) examined the effect of COVID-19 pandemic risks on the construction industry in the Gulf Cooperation Council (GCC) member countries and provided recommendations on how to help the industry survive during the COVID-19 pandemic. Nevertheless, despite the abundance of valuable research efforts related to COVID-19 and construction, to the best of the authors' knowledge, no previous studies have explored construction RM practices and implementation challenges and barriers during the COVID-19 era. To this end, this study fills this knowledge gap by (1) investigating and quantitatively analyzing the significance of the challenges and barriers to RM implementation, (2) identifying the indicators of RM practices, and (3) quantifying the level of efficacy of RM practices during COVID-19 pandemic, by examining the construction industry in Iraq as a case study.

In Iraq, the International Organization for Migration (IOM) reported in 2020 that the COVID-19 outbreak had resulted in a reduction of 52% in employment and a reduction of 68% in production (IOM 2020).At present, many construction companies in Iraq are still experiencing losses in profits and are facing challenges as a result of COVID-19 pandemic and its emerging risks, which adversely impact the successful implementation and delivery of construction projects within the agreed budget, planned schedule, and specified quality. Furthermore, there are many challenges facing the Iraqi construction industry, including poor suppliers, unskilled workers, logistics difficulties, poor RM practices (Al-Mhdawi 2020; Al-Mhdawi et al. 2020; Al-Mhdawi et al. 2022c), a lack of expertise in utilizing modern technologies for managing construction projects (Bekr 2015), and a lack of safety management practices.

With the impact of these existing challenges, the COVID-19 pandemic has increased the ceiling of challenges for the Iraqi construction industry, resulting in increases in materials costs, delays in payments, distribution of the supply chain, and contractual, legal, and insurance challenges (Al-Mhdawi et al. 2022). Most of the ongoing construction projects in Iraq have been delayed as a result of the pandemic due to full curfews or strict safety regulations imposed by the central government. Apart from the strict safety measures and curfews in Iraq, the vaccination rate remains low (about 19.3% as of Nov 12, 2022), which delays the post-pandemic recovery phase of the overall economy, including the construction industry. Furthermore, despite the unique and multidimensional impact of COVID-19 in Iraq, the government has not provided subsidies or financial support to construction contractors or other parties involved. This has primarily impacted small and medium-sized construction companies, resulting in bankruptcies and business losses for contractors (Al-Mhdawi et al. 2022b). Considering the lack of RM practices employed in the Iraqi construction industry, the effects of the COVID-19 pandemic will not only affect the construction industry during the pandemic but will also affect the Iraqi construction industry's sustainable growth and post-pandemic recovery.

This study is being conducted in Iraq for a reason. The practices of construction management in general, and those of RM in particular, are, by definition, local. Different countries may employ different practices as a result of differences in management knowledge, training, regulations, and policies. As a result, it is not possible to conduct a study that examines RM practices in the construction industry from a global perspective, particularly during times of extreme conditions, such as the COVID-19 pandemic. A study of this nature has to be conducted in a location/country that is preferably not trivial. To this end, Iraq was selected as a case study due to the following reasons:

1. The Iraqi output value of the construction industry is anticipated to present an annual growth rate at a compound rate of annual growth of 15.75% during (2019-2023) (Market Research Iraq 2021). The industry is consequently expected to rise from a value of US$9.2 billion in 2018 to US$19.2 billion in 2023 (Research and Marker 2021).
2. Iraq's government is heavily investing in its infrastructure and has taken legislative measures to attract foreign contractors to perform work within the country.
3. According to the Iraqi Contractors Association, when one considers the direct as well as indirect impacts of the construction industry on other sectors, the construction industry constitutes up to 22.5% of the Iraqi economy, and it employs 16.3% of the Iraqi workforce (ILFS 2021), making it the main branch of economic activity in Iraq.
4. In spite of the fact that each country has its own unique construction regulations and contractual provisions, those of Iraq are particularly unique. Contracts and regulations in Iraq differ considerably from those in other countries. Therefore, construction contractors are exposed to an increased number of risks and require frameworks to improve their understanding of what they will encounter when implementing construction projects under extreme conditions.

**Aim and Objectives**

The aim of this paper is to assess the level of significance of RMICB and the level of efficacy of RM practices in the construction industry during COVID-19 by considering the case of Iraq. The associated objectives areto (1) identify the key challenges and barriers to RM implementation, (2) identify the indicators of RM practices, and (3) quantitatively assess the level of significance of construction RMICB, and the level of efficacy of RM practices during the COVID-19 pandemic. Iraqi construction contractors and project managers may benefit from this study since it allows them to gain a deeper understanding of the factors that contribute to effective RM practices under extreme conditions such as the COVID-19 pandemic. In addition to improving construction practitioners' performance when managing risks, this understanding will enhance their competitive position in the Iraqi construction market.

**Research Methodology**

As depicted in Fig. 1, a multi-stage research methodology was adopted in order to achieve the research objectives. The following subsections outline the detailed steps adopted by the authors.

***Stage 1: Semi-Structured Interviews***

Semi-structured interview is highly effective in obtaining insights from participants in order to explain or explore complex phenomena or problems, and it provides reliable and comparable qualitative information (Galletta 2013). This type of interview consists of a series of prepared questions, with the interviewer allowing time for the interviewees to elaborate and explain concepts using open-ended questions. To this end, the authors used it to (1) identify the main challenges and barriers facing construction project RM implementation during the COVID-19 pandemic; and (2) identify the indicators of effective RM practices for construction projects. In order to identify any potential limitations or weaknesses within the interview questions, the authors conducted a pilot study with five construction experts in Iraq, each of whom has over 15 years of construction experience and works for the Iraqi Ministry of Construction, Housing and Municipalities and Public Works (IMCGMPW), and the private construction sector (see the profiles in Table 1). The authors used the feedback and suggestions from the pilot study to revise and enhance the questions for the semi-structured interviews.

1. *Interview Process*

To approach experts, the authors used previous contacts with several directors and managers at the IMCGMPW, and the heads of civil engineering departments at several public universities in Iraq. In addition, the authors identified construction experts and academics and located them using LinkedIn and other social media platforms. To this end, the authors identified 57 potential participants. However, additional selection criteria were developed by the authors to sifter the potential participants based on previous studies such as Abdul Nabi and El-adaway (2021). The selection criteria included (1) working in the Iraqi construction industry and/or engineering management education (2) having at least 15 years of experience in construction engineering and management, (3) being active members of Iraqi Engineers Union and/or registered contracting companies at the Iraqi Ministry of Trade, and (4) being active members of international professional bodies like the Association for Project Management, the American Society of Civil Engineering, or the Institution for Civil Engineers. Ultimately, the authors selected 30 construction experts and academics for the interviews.

Upon completion of the interviews, one of the authors, who is a native Arabic speaker and fluent in English, translated the transcripts from the local language (Arabic) to English. Then, a manual content analysis was performed to identify the main study factors. In content analysis, key information is extracted from verbal, written, or video files, either quantitatively or qualitatively (Krippendorff 2013). This method is highly effective in organizing and analyzing information within documentary data and has been employed extensively in previous construction engineering and management research. In this research, the key factors were identified and sorted in a constructive way during the analysis process. Furthermore, the authors reviewed the recorded material again to capture the comprehensiveness and details of the recorded materials.

***Stage 2: AHP-Questionnaire Survey***

1. *Survey development*

The authors developed a survey to assess the level of significance of RMICB during COVID-19 obtained from the interview. To quantify the importance and effect of RMICB, the respondents were asked to rate the identified RMICB according to (1) their level of the probability of occurrence (LP), such as how likely or how often these challenges and barriers occur on average during COVID-19; (2) their level of impact on cost (LIC) that is the anticipated impact on the project cost if these challenges and barriers occur; and (3) their impact on the schedule (LIS) indicating the anticipated impact on the project schedule if these challenges and barriers occur. It should be noted that these assessment criteria were used extensively in previous risk management studies (see e.g., Abdul Nabi and El-adaway 2021). The survey comprised of two sections; the first section sought the demographic information of the respondents, such as working sector, construction role, years of experience, and educational background. In the second section, the respondents were asked to assign relative weights to the identified RMICB based on Saaty's 9-point scale (Saaty 1987).

1. *Survey Pilot Testing*

To examine the level of effectiveness and clarity of the developed questionnaire survey, ten industry experts from Iraq were asked to complete a pilot questionnaire. All participants have over 15 years of construction experience and work for the IMCGMPW, the Iraqi Ministry of Higher Education and Scientific Research (IMHESR), or the private construction sector (see the profiles in Table 2). Based on the feedback, the authors made minor modifications to the survey questions.

1. *Survey administration*

The final version of the survey was administered to 200 construction experts in Iraq who (1) are working in the Iraqi construction industry, (2) have at least five years of experience in construction, (3) are active members of the Iraqi Engineers Association or registered contractors with the Iraqi Ministry of Trade, and (4) are active members of international professional bodies. The respondents include project managers, contractors, consultants, and safety engineers.

***Stage 3: Development of AHP-based RMICB Assessment Model***

1. *Background*

The Analytic Hierarchy Process (AHP) has been extensively used in different areas of engineering management as a multicriteria decision-making method for dealing with complex decision-making problems (Saaty and Alexander 1989; Su et al. 2015; Lin et al. 2021; Stumbauer and Lalis 2022; Al-Mhdawi et al. 2023c). AHP is chosen in this research over conventional methods such as Probability and Impact Matrices and Failure Modes and Effect Analysis because it has the ability to resolve conflicts of opinion or establish priorities by analyzing the respondents' objective and subjective factors through pairwise comparison matrices (Darko et al. 2019).

1. *Model Development*

In this research, the authors quantitatively assessed the level of significance of construction RMICB during COVID-19. All model inputs were derived from the expertise and engineering judgment of the interviewed construction professionals. While the experts have substantial knowledge of the construction industry, COVID-19 represents an unprecedented extreme condition that has not been encountered before (Al-Mhdawi et al. 2022a). Consequently, there may be uncertainty regarding the experts' responses due to imprecise or incomplete information. The details of the developed AHP model are discussed in the following steps:

***Step 1:*** *Establishment of the Hierarchy*

In this step, the authors structured the elements of the problem into three hierarchies (i.e., LP, LIC, and LIS) and each hierarchy consisted of three levels, namely the target level (i.e., the assessment criteria for RMICB), the factor level (i.e., the classification of RMICB), and the sub-factor level (i.e., the identified RMICB).

***Step 2:*** *Development of Pairwise Comparison Matrices*

In this step, the authors developed a set of(*k* x *y*) pairwise comparison matrices for the factor and sub-factor levels with respect to the target of each hierarchy.Table 3 presents the numerical scales and their descriptions for both factor and subfactor levels used in the pairwise comparison matrices. As a guide to the proper use of Table 3, the authors provided the experts with three guiding questions regarding the analysis criteria, which reflect the interdependence between the analysis criteria related to RMICB as outlined in Table 4.

It should be noted that these conditional questions are qualitative measures derived from experts’ opinions during the interview process. In the case of estimating probabilities (question 1), it is common that experts are asked to provide conditional probabilities in order to reduce the complexity of the questions and, therefore, obtain more reliable responses (Ayyub 2001). Once the experts' judgments were collected and computed using the geometrical mean (see Equation 1), they were placed into pairwise comparison matrices using Equation 2.

*aky (aky1 \* aky2 \* aky3…….. akyn)1/n* (1)

where *ky*  (*k*, *y*=1, 2, ...., *n*) represents the comparison ratios for the pairwise comparison matrix, and n represents the number of comparison elements.

(2)

Where L denotes the pairwise comparison matrix; its properties are as follows: *ky* > 0; *ky*  = (1/*ky*); ∀ *k* where *y =*1, 2, …, n.

***Step 3****: Normalization of pairwise comparison matrices*

In this step, the authors computed the normalized pairwise values of the developed matrices by summing the elements in each column (matrix cell values) (Equation 3) and dividing each element in each column by the sum of the respective column values using Equation 4.

*ky*  (3)

N= *ky*/ *ky* (4)

Afterward, the weights of the factors (also known as local priorities) were computed by averaging the matrices row values, which indicated the relative importance levels of the factors.

***Step 4:*** *Computation of the Consistency Ratio*

In this step, the authors computed the Consistency Ratio (CR) for the factor level. The computation of CR involved the following sub-steps:

1. Calculation of the weight sum vector using Equation 5.
2. Calculation of the consistency vector using Equation 6.
3. Calculation of the principal eigenvalue (also known as λmax) for each comparison matrix by averaging the values.
4. Calculation of the consistency ratios for all reciprocal matrices using Equations 7 and 8 to ensure consistency of expert judgment.

(5)

(6)

Consistency Ratio (*CR*)= (7)

Consistency Index (*CI*)= (8)

where *z* is the number of criteria (risks); λmax is the maximum eigenvalue; and *CI* is the consistency index of a pairwise comparison matrix (obtained from Table 5).

***Step 5:*** *Evaluation of the Consistency Ratio*

In this step, the authors evaluated the validity and consistency of the developed pairwise comparison matrices based on the calculated CR value of the factor level for each developed hierarchy. According to Park et al. (2015), a CR value of 10% or higher indicates poor consistency, and thus the pairwise comparison matrix should not be further analyzed. In contrast, a CR value of less than 10% indicates a valid and consistent matrix, which subsequently extends the analysis process by normalizing and checking the consistency of experts' decisions for the sub-factor level matrices using the same strategy as suggested in the aforementioned steps.

***Step 6:*** *Determination of the RMICB Level of Impact*

In this step, the authors calculated the Global Priority (GP) of the sub-factors level. GP refers to the overall factors’ prioritization with respect to the suggested assessment criteria by the construction experts, and it is determined by multiplying the local priorities of the factors by the global priority of their corresponding categories.

To this end, the authors calculated the Challenges and Barriers Priority Number (*Cbpn*) of the sub-factor level by aggregating the GPs of the LP, LIC, and LIS (Equation 9). It should be noted that Equation 9 was developed in accordance with experts' recommendations.

*Cbpn* = *Gblp* + *Gblic* + *Gblis* (9)

Where: *Cbpn* is the challenges and barriers priority number; *Gblp* is the global priority for the level of probability of occurrence; *Gblp* is the global priority for the level of impact on cost; and *Gblis* is the global priority for the level of impact on schedule

***Stage 4: Fuzzy-Questionnaire Survey***

In this stage, the authors used a second questionnaire survey to rank the level of effectiveness of RM practices in relation to the identified RMICB. The questionnaire survey consisted of two sections. The first section of the survey introduced the purpose of the survey and aimed to identify the characteristics of respondents, such as their working sector, their construction role, their years of experience, and their educational background. In the second section, the participants were asked to rate each factor of the RM practices in relation to each RMICB using a five-point Likert scale (0.1: very low to 1.0: extremely high). The authors used the same expert selection criteria and survey development process stated in Stage 3 of the research methodology. The survey was piloted by the same experts who piloted the AHP survey, where minor modifications were made to the survey questions. To this end, the final version of the survey was distributed to 200 construction experts working in the public and private sectors of the construction industry in Iraq.

1. *Survey Reliability*

In this research, Cronbach's alpha test was performed in order to determine the reliability and validity of the responses collected from the multipoint scales. Chirstmann and Van Aelst (2006) contend that a valid and reliable scale should result in a value of 0.75 or higher. To this end, the authors assessed the reliability of the scales used for fuzzy model input.

***Stage 5: Development of Fuzzy-based RM Practices Assessment Model***

1. *Background*

Fuzzy Set Theory (FST) is an extension of the classical notion of a set (Zadeh 1965). FST's main advantage lies in its ability to formalize and handle human knowledge and uncertainty (i.e., lack of complete and precise information) in decision making (Loh et al. 2019; Zhang et al. 2016), as well as vagueness and subjectivity associated with linguistic terms (e.g., very low, low, moderate, high, very high). According to this theory, linguistic terms are less precise than crisp values (i.e., numerical numbers) (Kurd and Kelly 2007). In other words, crisp values cannot satisfy the assessment criteria of an event (e.g., emerging risks of the COVID-19 pandemic) or practice (e.g., RM practices) because of ambiguity and conflicting expert judgment that is caused by ill-defined data and inadequate decision-making processes. Therefore, the authors used FST to quantify the level of efficacy of construction RM practices with respect to the identified RMICB.

1. *Model Development*

In this research, the authors developed a fuzzy-based model to quantitatively assess the efficacy of RM practices during the COVID-19 pandemic. The fuzzy-based assessment model was designed as a hierarchical structure with several inputs and one output using MATLAB® (V.2021a).

The following sub-sections describe the model components in detail.

*Model inputs*

The number of inputs corresponds to (1) the linguistic variables of the indicators of risk management practices in the construction industry; and (2) the significant RMICB obtained from the AHP model. To this end, 12 inputs were used in the model for each significant RMICB. These input values ranged from 1.0 (very low) to 5.0 (very high) and were provided by construction experts in Iraq through the survey instrument (refer to the fuzzy survey in Stage 4 of the Research Methodology). The RM practices inputs were categorized into six blocks, namely, 1) Stakeholders’ Involvement Level, 2) Organization Communication Level, 3) Risk Management Training level, 4) Organization Risk Culture, 5) Risk Management Policies, and Continuous Risk Monitoring. The factors of each block were obtained from expert interviews and presented in Section 4.5 in the Results and Discussion section.

*Fuzzy Controllers and Model Output*

In total, six fuzzy controllers and three fuzzy sub-systems were used in the developed model. Controllers 1 to 6 had three inputs, 125 IF-THEN conditional statements, and one output. In sub-system 1, the inputs consisted of the crisp values (outputs) of fuzzy controllers one to three. Additionally, subsystem 1 consisted of 125 IF-THEN rules with one output (i.e., the quantified practices of blocks one to three). In sub-system 2, the inputs were the crisp values (outputs) of fuzzy controllers three to six. In addition, there were 125 IF-THEN conditional statements and one output (i.e., the quantified practices of blocks four to six). Lastly, sub-system 3 consisted of two inputs (i.e., outputs of sub-system 1 and 2) and 25 IF-THEN rules, as well as one output. The output of sub-system 3 represents the Risk Management Quantified Practices (*Rmqp*) with respect to each RMICB. The *Rmqp* in relation to each RMICB may range from 0.1 to 1.0, where 0.1 represents very poor RM practices efficacy, while 1.0 represents very high RM practices efficacy.

Since the establishment of fuzzy IF-THEN rules should be based on experts' judgment and experience (Pourjavad and Shahin 2018), the conditional statements for the entire model were established based on interviews conducted with several industry experts in Iraq. To reduce bias during the statement formulation process, the authors ensured that (1) the interviewees were experienced in related areas and (2) multiple rounds of interviews were conducted to attain consensus among experts. To this end, the authors conducted five interviews with four construction management professors and one experienced project manager in Iraq. The authors chose the interviewed experts based on their experience in FST, as well as their knowledge of the Iraqi construction industry. Ultimately, five rounds were eventually required to ensure consensus among the interviewed industry experts. In total, 900 IF-THEN statements have been developed to encompass all input alternatives in this model.

The main processes associated with the model developed are fuzzification, fuzzy inference system, and defuzzification. The authors, given the length limitations of the paper, focused only on highlighting the key aspects of each process as follows:

1. For fuzzification, the authors used triangular membership functions to represent input and output variables due to its simplicity, effectiveness in capturing subjective and imprecise information, ease of defining the input range, and ease of performing arithmetic calculations.
2. For fuzzy inference system, the authors used Mamdani’s fuzzy inference system (MFIS) to assess the output variable. The authors used MFIS due to its (1) widespread usage in the literature, (2) intuitive nature, and (3) suitability for subjective inputs.
3. For defuzzification process, the authors used the centroid of area method, which is a widely used method of defuzzification to reflect the viewpoint of the experts.

It is important to note that the use of the fuzzy-based RM practices efficacy assessment model depends on (1) direct inputs from RM practices (i.e., RM practices indicators); and (2) outputs from the previous AHP-based challenges and barriers assessment model. The process of determining the level of significance (as weights) of the RMICB and how they affect the efficacy of RM practices cannot be accomplished using one singular model such as AHP, fuzzy logic, or other quantitative methods such as fuzzy synthetic evaluation. This is because this paper tries to integrate the findings of two objectives (i.e., determining the challenges and barriers to RM implementation, and RM practices efficacy) in a mechanism that focuses on the most significant challenges and barriers to RM and assesses the efficacy of RM practices based on these findings. By obtaining the results from one model (i.e., the AHP-based assessment model) and incorporating them into the other model (i.e., the fuzzy-based assessment model), decision-makers will be able to understand the significance of the identified RMICB individually and collectively and examine their impact on project success through the quality of the RM practices provided. This input-output relationship between the two assessment models was utilized to identify the three most significant RMICB from each of the challenges and barriers themes based on the output of the AHP-based assessment model, which was then used as inputs to quantify the efficacy of RM practices using the fuzzy-based assessment model. The importance of considering all the challenges and barriers affecting RM effectiveness cannot be overstated. However, construction projects usually operate within a dynamic environment involving a wide range of stakeholders and are subject to a variety of risks and uncertainties. Therefore, it is imperative to focus on the challenges and barriers that have the greatest impact on the efficacy of RM practices, which in turn have a significant impact on the success of construction projects (Goh and Abdul-Rahman 2013). This will enable decision-makers to focus their attention and resources on mitigating these challenges. Furthermore, the analysis of all the challenges and barriers to RM implementation would require an excessive length of data analysis and description, which is not appropriate for a journal article.

***Stage 6: Models Verification and Validation***

In this stage, the authors (1) verified the methodological steps for the AHP and Fuzzy assessment models in terms of their perceived practicality and ease of use; and (2) validated the research outputs with six construction professionals who held managerial positions at the IMCGMPW and the IMHESR. The members of the verification and validation panel were selected based on their management positions and their decision-making authority at their institutions. The results of this stage are presented in section 4.6 in the Results and Discussion section.

**Results and Discussion**

***Semi-structured interviews***

1. *Participants’ profile*

As mentioned previously, the authors interviewed 30 construction experts in Iraq, including project managers, contractors, safety engineers, and academics. A number of the participants in this study were from the upper management levels of their organizations and were involved in the construction and management of large-scale projects in Iraq. These 30 experts represented three Iraqi governorates, with the greatest number of respondents from Baghdad (BG), followed by Basrah (BS) and Al-Qadisiyah (AQ) governorates (see Fig. 2). Further, the profiles of the interviewees are presented in Table 6.

***Risk Management Implementation Challenges and Barriers***

Following the completion of the interviews, the authors were able to identify 34 RMICB and grouped them under four categories, namely analytical approach-related, behaviour-related, management-related, and team-related challenges and barriers. Table 7 presents the identified RMICB and their categories. **Appendix A** shows the semi-structured interview questions.

***Identified RM Practices Indicators***

In this section, the main indicators of RM practices are outlined, along with their factors (i.e., indicators rectifiers). The details on each RM indicator are provided in the following subsections.

1. *Stakeholders Involvement Level*

To effectively manage risk, stakeholders must be involved in all stages of the process, starting with the initial assessment of risks through risk allocation and monitoring and controlling. Project stakeholders in this research context include project managers, contractors, clients, consultants, etc. Each of these stakeholders represents a different role and responsibility within the organization. Thereby, their involvement in the RM processes can provide numerous benefits. Some of these include (Loosemore et al. 2012): improving the relationships between the parties involved, better understanding their risk and opportunity management responsibilities, and increasing the transparency of decisions. According to the interviews, stakeholders’ involvement level in RM processes depends on two factors, namely: the relative significance of each stakeholder to the other (LS) and the level of interest the stakeholders have in the project (LI).

1. *Organizational Communication Level*

Communication refers to the sharing of project information, which takes place throughout the course of the project. Project communication management processes are designed to ensure the proper production, collection, and dissemination of information related to the project (Steinheider and Al-Hawamdeh 2004). It plays a vital role in the success of a project and has a great impact on its stakeholders (El-Saboni et al. 2009). The greater the number of members in the project team and its stakeholders, the more crucial project communications management will be (Shakeri and Khalilzadeh 2020). According to the interviews, the organizational communication level in RM processes depends on two factors, namely: organizational communication culture (OCC), and usability of the communication tools (CT).

1. *Risk Culture*

The concept of risk culture refers to a group of people's values, beliefs, and attitudes concerning risk (Levy, Lamarre, & Twining, 2010). Managers and directors are responsible for communicating the organization's risk culture and setting the tone for compliance. Based on the interviews, the level of risk culture in the organization is determined by two factors, namely: willingness to collaborate and knowledge sharing (WCKS), and conflict in values (CV).

1. *Risk Management Training Level*

Risk management training can help improve the team's ability to manage risk, develop a more robust framework for risk management, and enhance the team's confidence in using risk management tools and techniques. The results from the interviews indicated that (1) the availability of expertise for training (AET) and (2) availability of resources (AR) were the main factors determining the level of risk management training in the construction projects in Iraq.

1. *Risk Management Polices*

The purpose of risk management policies is to provide guidelines regarding risk management in order to help facilitate the achievement of corporate goals and ensure financial sustainability. Based on the interviews, the level of adoption of risk management policies depends on upper management support and openness (UMSO) to adopt RM policies; and (2) RM potential benefits (RMPB).

1. *Continuous Risk Monitoring Level*

Continuous risk monitoring is a comprehensive process for identifying uncontrolled risks in a project, prioritizing audit and risk management control procedures, and supporting organizational decision-making (Kott and Arnold 2013). Clear monitoring processes must be established to ensure that all risk mitigation efforts are working and effective. This is a crucial aspect of any RM process and must be a continuous and constantly evolving process (Moon 2016). The results of the interviews indicated that (1) RM integration (RMI) with other management processes; and (2) project parties integration (PPI) were the main factors determining the level of continuous risk monitoring in the construction projects in Iraq.

***AHP-Questionnaire Survey***

As described in Stage 2 of the research methodology, the authors administered a questionnaire survey to rank the level of impact of construction RMICB during the COVID-19 era. Out of the 200 distributed surveys, 117 surveys were returned. However, only 84 out of 117 responses were complete and therefore were included in the analysis. As such, the response rate for the survey was 42%.

To ensure a solid basis for analysis, it is imperative to determine whether the data collected from the respondents are a representative sample of all respondents. Thus, the authors assessed the sufficiency of the data collected from this investigation based on the empirical data from previous survey-based studies, as suggested by Abdul Nabi and El-adaway (2021). To this end, evidence suggests that survey response rates for engineering and construction management-related research range from 20% to 30% (Assaad et al. 2020) due to low participation rates in surveys and questionnaires (Wu et al. 2015). Accordingly, the obtained survey response rate of 42% is considered sufficient. Fig. 3 to Fig. 6 show that the respondents' profiles reflect a wealth of experience drawn from a wide range of construction roles and academic backgrounds, ensuring the creditability of the survey responses.

***Fuzzy-Questionnaire Survey***

As per Stage 3 of the research methodology, the authors distributed a questionnaire survey to quantify RM practices in relation to RMICB. 138 out of 200 distributed surveys were returned. Of the 138 survey forms returned, only 107 were completed and included in the analysis. Accordingly, the response rate for this survey is 53.5%, indicating a sufficient response rate. Fig. 7 to Fig. 10 reveal that the survey participants exhibit a wide range of experiences in various construction roles and educational backgrounds, which enhances the credibility of the survey. The diversity of participant profiles ensures that the survey findings are not restricted to a narrow segment of the construction industry. This aspect is critical to the generalizability of the survey results and the development of meaningful conclusions.

To determine the validity and reliability of the survey data and scales, the authors conducted a Cronbach's alpha test after collecting the survey responses. The distribution survey had a Cronbach's alpha value of 0.83. As per Stage 3 of the methodology, a reliable survey should have a Cronbach's alpha value exceeding 0.75 (Chirstmann and Van Aelst 2006). Consequently, the distributed survey is valid and reliable.

***COVID-19 AHP-based Assessment of Construction RMICB***

As mentioned in Stage 3 of the research methodology, the authors quantified the challenges and barriers to construction risk management implementation during the COVID-19 pandemic under the AHP environment. In total, three hierarchies of assessment criteria were established for LP, LIC, and LIS. As presented in Fig. 11, each developed hierarchy consisted of three levels (i.e., target, factor, and sub-factor levels). The target level included the three main assessment criteria (i.e., LP, LIC, and LIS). The factor level included four categories of RMICB (i.e., analytical approach-related, behavior-related challenges and barriers, management-related, and team-related). Furthermore, the sub-factor level included 34 RMICB during the COVID-19 pandemic. To this end, the authors developed 15 reciprocal matrices to assist the AHP-survey respondents in determining the weights of the categories and RMICB. Ultimately, consistency ratios were calculated for the pairwise comparison of the challenge and barrier categories with respect to the assessment criteria, as can be seen in Table 8.The obtained consistency ratios were less than 10%, indicating that the matrices are valid and consistent (Park et al. 2015). Accordingly, the authors calculated the global and local priorities for the assessment criteria, their *Cbpn* values, and their group and overall ranking, as shown in Table 9.

The analytical approach-related RMICB pertain to the impediments and difficulties encountered while utilizing quantitative-based risk analysis techniques for managing risks associated with the COVID-19 pandemic in the construction industry. In this category, the complexity of quantitative risk assessment models (A02) was ranked first in this category and second overall, with a *Cbpn* value of 0.3443. The time-consuming process of implementing risk management strategies in a rapidly changing COVID-19 environment (A03) was ranked second in this category and fourth overall, with a *Cbpn* value of 0.2015. The ineffectiveness of quantitative-based approaches for managing risks due to the high expenses associated with licensing, training, and software familiarity (A05) was ranked third in this category and tenth overall, with a *Cbpn* value of 0.0995.

The behavior-related RMICB refer to obstacles that arise due to human behavior and attitudes that can hinder effective risk management in an organization. In this category, the increased occurrence of bribery due to financial strain caused by the COVID-19 pandemic (B02) was ranked first and held the first position overall (*Cbpn* =0.4215). The reduced willingness to collaborate among stakeholders due to social distancing measures and remote work arrangements caused by COVID-19 (B04) placed second in this category and held the third position overall (*Cbpn* =0.2218). Reluctance to adopt new project management practices due to uncertainty caused by COVID-19 (B01) was ranked third in this category and 12th overall (*Cbpn* =0.0728).

The team-related RMICB refer to the difficulties that arise within project teams or departments when attempting to implement risk management strategies within an organization. In this category, Lack of a unified risk management framework for construction projects during the COVID-19 pandemic (T04) was ranked first and sixth overall (*Cbpn* = 0.1368). Limited expertise and experience in managing COVID-19 related risks (T01) placed third within this category and 13th overall (*Cbpn* = 0.0651). Conflicts in subjective assessment by risk assessors due to the uncertain and rapidly changing nature of the pandemic (T08) was ranked second in this category and eighth overall (*Cbpn* = 0.1218).

The management related RMICB refer to the difficulties that managers may face when attempting to implement risk management strategies within an organization. In this category, the ineffective communication of risk-related information during the pandemic (M10) was ranked first in this category and fifth overall (*Cbpn* = 0.1415). Additionally, the lack of a unified risk management framework for construction projects during the COVID-19 pandemic placed second within this category and seventh overall (*Cbpn* = 0.1300). Moreover, inadequate integration of risk management with other project management processes during the COVID-19 pandemic (M06) was ranked third in the team-related category and ninth overall (*Cbpn* = 0.1060).

To this end, the three most critical RMICB in each category, with respect to the analysis criteria of the developed AHP assessment model, were used as inputs in the Fuzzy model to compute the level of efficacy of the construction RM practices during COVID-19 pandemic as described in the following section.

***COVID-19 Fuzzy-based Assessment of Construction RM Practices***

As mentioned in Stage 5 of the research methodology, the authors used the fuzzy logic toolbox in MATLAB® (V.2021a) to design and implement the proposed COVID-19 Fuzzy-based RM practices assessment model. The model consisted of 13 inputs, six fuzzy controllers and three fuzzy sub-systems, 900 conditional statements (i.e., for the controllers and sub-systems), and one output variable (i.e., *Rmqp*) as presented in Fig. 12.

In the model implementation, the LS, LI, OCC, CT, AET, AR, WCKS, CV, UMSO, RMPB, RMI, and PPI values rated by fuzzy-survey respondents served as inputs when developing the fuzzy inference system. These values were fuzzified using a triangular fuzzy membership function as presented in Equation 10. In addition, 900 IF-THEN statements were developed under the Mamdani interference system. Further, the *Rmqp* by each respondent was computed by defuzzifying the output membership function using the centroid of area method presented in Equation 11. Table 10 shows the *Rmqp* level of each significant challenge and barrier to RM implementation, along with the *Rmqp* average value for each of the significant RMICB and their categories.

The *Rmqp* values and their ranking (high to low) were as follow: M06 (ranked first, with a *Rmqp* value of 0.4960), T08 (ranked second, with a *Rmqp* value of 0.4519), M10 (ranked third, with a *Rmqp* value of 0.3683), A03 (ranked fourth, with a *Rmqp* value of 0.3594), T04 (ranked fifth, with a *Rmqp* value of 0.3508), M04 (ranked sixth, with a *Rmqp* value of 0.3458), B04 (ranked seventh, with a *Rmqp* value of 0.3386), A05 (ranked eighth, with a *Rmqp* value of 0.3321), B01(ranked ninth, with a *Rmqp* value of 0.3292), T01(ranked tenth, with a *Rmqp* value of 0.3271), A02 (ranked 11th, with a *Rmqp* value of 0.3265), B02 (ranked 12th, with a *Rmqp* value of 0.3168).

Furthermore, the average (Av) *Rmqp* for the Management-related challenges and barriers was ranked first among the four categories of the identified RMICB with Av. *Rmqp* equal to 0.4033. This was followed by team-related challenges and barriers (ranked second, with an Av. *Rmqp* value of 0.3766), AnalyticalApproach-related challenges and barriers (ranked third, with an Av. *Rmqp* value of 0.3393), and Behavior-related challenges and barriers (ranked fourth, with an Av. *Rmqp* value of 0.3282).

To this end, the results of the RM practices assessment using fuzzy set theory indicated a low level of practices in relation to the significant challenges and barriers to construction RM implementation during the COVID-19 pandemic.

***COVID-19 AHP-based and Fuzzy-based Models Verification and Validation***

As mentioned in Stage 6 of the research methodology, a selected panel of top management was asked to provide comments regarding the methodological steps of the developed AHP and Fuzzy assessment models and the outputs. In terms of their perceived practicality of use and ease of use. To this end, the models were commented on by a panel of six construction experts. It is important to mention that the validation and verification experts did not participate in the data collection and model development. Table 11 outlines the profiles of the panel members. Two criteria were used to verify the model, namely perceived practicality of use and ease of use. All respondents felt that the contents of the model were practical for the Iraqi construction industry and easy to understand and interpret, as well as being easy to customise to reflect the unique characteristics of each construction project. In fact, four out of six respondents thought the AHP assessment model covered all relevant aspects for the assessment of RMICB. Furthermore, five out of six respondents thought the architecture of the fuzzy assessment model covered all main aspects of the assessment criteria of RM practices during the COVID-19 pandemic. Based on the panel members' perceptions of the practicality of use of the developed models, they indicated that the model could be useful in determining (1) which RMICB and which RM practices are in need of an in-depth root cause analysis; (2) RMICB during a COVID19 pandemic that might be useful for lessons learned analysis; and (3) the level of effort (i.e., upper management support, training, and budget amount and allocation) required to address the poor RM practices in the Iraq construction industry. Further suggestions for improvement were also made. An expert, for instance, stated:

“The developed models captured two crucial angles of RM (i.e., RMICB and RM practices); however, the model could be further enhanced by capturing how experts respond to such challenges and quantifying the level of effectiveness of their response strategies.”

Ultimately, the experts were satisfied with the overall layout, content, and characteristics of the developed assessment models.

**Conclusions**

This research examined the RMICB and RM practices for construction projects during the COVID-19 pandemic by considering the case of Iraq. First, the authors conducted semi-structured interviews with 30 Iraqi construction professionals to identify the main RMICB and identify the indicators of effective RM practices. Second, an AHP-based survey was administrated and answered by 84 experts to rate the level of significance of RMICB. Third, a Fuzzy-based survey was administrated to and answered by 107 experts to rate the efficacy level of RM practices in relation to the identified RMICB. Fourth, an AHP-based model was established to quantify RMICB. Fifth, a Fuzzy-based model was developed to quantify RM practices efficacy in relation to RMICB. Finally, a panel of six construction decision-makers was interviewed to verify and validate the developed assessment models and their analysis outputs.

Based on the adopted methodology, the authors identified a total of 34 RMICB grouped under four categories, namely analytical approach-related RMICB, behavior-related RMICB, management-related RMICB, and team-related RMICB. According to the results, the three most significant analytical approach-related RMICB during the COVID-19 era were (1) the complexity of quantitative risk assessment tools, (2) the time-consuming process, and (3) the ineffectiveness of the cost of RM analytical approaches. In the case of behavioral barriers and challenges, the results revealed that the three most significant RMICB were bribery, lack of willingness for collaboration, and lack of willingness to change the current project management practices. Furthermore, the results indicated that ineffective risk communication, lack of a unified RM framework for construction projects, and inadequate integration of RM with other project management processes were the three most significant management-related RMICB. Finally, the results showed that insufficient familiarity with RM process, lack of expertise and experience, and the conflict between the subjectivity of risk assessors were the three most significant team-related RMICB.

Regarding construction RM practices and their level of efficacy during the COVID-19 era, the authors identified six indicators for measuring the efficacy level of RM practices. These indicators included 12 factors, namely the relative significance of each stakeholder to others; the level of interest the stakeholders have in the project; organization communication culture, usability of the communication tools, willingness to collaborate and share knowledge, and conflict in values, the availability of expertise for training, the availability of resources; upper management support and openness to adopting RM policies, RM potential benefits, and RM integration with other management processes, and project parties integration. The results showed that RM practices (as average values) in relation to the identified categories of RMICB were as follows: management-related (0.4033), team-related (0.3766), analyticalapproach-related (0.3393), and behavior-related challenges and barriers (0.3282). To this end, the research conclusions can be summarised as follows:

1. RM provides a structured framework for systematically guiding the process of managing unwanted events that would otherwise be overlooked. In the construction context, this process plays a vital role in improving communication among the team members, maximising the effective use of resources, discouraging the acceptance of financially unsound construction projects, reducing the instability of construction activities, preserving contracting firms’ credibility and reputations, and improving decision-making processes.
2. In extreme conditions such as the COVID-19 pandemic, RM becomes even more crucial. Despite the willingness of stakeholders to consider RM effectively in Iraq, without proper RM practices and the timely implementation of risk mitigation strategies, and without a strong commitment on the part of all project parties, Iraq may be regarded as one of the countries with the least effective RM practices.
3. The most significant challenges and barriers affecting RM practices in Iraq during the COVID-19 pandemic are not partial challenges (micro-challenges), but rather structural challenges (macro-challenges), which can be grouped into four categories of challenges and barriers: analytical approach-related, behaviour-related, management-related, and team-related challenges and barriers.
4. Identifying, analyzing, and responding to risks by construction experts in Iraq relies heavily on past experience and engineering judgment, regardless of the company’s working sector (private or public), size, type of contractor (general or subcontractor), and maturity level in risk decision-making practices
5. The majority of construction companies in Iraq view the implementation of a structured RM approach, whether it is qualitatively-based, quantitatively-based or a combination of both, as an unnecessary expense.
6. Managing construction project risks under extreme conditions, such as the COVID-19 pandemic, requires expert input, due to the absence of historical data from previous projects. This is another reason that leads decision-makers to rely solely on their engineering experience and judgment. The use of well-established methodologies, such as AHP and fuzzy logic, which can quantify the uncertainty of subjective judgments, is well observed by the Iraqi construction industry experts during such conditions.
7. The integration of RM into other project management processes when implementing construction projects in Iraq during the COVID-19 era is not effective due to a lack of expertise in managing risks, a lack of knowledge about the logical process of the risk management process, as well as its standards and professional guidelines, a lack of upper management support, a lack of collaboration between the contract parties, and the high level of uncertainties faced by construction projects, along with the urge to make fast deterministic decisions.
8. The most frequently required features of a desirable assessment methodology for RM implementation challenges and barriers, RM practices efficacy, and risk analysis during extreme conditions like the COVID-19 pandemic are: (1) ease of use and simplicity; (2) the ability to perform the analysis quickly; and (3) the ability to customise the analysis to reflect the unique characteristics of each construction project.
9. The risk practices assessment model based on FST developed in this paper suggested that construction RM practices during extreme conditions like the COVID-19 pandemic can be effectively assessed using six sub-systems (i.e., RM practices indicators and their components), namely stakeholders’ involvement level, organisational communication level, RM training, risk culture, RM policies, and continuous risk monitoring. It is evident from the fuzzy analysis results and the model validation that any construction company can measure its RM practices only if these five subsystems are working harmoniously together. Consequently, all of these factors should be considered equally important by decision makers throughout the entire project lifecycle.
10. The interviews conducted with Iraqi construction experts represent a diverse range of expertise from both the public and private construction sectors. These qualitative insights provided a deeper understanding of the actual challenges and barriers associated with RM practices. Additionally, these insights helped validate the developed models’ methodological aspects and the analysis outcomes. Furthermore, the statistically valid and reliable outputs of the surveys also provided insights into the perceptions of construction experts in Iraq, which enhanced and expanded the qualitative findings. Thus, the research outputs can be applied to all types of construction projects in Iraq, regardless of their complexity, size, or type.

**Contribution and Research Limitations**

In any research, the original contribution to knowledge is of utmost importance. According to Walker (1997), originality can be demonstrated in many ways such as the development of new methodologies, tools, and techniques, the development of new research areas, the interpretation or application of existing material in new ways, or the blending of existing theories. In this research, the literature review disclosed a lack of research into the main challenges and barriers facing construction RM practices during the COVID-19 pandemic. This research makes an original contribution to the body of knowledge in the field of construction RM research during extreme conditions like the COVID-19 pandemic. In fact, this research is the first to examine the effects of risk management challenges and practices during the COVID-19 pandemic. The main areas of this contribution to knowledge are summarised as follows:

1. Identification of the main challenges and barriers to RM implementation during the COVID-19 pandemic, and the key RM practices indicators.
2. Developing an integrated assessment methodology based on AHP and FST to assess RM implementation challenges and barriers, as well as the effectiveness of current risk management practices. Studies on COVID-19 and construction management have used a variety of analytical tools, such as qualitative content analysis (see e.g., Alsharef et al. 2021; Assaad and El-adaway 2021; Sierra 2021; Stiles et al. 2021; Umar 2022), mean score, and relative importance index (see e.g., Khalfan and Ismail 2020; Chigara and Moyo, 2021), exploratory factor analysis, and reliability analysis (see e.g., Salami et al. 2021) and simulation (see e.g., Araya 2021; Kim et al. 2021). In this study, an integrated assessment methodology based on AHP and FST was used to assess RMICB (i.e., using the AHP methodology), as well as the level of efficacy of the current RM practices (i.e., using fuzzy logic methodology). Both AHP and FST techniques were used to formalize and deal with human knowledge and uncertainties in RM decision-making during the COVID-19 pandemic. Another methodological contribution made in this study was related to the quantitative assessment of RM practices. When assessing the effectiveness level of RM practices, the authors considered the level of importance (weight) of each challenge and barrier that resulted from the AHP analysis as well as 12 inputs under six main RM indicators (i.e., stakeholders’ involvement, organizational communication, risk culture, risk management training, risk management policies, and continuous risk monitoring).

Besides contributing to knowledge, the study also contributes to managerial practice by helping construction practitioners to better understand the challenges and barriers hindering the effective implementation of RM strategies for construction projects during the COVID-19 pandemic. In addition, it provides valuable information to decision makers regarding the efficacy of current construction RM practices in Iraq.

Quantifying the level of significance of the key challenges and barriers facing the effective implementation of RM practices during COVID-19 pandemic are crucial to improve the quality of risk management and eventually support decision making process. However, due to the dynamic environment and complexity of the construction industry which involves a numerous number of stakeholders and is subject to countless risks and uncertainties, established response strategies for RMICB must focus on challenges and barriers that have the greatest impact on the efficacy of the RM practices. In fact, Goh and Abdul-Rahman (2013) stressed that the choice of response strategies must correspond to the significance of the challenges and barriers; it should be financially cost effective and realistic with regard to the project timing; it also must be accepted by other parties. Thus, the reported quantified levels of RMICB and RM practices are crucial for scholars and construction contractors to understand the required attention (i.e., expertise, and allocated budget) needed to develop appropriate strategies for ensuring the high efficacy of RM practices which contributes to the successful implementation and delivery of projects during COIVD-19 pandemic.

Despite its contributions, this study has some limitations. First, this research depends on expert judgment via interviews and questionnaire surveys. Other methods like case studies should be applied to complement the results obtained. Second, the authors identified only 34 RMICB under four categories. Other RMICB should be identified and categorized. Third, the study considered only 12 factors under four RM practices indication measurements. New indicators should be investigated to increase the scope of RM practices by capturing the perception of other stakeholder groups.

**Recommendations for Future Studies and Construction Practitioners**

1. Using the developed RM challenges and barriers assessment model (i.e., the AHP-based assessment model) and the RM practices assessment model (i.e., the fuzzy-based assessment model) on various case studies and at various stages of the project life cycle, and analyzing their impact on project success and related indicators.
2. Developing RM best practices guidelines and response strategies to address implementation challenges and barriers.
3. Contract parties should use the best practices in identifying and controlling the key RMICB during extreme conditions (e.g., COVID-19 emerging risks), and maintaining an updated RM register.
4. It is necessary to select the right set of effective and efficient tools and techniques that will assist with the assessment of the RMICB. Failure to use the appropriate tools and techniques during the identification or analysis of the RMICB could result in miscalculations during the RM process. This could negatively affect the construction firm's resources.
5. Construction companies should comply with the standards and general guidelines of the RM process (e.g., ISO:31000 and PMBOK guidelines) during the phases of planning, design, implementation, and project delivery and maintenance. Commensurate with this, they should ensure that all key stakeholders are included in the RM process, and establish a RM information and reporting system for each project.
6. Governmental bodies such as the Iraqi Engineers Association should provide training, education, and awareness for project managers and contractors on how to manage the key RMICB and improve the quality of the adopted RM practices.

**Disclosure statement**

No potential conflict of interest was reported by the authors. The authors received no financial support for the research.

**Data Availability Statement**

All data generated or analyzed during the study are included in the published paper.

**Acknowledgement**

This research is part of the first author's Ph.D. thesis conducted at the University of Southampton, UK.

**REFERENCES**

Abdul Nabi M, El-adaway I H. 2021. Understanding the Key Risks Affecting Cost and Schedule Performance of Modular Construction Projects. *Journal of Management in Engineering, 37*(4), 04021023.

Agyekum, K., Kukah, A.S. and Amudjie, J., 2021. The impact of COVID-19 on the construction industry in Ghana: the case of some selected firms. *Journal of Engineering, Design and Technology*.

Al-Mhdawi, M. K. S., Brito, M. P., Onggo, B. S., and Rashid, H. A. 2022b. Analyzing the Impact of the COVID-19 Pandemic Risks on Construction Projects in Developing Countries: Case of Iraq. In *Construction Research Congress 2022* (pp. 1013-1023).

Al-Mhdawi, M.K.S. 2022. *Risk management of construction projects under extreme conditions: A case study of Iraq*. PhD Thesis. Department of Decision Analytics and Risk, the University of Southampton, UK.

Al-Mhdawi, M.K.S., 2020. Proposed risk management decision support methodology for oil and gas construction projects. In *The 10th International Conference on Engineering, Project, and Production Management* (pp.407-420). Springer, Singapore.

Al-Mhdawi, M.K.S., Brito, M., Onggo, B.S., Qazi, A. and O'Connor, A., 2023b. COVID-19 emerging risk assessment for the construction industry of developing countries: evidence from Iraq. *International Journal of Construction Management*, pp.1-14.

Al-Mhdawi, M.K.S., Brito, M.P., Abdul Nabi, M., El-adaway, I.H. and Onggo, B.S., 2022a. Capturing the Impact of COVID-19 on Construction Projects in Developing Countries: A Case Study of Iraq. *Journal of Management in Engineering*, *38*(1), p.05021015.

AL-Mhdawi, M.K.S., Brito, M.P., Onggo, B.S., Qazi, A, O’Connor, A., Ayyub, B. A., and Chan, A. 2023a. A Structural Equation Model to Analyze the Effects of COVID-19 Pandemic Risks on Project Success: Contractors’ Perspective. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering* (In Press).

Al-Mhdawi, M.K.S., Dacre, N., Brito, M., Baxter, D., Xu, K. and Young, C., 2023c. An Agile Compliance Framework for the European Cooperation for Space Standardization. In *2023 IEEE Aerospace Conference* (pp. 1-12). IEEE.

Al-Mhdawi, M.K.S., Motawa, I. and Rasheed, H.A., 2020. Assessment of risk management practices in construction industry. In *The 10th International Conference on Engineering, Project, and Production Management* (pp. 421-433). Springer, Singapore.

Al-Mhdawi, M.K.S., O'Connor, A., Brito, M., Qazi, A., and Rashid, H. A., 2022c. Modeling the effects of Construction Risks on the Performance of Oil and Gas Projects in Developing Countries: Project Managers' Perspective. Civil Engineering Research in Ireland Conference (CERI 2022), Dublin, Ireland, 25-26 August 2022, Niall Holmes, Caitriona De Paor & Roger P. West, 2022, 486 - 491. [*http://hdl.handle.net/2262/101184*](http://hdl.handle.net/2262/101184)

Alsharef, A., Banerjee, S., Uddin, S.M., Albert, A. and Jaselskis, E., 2021. Early impacts of the COVID-19 pandemic on the United States construction industry. *International journal of environmental research and public health*, *18*(4), p.1559.

Amoah, C., Bamfo-Agyei, E. and Simpeh, F., 2021. The COVID-19 pandemic: the woes of small construction firms in Ghana. *Smart and Sustainable Built Environment*, *11*(4), 1099-1115. <https://doi.org/10.1108/SASBE-02-2021-0025>

Araya, F. 2021. Modeling the spread of COVID-19 on construction workers: An agent-based approach. *Safety science*, *133*, 105022.

Assaad, R., & El-adaway, I. H. 2021. Guidelines for responding to COVID-19 pandemic: Best practices, impacts, and future research directions. *Journal of Management in Engineering*, *37*(3), 06021001.

Assaad, R., El-Adaway, I.H. and Abotaleb, I.S., 2020. Predicting project performance in the construction industry. *Journal of Construction Engineering and Management*, *146*(5), p.04020030.

Ayyub, B. M. 2001. A practical guide on conducting expert-opinion elicitation of probabilities and consequences for corps facilities. *Institute for Water Resources, Alexandria, VA, USA*.

Bancalari, A. and Molina, O., 2020. Has cCvid-19 ‘infected infrastructure development in Peru?. *LSE Latin America and Caribbean Blog*.

Barkley, B. 2004. *Project risk management*. McGraw Hill Professional.

Bekr, G.A., 2015. Causes of delay in public construction projects in Iraq. *Jordan Journal of Civil Engineering*, *9*(2).

Boadu, E.F., Wang, C.C. and Sunindijo, R.Y., 2020. Characteristics of the construction industry in developing countries and its implications for health and safety: An exploratory study in Ghana. *International journal of environmental research and public health*, *17*(11), p.4110.

Chigara, B. and Moyo, T., 2021. Factors affecting the delivery of optimum health and safety on construction projects during the covid-19 pandemic in Zimbabwe. *Journal of Engineering, Design and Technology*, *20* (1), pp. 24-46.

Christmann, A. and Van Aelst, S., 2006. Robust estimation of Cronbach's alpha. *Journal of Multivariate Analysis*, *97*(7), pp.1660-1674.

Darko, A., Chan, A. P. C., Ameyaw, E. E., Owusu, E. K., Pärn, E. and Edwards, D. J., 2019. Review of application of analytic hierarchy process (AHP) in construction. *International journal of construction management*, *19*(5), 436-452.

Darvas, P. and Palmer, R., 2014. *Demand and supply of skills in Ghana: how can training programs improve employment and productivity?*. World Bank Publications.

El-Saboni, M., Aouad, G., and Sabouni, A., 2009. Electronic communication systems effects on the success of construction projects in United Arab Emirates. *Advanced Engineering Informatics*, *23*(1), 130-138.

Ferede, Y. S., Mashwama, N. X., & Thwala, D. W., 2022. Theoretical study of the cost of poor risk management in the construction industry. *Proceedings of International Structural Engineering and Construction*, *7*, 2.

Galletta, A., 2013. *Mastering the semi-structured interview and beyond: From research design to analysis and publication* (Vol. 18). NYU press.

Goh, C.S. and Abdul-Rahman, H., 2013. The identification and management of major risks in the Malaysian construction industry. *Journal of Construction in Developing Countries*, *18*(1), p.19.

IOM (International Organization for Migraiton). 2020. “Impact of COVID19 on small and medium-sized enterprises in Iraq.” Accessed Augest 5, 2022. <https://www.iom.int/>.

Khalfan, M. and Ismail, M., 2020, November. Engineering Projects and Crisis Management: A Descriptive Study on the Impact of COVID-19 on Engineering Projects in Bahrain. In *2020 Second International Sustainability and Resilience Conference: Technology and Innovation in Building Designs (51154)* (pp. 1-5). IEEE.doi: 10.1109/IEEECONF51154.2020.9319948.

Kim, S., Kong, M., Choi, J., Han, S., Baek, H. and Hong, T., 2021. Feasibility analysis of COVID-19 response guidelines at construction sites in south Korea using CYCLONE in terms of cost and time. *Journal of Management in Engineering*, *37*(5), p.04021048.

Kott, A. and Arnold, C., 2013. The promises and challenges of continuous monitoring and risk scoring. *IEEE Security & Privacy*, *11*(1), 90-93.

Krippendorff, K., 2018. *Content analysis: An introduction to its methodology*. Sage publications.

Kurd, Z. and Kelly, T. P., 2007. Using fuzzy self-organising maps for safety critical systems. *Reliability Engineering & System Safety*, *92*(11), 1563-1583.

Levy, C., Lamarre, E. and Twining, J., 2010. *Taking control of organizational risk culture*. McKinsey & Company.

Lin, S. S., Shen, S. L., Zhou, A. and Xu, Y. S., 2021. Novel model for risk identification during karst excavation. *Reliability Engineering & System Safety*, *209*, 107435.

Loh, T. Y., Brito, M. P., Bose, N., Xu, J. and Tenekedjiev, K., 2019. A fuzzy‐based risk assessment framework for autonomous underwater vehicle under‐ice missions. *Risk Analysis*, *39*(12), 2744-2765.

Loosemore, M., Raftery, J., Reilly, C. and Higgon, D., 2012. *Risk management in projects*. Routledge.

Market Research Iraq. 2021. “Construction and Infrastructure”. Accessed Nov 29, 2022. <https://www.marketresearchiraq.com/industry/construction-infrastructure>.

Moon, D. 2016. *Continuous risk monitoring and assessment.* PhD ThesisRutgers University, USA.

Nabil, F.R., Namian, M., Shukes, J., Batie, D. and Al-Mhdawi, M.K.S., 2022. COVID-19 Vaccine Acceptance Among Construction Workers. *EPiC Series in Built Environment*, *3*, pp.56-64.

Nordin, R. M., Takim, R. and Nawawi, A. H. 2011. Critical factors contributing to corruption in construction industry. In *2011 IEEE Symposium on Business, Engineering and Industrial Applications (ISBEIA)* (pp. 330-333). IEEE.

Park, J., Ojiako, U., Williams, T., Chipulu, M. and Marshall, A., 2015. Practical tool for assessing best value at the procurement stage of public building projects in Korea. *Journal of Management in Engineering*, *31*(5), 06014005.

Pourjavad, E. and Shahin, A., 2018. The application of Mamdani fuzzy inference system in evaluating green supply chain management performance. *International Journal of Fuzzy Systems*, *20*(3), 901-912.

Rani, H.A., Farouk, A.M., Anandh, K.S., Almutairi, S. and Rahman, R.A., 2022. Impact of COVID-19 on Construction Projects: The Case of India. *Buildings*, *12*(6), p.762.

Saaty, R. W., 1987. The analytic hierarchy process—what it is and how it is used. *Mathematical modelling*, *9*(3-5), 161-176.

Saaty, T. L. and Alexander, J. M., 1989. *Conflict resolution: the analytic hierarchy approach*. Rws Publications.

Salami, B.A., Ajayi, S.O. and Oyegoke, A.S., 2021. Tackling the impacts of Covid-19 on construction projects: an exploration of contractual dispute avoidance measures adopted by construction firms. *International Journal of Construction Management*, pp.1-9.

Shad, M.K. and Lai, F.W., 2015. A conceptual framework for enterprise risk management performance measure through economic value added. *Global Business and Management Research*, *7*(2), pp.1-11

Shakeri, H. and Khalilzadeh, M., 2020. Analysis of factors affecting project communications with a hybrid DEMATEL-ISM approach: A case study in Iran. *Heliyon*, *6*(8), e04430.

Shojaei, P. and Haeri, S. A. S., 2019. Development of supply chain risk management approaches for construction projects: A grounded theory approach. *Computers & Industrial Engineering*, *128*, 837-850.

Sierra, F., 2021. COVID-19: main challenges during construction stage. *Engineering, Construction and Architectural Management*, *29*(4), pp.1817-1834. https://doi:10.1108/ECAM-09-2020-0719.

Steinheider, B. and Al-Hawamdeh, S. 2004. Team coordination, communication and knowledge sharing in SMEs and large organisations. *Journal of Information & knowledge management*, *3*(03), 223-232.

Stiles, S., Golightly, D. and Ryan, B. 2021. Impact of COVID‐19 on health and safety in the construction sector. *Human Factors and Ergonomics in Manufacturing & Service Industries*, *31*(4), 425-437

Stumbauer, O. and Lalis, A. 2022. Progressing the aerospace performance factor toward nonlinear interactions. *Risk analysis*.

Su, X., Mahadevan, S., Xu, P. and Deng, Y. 2015. Dependence assessment in human reliability analysis using evidence theory and AHP. *Risk Analysis*, *35*(7), 1296-1316.

Umar, T., 2022. The impact of COVID-19 on the GCC construction industry. *International Journal of Service Science, Management, Engineering, and Technology (IJSSMET)*, *13*(2), 1-17.

Wu, C. L., Fang, D. P., Liao, P. C., Xue, J. W., Li, Y. and Wang, T. 2015. Perception of corporate social responsibility: The case of Chinese international contractors. *Journal of Cleaner Production*, *107*, 185-194.

Zadeh, L. A, 1996. Fuzzy sets. In *Fuzzy sets, fuzzy logic, and fuzzy systems: selected papers by Lotfi A Zadeh*, pp. 394-432.

Zhang, L., Wu, X., Qin, Y., Skibniewski, M. J. and Liu, W., 2016. Towards a fuzzy Bayesian network based approach for safety risk analysis of tunnel‐induced pipeline damage. *Risk Analysis*, *36*(2), 278-301.

Zhao, X., Hwang, B. G., Pheng Low, S. and Wu, P., 2015. Reducing hindrances to enterprise risk management implementation in construction firms. *Journal of Construction Engineering and Management*, *141*(3), 04014083.

**Table 1**. Profiles of Stage 1 pilot study participants

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **No. of interviewees** | **Role** | **Range of experience** | **Educational Level** | |
| **(years)** | **BSc** | **MSc** |
| **2** | Project managers | 19-28 | 2 | - |
| **1** | Consultant an academic | 25 | - | 1 |
| **1** | Contractor | 22 | 1 | - |
| **1** | Safety engineer | 15 | 1 | - |

**Table 2**. Profiles of Stage 2 pilot study participants

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **No. of interviewees** | **Role** | **Range of experience (years)** | **Educational Level** | | |
| BSc | MSc | PhD |
| **5** | Project managers | 16-28 | 4 | 1 | - |
| **2** | Contractors | 19-22 | 2 | - | - |
| **2** | Safety engineers | 15-21 | 1 | 1 | - |
| **1** | Academic | 32 | - | - | 1 |

**Table 3.** AHP Pairwise comparison scale

|  |  |
| --- | --- |
| **Numerical scale** | **Description** |
| 1 | Equal |
| 3 | Moderate |
| 5 | Strong |
| 7 | Very strong |
| 9 | Extreme |
| 2,4,6 | Intermediate (e.g., risk *k* is of strong importance than risk *y*) |
| 1/3, 1/5, 1/9 | Values of inverse comparison |

**Table 4.** Guiding questions for AHP matrices formulation

|  |  |
| --- | --- |
| **No.** | **Guiding Questions** |
| Question 1 | What is the probability of occurrence of *k* with respect to *y?* |
| Question 2 | What is the impact of schedule overrun of *k* with respect to *y?* |
| Question 3 | What is the level of cost overrun of *k* with respect to *y?* |

**Table 5.** Consistency Index (Data from Saaty 1987)

|  |  |
| --- | --- |
| **n\*** | **RI** |
| 2 | 0 |
| 3 | 0.58 |
| 4 | 0.90 |
| 5 | 1.12 |
| 6 | 1.24 |
| 7 | 1.32 |
| 8 | 1.41 |
| 9 | 1.45 |
| 10 | 1.49 |

\*n= size of the reciprocal matrix

**Table 6.** Profiles of interviewees

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. of interviewees | Construction role | Range of experience (years) | Educational Level | | |
| BSc | MSc | PhD |
| 13 | Project managers | 16-29 | 10 | 2 | 1 |
| 8 | Contractors | 15-24 | 8 | - | - |
| 6 | Safety engineers | 16-27 | 5 | 1 | - |
| 3 | Academics | 19-28 | - | - | 3 |

**Table 7.** Identified RMICB

|  |  |  |
| --- | --- | --- |
| **Code** | **Description** | **Group** |
| **A01.** | Difficulty in estimating the probabilities of occurrence of risks and their severity levels due to the uncertain nature of the COVID-19 situation. This can lead to inadequate risk management measures, resulting in increased exposure to risks and negative impacts on organizational performance. | **Analytical Approach-related Risk Management Challenges and barriers** |
| **A02.** | Complexity of quantitative risk assessment models, such as Monte Carlo Simulation, which may require more time and resources to apply due to the added uncertainty. |
| **A03.** | Time-consuming process of implementing risk management strategies in a rapidly changing COVID-19 environment. This challenge relates to the difficulty of implementing risk management strategies in a timely manner due to the rapidly changing nature of the COVID-19 situation, which may require frequent adjustments and modifications to risk management plans. |
| **A04.** | Lack of historical data to analyze and model risk behavior related to COVID-19 in the construction industry. This challenge highlights the lack of historical data related to COVID-19 in the construction industry, which makes it difficult to analyze and model the behavior of risks associated with the pandemic. |
| **A05.** | Ineffectiveness of the quantitative-based approaches for managing risks due to the high expenses associated with licensing, training, and software familiarity. Additionally, the urgent need for immediate responses to risks in the current escalated scale of the COVID-19 pandemic further limits the feasibility of using such approaches. |
| **A06.** | Difficulty in comprehending and interpreting the results of quantitative-based risk analysis methods during the COVID-19 pandemic due to incomplete, uncertain, or rapidly changing data. This challenge arises due to the constantly evolving nature of the COVID-19 situation, which makes it difficult to accurately interpret the results of risk assessments. |
| **A07.** | Insufficiency of reliable data to ensure the effectiveness of RM strategies in the construction industry during the COVID-19 pandemic. This challenge highlights the difficulty of ensuring the effectiveness of risk management strategies in the construction industry during the COVID-19 pandemic due to the limited availability of reliable data and uncertainty associated with the pandemic. |
| **B01.** | Reluctance to adopt new project management practices due to uncertainty caused by COVID-19. This challenge portrays a scenario where organizations exhibit reluctance towards adopting new project management practices, as they are apprehensive that such changes may cause further disruption or have adverse effects on their project operations. | **Behavior** **-related Risk Management Challenges and barriers** |
| **B02.** | Increased occurrence of bribery due to financial strain caused by the COVID-19 pandemic. This challenge refers to a situation where organizations may be more vulnerable to bribery and corruption due to the financial strain caused by the COVID-19 pandemic. The pandemic may have reduced their financial resources, making them more susceptible to the temptation of accepting bribes or other corrupt practices to maintain their operations. |
| **B03.** | Lack of commitment to RM due to competing priorities and resource constraints during the COVID-19 pandemic. This challenge pertains to a situation where organizations may prioritize other pressing matters over RM due to the resource constraints and competing priorities caused by the COVID-19 pandemic. As a result, they may not allocate enough resources to manage risks adequately or may overlook certain risks altogether. |
| **B04.** | Reduced willingness to collaborate among stakeholders due to social distancing measures and remote work arrangements caused by COVID-19. The lack of face-to-face interaction and reduced opportunities for informal communication may result in a breakdown of trust and collaboration among stakeholders, potentially leading to delays and increased risk in projects. |
| **T01.** | Limited expertise and experience in managing COVID-19 related risks. This refers to a lack of knowledge, skills, and experience among project management personnel in identifying and mitigating risks related to the COVID-19 pandemic. These risks could include issues related to supply chain disruptions, lack of cleanliness and sterilization, changes in laws, monopolization of construction materials, lack of face masks or coverings, and psychological stress. | **Team-related Risk Management Challenges and barriers** |
| **T02.** | Limited awareness and consciousness of COVID-19 related risks among the project management team. This challenge is related to a lack of understanding and recognition of the potential impact of COVID-19 related risks on project delivery and stakeholder well-being. This can result in a failure to implement appropriate risk management measures and mitigation strategies, such as implementing remote work policies or reconfiguring workspaces to promote physical distancing. |
| **T03.** | Lack of incorporation of extreme conditions, such as the COVID-19 pandemic, into existing risk management training and processes. This can result in project management personnel being ill-prepared to identify, assess, and manage risks related to the pandemic. |
| **T04.** | Lack of familiarity with the specific processes and protocols required to manage risks associated with extreme conditions, such as the COVID-19 pandemic. This can result in project management personnel being unable to effectively implement risk management measures, such as developing contingency plans and identifying alternative supply chain sources. |
| **T05.** | Doubts regarding the effectiveness of risk management techniques to address COVID-19 emerging risks. This challenge highlights the skepticism regarding the applicability and effectiveness of risk management techniques in addressing COVID-19 related risks, which are different in nature and severity compared to pre-COVID-19 risks. This can result in a lack of confidence in risk management measures and a failure to implement appropriate mitigation strategies, such as implementing health and safety protocols. |
| **T06.** | Poor interaction among project parties due to COVID-19 measures. This pertains to the challenges encountered in maintaining effective communication and collaboration among project stakeholders due to the restrictions imposed by the pandemic. Such constraints can result in a lack of clarity regarding project objectives, risks, and mitigation strategies, leading to miscommunication and delays. |
| **T07.** | Conflicts arising from subjective assessment of COVID-19 related risks due to subjective differences in the assessment and prioritization of such risks by different risk assessors. This can result in delays in decision-making and a failure to implement appropriate mitigation strategies, such as prioritizing certain health and safety measures over others. |
| **T08.** | Conflicts in Subjective Assessment by Risk Assessors due to the uncertain and rapidly changing nature of the pandemic. Risk assessors may have varying opinions and interpretations of the risks involved, leading to subjective assessments that can result in inconsistent risk management decisions. |
| **M01.** | **M01.** Lack of awareness of the potential benefits of RM during the COVID-19 pandemic, such as identifying and mitigating risks associated with supply chain disruptions, workforce illness, and financial instability. Without proper awareness, organizations may fail to prioritize risk management activities during COVID-19, which can increase their vulnerability to the pandemic's impact. |  |
| **M02.** | Insufficient risk management resources due to budget cuts and financial strains caused by the COVID-19 pandemic, resulting in reduced capacity to manage risks and implement risk management measures. With fewer resources, organizations are struggling to implement proper risk management measures and respond effectively to risks associated with the pandemic. | **Management-related Risk Management Challenges and barriers** |
| **M03.** | Lack of continuation and coordination among risk management activities at various stages of the project lifecycle during the COVID-19 pandemic, as changes in risk factors and mitigation strategies require ongoing assessment and adjustment. Changes in risk factors and mitigation strategies require ongoing assessment and adjustment, and without proper continuation and coordination, organizations are not able to respond effectively to changes in risk factors related to COVID-19. |
| **M04.** | Lack of a unified risk management framework for construction projects during the COVID-19 pandemic, which can result in confusion and inconsistencies in risk management approaches across different projects. Without a unified framework, there are confusion and inconsistencies in risk management approaches across different projects, leading to increased vulnerability to risks associated with COVID-19. |
| **M05.** | Time constraints and commercial pressures during the COVID-19 pandemic, which can lead to shortcuts in risk management processes and increased exposure to risk. With less time and pressure to meet commercial objectives, organizations are not fully implementing proper risk management measures, which can increase their exposure to risks associated with COVID-19. |
| **M06.** | Inadequate integration of risk management with other project management processes during the COVID-19 pandemic, such as supply chain management and workforce planning, resulting in missed opportunities for risk mitigation. This challenge has been exacerbated by the COVID-19 pandemic as it has introduced new risks and uncertainties that require careful consideration and planning. For example, supply chain disruptions and workforce shortages have become more common during the pandemic, making it crucial to integrate risk management with these processes to mitigate the impact of such risks. |
| **M07.** | Insufficient support from upper management during the COVID-19 pandemic, which can result in reduced commitment and resources allocated to risk management. Without adequate support from upper management, organizations may struggle to identify and mitigate COVID-19 related risks, which can have severe consequences for their operations and employees. |
| **M08.** | The difficulty of determining the risk-return trade-off during the COVID-19 pandemic, as uncertainties and rapidly changing conditions can make it challenging to assess risks and evaluate potential outcomes. This can result in a lack of confidence in decision-making, as the potential risks and outcomes associated with different options may not be clear. Ultimately, this can significantly impact an organization's ability to effectively respond to the pandemic. |
| **M09.** | Inadequate organizational structure during the COVID-19 pandemic, which can hinder effective risk management and decision-making. Organizations that lack a clear structure for managing COVID-19 related risks may struggle to identify and mitigate such risks effectively. This can result in disruptions to operations and the health and safety of employees. |
| **M010.** | Ineffective communication of risk-related information during the pandemic, which can lead to misunderstandings and missed opportunities for risk mitigation. |
| **M011.** | The absence of government legislation to address risks associated with the pandemic, which can leave organizations uncertain about their legal obligations and best practices for risk management. |
| **M012.** | Sluggish decision-making processes during the pandemic, which can result in missed opportunities to mitigate risks and adapt to changing conditions. Delays in decision-making can result in missed opportunities to mitigate risks and adapt to changing conditions, which can increase an organization's vulnerability to negative outcomes associated with the pandemic. |
| **M013.** | Limited participation of contractors in the design process of construction projects undertaken during the COVID-19 pandemic. Contractors may have valuable insights into risks associated with the pandemic, and their limited participation can result in overlooked risks and missed opportunities for risk mitigation. |
| **M014.** | Poor mechanism to document and/or share lessons learned during the pandemic resulting in missed opportunities for organizational learning and continuous improvement in risk management. This, in turn, can increase an organization's vulnerability to risks associated with the pandemic. |
| **M015.** | Poor risk management training system during the COVID-19 pandemic, which can result in inadequate skills and knowledge to effectively manage risks associated with the pandemic. Inadequate skills and knowledge can hinder an organization's ability to effectively manage risks associated with the pandemic, which can increase their vulnerability to negative outcomes. |

**Table 8.** The consistency ratios for pairwise comparison matrices

|  |  |  |  |
| --- | --- | --- | --- |
| Category | Assessment Criteria | | |
| LP  (CR %) | LIC  (CR %) | LIS  (CR %) |
| Analytical *a*pproach-related challenges and barriers | 8.5 | 7.6 | 7.6 |
| Behavior-related challenges and barriers | 4.6 | 6.5 | 4.6 |
| Management-related challenges and barriers | 9.4 | 9.8 | 9.7 |
| Team-related challenges and barriers | 8.7 | 8.5 | 7.2 |

**Table 9.** Results of the AHP Analysis

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| RMICB | | *Gblp* | *Gblic* | *Gblis* | *Cbpn* | Group Rank | Overall Rank |
|
| Analytical *a*pproach-related challenges and barriers | A01 | 0.0115 | 0.0125 | 0.0095 | 0.0335 | 5 | 22 |
| A02 | 0.0983 | 0.1115 | 0.1345 | 0.3443 | 1 | 2 |
| A03 | 0.0813 | 0.0670 | 0.0533 | 0.2015 | 2 | 4 |
| A04 | 0.0068` | 0.0060 | 0.0075 | 0.0203 | 6 | 25 |
| A05 | 0.0333 | 0.0353 | 0.0310 | 0.0995 | 3 | 10 |
| A06 | 0.0190 | 0.0175 | 0.0145 | 0.0510 | 4 | 18 |
| A07 | 0.0054 | 0.0063 | 0.0086 | 0.0203 | 6 | 18 |
| Behavior-related challenges and barriers | B01 | 0.0170 | 0.0388 | 0.0170 | 0.0728 | 3 | 12 |
| B02 | 0.1475 | 0.1265 | 0.1475 | 0.4215 | 1 | 1 |
| B03 | 0.0113 | 0.0110 | 0.0114 | 0.0337 | 4 | 21 |
| B04 | 0.0740 | 0.0738 | 0.0740 | 0.2218 | 2 | 3 |
| Management-related challenges and barriers | M01 | 0.0033 | 0.0030 | 0.0033 | 0.0095 | 13 | 31 |
| M02 | 0.0040 | 0.0073 | 0.0043 | 0.0155 | 10 | 28 |
| M03 | 0.0158 | 0.0303 | 0.0150 | 0.0610 | 5 | 14 |
| M04 | 0.0373 | 0.0393 | 0.0535 | 0.1300 | 2 | 7 |
| M05 | 0.0025 | 0.0035 | 0.0025 | 0.0085 | 14 | 32 |
| M06 | 0.0323 | 0.0353 | 0.0385 | 0.1060 | 3 | 9 |
| M07 | 0.0135 | 0.0118 | 0.0095 | 0.0348 | 8 | 20 |
| M08 | 0.0203 | 0.0185 | 0.0135 | 0.0523 | 6 | 16 |
| M09 | 0.0028 | 0.0030 | 0.0028 | 0.0085 | 14 | 32 |
| M10 | 0.0483 | 0.0395 | 0.0538 | 0.1415 | 1 | 5 |
| M11 | 0.0060 | 0.0050 | 0.0128 | 0.0238 | 9 | 24 |
| M12 | 0.0035 | 0.0040 | 0.0035 | 0.0110 | 12 | 30 |
| M13 | 0.0420 | 0.0328 | 0.0183 | 0.0930 | 4 | 11 |
| M14 | 0.0045 | 0.0060 | 0.0043 | 0.0148 | 11 | 29 |
| M15 | 0.0145 | 0.0113 | 0.0150 | 0.0408 | 7 | 19 |
| Team-related challenges and barriers | T01 | 0.0568 | 0.0083 | 0.0095 | 0.0651 | 3 | 13 |
| T02 | 0.0050 | 0.0273 | 0.0303 | 0.0323 | 6 | 23 |
| T03 | 0.0495 | 0.0065 | 0.0105 | 0.0560 | 4 | 15 |
| T04 | 0.0293 | 0.1075 | 0.0713 | 0.1368 | 1 | 6 |
| T05 | 0.0083 | 0.0433 | 0.0833 | 0.0516 | 5 | 17 |
| T06 | 0.0065 | 0.0120 | 0.0223 | 0.0185 | 7 | 26 |
| T07 | 0.0130 | 0.0053 | 0.0045 | 0.0183 | 8 | 27 |
| T08 | 0.0820 | 0.0398 | 0.0185 | 0.1218 | 2 | 8 |

**Table 10.** Risk management quantified practices

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| RMICB | *Cbpn* | Stakeholders’  involvement | | Communication  level | | Risk management  training | | Risk culture | | Risk management polices | | Continuous risk monitoring | | Risk management polices | | Continuous risk monitoring | | *Rmqp* | *Rmqp* Rank | Av. *Rmqp* | Av. *Rmqp* Rank |
| LS  (Mean) | LI  (Mean) | OCC  (Mean) | CT  (Mean) | AET  (Mean) | AR  (Mean) | WCKS  (Mean) | CV  (Mean) | UMSO  (Mean) | RMPB  (Mean) | RMI  (Mean) | PPI  (Mean) | UMSO  (Mean) | RMPB  (Mean) | RMI  (Mean) | PPI  (Mean) |
| A02 | 0.3440 | 0.30 | 0.27 | 0.32 | 0.20 | 0.38 | 0.26 | 0.39 | 0.26 | 0.20 | 0.23 | 0.33 | 0.29 | 0.20 | 0.23 | 0.33 | 0.29 | 0.3265 | 11 | 0.3393 | 3 |
| A03 | 0.2015 | 0.38 | 0.33 | 0.29 | 0.38 | 0.24 | 0.35 | 0.53 | 0.30 | 0.28 | 0.41 | 0.35 | 0.52 | 0.28 | 0.41 | 0.35 | 0.52 | 0.3594 | 4 |
| A05 | 0.0995 | 0.25 | 0.39 | 0.34 | 0.21 | 0.33 | 0.43 | 0.26 | 0.37 | 0.31 | 0.38 | 0.24 | 0.34 | 0.31 | 0.38 | 0.24 | 0.34 | 0.3321 | 8 |
| B04 | 0.4215 | 0.21 | 0.32 | 0.40 | 0.23 | 0.36 | 0.25 | 0.39 | 0.24 | 0.41 | 0.33 | 0.38 | 0.35 | 0.41 | 0.33 | 0.38 | 0.35 | 0.3386 | 7 | 0.3282 | 4 |
| B01 | 0.2218 | 0.30 | 0.49 | 0.36 | 0.32 | 0.29 | 0.30 | 0.25 | 0.36 | 0.24 | 0.27 | 0.21 | 0.42 | 0.24 | 0.27 | 0.21 | 0.42 | 0.3292 | 9 |
| B02 | 0.0728 | 0.27 | 0.38 | 0.31 | 0.37 | 0.21 | 0.20 | 0.38 | 0.26 | 0.24 | 0.35 | 0.23 | 0.49 | 0.24 | 0.35 | 0.23 | 0.49 | 0.3168 | 12 |
| M10 | 0.1415 | 0.32 | 0.35 | 0.29 | 0.43 | 0.23 | 0.41 | 0.30 | 0.53 | 0.36 | 0.32 | 0.63 | 0.46 | 0.36 | 0.32 | 0.63 | 0.46 | 0.3683 | 3 | 0.4033 | 1 |
| M04 | 0.1300 | 0.56 | 0.34 | 0.20 | 0.42 | 0.35 | 0.48 | 0.44 | 0.35 | 0.26 | 0.52 | 0.31 | 0.39 | 0.26 | 0.52 | 0.31 | 0.39 | 0.3458 | 6 |
| M06 | 0.1060 | 0.37 | 0.42 | 0.33 | 0.38 | 0.47 | 0.55 | 0.48 | 0.41 | 0.35 | 0.43 | 0.30 | 0.67 | 0.35 | 0.43 | 0.30 | 0.67 | 0.4960 | 1 |
| T04 | 0.1368 | 0.35 | 0.56 | 0.28 | 0.30 | 0.34 | 0.47 | 0.26 | 0.49 | 0.38 | 0.52 | 0.38 | 0.33 | 0.38 | 0.52 | 0.38 | 0.33 | 0.3508 | 5 | 0.3766 | 2 |
| T08 | 0.1218 | 0.37 | 0.49 | 0.37 | 0.43 | 0.59 | 0.52 | 0.32 | 0.56 | 0.40 | 0.46 | 0.42 | 0.39 | 0.40 | 0.46 | 0.42 | 0.39 | 0.4519 | 2 |
| T01 | 0.0651 | 0.25 | 0.42 | 0.28 | 0.39 | 0.33 | 0.58 | 0.48 | 0.35 | 0.31 | 0.38 | 0.24 | 0.36 | 0.31 | 0.38 | 0.24 | 0.36 | 0.3271 | 10 |

**Table 11.** Profiles of the verification and validation panel participants

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| No. | Role | Working Sector | Range of  experience (years) | Educational Level | | |
| BSc | MSc | PhD |
| 1 | Project manager | Public | 19 | - | 1 | - |
| 2 | Project manager | Public | 23 | - | 1 | - |
| 3 | General contractor and CEO | Private | 16 | - | 1 | - |
| 4 | General contractor and CEO | Private | 20 | 1 | - | - |
| 5 | Director of Engineering Affairs | Public | 25 | - | - | 1 |
| 6 | Professor and consultant | Public | 28 | - | - | 1 |

**Appendix A.** Semi structured Interviews Questions

|  |
| --- |
| Interview guiding questions |
| * To what extent is it challenging to estimate the probabilities of occurrence and severity levels of risks during the COVID-19 situation for the construction industry in Iraq? * To what degree of complexity are the quantitative risk assessment models utilized for the construction industry in Iraq during the COVID-19 pandemic? * What is the degree to which historical data is obtainable and qualified for scrutinizing and simulating risk behavior that is associated with COVID-19 in the construction sector of Iraq? * To what extent are quantitative-based risk management analytical approaches effective in managing COVID-19 emerging risks? * What is the extent to which the adequacy of reliable data ensures the efficacy of risk management strategies in the Iraqi construction industry during the COVID-19 pandemic? * To what extent has the COVID-19 pandemic impacted the occurrence of bribery within your organization? * What is the level of commitment demonstrated by organizations towards conducting risk management activities amid the COVID-19 pandemic? * How has the COVID-19 pandemic affected stakeholder collaboration within our organization? * What experience and expertise does your organization have in managing extreme conditions risks (e.g., COVID-19 emerging risks) in the construction industry of Iraq? * To what degree do you perceive the project management team to be cognizant of the COVID-19 emerging risks? * How well do you think the construction risk management training and responsibilities address extreme conditions like the COVID-19 pandemic? * To what extent do you comprehend the potential benefits of implementing risk management practices in the Iraqi construction industry during the COVID-19 pandemic? * Is there a unified risk management framework for construction projects during the COVID-19 pandemic? * To what extent has risk management been integrated with other project management processes, such as supply chain management, during the COVID-19 pandemic? * To what extent has the upper management provided support for the risk management efforts during the COVID-19 pandemic? Have any challenges arisen, or has there been any reduction in resources allocated towards risk management? * To what extent do you find it facile or challenging to ascertain the trade-off between risk and return during the COVID-19 pandemic, taking into account the uncertainties and rapidly changing conditions? * Describe your risk communication status and strategies during the COVID-19 pandemic? Have there been any instances of misinterpretation or missed opportunities for risk mitigation? * To what extent do contractors participate in the design process during the COVID-19 pandemic? * To what extent do you document and share lessons learned during the COVID-19 pandemic? * What is the level of efficacy of risk management training during the COVID-19 pandemic? |