University of Southampton

Faculty of Social Science

Decision Analytics and Risk

Risk Management of Construction Projects Under Extreme Conditions: A Case Study of Iraq

By

Mohammed Khalid Slmman Al-Mhdawi

Thesis for the degree of PhD

October 2022

University of Southampton

Abstract

Faculty of Social Science

Decision Analytics and Risk

Doctor of Philosophy

Risk Management in Construction Projects Under Extreme Conditions

by

Mohammed Khalid Slmman Al-Mhdawi

The COVID-19 pandemic has affected construction markets around the world, causing legislative changes, supply chain disruptions, and workforce restrictions. Construction industry stakeholders in developing countries are considered to be more susceptible to the challenges and emerging risks associated with the pandemic, exacerbated by poor risk management (RM) practices, undermining the successful delivery of construction projects. This thesis examines the impact of extreme conditions' risk management practices, the challenges associated with their implementation, and their emerging risks on the success of construction projects in developing countries by considering the Iraqi construction industry during the COVID-19 pandemic.

This thesis encompasses three papers written as part of a PhD by publication ("Three-Paper PhD"), situated between introduction and conclusion chapters. The first paper focuses on identifying and assessing the main challenges and barriers to RM effective application in the construction industry during COVID-19 pandemic, and assesses the level of efficacy of current RM practices adopted by Iraqi construction practitioners. The second paper explores the key emergent COVID-19 risks for the construction industry and investigates their risk level. The final paper analyses the direct and indirect effects of emergent COVID-19 risks on the successful delivery of construction projects.

Mixed (qualitative and quantitative) methods were used in each study to fulfil the objectives, including (1) semi-structured interview; (2) focus group discussion; (3) questionnaire survey; (4) fuzzy inference system; (5) analytical hierarchy process; and (6) structural equation modelling.

The results show that the five most critical challenges and barriers to construction RM implementation in Iraq are: (1) bribery, (2) the complexity of quantitative-based risk assessment tools, (3) a lack of willingness for collaboration among stakeholders, (4) time-consuming processes, and (5) ineffective risk communication. Also, the results indicate low risk management practices in relation to the identified RM challenges and barriers and their categories. The RM practices as average values on a scale of 0.1 to 1.0 (with 0.1 representing very poor RM practices efficacy and 1.0 representing very high RM practices efficacy) are as follows: (1) management-related challenges and barriers (0.4033), (2) team-related challenges and barriers (0.3766), (3) analytical approaches-related challenges and barriers (0.3393), and (4) behaviours-related challenges and barriers (0.3282). The results reveal that the most critical COVID-19 risks affecting the construction industry are (1) contract suspension, (2) contractor bankruptcy, (3) materials price escalation, (4) inappropriate risk allocation, and (5) claims arising under a construction contract. Furthermore, the results show that contractual implications-related risks have the strongest

total effects on project success, followed by organisational implications-related risks, construction financial market-related risks, health and safety of the construction workforce-related risks, and supply chain operations-related risks, respectively.

This research contributes to the body of knowledge by providing a foothold foundation for researchers and decision-makers to improve their understanding of the impact of the pandemic with its deep uncertainties in relation to developing countries. It can assist in the development of effective strategies to address RM implementation challenges and barriers, and extreme conditions' emerging risks, and ultimately enhance construction RM practices. Furthermore, understanding the nature of the relationship between the risks emerging from extreme conditions and project success should assist construction contractors in identifying the root causes of low-level project success; and in developing appropriate strategies for improving project success levels by addressing the direct and indirect effects of extreme conditions risks such as those of the COVID-19 pandemic.

Table of Contents

Appendices

Table of Tables

Table of Figures

Research Thesis: Declaration of Authorship

I, Mohammed Khalid Al-Mhdawi, declare that this thesis, titled "Risk Management of Construction Projects Under Extreme Conditions: A Case Study of Iraq", and the work presented in it is my own and has been generated by me as the result of my own original research.

I declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. None of this work has been published before submission

Signature:

Date: 10/10/2022

Acknowledgements

First and foremost, I would like to thank my PhD supervisors, Dr Mario Brito and Professor Stephan Onggo for their insightful guidance, constructive feedback and encouragement.

I am indebted to those who participated in this research and spared some of their time to reflect their experience and professional judgement.

I have to thank my father Professor Khalid Al-Mhdawi and my mother for their love and support throughout my life. Thank you both for giving me strength to chase my dreams. My brother, Dr Ammar Al-Mhdawi deserves my wholehearted thanks as well.

Furthermore, I would like to express my gratitude to my dear friends Eng. Mohammed Allawi and Dr. Odai Al-Jaloudi for their continued support and encouragement.

I also extend my acknowledgements to my mentor and close friend Professor Hatem Rashid, for his support and encouragement throughout my MSc and PhD studies.

Finally, I would like to express my gratitude to Miss Laura for her continued support and motivation during the difficult times of the COVID-19 pandemic

Preface: How to Read This PhD

In contrast to a traditional Ph.D. thesis consisting of multiple chapters following one singular narrative, the Three-Paper Ph.D. comprises three standalone research articles contextualised by introductory and concluding chapters. The introductory chapter explains the research background, knowledge gap, research objectives, and some of the key concepts related to the central themes of the research papers. It also introduces an overarching narrative of the research methods used in the research papers. For the most part, the papers themselves are presented in the original format required by the journals for which they were written. The concluding chapter summarises the findings from each paper and reflects on the overall research theme. Upon reading these five chapters in sequence, they can be compared to a traditional Ph.D. thesis. However, in the three-paper format, each paper can also be evaluated as an independent piece of work. In order to preserve the integrity of the research papers and the thesis as a whole, tables, figures and appendices from the papers have dual numbering systems, and the references cited in the papers are included with each paper.

Definitions and Abbreviations

AE	available expertise
AET	availability of expertise for training
AHP	analytical hierarchy process
AR	availability of resources
Av. RM-QP	average risk management quantified practices
CB-PN	challenges and barriers priority number
CB-SEM	covariance-based structural equation modelling
CFM	construction financial market
CV	conflict in values
F-RN	fuzzy risk number
FST	fuzzy sets theory
HSCW	health and safety of construction workforce
ICC	Iraqi civil code
ICCCEW	Iraqi *c*ontract conditions for civil engineering works
IPC	Impact on project cost
IPQ	Impact on project quality
IPT	Impact on project time
LIC	level of impact on cost
LIS	Impact on the schedule
LP	level of probability of occurrence
OCC	organization communication culture
OCF	out-of-control factors
OI	organisational implications
OLR	organisational level of readiness
PLS-SEM	partial least squares structural equation modelling
PPI	Project Partiers Integration
PSF	Political and Security Factors
RL	readiness level
RM	risk management
RMI	risk management Integration
RMPB	risk management potential benefits
RM-QP	risk management quantified practices
SCO	supply chain operations
SEM	structural equation modelling
WCKS	willingness to collaboration and knowledge sharing

Chapter 1: Introduction

1.1. General

In May 2020, the World Health Organization (WHO) declared a global pandemic caused by the novel coronavirus disease (COVID-19) (Dryhurst *et al*., 2020). The pandemic and resultant public health measures posed the greatest threat to global economic growth since the Great Recession (OECD, 2020 a, b). According to the World Bank, the global economy contracted by 4.3% as a result of the pandemic, making it one of the top four global recessions in modern history (World Bank, 2021). Such adverse effects are related to enforcing governmental regulations and measures to control the spread of the disease, such as travel restrictions, distancing measures, quarantine measures, and border controls and closures; the most fundamental barrier to economic activity was “lockdown” policies, which ceased production activities and caused massive supply chain issues (Ashurst, 2020; Porter, 2020; Assaad and El-adaway, 2021).

As highlighted by Franzese (2020), the response of the public and private sectors to the pandemic is expected to have a profound impact on the operation and performance of various national and global markets and sectors, including construction. In fact, the construction industry, unlike other industries and sectors whose activities are more geared towards internet technology and intangible products, was not able to implement telecommuting technologies to mitigate the safety concerns and productivity issues caused by the pandemic (Daniels *et al*., 2020). Consequently, the industry faced difficulties maintaining safety measures while delivering projects on time. In particular, the pandemic caused many project delays and challenges due to health and safety concerns, contractual implications and claims, shortage of workforce, disruptions to supply chain, suspensions of construction projects, unavailability of construction materials, tools, and equipment, changes in the laws, difficulties in accessing job sites, and financing pressures (O’Connor *et al*., 2020; Assaad and El-adaway, 2021; Al-Mhdawi *et al*., 2022).

Based on the duration and severity of the crisis in various construction markets and sectors, these challenges could continue to be deepen and be felt for many years to come (PWC, 2020). Globally, the outbreak of COVID-19 has significantly affected the construction markets (Agyekum *et al*., 2021; Rehman *et al*., 2021; Umar, 2022). Nonetheless, construction markets in developing countries are perceived as being more vulnerable to the effects of the pandemic and its emerging risks due to the following reasons:

1. Compared to developed countries, the developing world appears to be facing higher mortality rates (Gill and Schellekens, 2021). The high number of positive COVID-19 cases and deaths that have occurred in developing countries is generally attributed to poor health systems, lack of public health awareness, and non-compliance with global guidelines of wearing facemasks, hand sanitised, and social distancing, which have resulted in a significant shortage of skilled construction workers (Amoah and Simpeh, 2021; Chigara and Moyo, 2021).

2. Unlike other 21st century outbreaks (e.g., SARS1, MERS2, or H1N1pdm09), the COVID-19 pandemic is of unprecedented scale and intensity (Casady and Baxter, 2020) for the construction industry worldwide, and for developing countries in particular. In fact, the impact of the COVID-19 pandemic on the construction industry of developing countries was reported by several studies to have similar characteristics and behaviours leading to changes in laws, business closures, suspension and termination of construction contracts, and associated difficulties experienced by developers, contractors, and vendors (Agyekum *et al*., 2021; Olatunde *et al*., 2021). Moreover, the effect of the pandemic on developing countries caused significant challenges to the labour market that outweighed the effects of the Great Recession (OECD, 2020). Among the challenges workers face are not receiving their due wages from their employers, losing their jobs, being unable to access new employment opportunities, and not having adequate social protection (Walter, 2020).

Iraqi construction companies, an example of the construction industry in developing countries, are experiencing major disruptions and difficulties due to the pandemic's impact and its emerging risks. Based on OECD (2020 a, b) data, many construction companies in Iraq are experiencing losses of profits and are facing challenges as a result of COVID-19 and its emerging risks, which adversely impact the successful delivery of projects within the agreed budget, planned schedule, and specified quality.

To address this challenge, there is a need for the construction industry to gain a better understanding of the current practices for risk management and its implementation challenges and barriers to enable construction firms and companies to implement enhanced practices and implement proper planning and mitigation strategies to overcome the associated challenges; and to investigate how the COVID-19 pandemic and its emerging risks have affected the successful delivery of construction projects.

1.1.1. The case of the Iraqi construction industry

This research focuses on the case of Iraq for the following reasons:

1. Iraq is a major economic power in the West Asia and North Africa regions, due to its position as the fifth largest oil producer in the world and the second largest in OPEC (Al-Mhdawi *et al*., 2022).

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. 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 USD 9.2 billion in 2018 to USD 19.2 billion in 2023 (Research and Marker, 2021). Between 2003 and 2014, more than USD 220 billion was spent on construction and reconstruction efforts in Iraq.

Despite the economic position of the country and increased number of construction and reconstruction efforts, the construction industry in Iraq has always been plagued by inherent risks and weak outcomes (Al-Mhdawi *et al*., 2020). This is due to the following:

1. Iraqi contracting companies find significant challenges to mitigating risks in an environment characterised by poor suppliers, unskilled workforce, logistics difficulties, poor risk management practices (Al-Mhdawi, 2020; Al-Mhdawi *et al*., 2020), and a lack of expertise in using modern technologies for managing construction projects (Bekr, 2015). Moreover, the industry suffers from poor safety management practices (Buniya *et al*., 2020). In 2018 Iraq's construction industry accounted for 38% of all industrial accidents (Buniya *et al*., 2021), making it the most hazardous sector in the country.

2. The volatile security and political conditions pose enormous challenges to Iraqi civilians, the economy, and construction and reconstruction efforts (Matsunaga, 2019). For instance, the poor security profile in Iraq, limited private sector engagement, and low foreign direct investment lead to many projects being selected opportunistically.

3. Iraq's current economic context is characterised by extreme dependence on oil production, and the fluctuation of oil prices in the global market has a direct impact on all industries in Iraq. For instance, the collapse of oil prices in 2020 caused significant economic challenges, particularly to the construction industry. In April

2020, the oil prices had fallen by 70% compared to the start of the year, which severely impacted Iraq's government revenues. As reported in the latest issue of the Iraq Economic Monitor published by the World Bank (2020), the Iraqi government revenues fell by 47.5% in the first eight months of 2020. Declining oil prices in the global market caused a direct effect on the stability of the construction industry in Iraq (Abdulhussein and Shibaani, 2016).

In addition to these challenges, the impact of the COVID-19 pandemic on Iraq has raised the ceiling of challenges causing an increase in materials costs, delays in payments, supply chain distribution, contractual, legal, and insurance issues (Al-Mhdawi *et al*., 2022). Iraq represents one of the developing countries that has witnessed a severe impact on its construction industry due to COVID-19 pandemic. In fact, Iraq was particularly hard hit by the COVID-19 pandemic in 2020 due to the increased number of positive cases (AL-Monitor, 2020). In March 2020, the Iraqi government imposed a full curfew on the country, excluding security, medical, and media personnel as well as other essential services. The curfew comprised all construction activities (including essential repairs and maintenance) in residential, commercial, and public projects. At the beginning of June 2020, the Iraqi government imposed a partial curfew and allowed businesses to reopen to a 25% capacity. However, strict safety and precautionary measures were in place on site in conjunction with the reopening.

Apart from the strict safety measures and curfews in Iraq, the vaccination rate is still low, which delays the post-pandemic or recovery phase of the overall economy, including the construction industry. Construction companies are experiencing considerable disruptions and difficulties as a result of the pandemic. As indicated by the OECD (2020a, b), many Iraqi construction firms are experiencing loss of profits and are facing challenges as a result of COVID-19, which are affecting their sustainable growth and development. In addition, preliminary statistics revealed that the construction industry in Iraq is experiencing a 52% reduction in employment and a 68% decrease in production (IOM, 2020). A similar level of adverse impacts is also observed in other developing countries, including Zimbabwe (Chigara and Moyo, 2021); Ghana (Agyekum *et al*., 2021); India (Rani *et al*., 2022); and Peru (Bancalari and Molina, 2020). Accordingly, Iraq's construction industry represents the unique nature of the COVID-19 pandemic and the risks associated with it within a variety of developing countries facing similar challenges and sharing similar characteristics prior to and during the COVID-19 pandemic.

1.1.2. Previous work and knowledge gap identification

Emerging research is eagerly exploring the impacts of the COVID-19 pandemic in diverse industries and sectors, such as oil and gas, manufacturing, energy, water supply, tourism, health care, transportation, food and agriculture, finance, education, healthcare, trade and business, among others. For instance, studies have explored COVID-19 impacts on: oil price risk exposure of global financial and non-financial sectors (Akhtaruzzaman *et al*., 2021); the Vietnamese tourism industry and public and private sector responses (Quang *et al*., 2020); social work admissions and education at seven international universities in terms of changes to admissions, lockdowns and campus closures, and a rapid shift to distance learning (McFadden *et al*., 2020); front-line nurses' mental health (Van Steenkiste *et al*., 2021); and agricultural extension and food production in Zimbabwe, as well as the effectiveness of the suggested coping strategies (Prosper Bright *et al*., 2021).

While previous studies have examined the impact of the COVID-19 pandemic on a variety of industries, their findings and conclusions cannot be generalised to the construction industry, due to its unique features in relation to distinctive products, goods and services offered by this industry; the particular characteristics of its projects; and its dynamic nature and complexity (Kirchberger, 2018; Guerlain *et al*., 2019; Al-Mhdawi, 2020; Mohamed and Tran, 2021). Hence, it is imperative that the impact of the pandemic and its emerging risks on the construction sector are carefully examined, as the industry accounts for approximately 13% of global gross domestic product (GDP) (Martin, 2009), and employs about 7% of the world's paid workforce (Schilling, 2022). Consequently, as shown in Table 1, several previous research studies have investigated the impact of the pandemic on various areas of the construction industry using a variety of methods and analytical techniques.

For instance, in developing countries, Alsharef *et al*. (2021), captured construction experts' perceptions regarding the early adverse effects and opportunities of the COVID-19 pandemic on the construction industry by utilised data from US projects. Ling *et al*. (2022), used a number of methods to examine how COVID-19 affected construction demand, output production, prices, and project performance, including questionnaire surveys, published statistical data, and in-depth interviews with construction experts in Singapore. On the other hand, in developing countries, Olukolajo *et al*. (2021) surveyed Nigerian construction workforce to assess their adherence to various COVID-19 safety measures. Another example is the work of Amoah and Simpeh (2021), who examined the challenges faced by the South African construction industry in implementing COVID-19 safety measures on construction sites using qualitative surveys.

It is evident from Table 1 that most of the available literature focuses on developed regions, with little attention being paid to developing regions, despite the relatively more severe localised and macroeconomic consequences of the COVID-19 pandemic and its emerging risks on such countries and their construction industries. In fact, the available studies have predominantly either: (1) addressed the impact of the pandemic from a border perspective (Alsharef *et al*., 2021); or (2) focused on particular construction themes/operations such as health and safety (Stiles *et al*., 2020; Amoah *et al*., 2021), supply chain operations (Alsharef *et al*., 202), and legal implications (Harinarain, 2020). The current body of literature falls short in three key areas: (1) assessing the implementation challenges of risk management practices in the construction industry, as well as how these challenges affect the quality of risk management practices adopted to control and mitigate the adverse effects of emergent COVID-19 risks; (2) identifying and assessing the level of impact of the key risks emerging from the COVID-19 pandemic during the execution of construction projects; and (3) understanding the direct and indirect effects of emergent COVID-19 risks to project successes. This PhD research tries to fill this knowledge gap by considering the case of the Iraqi construction industry.

Table 1. *Summary of existing studies (source: author)*

Reference	Setting	Aim and methods	Main findings
Alsharef *et al*. (2021)	United States	Investigated the early adverse effects and opportunities of the COVID-19 pandemic on the construction industry in the United States using expert interviews.	Results indicated that the COVID-19 pandemic had caused material price escalation, reduced productivity rates, delayed project delivery, and supply chain disruption. On the other hand, the new emerging opportunities included recruiting skilled workers and constructing medical facilities on a fast-track basis.
Ling *et al*. (2022)	Singapore	Examined how COVID-19 affected construction demand, output production, prices, and project performance using survey, published statistical data analysis, and conducting in-depth expert interviews.	Results revealed that construction projects suffered significant delays and cost overruns, as well as quality deficiencies caused by the pandemic impact. In addition, the results indicated that both construction demand and output decreased by 27.9% and 28.6%, respectively.
Khalfan and Ismail (2020)	Bahrain	conducted exploratory research to assess the progression of construction projects in Bahrain and construction companies using Literature review; and questionnaire survey.	Results indicated that the pandemic caused shortage of supplies and materials, shifting to an online platform, financial difficulties affecting all involved parties, absence of employees either due to sickness or travel restrictions, reduced efficiency of work delivered, restricted site access, and lack of projects and less willingness of investors to launch new projects.

***Table 1.** Continued.*

Kim *et al*. (2021)	South Korea	Analysed the feasibility of the response guidelines of COVID-19 pandemic for construction projects using simulation (i.e., WebCYCLONE).	Results indicated that compliance with COVID-19 response guidelines increased the number of working days and the construction costs, but, because the risk of site closure was eliminated, construction delays were minimal, as well as liquidated damages.
Sierra (2021)	United Kingdom	Reviewed the literature concerning the major challenges faced by contractors in the UK as a result of COVID-19 using literature review.	Results indicated that the major challenges that contractors are facing due to the COVID pandemic in the UK construction industry are the instability of the supply chain and subcontractors, the uncertainty related to the constant and unpredictable evolution of the pandemic, workforce availability and possible legal exposures.
Assaad and El-adaway (2021)	United States	Identified best practices, impacts, and future research directions to address the pandemic within the construction industry following an in-depth review of current literature.	Results indicated that the pandemic had a positive and negative effect on various aspects of the construction project, including workforce, workplace, supply chain, contractual, legal, and insurance issues.
Raoufi and Fayek (2022)	Canada	Identified the most effective mitigation measures to assist construction organizations during the COVID-19 pandemic and developed evidence-based operational strategies using questionnaire survey.	Results revealed that construction organizations were greatly affected by the COVID-19 pandemic in terms of productivity, operational efficiency, and workforce practices, and many organizations anticipate having a higher percentage of employees working remotely post-pandemic as compared to pre-pandemic.
Araya (2021)	General	Modelled the potential impact of COVID-19 on construction workers using Agent-based simulation.	Findings indicated that the workforce involved in a construction project might decline by 30% to 90% as a result of COVID-19 impact.
Pirzadeh and Lingard (2021)	Australia	Analysed the effects of teleworking during the pandemic on the health and well-being of professionals and managers, using survey data derived from three construction projects.	Results indicated a gradual and consistent decline in mental health and well-being among participants.
Harinarain (2020)	General	Analysed the force majeure clause in the context of the pandemic using a qualitative approach.	Findings highlighted the necessity of clearly drafted force majeure clauses in the context of pandemics.

Table 1. *Continued****.***

Kim *et al*. (2021)	South Korea	Analysed the feasibility of disinfection techniques in construction sites as a response to the pandemic using cyclic operations networks and case studies.	Results indicated an increase in working days and project costs. Nevertheless, the reduced risk of closure of the construction site minimizes the overall project delay and the liquidated damages.
Kukoyi *et al*. (2021)	Nigeria	Evaluated the risk control systems of construction organizations, as well as the challenges that may be encountered when implementing safety measures on construction sites, through an open-ended survey.	Findings of this study revealed that construction professionals are not adequately informed of the severity of COVID-19 and are misusing personal protective equipment.
Olukolajo *et al*. (2021)	Nigeria	Examined the level of compliance of construction site workers with various Covid-19 protocols while working on construction sites using questionnaire survey.	Results indicated that although workers were aware of the Covid-19 pandemic, their attitude toward prevention measures on construction sites was controversial.
King *et al*. (2021)	Malaysia	Analysed the interrelationships between the COVID-19 pandemic and the architectural, engineering, and construction organizations using literature review and interviews	Results revealed that small and medium-sized businesses were significantly affected by disruptions to the supply chain, reduced demand for construction-related works, a reduction in the number of public projects, decreased demand for construction-related works, reduced construction productivity, and reduced foreign investment in the construction industry. Additionally, the decline in foreign investment in the construction sector was moderately associated with decreased demand for construction services, disruptions in the supply chain, and lower productivity.
Parr *et al*. (2020)	United States	Examined the effects of the pandemic on human travel behaviour by analysing traffic volumes.	Findings revealed a 4.5% reduction in traffic volumes, with differences in timing and extent between urban and rural areas, as well as in arterials and highways.
Umar (2022)	Gulf Cooperation Council	Examined the effect of the COVID-19 pandemic on the construction industry in the Gulf Cooperation Council (GCC) members countries and provided recommendations on how to help the industry survive during this period of crisis using expert interviews.	Findings indicated that the impact of the COVID-19 pandemic had resulted in delays in projects, disruptions in workforce management, health and safety issues, and legal consequences.

***Table 1.** Continued.*

Isa *et al*. (2021)	Asia and Australasia	Investigated the impacts of COVID-19 pandemic on road and transport sectors using questionnaire survey.	Findings showed that the factors affecting the road and transportation sectors include reduced revenue, losses, cash flow, turnover, interruptions of construction planning and scheduling, suspension of current activities, disruptions of supply chains, disruptions of mobility networks, and disruptions in both public and private transportation use.
Chigara and Moyo (2021)	Zimbabwe	Investigated the perceptions of construction professionals in relation to factors that affect the delivery of optimal health and safety on construction projects during the COVID-19 pandemic using questionnaire survey.	Findings indicated that the delivery of optimum health and safety during the COVID-19 pandemic were affected by job security and funding-related, production-related, access to information and health service-related, on-site facilities and welfare-related, risk assessment and mitigation-related, the change and innovation-related, cost-related, and COVID-19 risk perception-related, and monitoring and enforcement related factors.
Rehman *et al*. (2021)	United Arab Emirate	Studied the impact of COVID-19 on construction project performance using interviews.	Findings indicated that the performance of construction projects was adversely affected by several challenges, including delayed permits, disrupted cashflows, material and equipment shortages, serious health and safety concerns, travel restrictions, and schedule delays.
Amoah and Simpeh (2021)	South Africa	Examined the challenges faced by construction firms in implementing COVID-19 safety measures on construction sites using qualitative survey (open ended questions).	Results indicated that the main challenges facing the implementation of COVID-19 safety measures at South Africa's construction sites are failing to comply with social distancing rules, public transport usage by workers, shared construction tools and equipment, and shortage of Personal Protective Equipment .
Stiles *et al*. (2020)	United Kingdom	Investigated the impact of COVID-19 on health and safety in the construction sector using literature review.	The study highlighted the importance of integrated and promoted within a general construction risk management system.
Hansen (2020)	South African	Investigated the impact of the lockdown on various stakeholders in the construction market through semi-structured interviews.	Results showed that psychological challenges are a major disadvantage of the pandemic and lockdown, in addition to financial difficulties.

Table 1. *Continued.*

Al-Mhdawi *et al*. (2022)	Iraq	Captured the impact of the COVID-19 pandemic on the construction industry in developing countries using interviews; questionnaire survey; Mann-Whitney U test; and fuzzy sets theory.	Findings indicated that the pandemic had affected a total of 16 construction factors grouped under four construction themes, including contractual implications, the construction financial market, supply chain operations, as well as safety and risk management, the latter being the most impacted. Among the most significant impacts of the pandemic were safety management measures, interpretation of the contract language, prices of building materials, risk management practices, construction materials and labour, and construction contractors. Furthermore, the findings of the fuzzy model demonstrated significant differences in the captured impacts of the pandemic between the public and private sectors.
Agyekum *et al*. (2021)	Ghana	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 using interviews.	Findings indicated that the impact of the COVID-19 pandemic had resulted in a significant reduction in productivity, increased materials costs, and delayed payments. In addition to providing personal protective equipment, construction companies have implemented a number of other measures, including regular and effective screenings at entrances and exits from the job site and educating the workers about the virus.
Salami *et al*. (2021)	United Kingdom	Analysed the methods and practices adopted by construction companies in the United Kingdom in order to mitigate the risk of litigation resulting from potential contract breaches resulting from COVID-19, based on descriptive statistics, exploratory factor analysis, and reliability analysis.	The study revealed a number of effective practices, including establishing and maintaining good relations with contractual partners, reporting possible disputes quickly, collaborating with parties to build goodwill, making early decisions about closures, and reviewing contractual provisions for information about notice periods.
Osman and Ataei (2022)	United States	Investigated construction claims Due to COVID-19 for transportation construction projects through a review of the literature on technical contract language and an in-depth examination of the act of God and force majeure clauses	Results indicate that COVID-19 would be an acceptable trigger under the act of God clause

1.2. Research questions

1. What are the main challenges and barriers to the implementation of risk management in the Iraqi construction industry?
2. How can construction in risk management practices be measured in relation to their implementation challenges and barriers during extreme conditions?
3. What are the significant risks facing the Iraqi construction industry during COVID-19 pandemic?
4. How can COVID-19 emerging risk level be quantified for the Iraqi construction industry?
5. What are the direct and indirect impacts of emergent COVID-19 risks on the success of construction projects in Iraq?

1.3. Research aim and objectives

The aim of this research is to examine the impact of extreme conditions' risk management practices, the challenges associated with their implementation, and their emerging risks on the success of construction projects in developing countries by considering the Iraqi construction industry during the COVID-19 pandemic.

The associated objectives are as follows:

1. To investigate and quantitatively analyse the level of significance of the challenges and barriers to construction risk management implementation during COVID-19 pandemic using analytical hierarchy process (AHP);
2. To quantify the level of efficacy of risk management practices during COVID-19 pandemic in relation to risk management implementation challenges and barriers using a novel multi-dimensional assessment model under fuzzy environment;
3. To identify and categorise the risk factors emerging from the COVID-19 pandemic in the construction industry;
4. To quantify the level of riskiness of COVID-19 emerging risks COVID-19 emerging risk levels using a novel multi-criteria risk analysis model under fuzzy environment; and

5. To model the direct and indirect effects of the significant risks emerging from the COVID-19 pandemic on construction project success based on the perceptions of contractors.

1.4. Research scope

The scope of the research focuses on the construction industry of Iraq as a case study of developing countries. This study examines the main challenges and barriers associated with the implementation of construction RM procedures and methodologies and further evaluates the efficacy level of the current RM practices during the COVID-19 pandemic as an example of extreme conditions. The research also assesses the main risks emerging from the COVID-19 pandemic and measures its direct and indirect effects on the successful completion of construction projects. The challenges and barriers to RM implantation considered in this research include analytical approach-related, behaviour-related, management-related, and team-related challenges and barriers that adversely affect the effectiveness of construction RM practices during COVID-19 pandemic, leading to cost overrun, schedule delays, and quality deficiency.

Furthermore, the risks considered in this research include the risks related to contractual/legal implications, supply chain operations, construction financial market, and the health and safety of the construction workforce, as well as organisational implications, which adversely affect the success of construction projects in terms of adhering to project cost, meeting project deadlines, maintaining quality standards, and safety measures, as well as achieving commercial profitability, and client and end-user satisfaction. Most of the techniques upon which this study is based were derived from the AHP, fuzzy sets theory (FST), and structural equation modelling (SEM). The research participants of this research are construction experts and academics, including contractors, project managers, safety engineers, and construction management academics who work in public and private consultancy firms or contracting companies (general contractors) listed by the Iraqi Ministry of Construction, Housing, Municipalities, and Public Works; the Ministry of Trade; and the Ministry of Higher Education and Scientific Research.

1.5. Key Topics Linked to the Research

1.5.1. Risk and uncertainty

In the construction industry, decisions are made under conditions of risk and uncertainty. Decisions under risk are made when the decision-makers are able to estimate the likelihood of a risk event based on historical data and personal judgment. In contrast, decision-making under uncertainty happens when the likelihood of the event cannot be determined due to unpredictability. Several scholars have discussed the relationship between uncertainty and risk, arguing that risk is a consequence of uncertainty, and uncertainty is the source of risk (Olsson, 2007; Perminova *et al*., 2008; Cleden, 2017). As the nature and characteristics of risk differ from those of uncertainty, it is necessary to distinguish between these ostensibly overlapping terms.

The term “risk” was introduced to the English language in the 17th century. In its original sense, it refers to running into danger (McElwee, 2013). Today, the risk concept is applied in various fields, in which it is described as “threat”, “hazard”, “uncertainty”, or “challenge”. Various authors have adopted different definitions of risk. Willet (1951) defined it as “a phenomenon of objectivity associated with the subjective uncertainty that an unwanted event will occur”. The Association of Project Management (APM, 2006) defines risk as “any set of circumstances or uncertain events that, if they occur, will adversely affect the accomplishment of project objectives”. Similarly, Loosemore *et al*. (2012) described risk as an event that is uncertain in probability and impact, which (if it happens) will affect the achievement of the project’s objectives. The Institute of Risk Management (IRM), The Association of Insurance and Risk Managers (AIRMIC), and The Public Risk Management Association (Alarm), defined risk as the impact of uncertainty on project objectives. The effect on the project objectives (time, costs, and quality) may be a positive or negative, or a deviation from the expected value.

In addition, the Project Management Institute (PMI) has addressed the dual perspective of individual and overall risks in its Project Risk Management Practice Standard (PMI, 2009) and in the Project Management Body of Knowledge Guide (PMI, 2013). Individual risk is defined as any uncertain event that, if it occurs, has a positive or negative effect on the project’s objectives. In contrast, the overall project risk is defined as the impact of uncertainty on the project as a whole. Moreover, the International Organization for Standardization (SO 31000:2009) defined risk as the impact of uncertainty on the expected outcomes. Furthermore, Wibowo and Taufik (2017) described risk as a deep-rooted factor in any construction project and may cause cost and time overruns, which can substantially impact construction stakeholders. These definitions link the risk impact to the project objectives, which can be applied when the project objectives are comprehensive and clearly stated (IRM, AIRMIC, and Alarm, 2010). According to the previous definitions, risk can be expressed in a mathematical expression of the probability of occurrence and its impact on the project objectives as presented in Equation 1 (Khalaj *et al*., 2012):

$$R = P \times C \qquad (1)$$

Where: R is risk; P is probability, or likelihood of the event occurrence; and C is the consequences of the impact of the event occurrence.

Uncertainty refers to an absence of complete certainty; that is, the outcomes of any event are not known, and therefore cannot be predicted or measured (Vasile *et al*., 2015). In other words, uncertainty refers to events about which there is insufficient information to determine their probabilities. Furthermore, Clendon (2009) described uncertainty as an intangible measure of what we do not know. In other words, uncertainty is what remains after the risky events have been identified. Uncertainty in this context includes events that may or may not happen, events caused by lack of information, and/or positive or negative effects on the project set objectives. Uncertainty may result in opportunities or threats accompanied by unpredicted events or may result in irrelevant outcomes.

To this end, the definition of risk used in this thesis is that given by the PMI, as it is considered to be a comprehensive outline of the characteristics of the risks enunciated by the references cited previously, and the definition of uncertainty provided by Cleden (2017) is used.

1.5.2 Risk management

According to numerous researchers, the origin of modern risk management emerged during the 1950s and 1960s (Crockford, 1982; Arthur and Richard, 1995; Scott and Gregory, 2003). Two of the first scientific books to address pure risk management fundamentals and principles were published by Mehr and Hedge (1963) and Scott and Gregory (1964). Despite its significance to the industry, risk management was not systematically practiced until the mid-1980s (Rezakhani, 2012). Risk management is referred to as a proactive, continuous, and organised system for recognised, managing, and communicating risks (Hutchins, 2016) to guide better decision making (Govan and Damnjanovic, 2016). Risk management in construction projects typically aims to avoid threats and exploit opportunities (Smith *et al*., 2014). Effective risk management requires the use of historical data and/or experts' judgement, as well as looking ahead in advance to thoroughly plan for the prevention of future risks (Kendrick, 2015). Furthermore, it is important to note that risk management, in addition to focusing on minimising consequences, also supports activities that embrace innovation in order to achieve greater benefits.

According to Loosemore *et al*. (2012), risk management cannot be used to predict the future. Instead, it facilitates the project's ability to make appropriate decisions based on relevant information, which in turn enables decisions that are based on incomplete information to be neglected, leading to a more efficient project. Understanding the risks associated with a construction project increases the project team's ability to meet the expectations of all project parties. The assessment of these risks withdraws the decision makers' attention to the difficulties that might be encountered in fulfilling the project objectives and the firm's overall expectations (WSDPT, 2014). Zou *et al*. (2010) point out that there are many reasons for construction organisations to develop and implement risk management measures.

Firstly, all construction projects are prototypes in some way and undergo some degree of change (Isaac and Navon, 2008); in addition, each project is unique and inevitably involves various complex risks. Secondly, the types of risks and their impacts change throughout the life cycle of a construction project (Burcar and Radujkovic, 2005). Finally, construction projects necessitate a wide range of participants, construction methods, and teams equipped with various skills and backgrounds. Furthermore, the benefits of implementing systematic risk management, as described by previous studies (Hillson, 2006, Dinu, 2012; Siang and Ali, 2012; Shad and Lain, 2015) can be summarised as follows:

- It reduces threats and increases their opportunities, so it maximises the probability of accomplishing objectives.
- It enables effective management that maximises the effectiveness and efficiency of work while minimised stress and waste.
- It fills strategic gaps by shaping and updating risk culture at all levels within the organisation.
- It decreases the instability of construction activities.
- It discourages the acceptance of financially unsound projects.
- It preserves the credibility and reputation of the organisation.
- 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, the efficiency of data collection, and strengthens corporate governance.

1.5.3. Risk management process

The project risk management process includes the activities of planning, assessment, response planning, and monitoring of risks occurring on a project (Banaitiene and Banaitis, 2012). In accordance with the vast majority of construction risk management literature (Kululanga and Kuotcha, 2010; Jia *et al*., 2013; Yoon *et al*., 2015; Szymanski, 2017; Xia *et al*., 2018; Krechowicz, 2020), and standards and guidelines such as British Standards Institution (BS6079-3, 2000); Institute of Risk Management (IRM, 2002); Standards Australia/ Standards New Zealand (AS/NZS4360:2004); Canadian Standards Association (CAN/CSA Q850:1997 (R 2009)); International Electrotechnical Commission (IEC31010, 2009); International Organisation for Standards (ISO31000, 2009); National Institute of Standards and Technology (NIST800-30, 2012); Project Management Body of Knowledge-Project Management Institute (PMBOK-PMI, 2013); and American Management Association Handbook (AMA, 2014), the process of risk management can be broken down into the following steps: (1) risk management planning, (2) risk identification, (3) risk analysis, (4) risk response, (5) risk monitoring and controlling. The following subsections provide details on each step of risk management process.

1.5.3.1. Risk management planning step

Risk management planning outlines the responsibilities of the risk management team and schedules all activities and procedures necessary to observe, evaluate, and document the risks associated with the project (AMA, 2014). The output of this step is referred to as a risk management plan, which plays a crucial role in developing and updating the risk management strategy for the project, determining the most effective methods to implement the risk management strategy, and) designating the appropriate individuals for the task (Burek, 2007; Nicholas and Steynm, 2011).

In order to build up a successful risk management plan, enough data must be collected throughout the project work breakdown structure, alongside data on project performance standards, cost plan, and scheduling. Comprehensive data must be collected, including project performance standards, cost plan and schedule, as well as consideration of previous successful strategies employed in similar completed projects. All of such information is helpful in determining the project’s requirements and the challenges and barriers that may arise, which may entail re-evaluating options and re-planning project costs and schedule during the project implementation phase (which requires dynamic responsiveness in project planning). In accordance with PMI guidelines, an effective risk management plan can be achieved through holding planning meetings at the management level (i.e., project manager, team leaders, key stakeholders, and other key personnel). These meetings are critical in developing a tailored risk management plan.

1.5.3.2. Risk identification step

Risk identification is considered the most significant step in the risk management process, since the risk assessment and response actions can only be applied to risks that have been identified and recognised (Banaitiene and Banaitis, 2012; Berenger and Agumbra, 2016; Siraj and Fayek, 2019). Giannakis and Louis (2011) state that risk identification is crucial to identifying the risks that can negatively affect project objectives. In addition, project stakeholders (particularly interdisciplinary specialists, e.g., structural engineers and architects) can identify specific instances of uncertainty, which can then be analysed along with appropriate strategies for mitigating the undesirable effects (Zayed *et al.*, 2008). Failure to identify any risk factor may result in a poor implementation of the entire risk management process, which can then adversely affect the organisation's resources. According to Dinu (2012), risk identification involves two phases. The initial identification phase is normally performed by firms that have not previously identified their risk factors in a structured manner, or by new firms or projects. The second phase is continuous risk identification, which aims at identifying new risk factors that have never been identified before.

Risk identification techniques

The process of risk identification requires gathering useful information in order to investigate the possible risks facing the project. Several common methods of gathering risk information are discussed below.

a. Expert interviews

Experts are treated as assets in any organisation, and are critical in planning and estimating activities since their opinions and expertise are deemed valuable. Qualitative expert interviews gather in-depth information whose analysis can provide a synopsis of baseline knowledge concerning a subjects, such as for further identification and exploration of particular risks. Insights and judgments provided by experts can be very helpful in identifying the major and secondary risks facing an organisation. The use of this method is exceedingly common during the early phases of a project, when the data is unsuitable for predicting risk due to the high level of uncertainty. In the context of construction projects, interviews are conducted with project managers, contractors, consultants, and key stakeholders, which may be conducted face-to -face or in group settings. Interviews can be utilised to discuss existing concerns, identify new risks, and provide recommendations on what action should be taken in order to mitigate such risks. To ensure that the interviews with key personnel are efficient, it is recommended to prepare a set of questions in advance of each interview (Chenail, 2011). The process is time-consuming due to preparation, interpretation, documentation, and transcription (Adams, 2008). Moreover, this technique could generate irrelevant thoughts and concerns that will need to be filtered (Kotb and Ghattas, 2017).

b. Delphi technique

The Delph technique is a method of gathering data from respondents based on their area of expertise (Pathuri *et al*., 2020). The purpose of this technique is to obtain consensus and to ensure that there is no internal influence between respondents' opinions, notes, and suggestions (Soni *et al*., 2017). It consists of surveys, sent to a panel of experts, designed to answer specific questions of interest. In this procedure, the Delphi panel experts are identified, selected, and validated (Tymvios and Gambatese, 2016; Keeney *et al*., 2017). According to Chapman (1998), the main characteristics are of Delphi technique are anonymous group participation, controlled feedback, and a statistical group response. There are four main steps involved in the Delphi technique (McMillan *et al*., 2016): defining the problem, selecting the expert, preparing the questionnaire, administering the questionnaire, and recirculating the survey.

The risk manager directs the query to the expert group, after which the results of the query are analysed and evaluated. After a pre-determined period of time, the list of risks is recirculated to the professional for further discussion to narrow the list of the identified risks. While the Delphi methodology differs from conventional surveys in that it is an iterative process (rounds of questioning), which provides the opportunity to receive feedback from participants, to assemble responses, and to distribute those responses to experts for further review (Tengan and Aigbavboa, 2021). Despite its benefits, this method has the disadvantage of requiring highly motivated participants, and of being a lengthy and time-consuming process to administer and analyse.

c. Brainstorming

Brainstorming is a popular method to generate and collect creative ideas (Mandal, 2014). BS 31010 (2010) describes brainstorming as:

> "the process of stimulating and promoting a free-flowing discussion among a group of knowledgeable individuals to identify potential failure modes and associated hazards, risks, criteria for decisions, and/or response options".

The brainstorming process can be divided into two steps (Garrido *et al*., 2011): idea generation and idea selection. A key benefit of this technique is that it promotes a shift in thinking away from conventional boundaries in order to provide new perspectives and possibilities regarding potential risks, which can then be used to enhance the risk management practices of the organisation. The disadvantage of this approach is that it generates ideas without screening them, which takes a considerable amount of time if the group is not properly controlled (Baumann *et al*., 2016).

d. The Ishikawa cause and effect diagram

The Ishikawa Cause and Effect Diagram (commonly known as the "fishbone diagram") identifies and explains the root causes for each risk factor within a project (Hekmatpanah, 2011). The major objective of this technique is to identify the root causes of the risks. The fishbone diagram consists of a main horizontal line known as a bone, from which a number of diagonal lines grow (Bilsel and Lin, 2012). According to Ilie and Ciocoiu (2010), the six main steps of the Ishikawa fishbone diagram are: problem identification, formalisation of the problem, establishing the primary and secondary causes, completing the fishbone diagram, and diagram analysis. The disadvantage of this technique is that the figures can be overly complex for practical visualisation purposes (Kotb and Ghattas, 2017). In addition, this technique can sometimes be misleading as well as time-consuming.

Risk classification

Risk identification (or categorisation) is a crucial component of risk identification (Siraj and Fayek, 2019), which helps in achieving an inclusive procedure in which risk factors are systematically identified and brought together by harmonic details, which in turn improves the quality and effectiveness of the overall risk identification process (Bu-Qammaz *et al*., 2009). Further, it helps the project team structure the many and varied risks that may arise during the course of a construction project. To this end, risks can be categorised into certain groups depending on their source of origin, their nature and type (Renuka *et al*., 2014; Taylan *et al*., 2014; Hopkin, 2018).

1.5.3.3. Risk analysis step

Risk analysis is the process of defining, analysing, and prioritised the risk factors based on their importance (EL-Sayegh, 2018). The objective of the risk analysis is to gain a clear view of risks' circumstances and implications and then to rank them based on a set of priorities (Al-Mhdaw *et al*., 2020). The risk analysis process should be conducted periodically to identify any risks that may have a positive or negative impact on the project set objectives. The choice of analysis approach is primarily determined by the level of risk, the management experience, and the level of project complexity. There are two main paradigms that can be used to analyse risks: qualitative and quantitative approaches, as discussed in the following sections.

1.5.3.3.1. Qualitative risk analysis

The process of qualitative risk analysis, according to the PMI (2013), consists of assessing the probability and impact of the identified risks. It depends on relative values and risk descriptions derived from ranking risks into specific descriptive categories such as low, medium, and high (Yoe, 2011). Results of qualitative analysis might lead to deeper analysis or to immediate action. The analysis process may be conducted by internal experts directly, or through questionnaires sent both internally and externally. There are many advantages to using qualitative risk analysis including that it can cover a wide range of risk risks quickly and at a low cost; it is more flexible in terms of processes and reporting; and it is more helpful in understanding project risks at the early stages of the project (i.e., when there is a high level of uncertainty arising from lack of sufficient information). Its main disadvantages are that it is solely based on experts' subjective (and fallible) judgments and experiences, and it does not systematically encompass consideration of the cost analysis of risks (Stroie, 2011; Ming-Chang, 2014).

The following are the most commonly used methods for qualitative risk analysis in the construction industry.

a. Risk probability and impact matrix

The risk portability and impact matrix is an effective tool to present the results of simplified risk analysis, providing insight into various risks (Elmontsri, 2014). It is used to plot the probability of an event occurring against the impact of the event if it occurs (Sumner, 2009). This method is one of the most widely used for qualitative risk analysis and it is intended to present the results of the assessment in visual presentation (Dumbrava and Iacob, 2013). Using this method, risks are ranked by multiplying the probability score of each risk by its impact score, resulting in the risk score. The risk score is then allocated to the corresponding coloured zone in accordance with its importance. The most common is the 5x5 risk matrix (Figure 1) (Sumner, 2009). Table 2 shows the probability and impact rating systems for this method, and Table 3 shows the risk scores and their categories.

LIKELIHOOD					
5	LOW	MED	HIGH	EXT	EXT
4	LOW	MED	HIGH	HIGH	EXT
3	LOW	MED	MED	HIGH	HIGH
2	LOW	LOW	MED	MED	MED
1	LOW	LOW	LOW	LOW	LOW
	1	2	3	4	5

CONSEQUENCE

Figure 1. *5x5 risk matrix (source: Sumner, 2009)*

Table 2. *Risk probability and impact rating (source: RMB, 2012).*

Sub-score	Probability	Effects
1	Very low(rare)	Insignificant (negligible effects)
2	Low(unlike)	Minor (project might be delayed)
3	Moderate(possible)	Moderate (project will be delayed)
4	High(likely)	Major (project needs to be re-designed, re-approved and re-done)
5	Very high (almostcertain)	Catastrophic (project is interrupted so that objectives will notbe met)

Table 3. *Risk score (source: RMB, 2012)*

Score	Rank
0-5	Low
6-10	Medium
12-16	High
20-25	Extreme

Probability and impact matrix limitations

The main limitations of this technique were summarised by Cox (2008). They include the poor resolution of a typical risk matrix, which can only compare a small fraction (for example less than 10%) of randomly selected pairs of risk factors, by which it can assign similar ratings to qualitatively very different risks. It also utilises ambiguous inputs and outputs; risk matrix inputs (i.e., probability and impact) and outputs (risk score) are subject to subjective interpretation (i.e., different users may assign different ratings to different risk events).

b. Failure model and effect analysis (FMEA)

The failure mode effect analysis (FMEA) was developed in 1949 and was first used for military applications (Yazdi *et al*., 2017). In 1963 FMEA was adopted by NASA for reliability studies. Since then, it has been recognised as a useful technique for system safety and risk management (Bahrami *et al*., 2012). The technique is used for identifying and eliminating the possible causes of failure and prioritised potential failures within a system (Sultan, 2011). The process involves establishing the modes and effects of each failure in a system so that all types of failure modes are identified and ranked according to their priorities. In the construction context, this technique is used extensively to analyse risks and to define their impact on the project objectives (e.g., Wehbe and Hamzeh, 2013; Heidary *et al*., 2020). In the FMEA approach, the following parameters are used to calculate the rank of risks (Prakash *et al*., 2015):

- Likelihood (L): the probability of failure occurrence.
- Severity (S): the impact of failure on the project objectives.
- Detection (D): the ability to identify a potential failure before its occurrence, which means how detectable the failure is while something is still done, also called detect-ability.
- Risk Priority Number (RPN): a number used to express the priority of the failure, where: RPN = L * S * D

Table 4 shows the FMEA likelihood, severity and detection scales. Table 5 shows the RPN ranking categories for each range of RPN values from low to moderate, major, significant and extreme levels.

Table 4. *FMEA likelihood, severity and detection scales (source: Stamatis, 2019)*

Sub-score	**Likelihood**	**Impact**	**Detection**
1	Very low	Very low	Very high
2	Low	Low	High
3	Moderate	Moderate	Moderate
4	High	High	Low
5	Very high	Very high	Very low

Table 5. *The RPN ranking categories (source: Stamatis, 2019)*

RPN Range	**Rank**
90-125	Extreme
60-89	Significant
40-59	Major
18-39	Moderate
1-17	Low

FMEA limitations

The main limitations of this technique include that the RPN considers three major dimensions of risk analysis (occurrence, severity, and detection), without considering any other analysis dimension. It is also possible that the FMEA outcomes are affected by the expertise of the evaluator, rendering the technique vulnerable to human error. Furthermore, it does not provide an assessment of events involving multiple failures, and various risks may be assigned the same priority number, which will obscure the authentic risk characteristics (e.g., varying degrees of actual risk potential in practice) (Joshi and Joshi, 2014; Liu *et al*., 2017).

1.5.3.3.2. Quantitative risk analysis

A quantitative risk assessment is an approach to quantitative risk analysis that utilises formal and systematic methods to quantitative the relative risk of an engineering process (Smith and Simpson, 2020). This analysis supports decision makers in minimising overall project uncertainty. This can be performed after the qualitative analysis has been carried out to prioritise the risk factors, or it can be conducted directly if the available data is inappropriate for qualitative analysis first. There are many advantages to using qualitative risk analysis, including that it provides a clear and detailed understanding of the impact risks; the evaluation and results are based on objective criteria; and the cost is included in the analysis. Its main disadvantages are the complexity of calculation; the lack of universally accepted standards for implementation information; the results being presented only as monetary values, which are difficult to understand by individuals without relevant experience; and the implementation of this method is more expensive and complex than qualitative approaches to risk analysis (Ramona, 2011). The following are the most commonly used methods for quantitative risk analysis in the construction industry.

a. Monte Carlo simulation

Monte Carlo Simulation is a stochastic technique that works by selecting random numbers within a specified range of a specific probability distribution (Fang and Zhang, 2013; Zou *et al*., 2013) which is used for forecasting, estimations and risk analysis by generating different scenarios (Gonzalez *et al*., 2018). Monte Carlo analysis involves replacing the deterministic cost and schedule values in the project models with probability distributions that reflect the range of possible outcomes for each of these variables (Steyn, 2018). By using a random number generator, a value is calculated for each probability distribution in order to calculate the values of cost/schedule (Raychaudhuri, 2008). To this end, a probability distribution is derived from the value each time the program runs. Ultimately, risk assessors can examine the simulation statistics to determine how the project risk is represented in the model

Monte Carlo simulation limitations

The main limitations of this technique are that it is difficult to choose the probability distributions for each activity or event; and the use of this technique is only feasible if the information quality used in the model reflects the actual risk scenario (Kwak, 2009; Avlijas, 2019).

b. Sensitivity analysis

Sensitivity analysis (SA) examines how the uncertainty in the output of a model can be attributed to various sources of uncertainty in its input (Saltelli *et al*., 2008; Liburne and Tarantola, 2009; Razavi *et al*., 2021). In modelling, SA is a critical component because it allows a systematic investigation of the complex interactions of a model. SA execution entails that the analyst must identify the project variable and describe its likely range of variations; and examine the deterministic value for each of the parameters, calculated based on the value of the variable at each step (Smith *et al*., 2014). This analysis will then produce a sensitivity plot as the output.

Sensitivity analysis limitations

The main limitations of this technique are that analysis of the impact of change in each variable is complex and time-consuming; and no probabilistic measure of risk exposure is used, which indicates that the expected outcomes are not explicitly analysed (Bhat, 2009; Borgonovo, 2017).

1.5.3.4. Risk response step

The risk response is one of the most important steps in the risk management process (Motaleb, 2021). This step establishes a strategic approach to response to a particular risk in the most efficient, appropriate, and safe manner (Mubin and Mannan, 2013; Ahmadi-Javid *et al*., 2020). The type of risk response depends on whether it is a negative risk (downside risk) or an upside risk (opportunity). Downside risks are events that can negatively impact the project objective, whereas the upside risks are those that can increase the value of the project's output production (BS 8636-1, 2015). Response actions are generally classified into four categories, as explained below.

a. Risk avoidance

Risk avoidance refers to the elimination of risk by mitigating existing risks (Wan and Chiu, 2019). This involves changing the project management plan and the project objectives that are in jeopardy (PMI, 2013). Risk avoidance is considered to be an effective action of dealing with risks only when the estimated cost of risk avoidance is lower than the cost of handling the risks. Despite the fact that some risks cannot completely be avoided, this type of response action should be given first consideration since other types of response actions may require more expensive and time-consuming (WDPT, 2014).

b. Risk transference

Risk transference refers to the process of shifting the responsibility for risks to a third party that is capable of managing those risks (PMI, 2013). In other words, the risk is not terminated, but it becomes the responsibility of another party to eliminate it. Transferring risk to another party or organisation can be accomplished through a contract, whereby a party transfers its risk(s) and all of its financial obligations to the third party (Ballad *et al*., 2014). Typically, risk transfer occurs if the other party is competent, efficient, and qualified to take the necessary steps to minimise the impact of the risk (Smith *et al*., 2014). Risks can be transferred in the construction context by assigning risk(s) and their financial responsibilities to a third party, such as a subcontractor (Hosny *et al*., 2019); or transferring only the financial responsibility of the risk-subjected activity to a third party (i.e., insurance company) (Brockett *et al*., 2019).

c. Risk mitigation

Risk mitigation refers to reducing exposure by minimised the probability and/or impact of risks (Ehsan *et al*., 2010). This endeavour will result in reducing risk to an acceptable level of severity and probability. Nevertheless, risk mitigation can only be applied a few times before the project becomes unmanageable (Flanagan *et al*., 2007).

d. Risk acceptance

Some risks simply cannot be avoided, transferred, or mitigated, and must therefore be accepted and accommodated within project planning, especially when potential losses are smaller in the event they occur. A risk acceptance approach can be applied to low-probability and low-impact risk factors, in which case the management team will decide not to change the project plan and will deal with the risks as they arise. Risk acceptance can take either a passive or active forms.

Passive risk acceptance means that the management team will not take action with respect to risks and will only document them. Passive risk acceptance occurs when the cost of dealing with the risks is not a cost-effective action option, and when the response measure has not yet been established, or the impact of the identified risks has not been correctly measured. Active risk acceptance on the other hand is a strategy that prepares to deal with the impact of risk factors once they occur (IRMS, 2015). As part of active acceptance of risks, contingency plans may be developed to mitigate the effects of the risks (Khamooshi and Cioffi, 2009). In this case, there is need for higher contingencies.

1.5.3.5. Risk monitoring and controlling step

In this final step of the risk management process, the developed risk strategy is monitored to determine whether corrective actions are effective and to detect potential risks that have not been identified previously (Ennouri, 2013). Risk monitoring is the ongoing awareness and maintenance of risks (Kott and Arnold, 2013), which enables project decisions to be based on current information about overall project risk exposure and individual project risks (PMI, 2013). There are many techniques that can be employed to monitor and control risks, including the following (Harold, 2009):

a. **Earned value (EV):** EV uses standard cost/schedule data to evaluate a program's cost performance (and provide an indicator of schedule performance) in an integrated fashion.

b. **Program metrics (PMs):** PMs refers to a formal, periodic performance assessment of the selected development process, which evaluates the degree to which the process is achieving its objectives.

c. **Schedule performance monitoring (SPM):** SPM is the process of evaluating how well the programme is progressing towards completion using data from the program schedule data.

d. **Technical performance measurement (TPM):** TPM is a method for using engineering analysis and tests to estimate the values of key technical performance parameters of a design as affected by risk response actions.

1.5.4. Risk management implementation challenges and barriers

Construction projects operate in an increasingly dynamic environment and are subject to various risks and uncertainties (Zhao, 2013). These projects are further complicated by complex relationships with contractors, owners, project managers, subcontractors, government authorities, suppliers, and other stakeholders (Hwang *et al*., 2014). The increasing challenges and risks associated with construction projects entail the need for effective RM practices for managing project uncertainty and ensuring overall success (Bu-Qammaz *et al*., 2009). In order for risk management to be effective and efficient, Banaitiene and Banaitis (2012) found that it is imperative to have a systematic methodology as well as knowledge of and experience with the various types of construction operations. In the context of developing countries, construction practitioners tend to approach risk management with a set of poor practices that are usually insufficient, which leads to poor results most of the time (Adekele *et al*., 2019). In fact, Sliva *et al*. (2013) reported that construction practitioners in developing countries do not perceive the need for risk management to mitigate ongoing risks in the construction industry.

There is a plethora of studies on barriers and challenges to the effective application of RM practices in the construction industry of developing countries. Kikwasi (2011) identified the critical challenges of RM implementation in the Tanzanian construction industry to be the lack of a holistic approach to risk management, reluctance to spearhead the risk management process, inadequate risk management knowledge, and the lack of a priority in clients' requirements. Chileshe and Yirenkyi-Fianko (2012) identified six significant barriers to risk assessment and management in the construction industry of Ghana, namely the lack of RM consultants, the lack of information, the lack of time constraints, the lack of expertise, the lack of experience, the lack of coordination among parties involved, and lack of awareness. Furthermore, Chileshe *et al*. (2016) identified seven main barriers and challenges to the implementation of risk management in Iran, including the lack of support from clients and project stakeholders, the lack of agreement among the parties and stakeholders about risk management, the tight timing of projects, the high costs associated with risk management implementation, the lack of risk management consultants, the lack of experience among practitioners, and the lack of knowledge and necessary skills. The lack of use of RM practices is not only observed in developing countries but is also prevalent in developed countries (in terms of the construction industry), such as the United Arab Emirates (El-Sayegh, 2014), the Netherlands (Paape and Spekle, 2012), and Singapore (Hwang *et al*., 2013).

1.5.5. Project success

In many studies, cost, time, and quality compliance have been used as measures of project success (Meredith, *et al*., 2017). Although often criticised, these criteria are still considered the gold standard for assessing the success of a project (Papke-Shields *et al*., 2010). Project success in the construction industry is perceived differently by different contract parties (i.e., the owner/client and the contractor), as well as by different professionals, including civil and structural engineers, mechanical and electrical engineers, architects, and quantity surveyors. In fact, Baker *et al*. (1988) argued that there is no such thing as absolute success in a project, and success can only be perceived (and relative). According to Chan and Chan (2001), project success criteria refer to the set of principles or standards by which favourable outcomes can be achieved within a specific time frame.

There are a variety of criteria that are used in construction management literature to measure the success of a project. For instance, Ahadzie *et al*. (2008) measured project success based on five key success indicators, namely, time, budget, quality, customer satisfaction, and environmental impact. Al-Tmeemy *et al*. (2011) identified eight success indicators, including schedule, cost, quality, meeting project specifications, customer satisfaction, market development, competitive involvement, and reputation. Additionally, Shahrzad Khosravi (2011) measured project success in terms of five key success indicators, including time, cost, quality, health and safety, as well as the satisfaction of the client and end-user. In another study, Liyanage and Villalba-Romero (2015) used six criteria for assessing the success of construction projects, namely, time, cost, quality, contract, process and results, and stakeholders' satisfaction. Wu *et al*. (2017) and Viswanathan (2020) assessed construction projects' success based on schedule, budget, and client satisfaction. Furthermore, Buniya *et al*. (2022) stressed the importance of construction health and safety to the overall project success. In the following subsections, details are provided about the most frequently used success criteria in the construction management literature.

a. Project cost and time

Project cost refers to the extent to which the construction work was completed within the estimated budget. As described by Chan and Chan (2004), the term "cost" does not refer solely to the tender sum but includes any variations, modifications made during construction, and the costs incurred as a result of legal proceedings. Cost can be measured in terms of unit cost or percentage of net variation over final cost (cost overrun). Project time, on the other hand, refers to the duration agreed upon for the completion of a project. Construction time can be measured in terms of construction speed, construction time, and construction time overrun (Chan and Chan, 2004).

b. Project quality

According to Khorsravi and Afshari (2011), the quality of a project can be defined as its ability to meet its technical specifications. Serrador and Turner (2015) stated that quality is closely associated with technical performance, specifications, and achieving the functional objectives of a project. This is in agreement with the conceptualisations of Ali and Rahmat (2010) and Chan *et al*. (2020), which emphasised that quality, technical performance, and functionality are closely related to the objectives of the owner, designer, and contractor, and which are consequently subjectively assessed.

c. Project safety

Generally, safety refers to the extent to which the general conditions facilitate the successful completion of a project without major accidents or injuries (Chan and Chan, 2001). According to Buniya *et al*. (2021), meeting safety criteria will reduce potentially dangerous behaviour that may lead to an accident, and will also facilitate recognised and reporting safety issues and injuries. Also, it increases productivity, decreases absenteeism and turnover, decreases accident-related costs, and increases employee morale (Othman, 2010).

d. Client and customer satisfaction

The satisfaction of the client or customer is an important factor in the success of a project, and a project cannot be considered successful until this is achieved (Lechler and Gao, 2012). The understanding and satisfaction of the needs of stakeholders and customers are crucial to the existence and competitiveness of the global construction industry (Khosravi and Afshari, 2011; Chovichien and Nguyen, 2013). In the construction sector, there is a high rate of client/customer dissatisfaction that can be attributed to a variety of factors, including overrun project costs, delayed completion, inferior quality, and incompetent service providers (Li *et al*., 2013). Therefore, to measure the satisfaction level of stakeholders/clients, a performance measurement can be conducted (Rashvand and Majid, 2014). In performance measurement, an organisation establishes factors within which programs, investments, and achievements are achieving desired results (Tripathi and Jha, 2018).

1.5.6. Analytical hierarchy process

AHP was originally developed by T. L. Saaty, c. 1971-1975 (Saaty, 1987). This method deals with complex economic, socio-political, and technological issues (Saaty, 1977; Saaty and Vargas, 1982; Saaty, 1986; Saaty, 1988; Saaty and Alexander, 1989). AHP has been widely adopted as a multi-criteria decision-making method for dealing with complex decision-making problems (Kablan, 2004). With its ability to analyse respondents' objective and subjective factors through pairwise comparisons matrices (Jung and Choi, 2012; Lee *et al*., 2014), AHP can effectively resolve conflicts of opinion or establish priorities (Zhang and Zou, 2007; Darko *et al*., 2019). Using AHP has a variety of benefits, including the following (Saaty,1982):

- It assists with the analysis of the problem and the development of a rational decision hierarchy.

- It provides insight into the data that is required for the alternatives at hand by conducting pairwise comparisons under each of the criteria or sub-criteria.
- It prioritises alternatives based on predetermined criteria or makes a decision based on a variety of possible scenarios.
- It analyses the validity of comparisons between alternatives.

Due to these benefits, AHP has been extensively used in different areas of construction engineering management, such as construction risk management (Li and Zou, 2008; Sun *et al*., 2008; El-Sayegh, 2009; Abdelgawad and Fayek, 2010; Li *et al*., 2011; Wang and Chen, 2012; Li *et al*., 2013; Samaras *et al*., 2014; Banda, 2019; Vladeanu and Matthews, 2019; Bhatt and Sarkar, 2020; Tarebari and Hosseini, 2020; Sarkar and Singh, 2021; Providakis *et al*., 2021), construction safety management (Hu *et al*., 2009; Shapira and Simcha, 2009; Aminbakhsh *et al*., 2013; Raviv *et al*., 2017; Unver and Ergenc, 2021), construction supply chain operations (Plebankiewicz and Kubek, 2016; Hemanth *et al*., 2017; Kim and Nguyen, 2018; Marzouk and Sabbah, 2021; Petroutsatou *et al*., 2021), and construction materials and equipment selection (Shapira and Goldenberg, 2005; Plebankiewicz and Kubek, 2016; Petroutsatou *et al*., 2021). The AHP is based on three principles: the decomposition principle, the comparative judgments, and the synthesis of priorities (Saaty,1986), as discussed below.

a. The decomposition principle

Using this principle, the hierarchy must be constructed to capture the most fundamental elements of the problem. To accomplish this, it is most effective to work downward from the general goals or objectives to alternative solutions. Goals or objectives (e.g., risk analysis criteria) are placed in the first level, and criteria (e.g., risk categories) are placed in the second level, followed by subcategories (if any) in the third level, and so on. With the increasing complexity of a problem, a decision hierarchy needs to include more levels.

b. The comparative judgments principle

The second principle entails the development of a matrix to compare the relative importance of the elements at the second level in relation to the overall goal. Saaty (1990) developed a ranking scale to quantify the importance of the comparisons, as shown in Table 6. The five linguistic variables (i.e., equally important, moderately important, strongly important, very strongly important, and extremely important) are transformed into numerical values equivalent to 1, 3, 5, 7, and 9. Additional matrices should be used in the case of multiple criteria levels to compare elements in the next level on the hierarchy.

Table 6. *AHP pairwise comparison scale (source: Saaty, 1987)*

Numerical scale	**Explanation**
1	Equal importance
3	Moderate importance of one over another
5	Strong importance
7	Very strong importance
9	Extreme importance
2,4,6	Intermediate values between the two adjacent judgements.
1/3, 1/5, 1/9	Values of inverse comparison (If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i)

c. The synthesis of priorities principle

This principle requires the priority weights to be synthesised from the second level down by multiplying the local priorities by the priority of their corresponding criteria at the level above. The weights are then summed for each factor for each level according to the criteria that each factor influences.

1.5.7. Fuzzy sets theory

The main advantage of FST lies in its ability to formalise and manage human knowledge, uncertainty (i.e., lacking complete and precise information) in decision making (Islam and Nepal, 2016; Al-Mhdawi, 2020; Al-Mhdawi, 2022), as well as vagueness and subjectivity associated with linguistic terms (e.g., very low, low, moderate, high, very high) (Alhumaidi, 2015). In accordance with this theory, linguistic terms are less precise than crisp values (i.e., numbers) (Mohamed and Tran, 2021). In other words, crisp values cannot satisfy the assessment criteria of an event (such as risks or practices), as ambiguity and conflicting expert judgements are a result of ill-defined data and insufficient decision-making processes. The main processes associated with the FST model are fuzzification, fuzzy inference system, and defuzzification, as described below.

Step 1: Fuzzification

The process of fuzzification involves converting the numerical values of the inputs into fuzzy sets (Doskocil, 2016; Karimpour, 2016; Radhika and Parvathi, 2016), which is achieved through the use of information in the knowledge base (Kayacan and Khanesar, 2016). Membership functions are used to determine the degree of membership of each fuzzy set. These functions are modifiable and stimulate the human brain’s decision-making system. The most common types of membership functions are triangular, trapezoidal, and Gaussian (Jamshidi *et al*., 2012; Wulan and Petrovic, 2012).

Step 2: Fuzzy inference system

The fuzzy inference system operates by using knowledge stated as "IF-THEN" rules, and can be applied to predict the behaviour of many undefined systems and data-driven decision-making processes (Ahamed, 2016). Inference processes are carried out through the application of a broad range of linguistic IF-THEN rules, guided by expert judgment and engineering knowledge, in order to shape the relationships between input variables and output variables. The most common types of fuzzy inference systems are the Mamdani type (Mamdani and Assilian, 1975) and Sugeno type (Sugeno, 1985).

Step 3: Defuzzification

The defuzzificaiton process decodes fuzzy conclusions based on their degree of truth (membership function values) in order to produce crisp (non-fuzzy) results (Nieto-Morote and Ruz-Vila, 2011). There are various defuzzification techniques, such as the centroid of area method (also known as centre of gravity/ centre of area method), the bisector of area method, and the middle of maximum, largest of maximum, and smallest of maximum methods (Karimpour *et al*., 2016).

1.5.8. Structural equation modelling

Otis Dudley Duncan (1975) introduced SEM to the social sciences, and it flourished throughout the 1970s and 1980s. SEM represents an important advancement in quantitative research as it encompasses and extends correlation, regression, factor, and path analyses (Kassem *et al*., 2020). Prior to SEM measurements errors were evaluated separately, and were not explicitly included in tests of theory. In quantitative research, this separation posed a significant obstacle to developing theory. In SEM, measurement error is estimated, and theoretical parameters are adjusted according to this estimation. Using SEM, researchers are able to construct and analyse complicated relationships between diverse variables within a flexible framework that allows them to test theories and hypotheses (Russo *et al*., 2021). The advantages of SEM are explained below.

a. Incorporation of latent variables

One of the significant advantages of SEM is its ability to incorporate latent variables into the analysis (Lowry and Gaskin, 2014). Latent variables are used to account for measurement errors and thereby improve estimation accuracy (Hair *et al*., 2010). While conventional analysis methods, such as multiple regression analysis, have the advantage of analysing relationships between independent and dependent variables, they are limited to analysing only observed variables, thereby neglecting measurement error (Ho, 2006), a limitation that can be overcome with the use of SEM (Hair *et al*., 2011).

b. Simultaneous analysis

The traditional analysis techniques, such as factor analysis, cluster analysis, multiple analysis of variance (MANOVA), and multiple regression analysis, utilise a two-step approach to separate theory from measurement in an assessment. This makes these methods susceptible to bias, so it is necessary to integrate theory with measurement in the analysis model. The measurement model in SEM is used to test the convergent and discriminant validity of latent constructs, while the structural model is used to test causal relationships (Fan *et al*., 2013). The combination of theory and measurement allows for errors of the observed variables to be considered, thereby allowing more accurate estimation than that achieved using traditional analysis methods (Lowry and Gaskin, 2014).

c. Mediation analysis

Mediation analysis is often referred to as a mediating or indirect effect. The primary feature of the mediator in SEM is that it involves a third variable that plays an intermediary role between the independent and dependent variables, thereby facilitating causal relationship modelling in complex systems (Gunzler *et al*., 2013; Chen and Hung, 2016).

1.6. Research methodology

1.6.1. Research philosophy

The selection of appropriate research philosophy is an essential aspect of the research methodology. In fact, as Guba and Lincoln (1982) have emphasised, philosophical paradigms within research are of the utmost importance as they guide the investigation. In research, philosophy refers to the process of developing knowledge and its nature. Using the philosophical approach, the researcher can determine which approach should be adopted and why. Therefore, it is crucial to be familiar with various research philosophies before selecting the appropriate one (Saunders *et al*., 2009). According to Saunders *et al*. (2019), there are five distinct philosophies of research, including positivism, critical realists, interpretivism, postmodernism, and pragmatism. The following sub-sections provide details on each of these philosophies.

a. Positivism

Positivism refers to the view of natural scientists who work with observable social realities in order to produce generalisations that are, in essence, law-like. Further, it implies the importance of what is “posited” (i.e., “given” or “assumed”). Additionally, positivists stress the importance of a strict scientific empiricism and methods intended to produce pure data and facts. Thus, the positivist approach emphasises a strict scientific empiricist method designed to produce pure data and facts that are free of human interpretations or biases (Saunders *et al*., 2019).

b. Critical realism

In critical realism, the focus is on explaining what we perceive and experience in terms of underlying structural elements of reality that influence observable events. In the view of critical realists, reality is the most important philosophical consideration, and an ontology that is structured and layered is fundamental (Fleetwood, 2005). Critical realists assert that reality is external and independent, and not directly accessible through observation and knowledge. Instead, what we experience comprises empirical or sensational manifestations of what is actually happening in the world, rather than the actual things themselves (Saunders *et al*., 2019).

c. Interpretivism

Similar to critical realism, interpretivism developed as a critique of positivism but from a subjectivist viewpoint. A basic foundation of interpretivism is the notion that humans are different from physical phenomena due to their ability to create meanings. In fact, Interpretivists argue that human beings and their social worlds cannot be studied in the same way as physical phenomena, and that therefore social sciences research should be distinct from natural sciences research rather than attempting to emulate it (Saunders *et al*., 2019).

d. Postmodernism

A key characteristic of postmodernism is its emphasis on the role of language and power relationships, which is intended to challenge established ways of thinking and to give voice to alternative marginalised perspectives. Research that follows postmodernist philosophy aims to expose and question dominant realities (Calas and Smircich,1999). This involves deconstructing these realities as if they were texts, to discover instabilities within these widely accepted "truths", in addition to the absences and silences that are surrounded by them (Derrida, 2016).

e. Pragmatism

According to pragmatism, concepts are only relevant when they are used to support action (Kelemen and Rumens, 2008). It is concerned with reconciling objectivism and subjectivism, facts and values, accurate and rigorous knowledge, as well as varying contextualised experiences. This is achieved by considering ideas, concepts, theories, hypotheses, and research findings not in abstract terms, but rather as instruments of thought and action, and their practical significance when applied in specific contexts (Saunders *et al*., 2019).

The philosophical position of this thesis

This thesis is philosophically oriented towards pragmatism, since particular methods were selected based on their suitability for answering the research question(s), rather than a doctrinaire adherence to any particular paradigm or philosophical doctrine upon which it is supposed to be based (Bryman, 2006; Kaushik and Walsh, 2019). In fact, in the pragmatic paradigm, research is driven and sustained by researchers' doubts and beliefs, and researchers employ various methods with an emphasis on practical solutions and outputs (Saunders *et al*., 2015). Hence, pragmatists believe that there are a variety of approaches to interpreting the world and conducting research, as well as multiple perspectives that can provide a comprehensive picture. However, this does not imply that pragmatists use random methods; instead, they use methods that allow credible, well-founded, reliable, and relevant data to be collected, thereby allowing research to advance (Saunders *et al*., 2015). Additionally, scholars assert that pragmatism provides a philosophical foundation for social science research in general, and mixed-methods research in particular (Morgan, 2013), as is the case with this study.

1.6.2. Research approach

According to Saunders *et al*. (2012), there are two types of research approaches: deductive and inductive. Deductive research differs by its nature from inductive research. Rabbie (2010) observes that both deductive and inductive approaches involve collaboration between acumen and observations. According to the deductive approach, particular sets of theories are generally taken into account in order to contract them towards more specific issues that could lead to the implementation of better practices (Collis and Hussey, 2014). It can be explained in terms of theory driving research assumptions (Zalaghi and Khazaei, 2016). As such, a hypothesis or a research objective is developed by examining certain specific theories. Moreover, it provides the opportunity to link concepts to variables in order to explain causal relationships, as well as quantifying concepts and generalised research results to a certain extent (Erford, 2014). To this end, deductive approach is known as a top-down research approach (Khaldi, 2017), in which research moves from general ideas to particular situations so as to better understand the investigated subject.

The inductive approach, on the other hand, involves the identification of patterns from observations and the formulation of hypotheses (Bernard, 2011). Using this approach, the researcher uses the observations in order to develop an abstract or to describe the circumstances under investigation (Lodico *et al*., 2010). In fact, it is largely dependent on the views of participants, in order to frame broader themes and develop a theory that interconnects the themes together (Saunders *et al*., 2016). To this end, the inductive approach is known as bottom-up approach, as it moves from specific to general, based on the researcher's generalisation of specific circumstances to general conditions (Zalaghi and Khazaei, 2016). Figures 2 and 3 illustrate the conceptualisations of the deductive and inductive approaches as top-down and bottom-up approaches, respectively (Trochim and Donnelly, 2008; Burney, 2008).

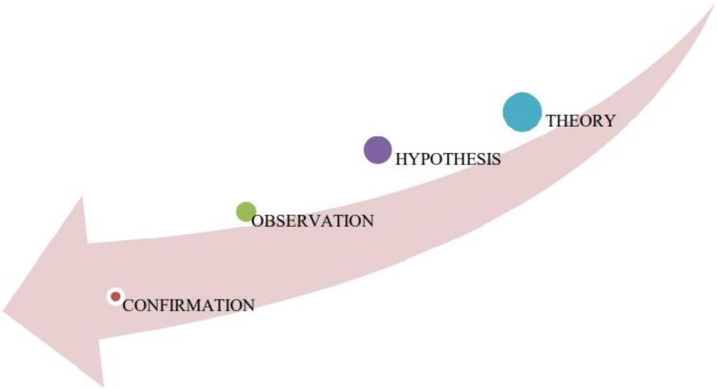

Figure 2. *Deductive approach (top-down) (Source: Burney (2008),Trochim and Donnelly (2008))*

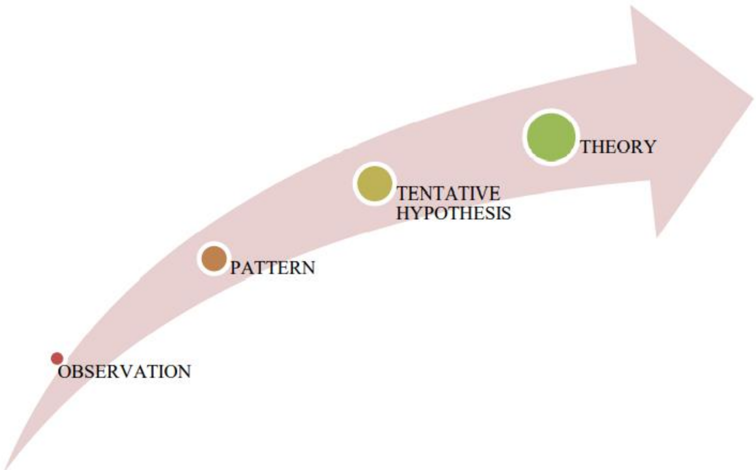

Figure 3. *Inductive approach (bottom-up) (Source: Burney (2008),Trochim and Donnelly (2008))*

Justification of the selected research reasoning approach

The present research relies heavily on the deductive research approach, which centres on the relationship between the theory and the research. The deductive approach was used to:

- Quantify the implementation barriers and challenges of risk management, as well as the level of risk management practices for construction projects during COVID-19.

- Quantify the impacts of emergent COVID-19 risks on the construction industry in Iraq.
- Quantify the direct and indirect effects of COVID-19 risks on project success and its indicators.

In addition, the inductive approach served the researcher's purpose in understanding the nature of the issue at hand. The researcher conducted semi-structured interviews and focus group sessions with construction experts with the aim of providing a concise focus point on the context of the study regarding COVID-19 risk management for construction projects in Iraq. To this end, this thesis uses a hybrid approach of reasoning, involving deductive and inductive reasoning during the research investigation process. In fact, the process can be seen as a continuous circle of reasoning, from observations to theories and back again to observations.

1.6.3. Research methods

The research method identifies the mechanisms by which the data will be collected and analysed. Research methods can be either quantitative, qualitative, or mixed in nature.

1.6.3.1. Qualitative research

Creswell and Creswell (2017) defined qualitative research as a systematic and subjective approach to examining and elucidating the meaning attributed by individuals or groups to a given social or human issue. Qualitative research aims to understand meanings, motives, intentions, beliefs, values, and attitudes concurrently with a broader range of relationships, processes, and phenomena that cannot be reduced to a set of variables (Maxwell, 2013). Since this method is exploratory in nature (i.e., to explain the *how* and *why* of specific social phenomena or programs in a particular setting) (Alase, 2017), it is associated with a variety of potential data collection and analysis techniques, including semi-structured interviews, focus groups, workshops, observations, and open-ended questionnaires (Zohrab, 2013). While offering the most in-depth data concerning sophisticated and emergent research problems, its main weakness is the specificity of findings, which cannot be widely generalised beyond the immediate contexts where the research is conducted.

1.6.3.2. Quantitative research

According to Creswell and Creswell (2017), a quantitative approach refers to the process of testing theories through the examination of the relationship between variables. In contrast to qualitative research, quantitative research requires the collection of numerical data and is appropriate when theories and hypotheses are being tested (Sheard, 2018). In fact, it is employed to quantify attitudes, opinions, and behaviours, and to generalise conclusions based on a larger sample size. Hakansson (2013) indicates that surveys, case studies, and experimental research are the most frequently employed research techniques in quantitative research. The main weakness of quantitative research is its lack of depth to understand complex phenomena, especially concerning human perceptions and interpersonal relations (Creswell and Creswell, 2017).

1.6.3.3. Mixed-method research

Mixed-method research approach incorporates both quantitative and qualitative methods in an iterative or simultaneous manner to produce more robust results than either method individually (Creswell and Plano, 2017). The combination of quantitative and qualitative methods enables the exploration of a more complex set of human and social phenomena. In fact, researchers can gain a more holistic view of their research landscape, viewing phenomena from various angles and from an array of perspectives (Ivankova, 2006).

A number of advantages can be gained by integrating qualitative and quantitative methods, including utilising qualitative data to assess the validity of quantitative findings, and using quantitative data to generate the qualitative sample, or to explain findings gleaned from exploratory qualitative investigations (Fetters *et al*., 2013). Furthermore, mixed-methods research is appropriate for answering research questions that cannot be answered solely by quantitative or qualitative approaches (Tashakkori, 2007). A mixed-method design within a single study can greatly increase the complexity of the research process. Often, additional resources (time and personnel) as well as training are required, since this type of research necessitates familiarity with alternative methodologies, and different approaches to data collection, sampling, analysis, and reporting (NCCMT, 2015).

Justification of the selected research method

Ponto (2015) points out that the choice of a research approach is primarily determined by a variety of factors, such as the nature and purpose of the research, the type of research question(s) to be answered, and the availability of resources. As such, a mixed-method research approach was adopted in this thesis to obtain more comprehensive outcomes. This combines the knowledge and experience of experts (qualitative data) with statistics (quantitative data). To be more specific, this research relies primarily on the quantitative method to collect and analyse data, while the qualitative method serves as a supplementary aid to facilitate the analysis process.

1.7. Linking research methods to the research objectives and the three studies

The selection of the research methods and the type of data to be collected depends on the research question(s), the objectives of the study (Creswell, 2013), and the availability of resources, and the philosophical orientation of the researcher. As described by De Vaus (2001) and Henjewele (2010), the research design is comparable to architectural design, in which the architect must determine the purpose of the building before beginning the design process. Therefore, prior to deciding the methods, the research objectives were carefully outlined and scrutinised, along with the available resources being examined, based on the expected inquiries to be addressed for each objective. Considering that this PhD consists of three papers that address the five thesis objectives, Table 7 shows the linkage between the research papers, objectives, methods, and guiding queries to address.

Table 7. *Linking the research methods to the objectives and the three papers (source: author)*

Research Papers	Research Objectives	Examples of research queries to address	Research Method(s)
The first paper (RM Challenges, barriers, and practices)	**Objective one**: to investigate and quantitatively analyse the level of significance of the challenges and barriers to construction risk management implementation during COVID-19 pandemic using Analytical Hierarchy Process	**Q1:** How can these challenges be identified and categorised? **Q2:** How can their impact be measured? **Q3:** Is the nature of these challenges structured or unstructured? **Q4:** Do these challenges affect the public or private sectors? Or both?	Semi-structured interviews Questionnaire survey AHP
	Objective two: to quantify the level of efficacy of risk management practices during COVID-19 pandemic in relation to risk management implementation challenges and barriers using a novel multi-dimensional assessment model under fuzzy environment;	**Q1:** What are the main measures of risk management and how can they be identified and classified/grouped? **Q2:** In the absence of historical data, how can their impact be quantified?	Semi-structured interviews Questionnaire survey FST

Table 7. *Continued.*

Research Papers	Research Objectives	Examples of research queries to address	Research Method(s)
The second paper (COVID-19 risk assessment paper)	**Objective three**: to identify and categorize the risk factors emerging from the COVID-19 pandemic in the construction industry;	**Q1**: How can to identify and categorize the main emerging risks associated with COVDI-19?	Focus group session
	Objective four: to quantify the level of riskiness of COVID-19 emerging risks using a novel multi-criteria risk analysis model under fuzzy environment; and	**Q1:** How to quantify the level of riskiness associated with emerging risks in COVID-19? **Q2:** How can the analysis outputs be improved in comparison with risk matrices? What criteria should be considered in the analysis?	Focus group session FST
The third paper COVID-19 and project success	**Objective five**: to model the direct and indirect effects of the significant risks emerging from the COVID-19 pandemic on construction project success based on the perceptions of contractors	**Q1:** How can construction PS be measured from the perspective of contractors? **Q2:** What are the main indicators of success? **Q3:** How can the effects of COVID-19 on PS be modelled?	Semi-structured interviews Questionnaire survey SEM

1.8. Data collection and processing methods

This research focuses on examining the impact of extreme conditions' risk management practices, the challenges associated with their implementation, and their emerging risks on the success of construction projects in developing countries by considering the case of the Iraqi construction industry during the COVID-19 pandemic. This involves combining data collection and processing methods which are highly dependent on the research objectives, availability of data, nature of the investigation, and the philosophical orientation of the researcher, as discussed previously. The linkage between data collection and processing methods is illustrated in Figure 4. The adopted research methods are explained in detail below.

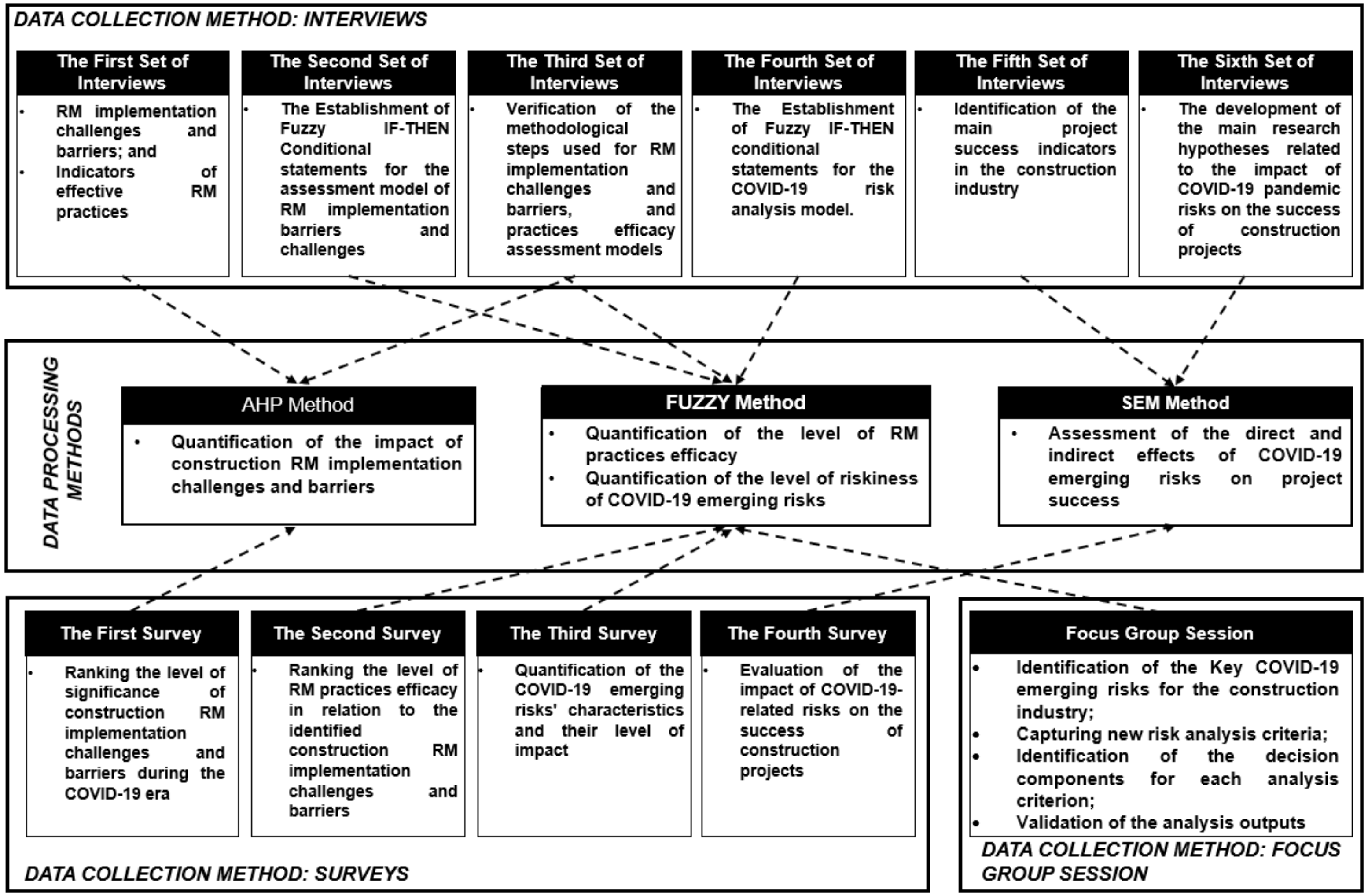

Figure 4. *Linking data collection and processing methods (source: author)*

1.9. Data collection methods

1.9.1. Interviews

An expert interview is an effective method of collecting rich and in-depth data from participants, which is vital for analysing phenomena or exploring complex situations. In the view of Haigh (2008), a good interview is an art of exploring the beliefs and opinions of the participants, as well as the subject knowledge. In addition, research has shown that three types of interviews are commonly used in social sciences, namely structured, unstructured, and semi-structured interviews. In structured interviews, the interviews are organised around a set of pre-determined questions that require a direct “yes” or “no” answer, or Likert-type numbering scales, which are germane to quantitative analysis (Berg, 2017). As such, it can be argued that this form of interview is similar to the quantitative self-administrated questionnaire survey. For unstructured interviews or open-ended interviews, greater freedom and flexibility are offered to the interviewer and the interviewees to plan and organise the interview’s questions and direction (Gubrium and Holstein, 2002). With semi-structured interviews, a more flexible version of structured interviews, depth is achieved by combining the advantages of both structured and unstructured interviews, where questions are planned prior to the interview, but the interviewer gives the interviewees the opportunity to elaborate and explain particular issues through open-ended questions (Alsaawi, 2014).

Semi-structured interviews are appropriate for researchers who have an overview of their topic to ask questions, but who do not wish to be confined to a predetermined structured format that may hinder the depth and richness of interviewees’ responses (Bryman, 2016). Furthermore, this type of interview provides reliable and comparable qualitative data (Galletta and Cross, 2013). Croswell (2007) discussed the importance of selecting suitable candidates for an interview. In order to obtain qualified candidates, the experts were selected upon a set of criteria as suggested by Abdul Nabi and El-adaway (2021) and Al-Mhdawi *et al*. (2022), as listed below.

Expert interviewee inclusion criteria:

- Working in the Iraqi construction industry and/ or construction management education.
- Having at least 15 years of experience in construction engineering and management.
- Active membership in the Iraqi Engineers Union and/or registered contracting companies at the Iraqi Ministry of Trade (for contractors).

- Active membership in professional international bodies such as Association for Project Management, Project Management Institute, American Society of Civil Engineering, or Institution for Civil Engineers.

To this end, five different sets/themes of semi-structured interviews were conducted in the study. The following subsections provide details on each set of expert interviews.

a. The first set of interviews

In the first set of interviews, the researcher interviewed Iraqi construction experts, including project managers, contractors, safety engineers, and academics in order to: (1) identify the main challenges and barriers to risk management implementation for construction projects during the COVID 19 pandemic; and (2) identify the key indicators of effective risk management practices for construction projects.

As this set of interviews is semi-structured, the researcher prepared initial questions (guiding questions) to guide the interview direction, and probing and follow-up questions were subsequently asked in response to participants' answers. The guiding questions asked during the semi-structured interviews were:

Q1: What are the main challenges and barriers facing the effective application of RM practices in the Iraqi construction industry?

Q2: How would you categorise these challenges to RM implementation?

Q3: Among the challenges and barriers to RM implementation, what challenges and barriers are most likely to impact RM's effectiveness? Why?

Q4: Are you also familiar with the entire process of risk management? (i.e., risk planning, risk identification, risk analysis, risk response, and risk monitoring and control).

Q5: Are risk management activities during extreme conditions (i.e., COVID-19) defined and included in the schedule?

Q6: Does the project budget include resources and costs for risk management activities in relation to the COVID-19 pandemic?

Q7: What are the most commonly used tools for identifying risks in your company during the COVID-19 pandemic?

Q8: What are the most commonly used tools for construction risk analysis during the COVID-19 era?

Q9: What method do you use to select the most appropriate response strategy for extreme conditions, such as the AHP, decision trees, or fuzzy logic?

Q10: Does your organisation have a designated risk manager? If not, who is responsible for managing risks under extreme conditions?

Sample size

There is no set number of interviewees required for qualitative interviews, and the appropriate number is that necessary to reach the point of theoretical saturation, after which no substantively novel insights emerge from interviewees' responses (Hennink *et al.*, 2017). Several studies have examined saturation in qualitative research. For instance, Hennink and Kaiser (2022) conducted a systematic review of the literature to determine the range of interviews in which theoretical saturation can be reached. According to their findings, 9-17 interviews can achieve theoretical saturation. Accordingly, the researcher planned to interview 30 Iraqi construction experts with the goal of achieving theoretical saturation with a large margin.

b. The second set of interviews

To explore fuzzy knowledge, the researcher conducted interviews with a small group (i.e., fuzzy panel) of construction management experts in Iraq who are familiar with fuzzy sets theory and the formulation of fuzzy interference systems' conditional statements to develop the IF-THEN statements for the proposed risk management practices assessment model.

Sample size

This study followed the recommendations of Al-Mhdawi *et al*. (2022) regarding the requirement of fuzzy sample size of at least four experts and multiple rounds when formulating fuzzy IF-THEN conditional statements. To this end, the researcher conducted interviewed three construction management professors and one experienced project manager in Iraq.

c. The third set of interviews

Here, the researcher conducted interviews with several Iraqi construction experts to: (1) verify the methodological steps for the AHP and fuzzy assessment models in terms of their perceived practicality of use, and ease of use; and (2) validate the outputs of RM implementation challenges and barriers. In the course of the interview, the researcher presented the developed assessment models and their analysis outputs to the interviewees and asked them for their comments on the models. The interviewees were asked to comment on the ease of use and practicality of the developed models and express their opinions regarding the significant analysis outputs (i.e., the key challenges and barriers to RM implementation).

Sample size

For the validation sample size, the researcher followed the recommendation of Abdelgawad and Fayek (2010) of a sample size of six experts to validate the methodological steps of AHP-Fuzzy based models. To this end, the researcher conducted interviews with two project managers, two contractors, a director, and an academic in Iraq.

d. The fourth set of interviews

Here, the researcher conducted several interviews with Iraqi construction experts to establish the conditional statements (i.e., IF-THEN) for the COVID-19 risk analysis model.

Sample size

The minimum requirement for fuzzy IF-THEN panel sample size (to achieve consensus among experts) is four, as recommended by Al-Mhdawi *et al*. (2022). Accordingly, the researcher conducted five interviews with five Iraqi construction managers and one risk management professor to develop the fuzzy IF-THEN conditional statements, to quantify the risk level of emergent COVID-19 risks.

e. The fifth set of interviews

Here, the researcher conducted four interviews (as a preliminary investigation) with four experienced contractors in Iraq in order to identify the main project success indicators. The key questions asked included: what are the key indicators of project success apart from the traditional time, cost, and quality indicators?

f. The sixth set of interviews

In the last set of interviews, the researcher interviewed several construction experts in Iraq in order to develop several hypotheses related to the impact of emergent COVID-19 risks to project success. The key questions asked were: what is the relationship between COVID-19 risk categories and project success? Which COVID-19 risk categories are most appropriate for mediating this relationship?

Sample size

In this research, the researcher followed the recommended sample size of seven experts (Dickinger *et al*., 2006) to formulise the SEM hypotheses. To this end, the researcher conducted interviews with five experienced contractors and two academics in Iraq.

Ultimately, the researcher translated the transcripts from the local language (Arabic) to English and conducted a manual content analysis 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 analysing information within documentary data (Krippendorff, 2013) and has been employed extensively in previous construction engineering and management research (see e.g., Al-Mhdawi *et al*. 2022). In this research, the key factors were identified and sorted in a constructive way during the analysis process. Furthermore, the researcher reviewed the recorded material again to capture the comprehensiveness and details of the recorded materials.

1.9.2. Focus group session

Focus groups are a type of group interview that emphasise the interaction between participants as a method to elicit data; they are more participant-led than one-to-one (researcher-led) interviews. This method aims to obtain information from a small number of individuals rather than a sample that statistically denotes a large population (Nyumba *et al*., 2018). Even though group interviews are typically utilised as a fast and efficacious approach to gather information from many people simultaneously, focus groups incorporate group interactions that can be problematic, especially with larger numbers of participants (Brewer *et al*., 2012). Some loud or powerful voices can dominate focus group discussions, and participants can be reticent or fearful to speak fully and frankly (leading to social desirability bias). Focus groups should optimally be sized to accommodate a reasonable level of discussion without becoming too large to become counter-productive (Creswell and Creswell, 2017). Consequently, with the appropriate number of participants in a given group, detailed views of all informants could be utilised.

Focus groups usually require small groups of participants, of about 6 to 12 people per group (Harthi, 2015). In this research, one focus group session was conducted with 11 experts working in the Iraqi construction industry in order to: (1) identify a list of emergent COVID-19 risks for the construction industry; (2) investigate the need to capture new analysis criterion(s) when analysing construction risks during extreme conditions; (3) identify the decision components for each analysis criterion; and (4) validate the COVID-19 risk assessment model’s outputs and highlight their importance.

For the selection of participants, the researcher adopted a judgmental or authoritative sampling method. This is a non-probability sampling method where the organiser/researcher contacts potential informants known to be area experts (Creswell and

Creswell, 2017). To fully comprehend the impact of the COVID-19 pandemic on construction, specialists from diverse backgrounds and levels of expertise were required to participate in the focus group session. For this reason, the researcher approached project managers, contractors, and architects. Another criterion for selection is that the participants must have extensive expertise in the construction industry in Iraq.

The guiding questions asked during the focus group session were:

Q1: What are the key COVID-19 risks facing the Iraqi construction industry? What are the categories in which these risks fall?

Q2: Which methods are most commonly used to analyse construction risks (qualitative or quantitative)?

Q3: What is your opinion of the risk matrix method?

Q4: Is there a need to capture more analytical criteria? How can we measure these criteria?

Qualitative data analysis

In this research, content analysis was used to analyse the qualitative data (the outputs of interviews and the focus group session). Bhattacherjee (2012) defines qualitative content analysis as "a systematic analysis of the content of a text (e.g., who says what to whom, why, to what extent, and with what effects) in a qualitative manner". Qualitative content analysis aims to systematically transform large amounts of text into a concise summary of the main findings. Qualitative content analysis is a reflective process that does not follow the conventional "Step 1, 2, 3, done!" pattern (Erlingsson and Brysiewicz, 2017). In other words, the process of identifying and condensing meaning units, coding, and categorising are not one-time operations. Instead, it is a continuous process of coding and categorising, followed by a reflection on the initial analysis (Erlingsson and Brysiewicz, 2017).

In this research, the starting point after recording the interviews was to translate them from the local language (Arabic) into English. The researcher then read the interview transcripts holistically, and performed initial screening and filtration of the content. The researcher at this point began to form an understanding of the main points or insights that the participants expressed. The researcher then began to divide the text into smaller parts, namely, units. Following this, the researcher labelled the condensed meaning units by formulating codes and then grouped these codes into a set of categories. These categories were then grouped under specific themes. An example of the content analysis process that was used in this research is presented in Figure 5.

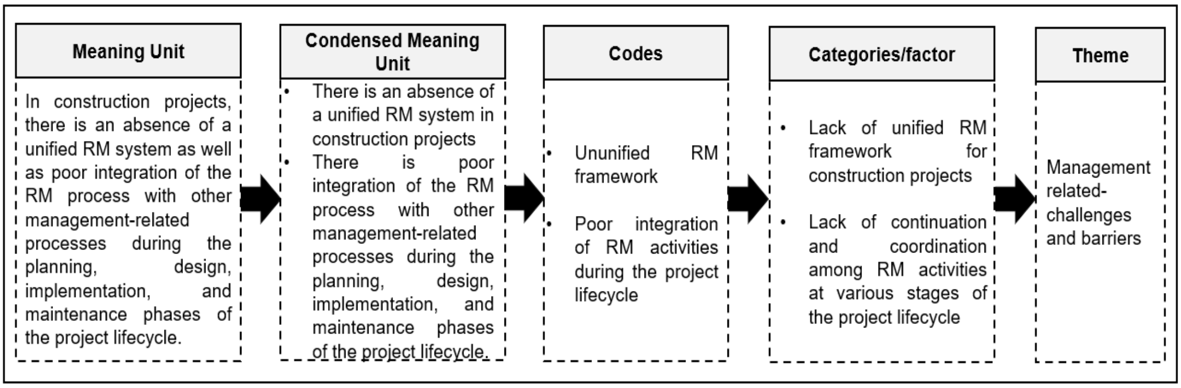

Figure 5. *An example of a qualitative content analysis (source: author)*

1.9.3. Questionnaire survey

In this research four different questionnaire surveys were distributed to construction experts in Iraq. The following subsections provide details on each survey.

a. The first survey

The objective of the first survey was to rank the level of significance of construction risk management implementation challenges and barriers during COVID-19 era. There were two sections to the survey: the first section focused on collecting information about the characteristics of survey respondents, including their working sector, job title, years of experience, and educational background; in the second section, respondents were asked to assign relative weights to the identified construction risk management implementation challenges and barriers based on Saaty's 9-point scale. In this study, the researcher contacted potential participants eligible for participation according to the criteria specified previously.

To this end, the survey was piloted among ten experts and was distributed to 200 construction experts including project managers, contractors, consultants, and safety engineers. The respondents were asked to rate the identified challenges and barriers according to: (1) their level of probability of occurrence, i.e., how likely or how often these challenges and barriers occur on average in the construction industry during the COVID-19 era; (2) their level of impact on cost, i.e., the anticipated impact on the project cost if these challenges and barriers occur; and (3) their impact on the schedule, i.e., the anticipated impact on the project schedule if these challenges and barriers occur. The first survey is presented in Appendix A.

b. The second survey

The objective of the second survey is to rank the level of risk management practices' efficacy in relation to the identified significant risk management implementation barriers and challenges. The questionnaire survey was divided into 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, the years of experience, and their educational background. In the second section, the participants were asked to rate each factor of the risk management practices in relation to each barrier and challenge to construction risk management implementation using a five-point Likert scale (ranging from 1 "very low" to 5 "very high"). The researcher followed the same expert selection criteria and survey development process as the first survey.

The survey was piloted among ten construction experts, and was distributed to 200 construction experts, including contractors, consultants, and safety engineers in Iraq. Furthermore, Cronbach's alpha coefficient test was used to determine the reliability and validity of the responses collected from the multipoint scales (Santos, 1999). According to Christmann and Van Aelst (2006), a valid and reliable scale should result in a value of 0.75 or above. The second survey is presented in Appendix B.

c. The third survey

The objective of the third survey is to quantify the characteristics of each COVID-19 risk. The developed survey allowed the respondents to rate each of the COVID-19 risks in terms of the components of the analysis criteria, i.e., AE and CLC (for the organisational level of readiness), PSF and OCF (for the probability of risk occurrence), and IPC, IPT, and IPC (for risk impact on project set objectives). For the purpose of this study, the researcher adopted a five-point Likert quintet scale (from 1 "very low" (V.L) to 5 "very high" (V.H)) for the assessment of analysis criteria. Additionally, the survey included questions regarding the respondents' construction role, working sector, years of experience in the construction industry, and educational qualifications. As in the first and second surveys, the researcher employed the same expert selection criteria and survey development process.

To this end, the survey was piloted among 12 experts and was distributed to 450 construction experts, including project managers, contractors, consultants, and safety engineers in Iraq. Cronbach's alpha test was performed in order to determine the reliability and validity of the responses collected from the multipoint assessment criteria. The third survey is presented in Appendix C.

d. The fourth survey

The objective of the fourth survey is to examine the impact of COVID-19-related risks on the success of construction projects in Iraq. The questionnaire consisted of three sections. The first section, which precedes the main body of the survey, outlines its objectives. In the second section of the survey, respondents provided demographic information, including their working sector, their employment history, and their educational background. In the third section, the respondents were asked to discuss their perceptions about the effects of COVID-19 risk factors on project success. This section comprised questions designed to solicit opinions on the perceived agreement of risk factors affecting project success and its indicators on a five-point Likert scale (ranging from 1 “strongly disagree” to 5 “strongly agree”). The researcher targeted experts who are involved in the Iraqi construction industry and who are registered contracting companies with the Iraqi Ministry of Trade. The survey was piloted among five experts and was distributed to 250 construction contractors in Iraq. The fourth survey is presented in Appendix D.

Surveys sample size justification

According to Al Khayat (2019), the number of construction workers in Iraq is approximately 66000. Kish sample size determination equations were used to calculate the required sample size for this research (this includes the first, second, third, and fourth surveys). Kish equations as mentioned by Kish (1995) are:

$$N = \frac{n'}{1+\left(\frac{n'}{n}\right)} \qquad (2)$$

$$n' = \frac{S^2}{V^2} \qquad (3)$$

Where:

N = Sample size from a finite population;

n = Total population number;

n' = Sample size from an infinite population;

S^2 = Standard error variance of population elements; 0.5 is the maximum value

V^2 = Standard error of the sample population, equal to 0.05 at a 95% level of confidence

By applying this equation the required number of the sample is $n' = \frac{0.5^2}{0.05^2} = 100$. Thus N≈100.

In order to ensure that the minimum calculated sample size of 100 is met, a total of 200, 200, 450, and 250 surveys were distributed for the first, second, third, and fourth surveys, respectively.

Quantitative data analysis

Depending on the method of survey administration, raw data can be transferred into an application such as Microsoft Excel or IBM's SPSS for analysis, either manually or automatically. Microsoft Excel was used in this study in order to analyse the results of the four surveys due to its ease of use and availability for researchers in Europe, since Microsoft packages are associated with their institutions. A further reason for selecting Microsoft Excel was its ability to perform a wide range of complex inferential static tests. Other applications require the purchase of licenses and are complex in their use.

1.10. Data processing methods

1.10.1. Analytical hierarchy process

In this research, AHP was used to quantify the impact of construction RM implementation challenges and barriers during the COVID-19 era. As previously explained, the RM challenges and barriers were derived from the first set of interviews. Although the experts may have extensive knowledge in the construction industry, COVID-19 is an unprecedented, extreme, and aberrant condition, whose like has not been encountered before (Al-Mhdawi *et al*., 2022). This may result in uncertainty regarding the experts' responses as a result of inaccurate or incomplete information.

In order to capture this uncertainty and reduce the inconsistency of expert judgments (Aminbakhsh *et al*., 2013), the researcher chose AHP to assess the level of impact of RM implementation challenges and barriers on the Iraqi construction industry in the COVID-19 era, since it is superior to conventional methods such as mean, weighted mean, and entropy (Vyas *et al*., 2019; Elsayegh and El-adaway, 2021).

In AHP method, numerical weights are assigned to each element of the hierarchy, allowing the comparison of diverse and incommensurable elements in a rational and consistent manner (Ramik, 2020). The steps for calculating the weights of RM practices and challenges based on the AHP method are illustrated in Figure 6 and discussed in the following subsections.

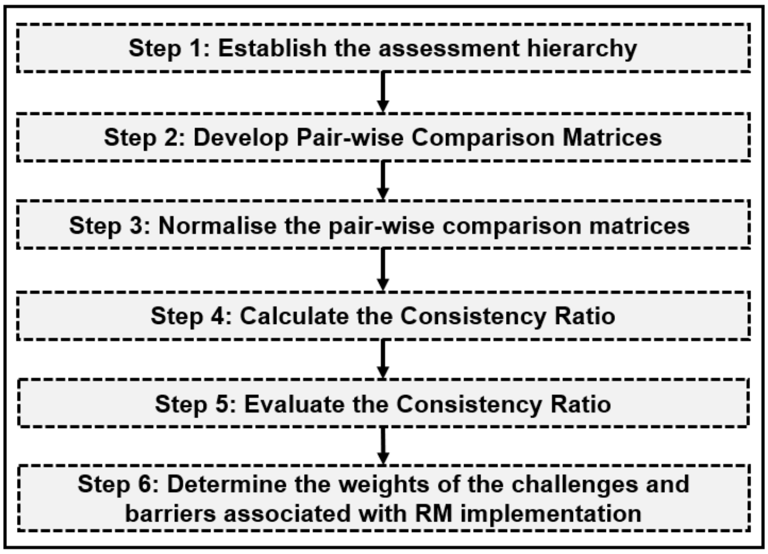

Figure 6. *Adopted AHP steps (source: author)*

Step 1: Establish of the hierarchy

In this step, the researcher structured the elements of the problem into three hierarchies of three levels each (the target, factor, and sub-factor levels). The goal of these hierarchies is to determine the probability, impact on time, and impact on the schedule for each RM implementation challenge and barrier.

Step 2: Develop of pair-wise comparison matrices

The aim of this step is to develop a set of pair-wise comparison matrices for the levels of each hierarchy. The numerical scales and their descriptions used in the pairwise comparison matrices are presented in Table 6. The expert judgments collected from the first survey of this thesis were computed using the geometric mean (see Equation 4), and were then placed into pair-wise comparison matrices using Equation 5.

$$aky = \sqrt[n]{aky1 \text{ X } aky2 \text{ X} \dots \text{. X } akyn} \qquad (4)$$

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

$$\text{L} = \begin{vmatrix} a_{11} & \dots & a_{1n} \\ \dots & \dots & \dots \\ a_{n1} & \dots & a_{nn} \end{vmatrix} \qquad (5)$$

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

Step 3: Normalise the pair-wise comparison matrices

The aim of this step is to normalise the pair-wise values of the developed matrices by summing the elements in each column (matrix cell values) (Equation 6), and dividing each element in each column by the sum of the respective column using Equation 7.

$$S = \sum_{k=1}^{n} aky \qquad (6)$$

$$N = aky / \sum_{k=1}^{n} aky \qquad (7)$$

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

Step 4: Calculate of the consistency ratio

The aim of this step is to calculate the Consistency Ratio (CR) for the hierarchy levels. The computation of CR involved the following sub-steps:

a. Calculation of the weight sum vector $\{Ws\}$ using Equation 8.

b. Calculation of the consistency vector $\{Cv\}$ using Equation 9

c. Calculation of the principal eigenvalue (also known as λmax) for each comparison matrix by averaging the $\{Cv\}$ values.

d. Calculation of the consistency ratios for all reciprocal matrices using Equations 10 and 11 to ensure consistency of expert judgment.

$$\{Ws\} = [L]\,\{W\} \qquad (8)$$

$$\{Cv\} = \{Ws\} * 1/\{W\} \qquad (9)$$

$$\textit{Consistency Ratio (CR)} = \frac{CI}{RI} \qquad (10)$$

$$\textit{Consistency Index (CI)} = \frac{\lambda max - z}{z-1} \qquad (11)$$

Where z is the number of criteria (risks); λmax is the maximum eigenvalue; and CI is the consistency index of a pair-wise comparison matrix (obtained from Table 8).

***Table 8**. Consistency Index (source: Saaty, 1990)*

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

*n= size of the reciprocal matrix

Step 5: Evaluate the consistency ratio

The aim of this step is to evaluate the validity and consistency of the developed pairwise comparison matrices based on the calculated CR value for each of the developed hierarchies. CR values of 10% or higher, according to Park *et al*. (2015), indicate poor consistency and are therefore not suitable for further analysis. In contrast, a CR value of less than 10% indicates a valid and consistent matrix. The process is then extended to normalising and examining the consistency of experts' decisions at the sub-factor level using the same strategy as in the aforementioned steps.

Step 6: Determine the weights of the challenges and barriers associated with RM

The aim of this step is to determine the Global Priorities for the developed hierarchies. Global Priority refers to the overall factors' prioritisation in accordance with the suggested assessment criteria by the construction experts and is calculated by multiplying the local priorities of each factor by the global priority of the corresponding category. Following this, the Challenges and Barriers Priority Number (CB-PN) is calculated by aggregating the Global Priorities of the assessment criteria (i.e., probability, impact on cost, and schedule).

1.10.2. Fuzzy sets theory

Among the main advantages of FST in assessment studies (for example, the assessment of practices, risks, failure modes, etc.) over other conventional methods such as risk matrices are its ability to formalise and manage human knowledge, uncertainty (i.e., a lack of complete and precise information) in decision-making (Islam and Nepal, 2016; Al-Mhdawi, 2020; Al-Mhdawi *et al*., 2022), and subjectivity associated with linguistics (Alhumaidi, 2015). To this end, the researcher used FST to quantify (1) the level of construction risk management practices with respect to the significant risk management implementation challenges and barriers; and (2) COVID-19 emerging risk levels on the construction industry. Ultimately, the researcher developed two assessment models, as described below.

a. The first fuzzy model: RM practices assessment

This model aims to quantify the efficacy of RM practices during the COVID-19 pandemic. This model contains two sets of inputs: (1) linguistic variables for the components and indicators of RM practices in the construction industry; and (2) significant challenges and barriers to RM implementation derived from the AHP model. A total of twelve inputs were used in the model for each significant challenge and barrier to RM implementation. The RM practices components and their indicators obtained from the first set of interviews were categorised into six fuzzy controllers: (1) stakeholders' involvement level, (2) organisation communication level, (3) RM training level, (4) organisation risk culture, (5) RM policies, and (6) continuous risk monitoring.

The input values to the model ranged from 0.1 (very low) to 1.0 (very high), and were provided by construction experts in Iraq from the second survey. In this model, the output represents the Risk Management Quantified Practices (RMQP) with respect to each challenge and barrier associated with RM implementation. The RMQP may range from 0.1 to 1.0, where 0.1 represents very poor RM practices efficacy, and 1.0 represents very high RM practices efficacy. Considering that fuzzy IF-THEN rules should be derived from experts' judgment and experience (Pourjavad and Shahin, 2018), the conditional statements for the entire model (n = 900) were developed based on interviews conducted with several Iraqi industry experts (i.e., the second set of interviews).

b. The second fuzzy model: COVID-19 risks analysis

The second model aims to quantify COVID-19 emerging risk levels identified in the focus group session. The decision components for each analysis criterion were also identified in the focus group session, while the IF-THEN conditional statements of the model (350 statements) were identified in the fourth set of interviews. A total of four fuzzy controllers were incorporated into the model. Specifically, these controllers estimate the organisation's level of readiness, the level of COVID-19 risks probability of occurrence, the level of impact of COVID-19 risks, and the risk level of each COVID-19 risk. The output of the model is the fuzzy-risk number (F-RN), which indicates the risk level of the emergent COVID-19 risks. The inputs to the model were obtained from the third survey.

MATLAB® (version 2021a) was used in this research to develop assessment models. Specifically, the researcher used the Simulink library and the fuzzy logic toolbox, which contains graphical tools such as a membership function editor, a fuzzy interface editor, an IF-THEN rule editor, a rule viewer, and a surface viewer. To this end, MATLAB was selected to develop the model due to its simplicity, and its wide usage in the engineering management and risk assessment fields (Gunduz *et al*., 2015; Doskocil, 2016). There are three main processes associated with the model: fuzzification, fuzzy inference, and defuzzification. In the following subsections, the justifications for the selected methods/approaches for each process are outlined.

Step 1: Fuzzification

For this study, the researcher used a triangular-type membership function 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

(Barua *et al*., 2014; Nayak *et al*., 2020). The membership function for a triangular fuzzy number.

Ă = TFN (a, b, c) for a < b < c and its membership function μĂ(x) is given by Equation 12 where 0 ≤ a ≤ b ≤ c ≤ 1 (Gong *et al*., 2013)

$$\mu\breve{A}(x) = \begin{cases} 0, & x < a \\ \frac{x-a}{b-a}, & a \le x \le b \\ 1, & x = b \\ \frac{c-x}{c-b}, & b \le x \le c \\ 0, & x \ge c, \end{cases} \qquad (12)$$

where a, b and c represent the lower, modal and upper values, respectively (Zhang *et al*., 2013). The membership function of the triangular fuzzy number can be seen in Figure 7.

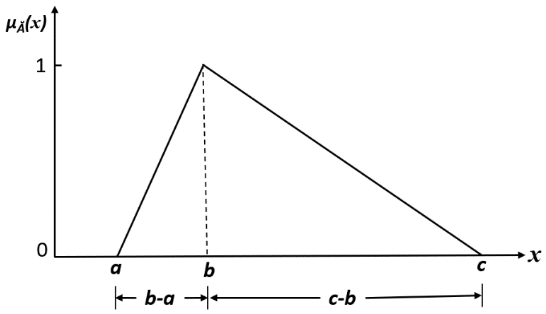

Figure 7. *The membership function of the triangular fuzzy number (source: Lee, 2005)*

Step 2: Fuzzy inference system

This research utilized Mamdani's fuzzy inference system (Mamdani and Assilian, 1975) in order to assess the output variable (i.e., the level of RM practices for each significant challenge and barrier to RM implementation, and COVID-19 riskiness level). Thus, the Mamdani-type interference system was selected as it is (1) widely used in literature, (2) intuitive, and (3) well suited to subjective inputs (Kaur *et al*., 2020).

Step 3: Defuzzification

In this research, the researcher applied the centroid of area method (Yager, 1980), which is one of the most common methods of defuzzification, to reflect the viewpoint of the assessment experts.

1.10.3. Structural equation modelling

SEM is a statistical technique used to analyse the relationship between dependent and independent variables in a quantitative manner (Alaloul *et al*., 2020). Compared to other techniques, such as least square regression, logistic regression, and log-linear modelling, SEM allows the estimation and evaluation of the entire conceptual model rather than simply testing individual hypotheses (Shackman, 2013). As a result, the researcher used SEM to assess the direct and indirect effects of the emergent COVID-19 risks on the success of construction projects.

There are two types of structural equation models: covariance-based structural equation models (CB-SEM) and partial least squares structural equation models (PLS-SEM). In many cases, CB-SEM is used to test, confirm, or compare theories (Zhang *et al*., 2021). PLS-SEM, on the other hand, is used in exploratory research or as an extension of an existing structural theory (Hair *et al*., 2011). Due to the exploratory nature of this study (i.e., to examine the impact of emergent COVID-19 risks to project success), the researcher used PLS-SEM to test the measurement model's reliability and validity, and to examine the hypothesised relationships between the constructs.

In the model, there are two primary components, namely emergent COVID-19 risks and PS and its indicators. Emergent COVID-19 risks were identified through focus groups with 11 Iraqi construction experts. As for PS indicators, they were obtained through interviews with four construction experts in Iraq (the fifth set of interviews). In addition, the authors developed three sets of hypotheses based on the sixth set of interviews which capture the impact of emergent COVID-19 risks to project success, the impact of emergent COVID-19 risks on contractual implications (the mediator), and the indirect impact of emergent COVID-19 risks to project success through the mediator. The model was developed using SMART PLS Version 3.0 software. Responses to the fourth survey of this thesis were entered into the software to model the direct and indirect effects of the COVID-19 pandemic on PS. To this end, the PLS-SEM methodology adopted in this research is illustrated in Figure 8.

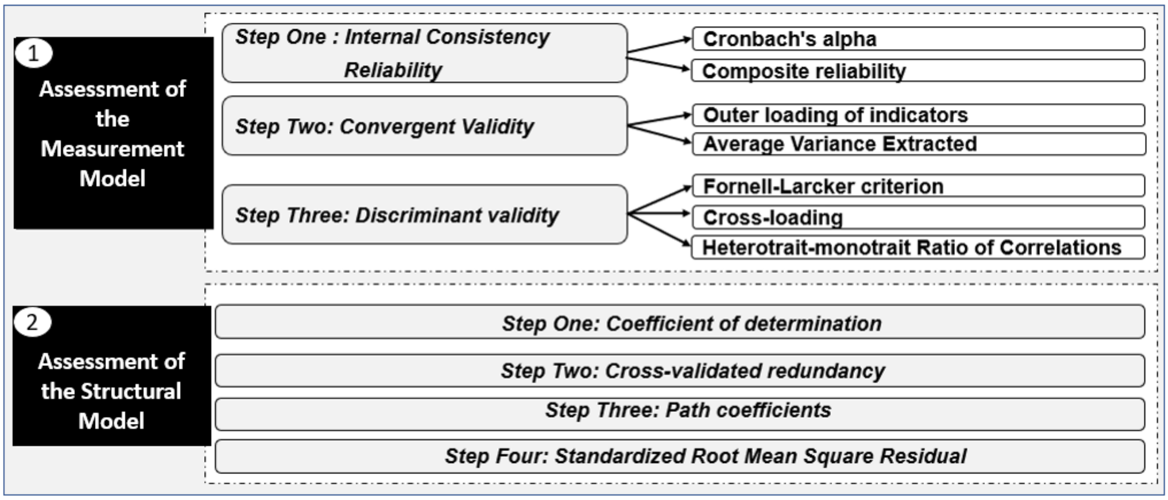

Figure 8. *PLS-SEM Methodology (source: author)*

a. Assessment of the measurement model

Hair *et al*.'s (2010) "measurement model" specifies the rules of correspondence between measured and latent variables and is assessed using internal consistency reliability, convergent validity, and discernment validity (Hair *et al*., 2014). The measurement model involves the following steps.

Step 1: Internal consistency reliability test

Revicki (2014) defines internal consistency reliability as the consistency of measurement when repeated under similar conditions. The internal consistency reliability of PLS-SEM inputs is measured using two criteria, Cronbach's alpha and composite reliability. Cronbach's alpha provides an estimate of the correlation between the observations of the indication variables (Taber, 2018). In contrast, composite reliability is a measure of internal consistency among scale items, that incorporates the different outer loadings of the indicator variables (Cho, 2016). Generally, Cronbach's alpha and composite reliability are considered adequate if their values exceed the recommended threshold of 0.707 (Nunnaly and Bernstein, 1994).

Step 2: Convergent validity test

According to Freson (2015), convergent validity can be defined as the degree to which the new scale is related to other measures and variables of the same construct. In PLS-SEM, two criteria are used to determine convergent validity: outer loading of indicators and average variance extracted (Hair *et al*., 2013). Outer loading refers to the strength of the relationship between the indicators (Hair *et al*., 2021). On the other hand, the average variance extracted (AVE) measures the variance captured by a construct, as compared to the amount of variance caused by measurement error (Fornell and Larcker, 1981). The outer loading of indicators and the AVE tests are considered adequate when their values exceed the recommended thresholds of 0.60 and 0.5, respectively (Gefen and Straub, 2005; Ringle *et al*., 2018).

Step 3: Discriminant validity test

According to Buniya *et al*. (2021), discriminant validity refers to the degree of differentiation and independence between a set of variables. In PLS-SEM, three criteria are used to measure the discriminant validity of a construct: the Fornell-Larcker criterion, the cross-loading factor, and the heterotrait ratio of correlations. According to the Fornel-Larcker criterion, discriminant validity is measured by comparing the square root of the average variance extracted with the off-diagonal correlations (Li *et al*., 2021). According to Bagozzi (1991), when the square root of the AVE is larger, then the construct is considered to have a supported discriminate validity. As part of the cross-loading test, items are examined to determine if they load highly on one specific construct as well as on multiple constructs (Henseler *et al*., 2015). When the loading indicators for the latent constructs are greater than the cross-loading for the related constructs, then the discriminant validity is satisfactory. The Heterotrait-Monotrait Ratio of Correlations measures the degree of similarity between latent variables (Suzuki and Pheng, 2019). When the heterotrait-monotrait ratio of correlations is equal to or lower than 0.90, it is considered indicative of supported discriminant validity (Henseler *et al*., 2015).

b. Assessment of the structural model

According to Le *et al*. (Le *et al*., 2021), the structural model examines relationships among constructs and is measured using the coefficient of determination, cross-validated redundancy, path coefficients, and standardised root mean square residual (Hair *et al*., 2017). The structural model involves the following steps.

Step 1: Coefficient of determination test

Hair *et al*. (2017) referred to the coefficient of determination as a measure of the predictive accuracy of the model. Using this coefficient, it is possible to determine the proportion of difference in the dependent variables that can be explained by one or more predictor variables (Elliott and Woodward, 2007). As recommended by Falk and Miller (1992), a coefficient of determination of greater than 0.1 is considered acceptable.

Step 2: Cross-validated redundancy test

The cross-validated redundancy of the inner model is a measure of its predictive relevance (Perry *et al*., 2014). As recommended by Hair *et al*. (2017), cross-validated redundancy values are deemed satisfactory if they exceed the threshold level of 0.0.

Step 3: Path coefficient test

In SEM, a path coefficient is a standardised version of a linear regression weight that can be used to assess the hypothesised relationship between constructs (Shipley, 2016). In accordance with Hair *et al*. (2017), the T-value must be greater than 1.96, and the p-value must be less than 5% in order to accept a hypothesis.

Step 4: Standardised root mean square residual

The standardised root mean square residual is a measure of the goodness of fit for PLS-SEM introduced by Henseler *et al*. (2014), which can be used to avoid model misspecification. Generally, standardised root mean square residual values less than 0.10 indicate a good fit for the model (Hu and Bentler, 1999).

1.11. Introduction to the three papers

The core of this thesis relies on three main papers as part of the “three-paper PhD” format. The first paper of this thesis is entitled **Risk Management Implementation Challenges, Barriers, and Practices Efficacy in the Construction Industry of Developing Countries During the Covid-19 Pandemic: the Case of Iraq,** as presented in Chapter Two. The focus of the first paper was to assess the level of significance of the main challenges and barriers to RM implementation, as well as the level of efficacy of RM practices in the construction industry of developing countries during the COVID-19 era by considering the case of Iraq. This paper achieves objectives 1 and 2 of this thesis.

The outputs of this paper serve to contextualise this PhD study, since understanding and assessing the main challenges and barriers to risk management implementation, and how the latter affect the effectiveness of the current and adopted risk management strategies and methodologies by construction experts in Iraq during COVID-19 pandemic, is crucial for understanding how upper management is responding to the new risks of this disease. In other words, the results of the first paper helped in shaping the context and direction of the present exploratory research and motivated the researcher to identify and analyse the key risks emerging and their potential impact on construction operations during the pandemic.

The second paper in this thesis is entitled **Assessment of the Covid-19 Emerging Risks for the Construction Industry of Developing Countries: a Case Study of Iraq,** which is presented in Chapter Three. Here, the focus was narrowed to identify and categorise the key emergent COVID-19 risks facing the construction industry of Iraq, as well as quantify their risk level. This paper achieves objectives 2 and 3 of this thesis.

Chapter Four presents the third paper, entitled **Modelling the Direct and Indirect Effects of the Covid-19 Pandemic Risks on the Success of Iraqi Construction Projects**. In this study, the focus was further narrowed to investigate the direct and indirect effects of emergent COVID-19 risks on the success of construction projects during the COVID-19 pandemic in Iraq. This paper achieves objective 5 of this thesis.

To this end, the integration of understanding risk management practices and their challenges (management-wise), and project risks and how they impact project success during COVID-19 pandemic (project-wise) establishes the fundamental framework for academics and practitioners to formulate strategies for how to address COVID-19 and future pandemics or other severe disruptions. It thus contributes to strengthening risk management practices, to play a critical role in ensuring project success. The input-output relationship between the three papers is presented in Figure 9.

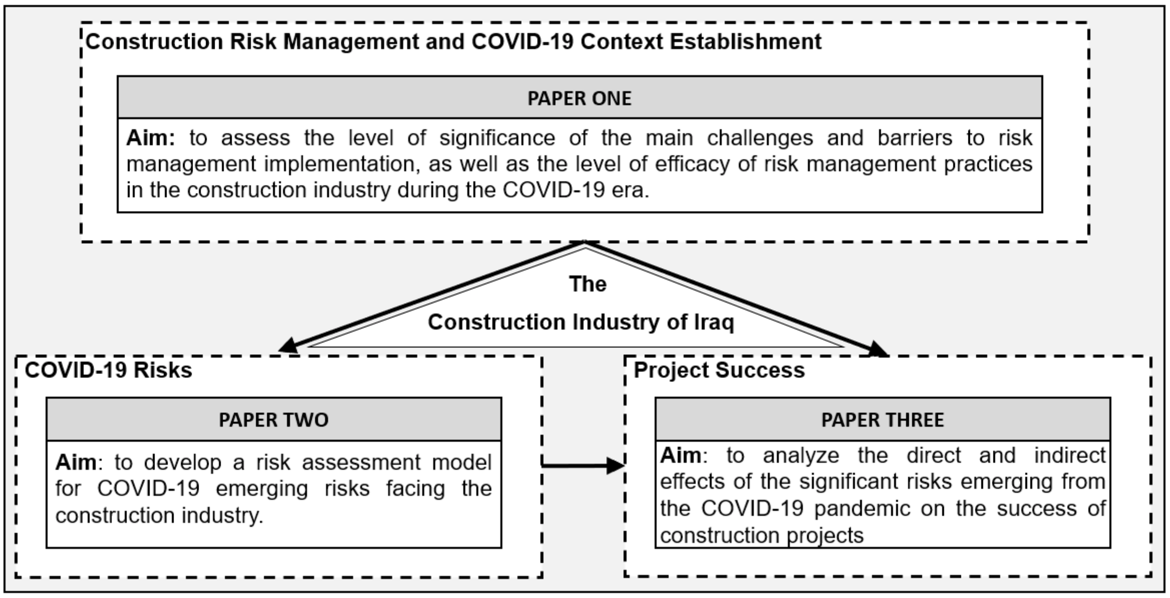

Figure 9. *Linking the three PhD papers (source: author)*

Chapter 2. Risk Management Implementation Challenges, Barriers, and Practices Efficacy in the Construction Industry of Developing Countries During the Covid-19 Pandemic: the Case of Iraq

Abstract

The COVID-19 pandemic has heightened the level of challenges facing the construction industry worldwide, the worse of which is in developing countries, causing a significant reduction in productivity, an increase in materials costs, delays in payments, supply chain distribution, contractual, legal, and insurance issues. 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 risk management (RM) practices in the construction industry of developing countries 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, behaviour-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 practices of construction RM in developing countries.

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 of RM in developing countries are low (Al-Mhdawi, 2022c). This perception has discouraged upper management in developing countries 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 many challenges and barriers that hinder its effectiveness, such as skills shortages and lack of training (Boadu *et al*., 2020).

The COVID-19 pandemic has heightened the level of challenges facing the construction industry worldwide, the worse of which is in developing countries. In fact, the pandemic has caused a severe impact on the construction industry in developing countries and their workforce. For instance, Agyekum *et al*. (2021), and Al-Mhdawi *et al*. (2022a) reported that the pandemic in developing countries resulted in a significant reduction in productivity, increased materials costs, delayed payments, supply chain distribution, contractual, legal, and insurance implications, and psychological challenges caused by the loss of employment and the absence of social security systems. In addition, these adverse implications have formed a new set of short-term and long-term risks (Al-Mhdawi *et al*., 2022b). In fact, Al-Mhdawi (2022c) reported that COVID-19 emerging risks have significantly impacted the success of construction projects in developing countries. Many factors can be attributed to these effects, 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 of developing countries during extreme conditions such as the COVID-19 pandemic.

Accordingly, the objectives of this paper are to (1) identify the key challenges and barriers to RM implementation, (2) identify the indicators of RM practices adoptability, and (3) quantitatively assess the level of significance of construction RMICB, and the level of efficacy of RM practices during the COVID-19 pandemic by considering the case of Iraqi construction industry.

The Case of Iraqi Construction Industry

As a case study of the construction industry of developing countries, the Iraqi construction industry was examined due to the similarities between the construction industries of Iraq and other developing countries, as well as the ongoing challenges and challenges arising from the COVID-19 pandemic.

For the ongoing challenges, the construction industry in developing countries, such as Iraq, has similar characteristics of poor project management culture, which include limited use of technology, skills shortages, and insufficient training, materials supply problems, a lack of skilled, educated, and experienced workforce, and culturally inappropriate procurement methods (Darvas and Palmer, 2014; Boa *et al*., 2020). Therefore, our results can be applied to construction projects implemented by any developing country during the COVID-19 era and other future pandemics and raise awareness among construction companies in the public and private sectors about planning and implementing effective pandemic response strategies.

With respect to the COVID-19 pandemic challenges, construction firms in Iraq are experiencing a loss of profits and challenging circumstances, which hinder their sustainable development and growth (OECD, 2020). Additionally, the International Organization for Migration (IOM) has reported that COVID-19 has led to a 52% reduction in employment and a 68% reduction in production in Iraq (IOM, 2020). A similar level of adverse impacts is also observed in other developing countries, including Zimbabwe (Chingara and Moyo, 2021); Ghana (Agyekum *et al*., 2021); India (Rani *et al*. 2022); and Peru (Bancalari and Molina, 2020).

Accordingly, Iraq's construction industry represents the unique nature of the COVID-19 pandemic and the risks associated with it within a variety of developing countries facing similar challenges and sharing similar characteristics before and during the COVID-19 pandemic.

Previous studies and knowledge gap identification

As outlined in Table 1, previous research studies conducted in developing and developed countries 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; Salami *et al*., 2021; Al-Mhdawi *et al*., 2022a) or on specific construction operations or themes such as risk management (Al-Mhdawi *et al*., 2022b), supply chain operations (Araya, 2021), legal implications (Harinarain, 2020), and health and safety (Amoah and Simpeh, 2020). 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 analysing 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.

Table 9. *Summary of existing research studies (source: author)*

(RM challenges and practices paper, Table 1)

Ref.	**Region**	**Aim and methods**	**Main findings**
(Agyekum *et al*., 2021)	Ghana	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 using interviews	Findings indicated that the impact of the COVID-19 pandemic had resulted in a significant reduction in productivity, increased materials costs, and delayed payments. In addition to providing Personal Protective Equipment (PPE), construction companies have implemented a number of other measures, including regular and effective screenings at entrances and exits from the job site and educating the workers about the virus.
(Alsharef et al., 2021)	United States	Investigated the early adverse effects and opportunities of the COVID-19 pandemic on the construction industry using interviews	Results indicated that the COVID-19 pandemic has caused material price escalation, reduced productivity rates, delayed project delivery, and supply chain disruptions. On the other hand, the new emerging opportunities included recruiting skilled workers and constructing medical facilities on a fast-track basis.

Table 9. *Continued.*

(Al-Mhdawi *et al*., 2022a)	Iraq	Captured the impact of the COVID-19 pandemic on the construction industry in developing countries using interviews, questionnaire survey, Mann-Whitney U test, and fuzzy sets theory	Findings indicated that the pandemic had affected a total of 16 construction factors grouped under four construction themes, including contractual implications, the construction financial market, supply chain operations, and safety and risk management, the latter being the most impacted. The most significant impacts of the pandemic were safety management measures, interpretation of the contract language, prices of building materials, risk management practices, construction materials and labour, and subcontractors. Furthermore, the findings of the fuzzy model demonstrated significant differences in the captured impacts of the pandemic between the public and private sectors.
(Khalfan and Ismail, 2020)	Bahrain	Conducted exploratory research to assess the progression of construction projects using literature review and survey	Results indicated that the pandemic has caused a shortage of supplies and materials, financial difficulties, absence of employees, reduced work efficiency, restricted site access, and less willingness of investors to launch new projects.
(Salami *et al*., 2021)	United Kingdom	Analysed the methods and practices adopted by construction companies in the United Kingdom in order to mitigate the risk of litigation resulting from potential contract breaches resulting from COVID-19, based on descriptive statistics, exploratory factor analysis, and reliability analysis	The study revealed a number of effective practices, including establishing and maintaining good relations with contractual partners, reporting possible disputes quickly, collaborating with parties to build goodwill, making early decisions about closures, and reviewing contractual provisions for information about notice periods.
(Araya, 2021)	General	Modelled the potential impact of COVID-19 on construction workers using agent-based simulation.	Findings indicated that the workforce involved in a construction project might decline by 30% to 90% as a result of the COVID-19 impact.
(Harinarain, 2020)	General	Analysed the force majeure clause in the context of the pandemic using a qualitative approach	The results highlighted the necessity of clearly drafted force majeure clauses in the context of pandemics.
(Amoah and Simpeh, 2020)	South Africa	Examined the challenges faced by construction firms in implementing COVID-19 safety measures on construction sites using a qualitative survey (open-ended questions).	Results indicated that the main challenges facing the implementation of COVID-19 safety measures at South Africa's construction sites are failing to comply with social distancing rules, public transportation usage by workers, shared construction tools and equipment, and shortage of Personal Protective Equipment (PPE) .

Table 9. *Continued.*

(Assaad and El-adaway 2021)	United States	Identified best practices, impacts, to address the pandemic within the construction industry following an in-depth review of current literature	Results indicated that the pandemic had a positive and negative effect on various aspects of the construction industry, including workforce, workplace, supply chain, contractual, legal, and insurance issues.
(Sierra, 2021)	United Kingdom	Reviewed the literature concerning the major challenges faced by contractors in the UK as a result of COVID-19 using a literature review	Results indicated that the major challenges that contractors are facing due to the COVID pandemic were the instability of the supply chain and subcontractors, the workforce unavailability, and possible legal exposures.
(Umar, 2022)	Gulf Cooperation Council	Examined the effect of the COVID-19 pandemic on the construction industry in the Gulf Cooperation Council (GCC) member countries and provided recommendations on how to help the industry survive during this period of crisis using expert interviews	Findings indicated that the impact of the COVID-19 pandemic had resulted in delays in projects, disruptions in workforce management, health and safety issues, and legal consequences.
(Stiles *et al.* 2021)	United Kingdom	Investigated the impact of COVID-19 on health and safety in the construction sector using a literature review	The study highlighted the importance of integrating a unified health and safety system within a general construction risk management framework.
(Chigara and Moyo, 2021)	Zimbabwe	Investigated the perceptions of construction professionals in relation to factors that affect the delivery of optimal health and safety on construction projects during the COVID-19 pandemic using a questionnaire survey	Findings indicated that the delivery of optimum health and safety services during the COVID-19 pandemic was affected by job security and funding-related, production-related, access to information and health service-related, on-site facilities and welfare-related, risk assessment and mitigation-related, the change and innovation-related, cost-related, and COVID-19 risk perception-related, and monitoring and enforcement-related factors.
(Kim *et al.* 2021)	South Korea	Analysed the feasibility of the response guidelines of the COVID-19 pandemic for construction projects using simulation	Results indicated that compliance with COVID-19 response guidelines resulted in an increase in the number of working days and construction costs, however, because the site closure risk was eliminated, construction delays and liquidated damages were minimized.

Methodology

As depicted in Figure 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.

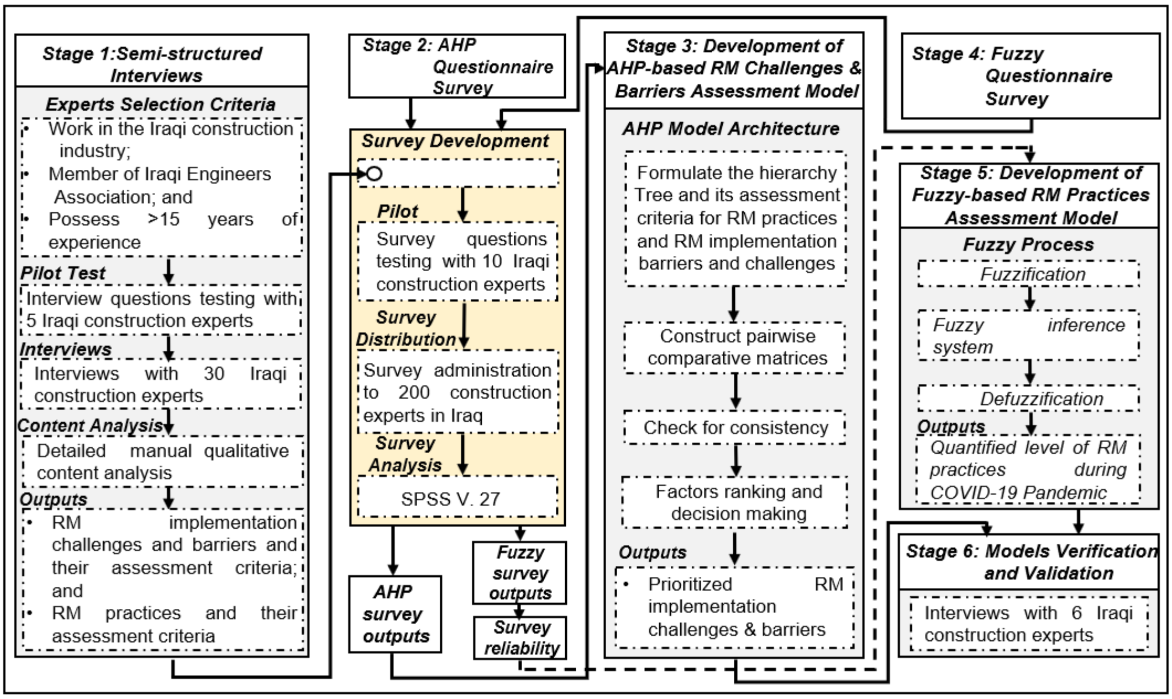

Figure 10. *Adopted research methodology (source: author)*

(RM challenges and practices paper, Figure 1)

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. The authors used the feedback and suggestions from the pilot study to revise and enhance the questions for the semi-structured interviews.

A) 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 analysing 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

A) 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).

B) 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. Based on the feedback, the authors made minor modifications to the survey questions.

C) 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

A) 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). 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 analysing the respondents' objective and subjective factors through pairwise comparison matrices (Darko *et al*., 2019).

B) 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 2 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 2, 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 3.

Table 10. *AHP Pairwise comparison scale*

(RM challenges and practices paper, Table 2)

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 11. *Guiding questions for AHP matrices formulation*

(RM challenges and practices paper, Table 3)

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?*

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.

$$aky = \sqrt[n]{aky1 \text{ X } aky2 \text{ X} \dots \text{X } akyn} \qquad (1)$$

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

$$\text{L} = \begin{vmatrix} a_{11} & \cdots & a_{1n} \\ \cdots & \cdots & \cdots \\ a_{n1} & \cdots & a_{nn} \end{vmatrix} \qquad (2)$$

Where L denotes the pairwise comparison matrix; its properties are as follows: $a_{ky} > 0$; a_{ky} = (1/aky); ∀ 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.

$$S = \sum_{k=1}^{n} aky \qquad (3)$$

$$\text{N} = aky / \sum_{k=1}^{n} aky \qquad (4)$$

Afterward, the weights of the factors $\{W\}$ (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:

- **a)** Calculation of the weight sum vector $\{Ws\}$ using Equation 5.
- **b)** Calculation of the consistency vector $\{Cv\}$ using Equation 6.
- **c)** Calculation of the principal eigenvalue (also known as λmax) for each comparison matrix by averaging the $\{Cv\}$ values.

d) Calculation of the consistency ratios for all reciprocal matrices using Equations 7 and 8 to ensure consistency of expert judgment.

$$\{Ws\} = [L]\,\{W\} \quad (5)$$

$$\{Cv\} = \{Ws\} * 1/\{W\} \quad (6)$$

$$\text{Consistency Ratio (CR)} = \frac{CI}{RI} \quad (7)$$

$$\text{Consistency Index (CI)} = \frac{\lambda max - z}{z-1} \quad (8)$$

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 4).

Table 12. *Consistency Index (source: Saaty, 1990)*

(RM challenges and practices paper, Table 4)

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

*n= size of the reciprocal matrix

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 analysed. 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 (Cb_{pn}) 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.

$$Cb_{pn} = Gb_{lp} + Gb_{lic} + Gb_{lis} \quad (9)$$

Where: Cb_{pn} is the challenges and barriers priority number; Gb_{lp} is the global priority for the level of probability of occurrence; Gb_{lp} is the global priority for the level of impact on cost; and Gb_{lis} 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.

A) 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

A) 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.

B) 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 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 (Rm_{qp}) with respect to each RMICB. The Rm_{qp} 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:

a) 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.
b) 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.
c) 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.

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

Participants' profiles in the pilot study

As mentioned before, the authors conducted three pilot studies to enhance the quality of the interview questions, the AHP based survey, and the Fuzzy based survey. The profiles of the interview pilot study participants are presented in Table 5. In addition, Table 6 presents the profiles of participants in the pilot studies for the AHP and Fuzzy surveys.

Table 13. *Profiles of interviews pilot study participants (source: author)*

(RM challenges and practices paper, Table 5)

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

Table 14. *Pilot study participants' profiles for the Fuzzy and AHP surveys (source: author)*

(RM challenges and practices paper, Table 6)

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

Semi-structured interviews

A) 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 Figure 2). Further, the profiles of the interviewees are presented in Table 7.

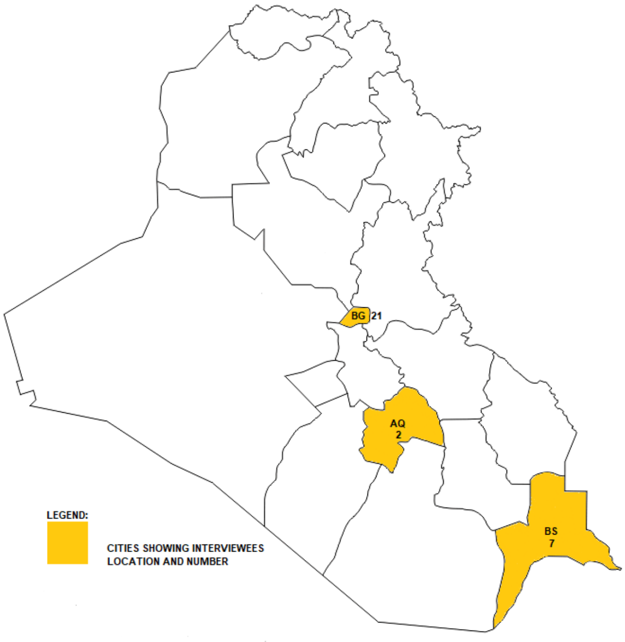

Figure 11. *The distribution of interview participants in Iraqi governates (source: author)*

(RM challenges and practices paper, Figure 2)

Table 15. *Profiles of interviewees (source: author)*

(RM challenges and practices paper, Table 7)

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

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. Figure 3 presents the identified RMICB and their categories.

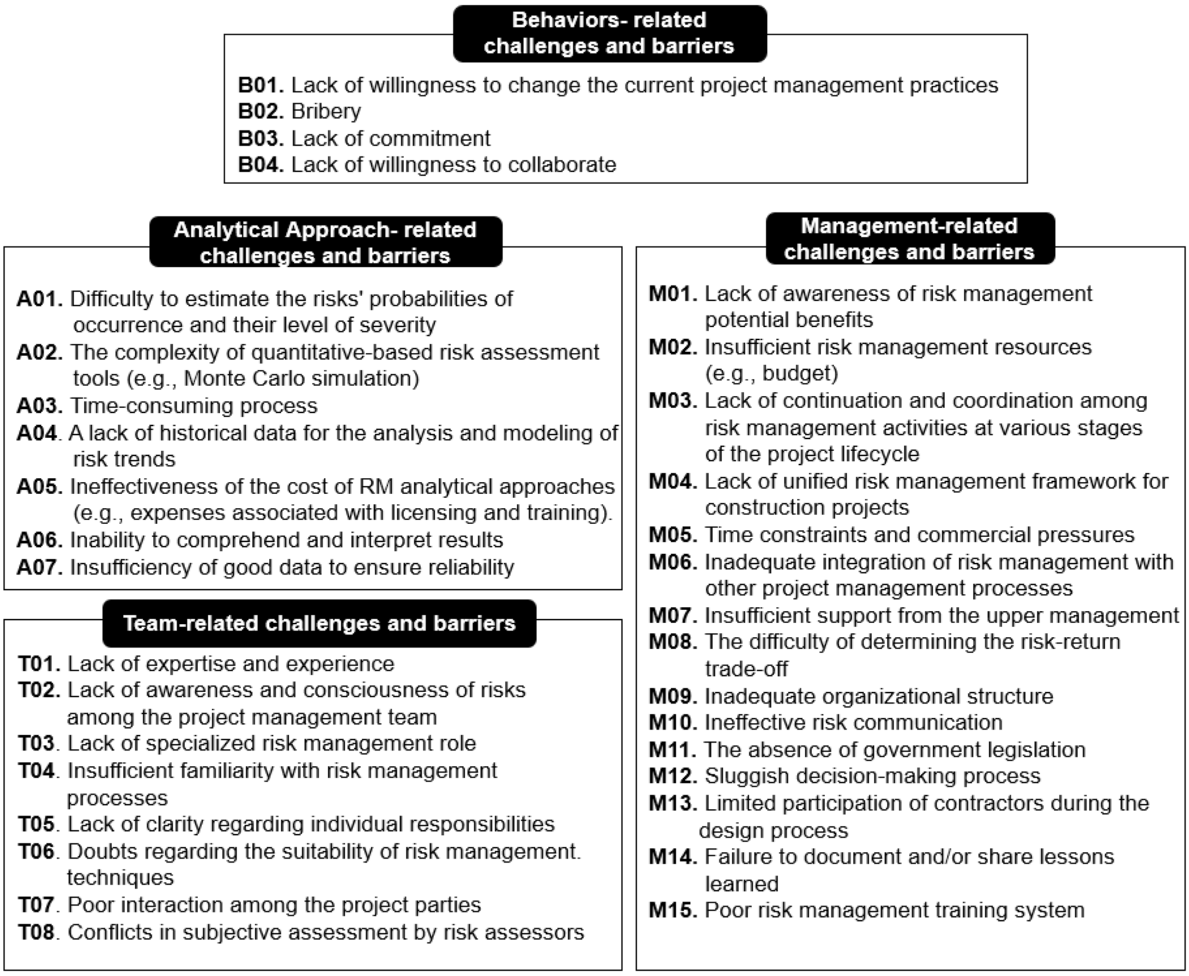

Figure 12. *Identified Construction RMICB (source: author)*

(RM challenges and practices paper, Figure 3)

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.

A) 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).

B) Organisational 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 organisational communication level in RM processes depends on two factors, namely: organisational communication culture (OCC), and usability of the communication tools (CT).

C) Risk Culture

The concept of risk culture refers to a group of people's values, beliefs, and attitudes concerning risk (Levy *et al*., 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).

D) 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.

E) 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).

F) Continuous Risk Monitoring Level

Continuous risk monitoring is a comprehensive process for identifying uncontrolled risks in a project, prioritising audit and risk management control procedures, and supporting organisational 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. Figures 4 to 7 shows 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.

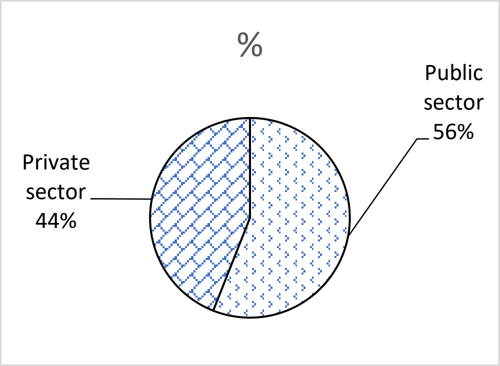

Figure 13. *Participants' working sector*

(RM challenges and practices paper, Figure 4)

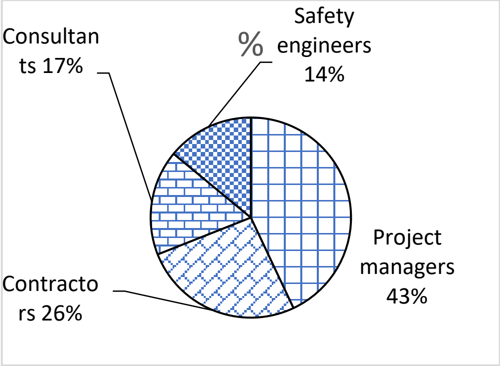

Figure 14. *Participants' construction role*

(RM challenges and practices paper, Figure 5)

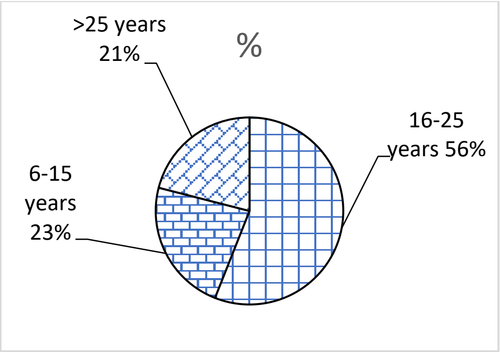

Figure 15. *Participants' years of experience*

(RM challenges and practices paper, Figure 6)

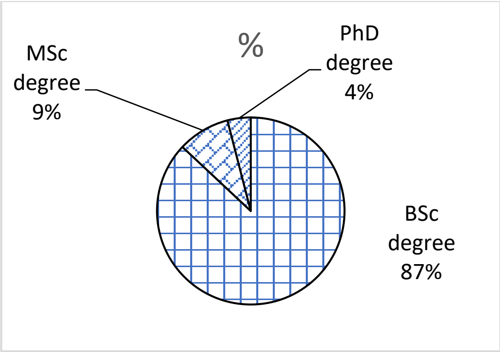

Figure 16. *Participants' educational qualifications*

(RM challenges and practices paper, Figure 7)

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. Figures 8 to 11 show that the respondents' profiles reflect a wide range of experiences in various construction roles and educational backgrounds, which ensures the credibility of the survey data.

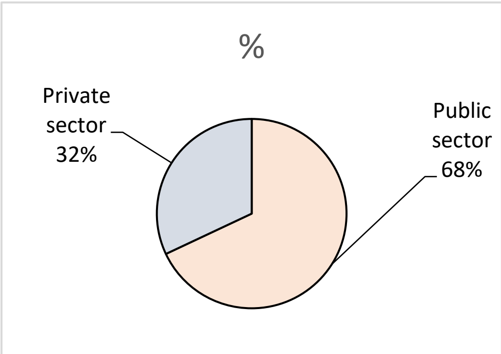

Figure 17. *Participants' working sector*

(RM challenges and practices paper, Figure 8)

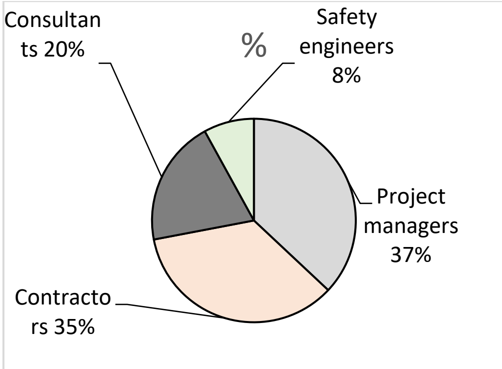

Figure 18. *Participants' construction role*

(RM challenges and practices paper, Figure 9)

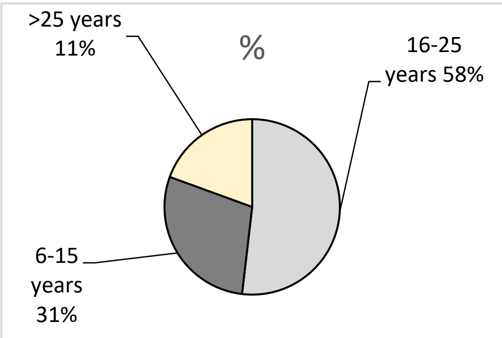

Figure 19. *Participants' years of experience*

(RM challenges and practices paper, Figure 10)

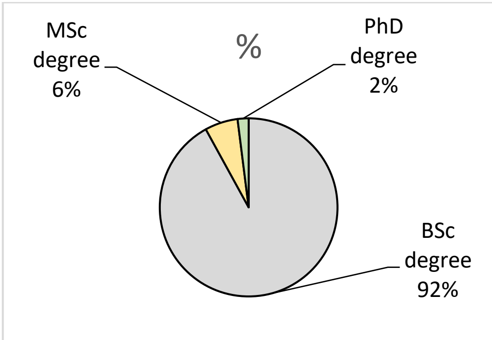

Figure 20. *Participants' education*

(RM challenges and practices paper, Figure11)

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. 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 Figure12, 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, behaviour-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. Accordingly, the authors calculated the global and local priorities for the assessment criteria, their Cb_{pn} values, and their group and overall ranking, as shown in Table 9.

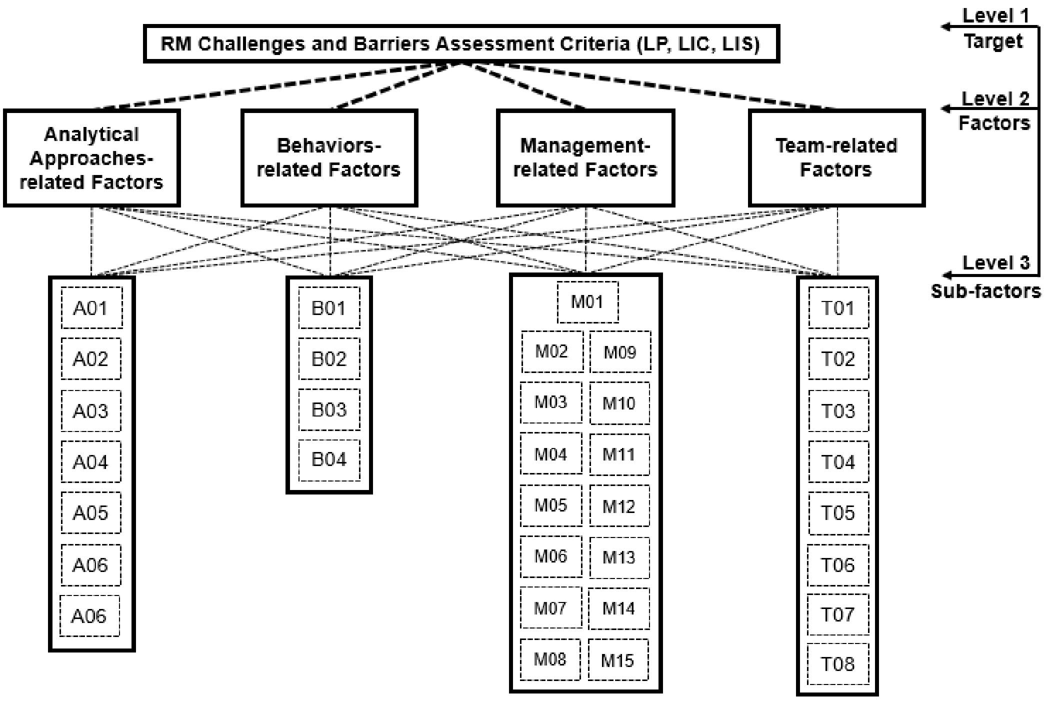

Figure 21. *The hierarchical structure of the developed assessment model (source: author) (RM challenges and practices paper, Figure 12)*

Table 16. *The consistency ratios for pairwise comparison matrices (source: author)*

(RM challenges and practices paper, Table 8)

Category	**Assessment Criteria**		
	LP (CR %)	**LIC (CR %)**	**LIS (CR %)**
Analytical approach-related challenges and barriers	8.5	7.6	7.6
Behaviour-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 17. *Results of the AHP Analysis (source: author)*
(RM challenges and practices paper, Table 9)

RMICB		Gb_{lp}	Gb_{lic}	Gb_{lis}	Cb_{pn}	Group Rank	Overall Rank
Analytical approach-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
Behaviour-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

The following sections discuss the three most critical RMICB in each category with respect to the analysis criteria of the developed assessment model.

I. Analytical Approach-related Challenges and Barriers

A) Complexity of Quantitative-based Risk Assessment Tools

The complexity of quantitative-based risk assessment tools (A02) refers to the complexly of using quantitative risk assessment tools when addressing numerous variables of extreme conditions, such as COVID-19. A02 was perceived by the AHP-survey respondents as a significant challenge to the effective implementation of construction RM practices during the COVID-19 era. A02 was ranked first in the analytical approaches category and second overall (Cb_{pn} =0.3443).

One of the interviewees had this to say:

> *“The complicated mathematical methodologies involved in risk assessment and forecasting, as well as some of the risk management software requirements and limitations, make it challenging for decision-makers to utilize the results and methodologies of these approaches and continue to make decisions based on personal experience and intuition; in addition, in some cases, complicated methodologies prompted some decision-makers to completely disregard risk management processes.”*

The quote below adequately convey the current practices and needs:

> *“Due to the various variables involved with the COVID-19 pandemic and the many sources of uncertainties associated with it, the current risk assessment analytical approaches are ineffective at capturing all dimensions of the risk analysis [...]. There are no historical data available for COVID-19's impact on the construction industry, thus making it difficult to quantify uncertainties and risks. There is a need to develop methods that are flexible to incorporate new variables and dimensions, easy to work out mathematically.”*

B) Time-consuming Process

Time-consuming process (A03) refers to the effort required for (1) planning for risk management and understanding the parameters and constraints associated with the RM process; (2) identification of risks, including conducting interviews and focus groups or workshops with experts to identify risks and the process of content analysis of the outputs; (3) analysis of risks, including the understanding of analytical methodologies, quantitative or qualitative, and the interpretation of the analysis results; (4) response to risks, including the preparation of feasibility studies of cost-effective measures and their potential impacts on project objectives (time, cost, and quality), and (4) monitoring and controlling of risks, including the establishment of risk monitoring mechanism depending on the nature of the project and the availability of resources. The ranking of A03 was second in the analytical approaches category and fourth overall (Cb_{pn} =0.2015).

Most of the interviewees stressed the direct effect of A03 on the effective implementation of construction RM processes during extreme conditions such as COVID-19. For example, one of the interviewees, who is a professor of risk management and consultant, had this to say:

> *"When you have a large number of variables bound to different constraints, it requires a great deal of computation and effort to find effective risk measures, especially when dealing with complex projects with deep uncertainties, as in the case of COVID-19 pandemic."*

Moreover, respondents highlighted that the adoption of time-efficient tools and techniques for managing project risks, together with properly archiving historical risk data from previously completed construction projects, could result in substantial time savings.

C) Ineffectiveness of the Cost of RM Analytical Approaches

Ineffectiveness of the cost of RM analytical approaches (A05) refers to the high cost of utilizing RM analytical techniques for construction projects. A05 was ranked third in the analytical approaches category and tenth overall (Cb_{pn} = 0.0995).

The following quote describes the impressions of many interviewees:

> *"The costs associated with the use of RM analytical approaches, such as purchasing software licenses and conducting training sessions outside of Iraq, have been the primary reasons for not implementing risk management and assessment methodologies and instead relying on the judgments and intuition of the stakeholders involved."*

In addition, one of the interviewees, who is an experienced project manager, had this to say:

> *"Unfortunately, the majority of construction projects in Iraq do not include a budget for risk management and investing in the transition of qualitative-based to quantitative-based decisions is viewed as an unnecessary cost by the majority of decision-makers."*

Furthermore, the same expert stated:

"I believe that the time has come to move beyond the old management methodologies and invest in an approach that quantifies the various uncertainties and risks that may arise during extreme conditions, such as the COVID-19 pandemic […]. Complete reliance on the subjective judgment will only result in cost and time overruns."

II. *Behaviour-related Challenges and Barriers*

A) Bribery

In the construction and engineering field, bribery (B02) is a widespread form of corruption and is considered to be more prevalent than in any other fields (Nordin *et al*., 2011). The ranking of B02 was first in the team-related category and first overall (Cb_{pn} =0.4215). The following quote describes the impression of one of the interviewees who is a project manager in the public sector:

"Bribery has unfortunately infiltrated many aspects of the Iraqi construction industry. For example, the adoption of effective RM processes and methodologies is not in the interests of many stakeholders in the construction industry. In fact, it can sometimes be advantageous for corrupt stakeholders to not adopt the RM processes and methodologies."

In addition, a contractor and a CEO in the private sector has this to say:

"The bribery is more common in the public sector. This is because of the involvement of numerous stakeholders, high capital costs, and poor cost control measures."

Moreover, the following statement describe the impression of many interviewees:

"Sadly, the COVID-19 pandemic created a conducive environment for bribery in the construction industry, as project parties exploited such extreme conditions for their own personal gain. Examples include the selection of contractors, the processing of work permissions and the issuance of work certificates without meeting the specifications of the implemented work."

B) Lack of willingness for collaboration

Lack of willingness for collaboration (B04) refers to the unwillingness to share information, teamwork engagement, and fulfilling expectations. B04 was ranked second in the behaviour-related category and third overall (Cb_{pn} =0.2218).

The interviewed experts emphasized the importance of B04. One of the several interviewees with the same concerns mentioned that:

"The lack of collaboration between the contract parties (i.e., the project manager, on behalf of the client/owner, and the contractor) and those within the project manager

and contractor teams can have many adverse consequences, the most important of which is the lack of trust among team members or between teams."

In a similar vein, the following quote describes the impression of one of the interviewees who is a project manager in the public construction sector:

"Lack of willingness for)collaboration can be disadvantageous due to a lack of trust, but team management can contribute to its prevention. Team leaders may determine clear expectations for the group as a whole, followed by expectations for individual members."

Additionally, the interviewees stressed the importance of establishing a solid culture of collaboration in the construction industry in Iraq. In fact, one of the interviewees who is a project manager in the public sector had this to say:

"Creating a framework for collaboration among stakeholders to capture the key collaborative drivers such as the assessment of the present processes and the development of feedback systems is critical to ensuring the survival of construction projects under extreme conditions, such as the COVID-19 pandemic."

C) Lack of Willingness to Change the Current Project Management Practices

Lack of willingness to change the current project management practices (B01) refers to the culture and organisational structure that hinder change and the lack of executive support and active sponsorship. Barkley (2004) stressed that the challenge for an organization is to educate and train project managers and team members to think in terms of risk as well as to internalize the risk management process into their daily routines. The ranking of B01 was third in the team-related category and 12th overall (Cb_{pn} = 0.0728).

Most of the interviewees stated that B01 is one of the most defining characteristics of the Iraqi construction industry. In addition, the experts have stated that management practices are similar to those employed before the COVID-19 pandemic.

Moreover, the experts stressed the necessity of adopting new management practices and methodologies that are empirically proven. In fact, the following quote describes the impression of a contractor in the private construction sector:

"It is now the time for construction decision-makers and stakeholders to sit down together to thoroughly examine the barriers and limitations of current practices, address these issues, and broaden the scope of existing practices to equip the construction industry for future extreme conditions."

III. Management-related Challenges and Barriers

A) Ineffective Risk Communication

Ineffective risk communication (M10) refers to the ineffective supply of information for team members to make informed, independent judgments regarding risks. M10 was ranked first in the management-related category and fifth overall (Cb_{pn} = 0.1415). The following quote describes the impression of a contractor in the private sector:

"A poorly designed risk communication process may result in incorrect interpretation of the scientific evidence regarding project success and missed opportunities to develop strategic capabilities regarding the larger-scale dimensions of the pandemic and its emerging risks."

The following quote from a project manager who works in the public construction sector demonstrates current practices and needs:

"In practice, it has been proven that ineffective risk communication contributes to time and cost overruns. It is different when you work under high levels of uncertainty caused by the pandemic, and you have to deal with new sets of risks that are unfamiliar to experts [...]. I do not think the construction industry in Iraq utilizes a system of risk communication [...]. There is an urgent need to develop such a system for risk communication during pandemics because many of the projects are urgently needed (for example, hospitals and testing/vaccination centres) and are driven by strict budgets."

B) Inadequate Integration of RM with Other Project Management Processes

Inadequate integration of RM with other project management processes (M06) refers to the lack of integration of risk management processes into the main phases of the project lifecycle (i.e., planning, design, execution/implementation, and delivery and maintenance). M06 was ranked third in the team-related category and ninth overall (Cb_{pn} =0.1060). Most interviewees indicated that in the COVID-19 era, they encountered the main challenges during the transition

towards the integration of RM processes into project phases, including a lack of experience and a lack of upper management support and commitment.

In addition, a project manager in the private sector stated the following:

"Risk management practices are mostly applied during the project implementation phase. Because of high implementation costs and commercial pressures, RM procedures are not applied effectively. Whereas if it was used in the pre-

implementation phase, the outcomes would be much more positive. Yet, if RM practices were adopted in the pre-implementation phase, the level of risks and uncertainties would be considerably lower in subsequent project phases."

The following quote describes the impression of a contractor in the private sector:

"It is more common to conduct risk management methodologies periodically rather than continuously throughout project phases […]. Unfortunately, the integration of RM into other project management processes when implementing projects during the COVID-19 era is not effective due to the overall poor level of readiness of RM; the poor integration culture of projects in Iraq; and the high level of uncertainties faced by construction projects along with the urge to make fast deterministic decisions, resulting in the decision process being based on weak grounds."

IV. Team-related Challenges and Barriers

A) Insufficient Familiarity with RM Process

Insufficient familiarity with the RM process (T04) refers to the lack of knowledge about the logical processes of the risk management process and its standards (e.g., BS 31100 and ISO: 31000) and professional guidelines (e.g., the Project Management Body of Knowledge by the Project Management Institute). M06 was ranked first in the team-related category and sixth overall (Cb_{pn} = 0.1368). In this regard, an interviewee who is a professor of risk management and consultant had this to say:

"One of the most prominent impressions that construction practitioners have about risk management is its analysis. A majority of them believe that risk management refers to assessing risks and ranking them. The process, however, is more comprehensive. Ranking risks provide a good indication to decision-makers as to how they should respond to these risks. There is poor understanding by industry decision-makers of risk planning (risk management content establishment), risk identification, risk response, and monitoring and controlling. Without these processes, risk management is of little value."

In addition, the following quote reflects the opinions of a project manager who works in the public construction sector:

"During the COVID-19 era, I believe that risk management is the weakest link in the construction project management chain […]. The process is not understood sufficiently, and priorities have not been established to effectively incorporate into the project life cycle since there are other issues in Iraq besides the pandemic effect, such as political

and economic instabilities […]. I think investing in adopting risk management processes in the Iraqi construction industry is worth its weight in gold."

B) Lack of Expertise and Experience

Lack of expertise and experience (T01) refers to the lack of knowledge of the practical implementation of RM processes and the unavailability of skilled personnel for managing project risks. T01 was ranked third in the team-related category and 13th overall (Cb_{pn} =0.0651). The following quote describes the impressions of one of the many experts

"In the COVID-19 era, it is extremely important for the construction industry to have the experience and expertise to manage the dynamic COVID-19 emerging risks. In this regard, there are numerous constructions needs, such as hospital construction, expansion, and maintenance. Unfortunately, in Iraq, there is a lack of expertise in risk management. As a result, this presents a major challenge as it has a direct impact on the delivery of infrastructure projects on time. Now, the industry stakeholders have begun to consider risk management in an effective manner."

C) Conflicts in Subjective Assessment by Risk Assessors

Conflicts in subjective assessment by risk assessors (T08) refers to the disagreement between construction practitioners concerning risk decision-making, where decisions are made based on intuition, experience, and engineering judgment. Among the examples are conflicts in risk priorities and risk response strategies selection. T08 was ranked second in the team-related category and eighth overall (Cb_{pn} = 0.1218). The following quote describes the impressions from one of many of the experts.

"Despite the importance of human input, when managing project risks under extreme conditions, such as the COVID-19 pandemic, the data on which decisions are made may not be accurate and complete, leading decision-makers to rely completely on their engineering experience and judgment, thereby resulting in conflicts in decision-making."

In addition, the interviewees discussed the absence of formalized methodologies to utilize experts' judgment in the management of project risks and expressed the need to adopt methodologies that effectively control the level of ambiguity and uncertainty when making risk-related decisions. In fact, one of the interviewees, who is a contractor in the private sector, had this to say:

"Despite the importance of human input, when managing project risks under extreme conditions, such as the COVID-19 pandemic, the data on which decisions are made may not be accurate and complete, leading decision-makers to rely completely on their engineering experience and judgment, thereby resulting in conflicts in decision-making

[…]. The use of some well-established methodologies, such as AHP and fuzzy logic that can quantify the uncertainty of subjective judgments are greatly needed for the construction industry during and after the COVID-19 pandemic."

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., Rm_{qp}) as presented in Figure 13.

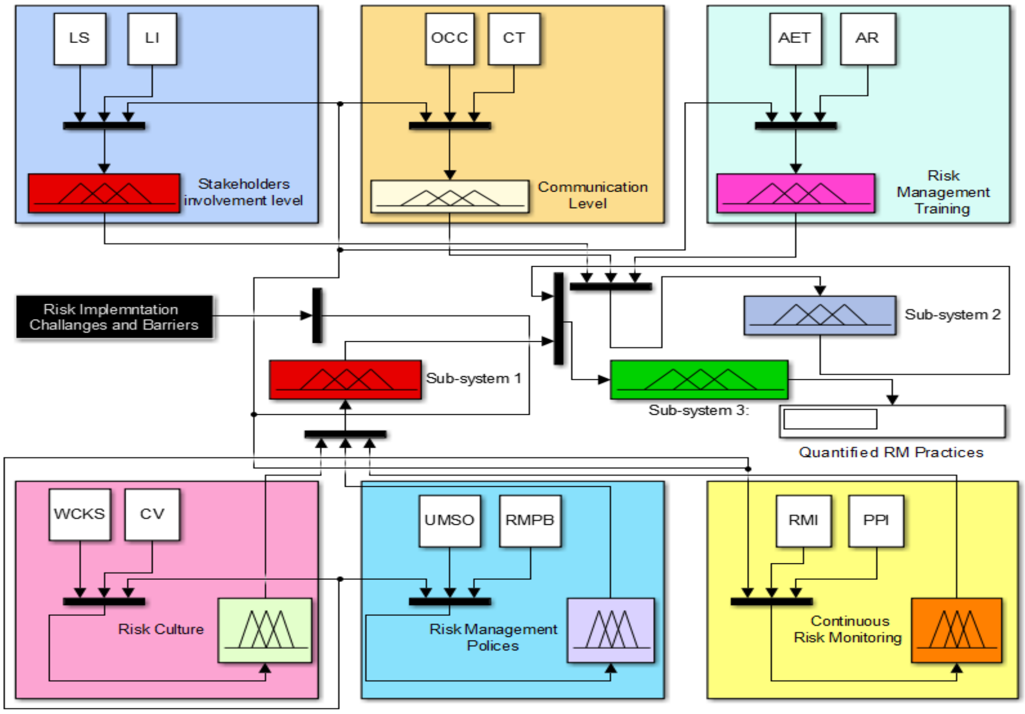

Figure 22. *The architecture of the developed RM practices assessment model (source: author)*

(RM challenges and practices paper, Figure 13)

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 Rm_{qp} 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 Rm_{qp} level of each significant challenge and barrier to RM implementation, along with the Rm_{qp} average value for each of the significant RMICB and their categories. The Rm_{qp} values and their ranking (high to low) were as follow: M06 (ranked first, with a Rm_{qp} value of 0.4960), T08 (ranked second, with a Rm_{qp} value of 0.4519), M10 (ranked third, with a Rm_{qp} value of 0.3683), A03 (ranked fourth, with a Rm_{qp} value of 0.3594), T04 (ranked fifth, with a Rm_{qp} value of 0.3508), M04 (ranked sixth, with a Rm_{qp} value of 0.3458), B04 (ranked seventh, with a Rm_{qp} value of 0.3386), A05 (ranked eighth, with a Rm_{qp} value of 0.3321), B01(ranked ninth, with a Rm_{qp} value of 0.3292), T01(ranked tenth, with a Rm_{qp} value of 0.3271), A02 (ranked 11th, with a Rm_{qp} value of 0.3265), B02 (ranked 12th, with a Rm_{qp} value of 0.3168). Furthermore, the average (Av) Rm_{qp} for the Management-related challenges and barriers was ranked first among the four categories of the identified RMICB with Av. Rm_{qp} equal to 0.4033. This was followed by team-related challenges and barriers (ranked second, with an Av. Rm_{qp} value of 0.3766), Analytical Approach-related challenges and barriers (ranked third, with an Av. Rm_{qp} value of 0.3393), and Behaviour-related challenges and barriers (ranked fourth, with an Av. Rm_{qp} 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.

Table 18. *Risk management quantified practices (source: author)*

(RM challenges and practices paper, Table 10)

RMICB	Cb_{pn}	Stakeholders' involvement		Communication level		Risk management training		Risk culture	
		LS (Mean)	LI (Mean)	OCC (Mean)	CT (Mean)	AET (Mean)	AR (Mean)	WCKS (Mean)	CV (Mean)
A02	0.3440	0.30	0.27	0.32	0.20	0.38	0.26	0.39	0.26
A03	0.2015	0.38	0.33	0.29	0.38	0.24	0.35	0.53	0.30
A05	0.0995	0.25	0.39	0.34	0.21	0.33	0.43	0.26	0.37
B04	0.4215	0.21	0.32	0.40	0.23	0.36	0.25	0.39	0.24
B01	0.2218	0.30	0.49	0.36	0.32	0.29	0.30	0.25	0.36
B02	0.0728	0.27	0.38	0.31	0.37	0.21	0.20	0.38	0.26
M10	0.1415	0.32	0.35	0.29	0.43	0.23	0.41	0.30	0.53
M04	0.1300	0.56	0.34	0.20	0.42	0.35	0.48	0.44	0.35
M06	0.1060	0.37	0.42	0.33	0.38	0.47	0.55	0.48	0.41
T04	0.1368	0.35	0.56	0.28	0.30	0.34	0.47	0.26	0.49
T08	0.1218	0.37	0.49	0.37	0.43	0.59	0.52	0.32	0.56
T01	0.0651	0.25	0.42	0.28	0.39	0.33	0.58	0.48	0.35

Table 18. *Continued.*

RMICB	Cb_{pn}	Risk management polices		Continuous risk monitoring		Rm_{qp}	Rm_{qp} Rank	Av. Rm_{qp}	Av. Rm_{qp} Rank
		UMSO (Mean)	RMPB (Mean)	RMI (Mean)	PPI (Mean)				
A02	0.3443	0.20	0.23	0.33	0.29	0.3265	11	0.3393	3
A03	0.2015	0.28	0.41	0.35	0.52	0.3594	4		
A05	0.0995	0.31	0.38	0.24	0.34	0.3321	8		
B04	0.4215	0.41	0.33	0.38	0.35	0.3386	7	0.3282	4
B01	0.2218	0.24	0.27	0.21	0.42	0.3292	9		
B02	0.0728	0.24	0.35	0.23	0.49	0.3168	12		
M10	0.1415	0.36	0.32	0.63	0.46	0.3683	3	0.4033	1
M04	0.1300	0.26	0.52	0.31	0.39	0.3458	6		
M06	0.1060	0.35	0.43	0.30	0.67	0.4960	1		
T04	0.1368	0.38	0.52	0.38	0.33	0.3508	5	0.3766	2
T08	0.1218	0.40	0.46	0.42	0.39	0.4519	2		
T01	0.0651	0.31	0.38	0.24	0.36	0.3271	10		

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. 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 .

Table 19. *Profiles of the verification and validation panel participants (source: author)*

(RM challenges and practices paper, Table 11)

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

Conclusions

This research examined the RMICB and RM practices for construction projects during the COVID-19 pandemic in developing countries 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, behaviour-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 behavioural 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), analytical approach-related (0.3393), and behaviour-related challenges and barriers (0.3282). To this end, the findings of this research offer warning signs regarding the impact of the RMICB, as well as the low levels of RM practices in construction projects during the COVID-19 pandemic.

Methodological Implications

Studies of 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 effectiveness of current RM practices (i.e., using fuzzy logic methodology).

Both AHP and fuzzy sets were used to formalize and deal with human knowledge and uncertainties in risk management decision-making during the COVID-19 pandemic. Another methodological implication made in this study was related to the 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, organisational communication, risk culture, risk management training, risk management policies, and continuous risk monitoring). The authors believe that it is crucial to understand the current level of RMICB and their impact on the project when assessing the quality of RM practices since many challenges are the root cause of poor practice.

Practical and Theoretical Implications

This study significantly contributes to the body of knowledge by helping construction practitioners and researchers to better understand the challenges and barriers hindering the effective implementation of risk management strategies for construction projects during extreme conditions such as COVID-19 pandemic. Furthermore, it provides valuable information to decision-makers regarding the current practices of construction RM in developing countries, such as Iraq. In fact, the results of this research could be used as a baseline for construction companies and governments to develop effective strategies to address these challenges and barriers and enhance the practices of RM.

Research Limitation and Future Research Direction

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.

For future studies, the findings of this research can be utilized by research scholars to (1) implement the developed AHP and Fuzzy models in various case studies and track the corresponding RMICB and their effect on project success and its indicators, (2) develop RM guidelines and response strategies to their implementation challenges and barriers, and (3) investigate the RM implementation challenges and barriers and the level of RM practices in developing vs. developed countries.

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., & 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., Abdul Nabi, M., El-Adaway, I. H., & 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), 05021015.

Al-Mhdawi, M. K. S., Brito, M. P., Onggo, B. S., & 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. (2022c). Risk Management of Construction Projects Under Extreme Conditions: A Case Study of Iraq. (In Press). PhD Thesis. University of Southampton, UK.

Alsharef, A., Banerjee, S., Uddin, S. M., Albert, A., & 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), 1559.

Amoah, C., & Simpeh, F. (2020). Implementation challenges of COVID-19 safety measures at construction sites in South Africa. *Journal of Facilities Management*.

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., & Abotaleb, I. S. (2020). Predicting project performance in the construction industry. *Journal of Construction Engineering and Management*, *146*(5), 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.

Boadu, E. F., Wang, C. C., & 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), 4110.

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., & 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*.

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

Darko, A., Chan, A. P. C., Ameyaw, E. E., Owusu, E. K., Pärn, E., & 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., & 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. In *Mastering the semi-structured interview and beyond*. New York University Press.

Harinarain, N. (2020). Despair during the COVID-19 lockdown for the South African construction industry. *Journal of Construction*, *13*(1), 52-63.

IOM (International Organization for Migraiton). 2020. “Impact of COVID19 on small and medium-sized enterprises in Iraq”. Accessed January 4, 2021. https://www.iom.int/.

Khalfan, M., & 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.

Kim, S., Kong, M., Choi, J., Han, S., Baek, H., & 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), 04021048.

Kott, A., & 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., & 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., & Twining, J. (2010). Taking control of organizational risk culture. *McKinsey & Company*.

Lin, S. S., Shen, S. L., Zhou, A., & 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., & 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., & Higgon, D. (2012). *Risk management in projects*. Routledge.

Moon, D. (2016). *Continuous risk monitoring and assessment: CRMA* (Doctoral dissertation, Rutgers University-Graduate School-Newark).

Nordin, R. M., Takim, R., & Nawawi, A. H. (2011, September). 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., & 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., & 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., & Alexander, J. M. (1989). *Conflict resolution: the analytic hierachy approach*. Rws Publications.

Salami, B. A., Ajayi, S. O., & 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*, 1-9.

Shad, M. K., & Lai, F. W. (2015). A conceptual framework for enterprise risk management performance measure through economic value added.

Shakeri, H., & 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., & 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*.

Steinheider, B., & 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., & 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., & Lalis, A. (2022). Progressing the aerospace performance factor toward nonlinear interactions. *Risk analysis*.

Su, X., Mahadevan, S., Xu, P., & 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., & 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., & 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., & Wu, P. (2015). Reducing hindrances to enterprise risk management implementation in construction firms. *Journal of Construction Engineering and Management*, *141*(3), 04014083.

Chapter 3. Assessment of the Covid-19 Emerging Risks for the Construction Industry of Developing Countries: a Case Study of Iraq

Abstract

The construction industry has been impacted significantly by the COVID-19 pandemic. The direct and indirect impact of the pandemic have created a whole new set of risks and uncertainties, causing workforce-related issues, procurement and supply chain disruptions, and contractual, legal and insurance implications. All these factors are interconnected and have created a chain of delays, cost overrun and loss of productivity.

Previous research efforts have concentrated on capturing the impact of COVID-19 pandemic on the construction industry and there is a lack of study that identifies and quantitatively analyses the risks emerging from COVID-19 pandemic. To fill this knowledge gap, a multi-stage methodology is devised. First, the risks emerging from COVID-19 pandemic and their categories are identified using focus group session with eleven construction experts in Iraq. Second, a multi-dimensional risk analysis model under fuzzy environment is developed based on experts' opinions. Finally, a survey is administered to and responded by 194 Iraqi construction experts to examine the impact of COVID-19 on the construction industry of developing countries using the developed risk analysis criteria and their components.

To this end, a total of 46 risks are identified and categorized under five construction themes namely, contractual implications, construction financial market, health and safety of construction workforce, and organisational implications. Results indicate that the most critical COVID-19 risks affecting the construction industry of developing countries are (1) contract suspension, (2) contractor bankruptcy, (3) materials prices escalation, (4) claims arising under a construction contract, (5) inappropriate risk allocation, (6) non-compliance with social distancing guidelines, (7) skills shortage, and (8) poor site and virtual communication. The study contributes to the body of knowledge by providing construction decision-makers and academics with a better understanding of the risks emerging from the COVID-19 pandemic. In addition, this paper presents a novel model for analysing extreme conditions' risks related to COVID-19 pandemic and future pandemics.

Introduction

In most countries, the construction industry is a significant contributor to economic and social welfare (Sierra, 2021). The industry employs approximately 7% of the total world's workforce and accumulates 13% of the global GDP (Deloitte, 2017). Annually, around $10 trillion is spent on construction-related services and goods around the world (McKinsey Global Institute, 2020). According to Shahbazi (2019), the industry expenditures are anticipated to reach $15 trillion worldwide by 2025.

In Iraq, the output value of the construction industry is anticipated to present an annual growth rate at a Compound Annual Growth Rate (CAGR) 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). Between 2003 and 2014, more than US$220 billion was spent on construction and reconstruction efforts following the armed conflict in 2003.

However, the construction industry in Iraq has always been plugged with risks and weak outcomes (Al-Mhdawi *et al*., 2020). This is due to the following:

(1) Iraqi contracting companies find a big number of challenges to mitigate risks in an environment characterized by poor suppliers, unskilled workforce, logistics difficulties, poor risk management practices (Al-Mhdawi, 2020; Al-Mhdawi *et al*., 2020), and a lack of expertise in using modern technologies for managing construction projects (Bekr, 2015). Moreover, the industry suffers from poor safety management practices (Buniya *et al*., 2021a). The accidents rate in Iraqi construction industry in 2018 was 38% of overall industrial accidents (Buniya *et al*., 2021b), which made it one of the *hazardous* industries in Iraq.

(2) The volatile security and political conditions posed an enormous challenge to Iraqi civilians, the Iraqi economy, and construction and reconstruction efforts (Matsunaga, 2019). For instance, poor security profile in Iraq, limited private sector engagement, including foreign direct investment, leading to many projects being selected opportunistically.

(3) Iraq's current economic context is characterized by extreme dependence on oil production. It is one of the world's largest producers and the 3rd largest oil exporter, with an 8.3% market share worth $83.3 billion in 2019; and holds the world's 5th largest proven reserves of petroleum at 144.2 billion barrels (World Bank, 2022). However, the fluctuation *of* oil prices in the global market has a direct impact on industries in Iraq. For instance, the collapse of oil prices in 2020 caused significant economic challenges, particularly to the construction industry. In April 2020, the oil prices had fallen by 70%

compared to the start of the year, which severely impacted Iraq's government revenues. According to the new issue of the World Bank's Iraq Economic Monitor (World Bank, 2020), the Iraqi government revenues fell by 47.5% in the first 8 months of 2020. Declining oil prices in the global market caused a direct effect on the stability of the construction industry in Iraq (Abdulhussein and Shibaani, 2016).

In addition to this, the impact of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), which is known as the novel coronavirus disease (COVID-19), on Iraq has raised the ceiling of challenges. Unlike other 21st century outbreaks (e.g., SARS1, MERS2, or H1N1pdm09), the COVID-19 pandemic is of unprecedented scale and intensity (Casady and Baxter, 2020). The COVID-19 pandemic has caused considerable economic and operational uncertainties to different industries, leading to business closures, mass job loss, and suspension and termination of contracts. The construction industry has been amongst the hardest hit by the COVID-19 pandemic (Alsharef *et al*., 2021; Stiles *et al*., 2020). The direct and indirect impact of the pandemic has created a whole new set of risks and uncertainties, causing workforce-related issues, procurement and supply chain disruptions, and contractual, legal and insurance implications (Assaad and El-adaway, 2021). All these factors are interconnected and have created a chain of delays, cost overrun and loss of productivity (Sierra, 2021).

The Iraqi construction industry has quickly felt the pandemic impact. This impact was felt more by the private construction sector (Al-Mhdawi *et al*., 2022), leading to reduced workforce wages, increased unemployment rates, contract payment stoppage, and contract suspension and termination. As of August 2021, 1.3% of the Iraqi population are fully vaccinated, which significantly delays the economic recovery and increases the severity and complexity of the pandemic risks on the construction industry.

A handful of studies have investigated the impact and challenges of the COVID-19 pandemic on the construction industry (Khalfan and Ismail, 2020; Agyekum *et al*., 2021; Alsharef *et al*., 2021; Rehman *et al*., 2021; Sierra, 2021). However, none of them has identified and quantitatively analysed the key risks emerging from the COVID-19 pandemic in the construction industry.

The goal of this paper is to develop a risk assessment model for construction projects under extreme conditions by considering the case of Iraqi construction industry during the COVID-19 pandemic era. The associated objectives are to (1) identify and classify the risk factors emerging from the COVID-19 pandemic in the construction industry; and (2) quantify the level of riskiness of the identified risks using a novel multi-criteria risk analysis model under fuzzy environment.

Existing Studies and Identification of Knowledge Gap

In most previous studies, scholars have attempted to understand the impact of COVID-19 pandemic on the construction industry by identifying the industry dimensions that are prone to risks. These dimensions include contractual/legal implications, supply chain operations, construction financial market, and the health and safety of the construction workforce. For instance, Alsharef *et al*. (2021) investigated the early impact of COVID-19 pandemic on the U.S. construction industry and found that the main risks facing the industry include material delivery delays, shortage of material, permitting delays, lower productivity rates, cash flow-related challenges, project suspension, price escalations, and potential conflicts and disputes. Khalfan and Ismail (2020) conducted exploratory research to assess the progression of construction projects in Bahrain and construction companies include project delays as a result of the pandemic, maintaining employees' salary payments, implementing new modes of conducting work, shortage of supplies and materials, shifting to an online platform, financial difficulties affecting all involved parties, absence of employees either due to sickness or travel restrictions, reduced efficiency of work delivered, restricted site access, and lack of projects and less willingness of investors to launch new projects. Sierra (2021) found that the major challenges that contractors are facing due to the COVID pandemic in the UK construction industry are the instability of the supply chain and subcontractors, the uncertainty related to the unpredictable evolution of the COVID-19 pandemic, workforce availability and possible legal exposures. Agyekum *et al*. (2021) investigated the impact of COVID-19 on the Ghanaian construction industry and found that the main challenges facing the industry are an increase in the cost of construction materials, delays in payments, and a decrease in work progression rate. Rehman *et al*. (2021) examined the impact of COVID-19 pandemic on construction project performance in the UAE and found that construction material and equipment shortage, travel restriction, delayed permits and work approval and inspections, and serious health and safety concerns are the main causes of schedule delays and cost overrun. Amoah and Simpeh (2021) indicated that the main challenges facing the implementation of COVID-19 safety measures at South Africa's construction sites are failing to comply with social distancing rules, public transport usage by workers, shared construction tools and equipment, and shortage of Personal Protective Equipment. Finally, Stiles *et al*. (2020) highlighted the importance of integrating COVID-19 safety measures within the UK construction industry's general risk management system.

The aforementioned studies investigated the main challenges emerging from the COVID-19 pandemic for construction projects worldwide. However, no previous studies focused on providing an in-depth analysis of the key COVID-19 risks causing projects' schedule delays, cost overrun, and quality deficiency. To this end, this research seeks to fill this knowledge gap by considering the case of the construction industry in Iraq.

Methodology

A multi-stage research methodology was adopted in this research. The following subsections provide details regarding each stage.

Stage One: COVID-19 Risks Identification

Few studies have examined the impact of the COVID-19 pandemic and its emerging risks on the construction industry. The current literature, however, is insufficient to identify the significant COVID-19 risks. To this end, a focus group session with several Iraqi construction experts was conducted to identify the COVID-19 emerging risks. Focus groups denote a type of group interview that takes advantage of communication between research participants for data generation. This method aims to seek data from a select few individuals as opposed to a sample that statistically denotes a larger population (Nyumba *et al*., 2018). Even though group interviews are typically utilized as a fast and efficacious approach to gathering information from many people simultaneously, focus groups incorporate the use of group interaction (Brewer *et al*., 2012)**.** Notably, the reason behind creating a group involving research participants is that the group must be able to accommodate a reasonable discussion without making it so large that it prevents the participation of certain members (Creswell and Creswell, 2017). As such, detailed viewpoints of all informants could be utilized with the appropriate number of participants in a given group.

To this end, we chose this method of data collection because (1) there are limited intentional and local (Iraq context) studies on COVID-19 risks in the engineering and construction field, (2) this method is beneficial in exploring and gaining a deeper understanding of phenomena or situations (Breen, 2006), and (3) it has been used extensively in previous studies to identify risks and challenges related to engineering and construction research (Hoseini, 2019).

The focus group session was carried out with eleven experts in the Iraqi construction industry. For the selection of participants, we adopted a judgmental or authoritative sampling method. This is a non-random sampling method where the organizer/researcher contacts potential informants that are known to be area experts (Creswell and Creswell, 2017). Understanding the impact of the pandemic and its emerging risks on construction projects is a difficult matter. Therefore, it is critical that specialists from various professional levels and backgrounds participate in the focus group session. Thus, we approached project managers, main contractors, and architects. Another criterion for selection is that the participants must have extensive expertise in the construction industry in Iraq. During the session, the key COVID-19 risks were discussed in-depth. Thereafter, a comprehensive and validated list of COVID19 risks and their classification was developed.

It is important to mention that clients/owners were excluded as the focus was to investigate the perceived COVID-19 risks by day-to-day involved key stakeholders during the project life cycle. Furthermore, the involvement of owners under the Iraqi Civil Code (ICC), and the Iraqi Contract Conditions for Civil Engineering Works (ICCCEW) for public and private construction projects is minimal (regardless to the contract type). This is because the project manager acts on behalf of the client in all aspects of the project. This includes contracting with the main contractor, approving change orders, approving the accomplished work and releasing payments to the contractor, and others. Ultimately, the focus group outputs were analysed manually using the content analysis method. In content analysis, the main facets and valid inferences from verbal, written or communication messages, are examined either quantitatively or qualitatively are determined (Krippendorff, 2013). During this process, key factors were highlighted and sorted in a coherent fashion. The focus group sessions were recorded, those records were reviewed again, and further decisive factors being identified.

Stage Two: Development of a Multi-criteria Risk Analysis Model

Risk matrices are used to determine the degree of risk level by considering the category of risks' probability of occurrence against the category of risk's impact (Cox, 2008). The reason for the popularity of these methods is due to their visual appearance, simplicity, and ease of use, which is claimed to support the decision-making process. Risk matrices are also recommended by several international standards (see, e.g., ISO 31000:2009 and NIST800-30: 2012 and others) and are widely used among scholars in different engineering and construction sectors to analyse project risks (see, e.g., Qazi *et al*., 2021; Kassem *et al*., 2019 and others).

To this end, experts who participated in the focus group session were also asked to: (1) evaluate the effectiveness of using the risk matrices; (2) investigate the need to capture new analysis criterion(s) when analysing construction risks during extreme conditions such as COVID-19 pandemic; (3) identify the decision components for each analysis criterion; and (4) establish the conditional statements between the components of each analysis criterion and between the analysis criteria.

Ultimately, a new risk analysis criterion/dimension was added to the probability and impact (PI) matrix. The new criterion is called the organization's Readiness Level (RL). The new dimension measures the organization RL in terms of the availability of resources and expertise. In this research, the components of the RL analysis criteria are (1) available expertise (AE), this includes assessor's level of technical experience in design, construction and project management, their contractual, legal, and financial experience, and their health and safety; (2) the company's level of contingencies (CLC). The components of the risk probability of occurrence depend on (1) organization LR; (2) political and security factors (PSF); and (3) out of control factors (OCF) (e.g., adverse weather conditions, pandemics, etc.). Finally, the components of the risk impact are (1) impact on project cost (IPC); (2) impact on project time (IPT); and impact on project quality (IPQ).

The proposed risk analysis model is called Risk Probability, Impact, and Readiness (R-PIR) model, in contrast to the PI model. The relationship between the analysis criteria is defined using Equation 1.

$$R= RL^{*} LP^{*}LI \qquad (1)$$

Where R=risk; RL= readiness level; PL= probability level; and IL= impact level.

Stage Three : COVID-19 Risk Rating

The identified risks and assessment criteria derived from the focus group session were used to develop the survey. Data collection efforts are discussed in detail in the following subsections:

Survey Development

Upon identifying the COVID-19 risks affecting construction projects, we administrated a survey to construction experts in Iraq to quantify the characteristics of each COVID-19 risk. The developed survey allowed the respondents to rate each of the COVID-19 risks in terms of the components of the analysis criteria, i.e., AE and CLC (for the organization level of readiness), PSF and OCF (for the probability of risk occurrence), and IPC, IPT, and IPC (for risk impact on project set objectives)

In this research, we adopted a five-point Likert's quintet scale (1: very low (V.L)) to (5: very high (V.H)) for the assessment of the analysis criteria. Moreover, the survey included questions related to the respondents' (1) construction role, (2) working construction sector, (3) years of construction experience, and (4) educational qualifications.

Pilot Testing

A pilot test was first carried out with 12 respondents working as contractors, project managers, and construction risk management academics. Additionally, all participants in the pilot study had more than 15 years of experience in the construction industry. The respondents were asked to: (1) identify potential for misunderstanding of instructions or questions; (2) determine the comprehensiveness of the questionnaire; and (3) examine the technical terms, layout, sequencing, and survey completion time. Finally, we revised all the respondents' comments and amended the survey accordingly.

Survey Administration

The final version of the survey was sent to the targeted construction experts, including architects, project managers, contractors, and safety engineers. The respondents targeted in this research were construction professionals (1) working in the Iraqi construction industry; (2) members of various professional bodies in Iraq, including Iraqi Engineers Association and/or registered contracting companies at the Iraqi Ministry of Trade; (3) have at least five years of experience in construction projects. To this end, we administrated the survey to 450 construction experts, 213 of whom actually returned the survey. Of the 213 responses, 19 were not completed. As such, the study only considered 194 responses for further analysis, reflecting a response rate of 64.67%. The results and analysis section provides a more detailed discussion on the respondents' profiles.

Stage Four : Analysis and Validation of COVID-19 pandemic Risks Under Fuzzy Environment

In the construction industry, experts input form an important role in the risk management process, from risk planning, identification, analysis to risk response and monitoring and controlling. Despite automated techniques that aid in the speedy processing of large amounts of data, the entire process is carried out by experts. Their perspectives, engineering expertise, and experience provide a wealth of information for the entire risk management process. However, in many situations, the data on which the decision-making process is based might be incomplete and/or unreliable. The importance of Fuzzy Sets Theory (FST) comes when decision-makers have to make decisions with uncertain, ambiguous, vagueness data (Elbarkouky *et al*., 2016). FST is a mathematical approach introduced by Zadeh (1965) to deal with information or data that is too complex or ill-defined to be processed in a conventional algorithm.

The key advantage of fuzzy sets in comparison with the classical set theory is its capability to capture the vagueness of concepts (Gunduz *et al*., 2015) due to uncertainty and human subjectivity (Al-Mhdawi, 2020). One of the essential advantages of using fuzzy logic when analysing risks is that the whole process leads to creating a control system that can reduce risks efficiently and effectively (Mazher *et al*., 2018). Furthermore, fuzzy logic applications for risk analysis can minimize the subjectivity to an acceptable level. This happens when using qualitative data as an input; subjectivity creates relations and dependencies between inputs data and risk analysis in which it can be better controlled. In the context of this research, the high levels of uncertainties associated with the COVID-19 pandemic impact adversely the effectiveness of the decision-making process. Accordingly, we used FST to analyse COVID-risks due to its capability in providing a robust mathematical framework to capture the uncertainties related to (1) poorly defined data; (2) lack of information; and/or (3) conflicting of experts' opinions.

In this research, we used four fuzzy controllers. The first controller estimates the organization level of readiness depending on its components i.e., AE and CLC. The second controller estimates the level of COVID-19 risks probability of occurrence depending on RL, PSF and OCF. The third controller estimates the level of impact of COVID-19 risks depending on IPC, IPT and IPQ. Finally, the fourth controller (the main controller) estimates the overall level of riskiness of each COVID-19 risk factor depending on the main analysis criteria i.e., RL, PL, and IL. In each controller, the risk analysis criteria and their components were fuzzified using a set of membership functions. The fuzzy inputs were evaluated in the fuzzy inference engine to determine the estimated level of each analysis criteria and the overall level of riskiness of each COVID-19 risk, using a well-defined rule base consisting of conditional statements and fuzzy logic operations. After that, the fuzzy conclusion was defuzzified to obtain a fuzzy risk number (F-RN). The Fuzzy Linguistic assessment model was developed using MATLAB® (Version 2019b). The architecture of the proposed COVID-19 risk analysis model depends on three modules i.e., fuzzy system Input/output interference module and knowledge base module. 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:

a) For fuzzification, we 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.
b) For fuzzy inference system, we used Mamdani's fuzzy inference system (MFIS) to assess the output variable. We used MFIS due to its (1) widespread usage in the literature, (2) intuitive nature, and (3) suitability for subjective inputs.
c) For defuzzification process, we used the centroid of area method, which is a widely used method of defuzzification to reflect the viewpoint of the experts.

As mentioned previously, the risk analysis model is supported by four fuzzy controllers with seven input variables and one output variable. The inputs and outputs are defined using a five-point Likert scale and are associated with five linguistic terms (Low (V.L) to Very High (V.H)). Thus, we assigned five membership functions for the assessment components, criteria, and output variables as presented in Figure 1.

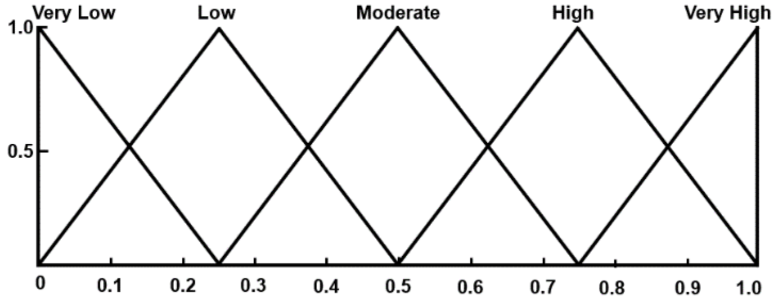

Figure 23. *Functions for all linguistic variables (i.e., for inputs and outputs) (source: author)*

(COVID-19 risk assessment paper, Figure 1)

As for the establishment of IF-THEN rules, we interviewed a panel of five experienced Iraqi construction managers and one risk management professor. Those participants were experienced with the application of fuzzy sets theory in the construction industry; they also possess wide engineering experience in managing projects under extreme conditions. Ultimately, a total of four rounds were needed to achieve the consensus among experts.

At the end, 350 rules were developed for the model. 25 rules for RL estimation, and 125 rules for COVID-19 PL, IL and riskiness level estimation, respectively. Figure 2 present examples of the developed rules for RL, LP, L.I and COVID-19 riskiness level, respectively. Upon completion of the analysis, the results were validated with participants in a follow-up focus group session. We chose this validation method, due to the lack of supporting literature regarding the impact of each COVID-19 emerging risk on construction projects. In addition, it is important to mention that the participants in the focus group sessions did not participate in the survey.

If-Then Rules for Readiness Level

Rule#	IF	AND	THEN
1	If AE is Very Low	CLC is Very Low	RL is Very Low
6	If AE is Low	CLC is Very Low	RL is Very Low
12	If AE is Moderate	CLC is Low	RL is Low
18	If AE is High	CLC is Moderate	RL is High
25	If AE is Very High	CLC is Very High	RL is Very High

If-Then Rules for Probability Level

Rule#	IF	AND	AND	THEN
1	If RL is Very High	PSF is Very Low	OCF is Very Low	PL is Very Low
28	If RL is High	PSF is Very Low	OCF is Moderate	PL is Low
68	If RL is Moderate	PSF is High	OCF is Moderate	PL is Moderate
90	If RL is Low	PSF is Moderate	OCF is Very High	PL is High
125	If RL is Very Low	PSF is Very High	OCF is Very High	PL is Very High

If-Then Rules for Impact Level

Rule#	IF	AND	AND	THEN
1	If IPC is Very High	IPT is Very Low	IPQ is Very Low	IL is Very Low
32	If IPC is Low	IPT is Low	IPQ is Very Low	IL is Low
48	If IPC is Low	IPT is Very High	IPQ is Moderate	IL is High
93	If IPC is High	IPT is High	IPQ is Moderate	IL is High
125	If IPC is Very High	IPT is Very High	IPQ is Very High	IL is Very High

If-Then Rules for F-RN Riskiness Level

Rule#	IF	AND	AND	THEN
1	If PL is Very Low	I.L is Very Low	RL is Very Low	F-RN is Low
29	If PL is Low	I.L is Very Low	RL is High	F-RN is Very Low
73	If PL is Moderate	I.L is Very High	RL is Moderate	F-RN is High
105	If PL is Very High	I.L is Very Low	RL is Very High	F-RN is Very Low
125	If PL is Very High	I.L is Very High	RL is Very Low	F-RN is Moderate

Figure 24. *Examples of the developed model's IF-THEN rules (source: author)*

(COVID-19 risk assessment paper, Figure 2)

Results and analysis

Profiles of Focus Group Participants

The session's members were experts in the Iraqi construction industry with design and management experience. Those experts were contractors, project managers and architects. The profiles of the participants are presented in Table 1

***Table 20.** Profiles of Focus Group Participants (source: author)*

(COVID-19 risk assessment paper, Table 1)

Number of Group Participants	Construction Role	Range of Experience	Education Level			
			Dip	BSc	MSc	PhD
3	Contractors	17-21	0	2	0	0
6	Project managers	14-23	0	2	1	1
2	Architects	9-15	1	1	0	0

Profiles of the Fuzzy panel

A panel of five Iraqi construction managers and a risk management professor were interviewed to develop the IF-THEN rules for the model. Table 2 presents the profiles of the participants in the Fuzzy panel.

***Table 21.** Fuzzy panel Profiles (source: author)*

(COVID-19 risk assessment paper, Table 2)

Number of Group Participants	Construction Role	Range of Experience	Education Level		
			BSc	MSc	PhD
5	Project managers	15-24	3	1	0
1	Risk management academic	21	0	0	1

Identified COVID-19 Risks

As mentioned in Stage One of the research methodology, we identified 46 COVID-19 emerging risks for the construction industry through a focus group session with 11 Iraqi construction experts. The identified risks were categorized under five categories, namely contractual implications, supply chain operation, construction financial market, health and safety of the construction workforce, as well as organisational implications, as presented in Figure 3.

Contractual/Legal Implications

C01. Lack of clarity in the contract language
C02. Claims arising under a construction contract
C03. Change of law
C04. Inappropriate risk Allocation
C05. Contract suspension
C06. Contract termination

Construction Financial Market

C07. Increase insurance rates C08. Increase of tax rate
C09. Fluctuations in currency exchange rates
C10. Materials prices escalation
C11. Equipment prices escalation
C12. Reduction in labor wages
C13. Lack of fiscal headroom for local government.
C14. Contractors' bankruptcy
C15. Delayed in payments
C16. Suppliers' bankruptcy

Supply Chain Operations

C17. Scarcity of manpower
C18. Lack of construction contractors
C19. Skills shortage
C20. Machine failure
C21. Damaged materials due to forced prolonged time in storage, and poor storage of materials on construction sites.
C22. Construction materials shortage
C23. Material delivery delays
C24. Cargo theft
C25. Monopolization of construction materials

Health and Safety of the Construction Workforce

C26. Non-compliance with social distancing guidelines
C27. Increased subsidy rates
C28. Psychological stress
C29. Poorly ventilated spaces
C30. Delays caused by workforce self-isolating
C31. Virus spreading due to poor hygiene and lack of sanitizing stations
C32. Virus spreading in the commonly used or high traffic construction area
C33. Lack of cleanliness and sterilization of commonly used surfaces, tools, and workstations by construction workers
C34. Contracting or spreading the virus when traveling to work
C35. Contracting or spreading the virus in changing showers, and toilets facilities.
C36. Contracting or spreading the virus during site meetings and training.
C37. Lack of face masks or coverings
C38. Re-using face masks or covering

Organizational Implications

C39. Delays caused by confusion arising out of the status or effect of government guidance.
C40. Delayed due to Municipalities' prolonged procedures and routine
C41. Delayed work inspection and approval.
C42. Poor site and virtual communication
C43. Restricted site access
C44. Delayed contractor mobilization to the site.
C45. Delay of work progress and reporting
C46. Delayed design submission

Figure 25. *Identified COVID-19 risks (source: author)*

(COVID-19 risk assessment paper, Figure 3)

Profile of Survey Respondents

Working Sector. As mentioned before, a total of 194 survey responses from construction experts in Iraq were considered for analysis. The latter is equivalent to a response rate of 64.67%, which is considered high compared to previous relevant studies (Yates, 2014; Tabish and Jha, 2018). The distribution of respondents between the public and private sectors was as follows: public (state) sector, 69%; and private sector 31%.

Construction Role. The survey respondents had different construction roles in the Iraqi construction industry, including architects (13.18%), contractors (44.16%), project managers (31.45%), safety engineers (11.20%). With such a variety of respondents' construction roles, the views and opinions of experts captured the impact of COVID-19 pandemic risks on the Iraqi construction industry.

Range of Experience. Most of the survey respondents (approximately 69%) had more than 15 years of experience in the Iraqi construction industry. The distribution of the respondents' range of experience was as follows: 1-5 years, 3.23%; 6-15 years; 27.83%; 16-25 years, 37.84%; and over 25 years; 31.30%. Ultimately, with such a diverse variety of experience, the collected responses can be considered a good representative of the Iraqi construction industry.

Educational Qualifications. The survey respondents held different educational qualifications, including diplomas (8%), bachelor’s degree (72%), master’s degree (15%), and doctorate degree (5%).

Table 3. provides detailed information about the respondents' profile in terms of construction role, experience, and education qualification in the Iraqi construction industry.

Table 22. *Profile of Survey Respondents (source: author)*

(COVID-19 risk assessment paper, Table 3)

Respondents Profile	Category	Distribution (%)
Working Sector	Public Sector	69
	Private Sector	31
Construction Role	Consultants	13.18
	Contractors	44.16
	Project manager	31.45
	Safety engineers	11.20
Range of Experience	1-5 Years	3.23
	6-15 Years	27.83
	16-25 Years	37.84
	>25 Years	31.30
Educational qualifications	Diploma	8
	Bachelor’s degree	72
	Masters’ Degree	15
	Doctorate degree	5

COVID-19 Risk Analysis Under Fuzzy Environment

As mentioned in Stage Four of the research methodology, the architecture of the proposed risk analysis model consisted of four fuzzy controllers. The inputs for the first controller were AE, CLC, and RL and the output variable was RL. For the second controller, the input variables were RL, OCF and PSF and the output variable was PL. For the third controller, the input variables were IPC, IPT, and IPQ and the output variable was IL. Lastly, for the fourth controller, the input variables were RL, PL, and IL and the output variable was the riskiness level for COVID-19 risks. Furthermore, the IF-THEN rules presented in Figure 2 were used in the design of the fuzzy controllers. Figure 4 shows the architecture of the proposed risk analysis model. The correlation between fuzzy controllers' inputs and output variables was presented as three-dimensional mapping via Fuzzy logic Surface Viewer. The graphical display of dependencies for each controller included two inputs and one output, as shown in Figures 5 to 8. For instance, Figure 8 shows the riskiness surface for the developed fuzzy model. As the colour intensity increases, the level of COVID-19 riskiness on construction projects increases.

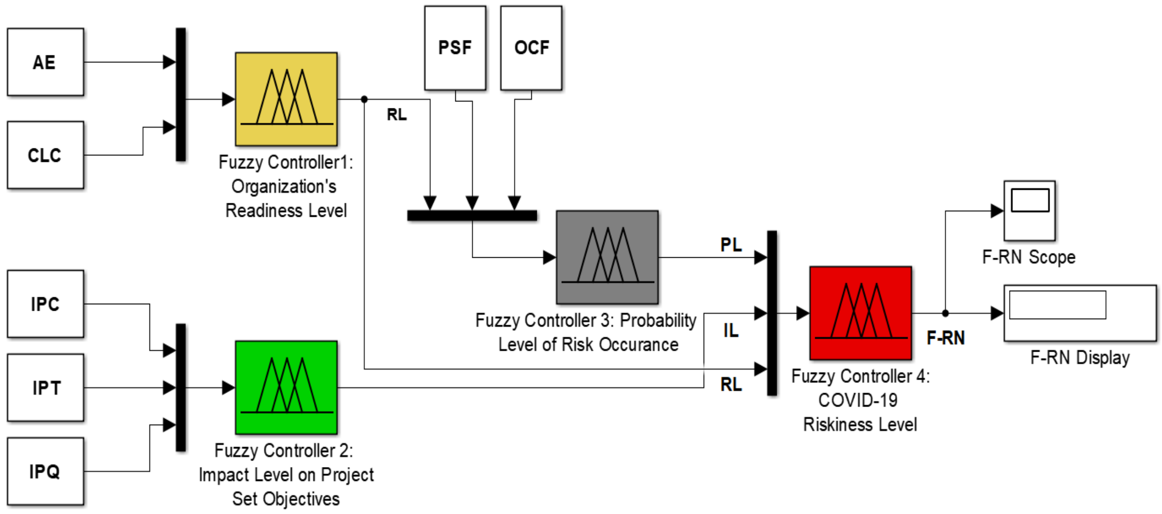

Figure 26. *The proposed risk analysis model (source: author)*

(COVID-19 risk assessment paper, Figure 4)

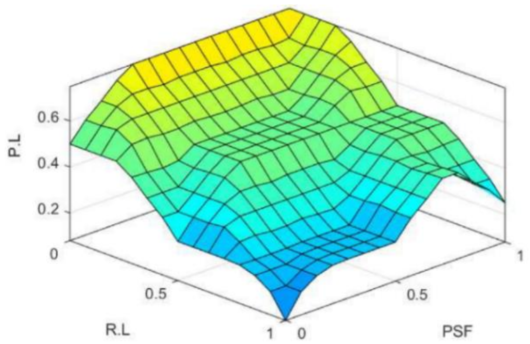

Figure 27. *Probability level surface*

(COVID-19 risk assessment paper, Figure 5)

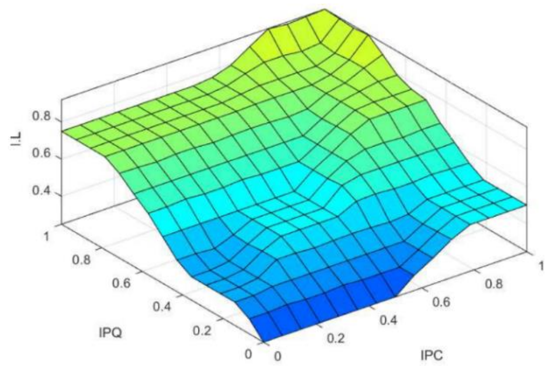

Figure 28. *Impact level surface*

(COVID-19 risk assessment paper, Figure 6)

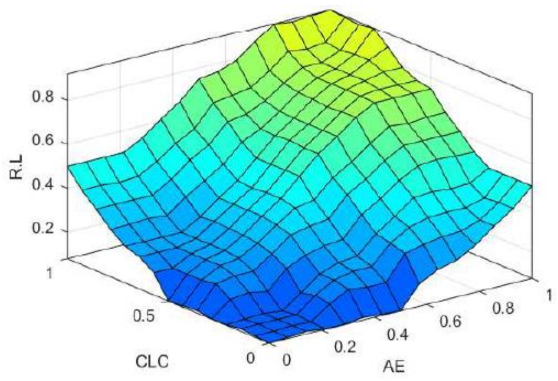

Figure 29. *Readiness level surface (COVID-19 risk assessment paper, Figure 7)*

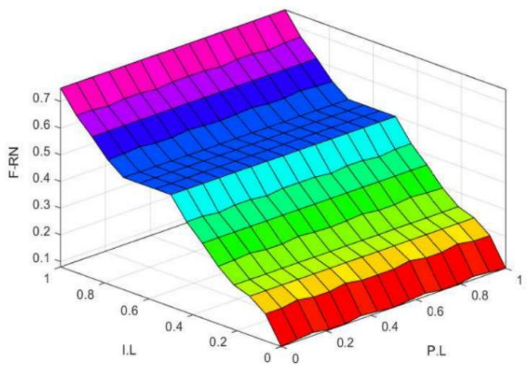

Figure 30. *COVID-19 risks riskiness level surface*

(COVID-19 risk assessment paper, Figure 8)

COVID-19 Risk Analysis

Upon developing the proposed model, we used the mean values of AE, CLC, PSF, OCF, IPC, IPT, and IPQ as inputs (crisp values) to the model as presented in columns 2 to 8 in Table 4 below. The mean values of inputs were (1) fuzzified using triangular membership functions (2) processed conditionally using IF-THEN rules as presented in Figure 2; (3) controlled using a Mamdani-type inference system, and defuzzified using the centre of area method. Ultimately, the riskiness level for each COVID-19 risk factor which is represented by F-RN and its rank was generated for all the risk factors as presented in columns 9 and 10 in Table 4.

Table 23. *Risk level for each COVID-19 risk factor (source: author)*

(COVID-19 risk assessment paper, Table 4)

Risk ID	Probability Level (Mean values)		Impact Level (Mean values)			Readiness Level (Mean values)		Fuzzy Risk Number (F-RN)	Rank
	PSF	OCF	IPC	IPT	IPQ	AE	CLC		
C01	0.42	0.56	0.64	0.33	0.29	0.23	0.16	0.6617	9
C02	0.85	0.65	0.53	0.41	0.74	0.30	0.26	0.7350	4
C03	0.72	0.63	0.23	0.52	0.16	0.28	0.31	0.5302	38
C04	0.71	0.59	0.48	0.67	0.69	0.16	0.13	0.6966	5
C05	0.62	0.81	0.78	0.94	0.63	0.22	0.25	0.8104	1
C06	0.63	0.76	0.38	0.95	0.32	0.34	0.27	0.5983	25
C07	0.73	0.89	0.68	0.39	0.56	0.47	0.32	0.6346	16

Table 23. *Continued.*

Risk ID	Probability Level (Mean values)		Impact Level (Mean values)			Readiness Level (Mean values)		Fuzzy Risk Number (F-RN)	Rank
	PSF	**OCF**	**IPC**	**IPT**	**IPQ**	**AE**	**CLC**		
C08	0.46	0.69	0.72	0.41	0.62	0.26	0.32	0.6471	13
C09	0.64	0.72	0.24	0.46	0.14	0.18	0.15	0.6353	17
C10	0.48	0.68	0.78	0.84	0.55	0.39	0.22	0.7520	3
C11	0.74	0.48	0.35	0.69	0.26	0.20	0.25	0.6587	10
C12	0.63	0.57	0.72	0.69	0.62	0.39	0.48	0.6165	22
C13	0.69	0.58	0.34	0.51	0.39	0.37	0.41	0.5223	40
C14	0.58	0.73	0.69	0.78	0.53	0.21	0.23	0.8098	2
C15	0.54	0.76	0.46	0.71	0.34	0.35	0.43	0.6020	24
C16	0.17	0.75	0.64	0.47	0.24	0.30	0.43	0.4751	42
C17	0.47	0.63	0.18	0.75	0.53	0.32	0.54	0.5631	34
C18	0.11	0.45	0.59	0.74	0.24	0.36	0.23	0.5507	36
C19	0.44	0.63	0.36	0.74	0.38	0.26	0.22	0.6681	7
C20	0.12	0.74	0.15	0.58	0.40	0.54	0.36	0.3912	46
C21	0.52	0.63	0.42	0.72	0.84	0.47	0.44	0.5938	27
C22	0.58	0.68	0.46	0.51	0.42	0.34	0.27	0.5263	39
C23	0.61	0.74	0.38	0.85	0.28	0.23	0.30	0.6038	23
C24	0.55	0.47	0.78	0.73	0.15	0.42	0.38	0.5651	33
C25	0.43	0.58	0.52	0.66	0.28	0.42	0.25	0.5598	35
C26	0.49	0.68	0.37	0.63	0.51	0.14	0.21	0.6755	6
C27	0.68	0.33	0.37	0.62	0.21	0.13	0.18	0.6504	11
C28	0.58	0.76	0.61	0.30	0.32	0.43	0.39	0.5918	29
C29	0.21	0.17	0.47	0.56	0.33	0.29	0.32	0.5817	31
C30	0.18	0.39	0.33	0.78	0.15	0.32	0.28	0.5183	41
C31	0.13	0.32	0.24	0.54	0.19	0.26	0.23	0.6439	14
C32	0.11	0.43	0.56	0.62	0.14	0.39	0.35	0.4017	45
C33	0.15	0.24	0.43	0.58	0.16	0.27	0.21	0.6279	19
C34	0.12	0.54	0.48	0.65	0.33	0.14	0.10	0.6433	15
C35	0.24	0.58	0.36	0.58	0.20	0.28	0.41	0.4680	43
C36	0.22	0.47	0.59	0.64	0.24	0.33	0.26	0.5506	37
C37	0.33	0.41	0.45	0.72	0.37	0.35	0.48	0.6218	20

Table 23. *Continued.*

Risk ID	Probability Level (Mean values)		Impact Level (Mean values)			Readiness Level (Mean values)		Fuzzy Risk Number (F-RN)	Rank
	PSF	**OCF**	**IPC**	**IPT**	**IPQ**	**AE**	**CLC**		
C38	0.30	0.29	0.53	0.68	0.31	0.42	0.34	0.5822	30
C39	0.34	0.81	0.38	0.58	0.14	0.22	0.19	0.6319	18
C40	0.53	0.43	0.22	0.51	0.17	0.13	0.24	0.6489	12
C41	0.42	0.57	0.35	0.44	0.26	0.21	0.28	0.6172	21
C42	0.13	0.84	0.67	0.64	0.44	0.24	0.29	0.6677	8
C43	0.61	0.76	0.56	0.21	0.48	0.40	0.55	0.4561	44
C44	0.49	0.76	0.31	0.57	0.39	0.25	0.36	0.5927	28
C45	0.56	0.49	0.41	0.53	0.20	0.34	0.18	0.5654	32
C46	0.42	0.58	0.32	0.49	0.13	0.29	0.26	0.5951	26

Discussion

This section discusses the top eight critical risks emerging from the COVID-19 pandemic in the construction industry depending on the findings of the developed assessment model. As mentioned in Stage Four of the research methodology, the analysis outputs were further discussed with the focus group session's experts to highlight their significance.

Contract Suspension

Contract suspension (C05) refers to temporary cessation of performance. In the context of Iraq, there are no specific construction regulations regarding health pandemics in the ICC and ICCCEW. In fact, a construction contract may be suspended under certain circumstances such as adverse weather conditions, national holidays, military operations, revolutions, rebellion, usurpation of power, civil wars and radiation hazards (ICCCEW, 1981).

The following quotes reflect the impression of many of the focus group session participants:

> *"The suspension of contractual obligations by any party affected by the COVID-19 pandemic was treated as an unexpected event that is beyond the parties' reasonable control, which allowed for work stoppages and time extensions [...]. For loss and expense, a contractor who suspends a contract under ICC and ICCCEW is not entitled to financial compensation from the owner, and the contractor must bear the entire cost and risk."*

This explains the results of this research, in which C05 was found to be one of the main risks facing the construction industry in Iraq (ranked first).

Contractor Bankruptcy

In the construction industry, there is typically a delay between the time the work is performed and the time that the payment is received. The majority of contracts provide for stage payments in arrears, resulting in the supply chain having substantial work in progress until the payments are received. Businesses may suffer from cash flow issues as a result of a lag in monetary recovery, because they are required to wait up to 90 days or more for their invoices to be paid. To this end, late payments by the client, and supply chain distribution due to extreme conditions and are the most significant causes of contractor's insolvency, which may ultimately lead to bankruptcy for the contracting company. As a result of the emergency financial crisis caused by the COVID-19 pandemic, construction companies have been unable to find sufficient workforce, materials, and equipment to continue their progress based on the planned activities and the project finish date (Assaad and El-adaway, 2021) which potentially led and continues to lead many contracting companies to file for bankruptcy (Strickland, 2020). For instance, and in the context of Iraq, the Iraqi Contract Conditions for Civil Engineering Works (ICCCEW, 1987) stated that during crises contractors are only entitled to time extensions without providing cost reimbursements which may also contribute to contracting companies' bankruptcy. Further, one of the focus group participants, who is a contractor in the private sector, highlighted the adverse impact of contractor bankruptcy (C14) in Iraq during COVID-19 pandemic on the construction market:

> *"The most bankruptcies during the COVID-19 era in Iraq were recorded for small and new contracting companies. This led to a scarcity of small construction companies, resulting in a void in the market that cannot be filled by large contractors […]. I believe the government should revise their policy and plan during periods of extreme conditions to provide financial support to small and new construction companies."*

This explains the results of this research, in which C14 was found to be one of the main risks facing the Iraqi construction industry during the COVID-19 pandemic (ranked second).

Materials Prices Escalation

Materials price escalation (C10) refers to a persistent rise in the prices of the materials used in construction. C10 is caused by a variety of factors, including inflation, supply and demand, politics, macroeconomics, and extreme conditions.

Construction materials typically increase in price each year due to inflation (a problem that contractors faced even prior to the pandemic). Inflation associated with the pandemic, however, has been very different and has played a significant role in the increase of construction costs. Iraq's construction industry heavily relies on foreign construction materials. As COVID-19 is a global pandemic, international factories that manufacture construction materials have experienced production delays. Thus, the supply of construction materials in Iraq dramatically decreased, and what was left became much more expensive.

The following quotes reflect the impression of many of the focus group session participants:

> *"The Iraqi supply chain was disrupted by the volatile global market, creating an increase in material costs largely linked to copper, aluminium, and other products, pushing prices out of reach across most industries."*

This explains the results of this research, in which C10 was found to be one of the main risks facing the Iraqi construction industry during the COVID-19 pandemic (ranked third).

Claims Arising Under a Construction Contract

C02 refers to the extent of integration of special construction terms into the contractual conditions to address health-related pandemics Globally, the COVID-19 pandemic continues to affect construction projects, leading to an increase in construction claims. Compared to developed countries, where vaccine roll-out is faster, contractors in developing countries anticipate that Covid-19 will continue to affect their projects and that the recovery of the industry will take longer than it does in developed countries (Olatunde *et al*., 2021).

One of the focus group session participants, who is an experienced project manager, had this to say:

> *"Iraq has introduced economic support measures in the majority of its major markets. However, no economic support has been provided to Iraq's construction sector [**…**]. Despite the fact that contracting companies are covered by insurance schemes in most countries, the insurance mechanism for contracting companies in Iraq is inadequate, resulting in many claims [**…**]. Even though some claims arising from delays related to Covid have been settled, we are still lacking clarity from courts and arbitral institutions regarding how these disputes will be resolved."*

This explains the results of this research, in which C02 was identified as one of the major risks facing the construction industry in Iraq (ranked fourth).

Non-compliance with Social Distancing Guidelines

Complying with social distancing is one of the best practices to reduce the spread of the virus in the construction industry (Assaad and El-adaway, 2021). Due to the rapid spread of COVID-19 virus worldwide and the extremely low vaccination rate in Iraq, the Iraqi central government has placed a great deal of emphasis on social distancing.

According to the participants in the focus group session, the vast majority of Iraqi construction workers do not adhere to the recommendations of COVID-19 regarding maintaining social distance and wearing personal protective equipment. On the other hand, experts stressed the importance of establishing onsite health and safety management units specialized in COVID-19 testing, enforcing social distancing measures, and ensuring that proper construction safety measures are in place to control the spread of the COVID-19 virus.

This explains the findings of this study, in which C26 was found to be one of the main risk factors affecting construction worker health and safety (ranked sixth).

Skills Shortage

Skills shortage (C19) refers to the state of the workforce at the market or project level. In developing countries, the shortage of skilled workers has posed a significant challenge to the construction industry during the COVID-19 pandemic (Olatunde *et al*., 2021). Most of the participants in the focus group indicated that the severe impact of COVID-19 on industries in general, and construction in particular, has contributed to a shortage of skilled workers in Iraq. Additionally, experts have identified several secondary factors that may contribute to this shortage, including (1) an increased retirement rate, (2) work-related injuries, and (3) unstable wages. This explains the results of this research, in which C19 was found to be one of the main risks facing the construction industry in Iraq (ranked seventh).

Poor Site and Virtual Communication

Several studies have identified poor communication practices as one of the major causes of project delays in the construction industry (Ruqaishi and Bashir, 2015; Seddeeq, 2019; Abdul Nabi and El-adaway, 2021). During COVID-19 era, the shift to video conferencing for regular meetings has been one of the most significant changes in the form of communication for industries (Encinas *et al*., 2021). However, this shift has been countered by many challenges, particularly in the context of developing countries like Iraq.

One of the focus group session participants, who is an experienced project manager, had this to say:

The inaccessibility of the internet, particularly at remote locations, is one of the primary obstacles to effective communication within project teams.

Furthermore, one of the focus group session's participants highlighted the following:

"Digital channels are less interpersonal and more difficult to engage the project team compared to site meetings."

This explains the results of this study, in which C42 was found to be one of the main risk factors impacting project performance (ranked eighth).

Conclusion

This research proposes a novel risk assessment model for construction projects under extreme conditions by considering the case of Iraqi construction industry during the COVID-19 pandemic era. We : (1) identified and classified the risk factors emerging from the COVID-19 pandemic in the construction industry; and (2) quantified the identified risks using multi-criteria risk in terms of their probability of occurrence, probability of risk occurrence, risk impact on project set objectives, and organization's level of readiness. First, we conducted a focus group session with 11 Iraqi construction experts to identify a list of COVID-19 risks for the construction industry. Second, a multi-criteria risk analysis model based on FST was established depending on experts' recommendations. Third, a survey was distributed to and answered by 194 construction professionals to quantify the PL, IL and the RL and their components (i.e., PSF, OCF, IPC, IPT, IPQ, AE, and CLC) for each identified risk factor. Finally, the identified COVID-19 risks were analysed using the developed model and validated by experts in a follow up focus group session. Ultimately, we identified a total of 46 risks categorized under five themes, namely contractual/legal Implications, construction financial market, health and safety of construction workforce, and organisational implications.

The results showed that the following eight risks were common factors affecting construction project objectives during COVID-19 era: (1) contract suspension; (2) contractor bankruptcy; (3) materials prices escalation; (4) claims arising under a construction contract; (5) inappropriate risk allocation; (6) non-compliance with social distancing guidelines; (7) skills shortage; and (8) poor site and virtual communication.

Methodological Implications

Previous research on COVID-19 and the construction industry has employed different tools to capture the negative impact on project objectives like agent-based modelling (Araya, 2021), and discrete-event simulation (Afkhamiaghd and Elwakil, 2020). This research proposed a new risk analysis model that considered the available expertise, company's level of contingencies, political and security factors, out of control factors, and the impact on the project, time, cost, and quality. In addition, this research employed the proposed model under the fuzzy environment to formalize and deal with human knowledge and uncertainties in decision making (Al-Mhdawi, 2020; Islam and Nepal, 2016).

Theoretical and Practical Implications

The outputs of this study will be of great benefit to construction decision-makers and academics in terms of providing a better understanding of the significant risks emerging from the COVID-19 pandemic. In addition, this paper presents a novel model for analysing extreme conditions' risks related to COVID-19 pandemic and further pandemics. Ultimately, the outcomes of this research would enhance the risk management effectiveness in the construction industry of developing countries and minimize project losses by capturing the role of organization's level of readiness and considering the components of analysis criteria which are much needed when projects are subjected to high levels of uncertainties during extreme conditions.

Research Limitation

Despite its value, this study has some limitations. First, this research relies on expert judgment through focus group sessions and questionnaire surveys. Other methods, such as project-based case studies, should be considered to complement the results. Third, we identified only 46 risks that were classified under five main construction themes. Other risks emerging from the COVID-19 pandemic should be identified and classified under the study existing themes or under new construction themes. Finally, not all the stakeholder's groups were involved in the COVID-19 risk identification and analysis. Other stakeholders such as suppliers and end-users should be invited to conduct follow up studies.

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.

Abdulhussein, H. and Shibaani, A., 2016. Risk management in construction projects in Iraq: contractors' perspective. *International Journal of Engineering Research*, *4*(3), pp.114-130.

Afkhamiaghd A M, Elwakil E. 2020. Preliminary modeling of Coronavirus (COVID-19) spread in construction industry. Journal of emergency management (Weston, Mass.), *18*(7), pp.9-17.

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*, *20*(1), pp.222-244.

Al Mhdawi, M.K., 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 P, Qazi A, Rashid H A. 2022 (In press). Modeling the effects of construction risks on the performance of oil and gas projects in developing countries: project managers' perspective. Proceedings of Civil Engineering Research in Ireland (CERI 2022).

Al Mhdawi, M.K., 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.

Alsharef, A., Banerjee, S., Uddin, S.J., 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. and Simpeh, F., 2020. Implementation challenges of COVID-19 safety measures at construction sites in South Africa. *Journal of Facilities Management*, *19* (1), pp. 111-128.

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

Assaad, R. and 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), p.06021001.

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

Bin Seddeeq, A., Assaf, S., Abdallah, A. and Hassanain, M.A., 2019. Time and cost overrun in the Saudi Arabian oil and gas construction industry. *Buildings*, *9*(2), pp.1-17.

Breen, R.L., 2006. A practical guide to focus-group research. *Journal of geography in higher education*, *30*(3), pp.463-475.

Brewer, G., Gajendran, T. and Le Goff, R., 2012. Building information modelling (BIM): Australian perspectives and adoption trends. *Centre for Interdisciplinary Built Environment Research (CIBER).*

Buniya, M.K., Othman, I., Durdyev, S., Sunindijo, R.Y., Ismail, S. and Kineber, A.F., 2021a. Safety program elements in the construction industry: the case of Iraq. *International journal of environmental research and public health*, *18*(2), pp.1-13.

Buniya, M.K., Othman, I., Sunindijo, R.Y., Kineber, A.F., Mussi, E. and Ahmad, H., 2021b. Barriers to safety program implementation in the construction industry. *Ain Shams Engineering Journal*, *12*(1), pp.65-72.

Casady, C.B. and Baxter, D., 2020. Pandemics, public-private partnerships (PPPs), and force majeure| COVID-19 expectations and implications. *Construction Management and Economics*, *38*(12), pp.1077-1085.

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.

Cox A. 2008. What's wrong with risk matrices?. *Risk Analysis: An International Journal*, *28*(2), pp.497-512.

Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Elbarkouky, M.M., Fayek, A.R., Siraj, N.B. and Sadeghi, N., 2016. Fuzzy arithmetic risk analysis approach to determine construction project contingency. *Journal of construction engineering and management*, *142*(12), p.04016070.

Encinas, E., Simons, A. and Sattineni, A., 2021. Impact of COVID-19 on Communications within the Construction Industry. *EPiC Series in Built Environment*, *2*, pp.165-172.

Deloitte. 2017. “Deloitte GCC Powers of Construction 2017, If it’s fundable it’s feasible”. Accessed June 14, 2021.https://www2.deloitte.com/content/dam/Deloitte/xe/Documents/realestate/construction/gccpowersofconstruction/ me_construction_gccpoc2017.pdf

Gunduz, M., Nielsen, Y. and Ozdemir, M., 2015. Fuzzy assessment model to estimate the probability of delay in Turkish construction projects. *Journal of Management in Engineering*, *31*(4), p.04014055.

Hoseini, E., Hertogh, M. and Bosch-Rekveldt, M., 2021. Developing a generic risk maturity model (GRMM) for evaluating risk management in construction projects. *Journal of Risk Research*, *24*(7), pp.889-908.

Kassem, M.A., Khoiry, M.A. and Hamzah, N., 2019. Using probability impact matrix (PIM) in analyzing risk factors affecting the success of oil and gas construction projects in Yemen. *International Journal of Energy Sector Management*, *14*(3), 527-546.

IOM (International Organization for Migraiton). 2020. “Impact of COVID19 on small and medium-sized enterprises in Iraq”. Accessed January 4, 2021. 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.

King, S.S., Rahman, R.A., Fauzi, M.A. and Haron, A.T., 2021. Critical analysis of pandemic impact on AEC organizations: The COVID-19 case. *Journal of Engineering, Design and Technology*, *20*(1), pp. 358-383.

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

Market Research Iraq. 2021. “Construction and Infrastructure”. Accessed June 18, 2021. https://www.marketresearchiraq.com/industry/construction-infrastructure.

Matsunaga, H., 2019. *The reconstruction of Iraq after 2003: learning from its successes and failures*. World Bank Publications.

Mazher, K.M., Chan, A.P., Zahoor, H., Khan, M.I. and Ameyaw, E.E., 2018. Fuzzy integral–based risk-assessment approach for public–private partnership infrastructure projects. *Journal of Construction engineering and Management*, *144*(12), p.04018111.

McKibbin, W. and Fernando, R., 2021. The global macroeconomic impacts of COVID-19: Seven scenarios. *Asian Economic Papers*, *20*(2), pp.1-30.

McKinsey global institute. 2020. “Reinventing Construction”. Accessed August 22, 2021. https://www. mckinsey.com

Mohamed M, Tran D Q. 2021. Risk-Based Inspection Model for Hot Mix Asphalt Pavement Construction Projects. *Journal of Construction Engineering and Management*, *147*(6): 04021045.

Islam, M.S. and Nepal, M., 2016. A fuzzy-Bayesian model for risk assessment in power plant projects. *Procedia Computer Science*, *100*, pp.963-970.

OECD (Organisation for Economic Co-operation and Development). 2020. “Coronavirus (COVID-19): SME policy responses”. Accessed July 01, 2022. https://www.oecd.org.

Olatunde, N.A., Awodele, I.A. and Adebayo, B.O., 2021. Impact of COVID-19 pandemic on indigenous contractors in a developing economy. *Journal of Engineering, Design and Technology*, *20*(1), pp. 267-280.

Pamidimukkala, A., Kermanshachi, S. and Jahan Nipa, T., 2021, June. Impacts of COVID-19 on health and safety of workforce in construction industry. In *International Conference on Transportation and Development 2021* (pp. 418-430).

Parasher, A., 2021. COVID-19: Current understanding of its pathophysiology, clinical presentation and treatment. *Postgraduate medical journal*, *97*(1147), pp.312-320.

Qazi, A., Shamayleh, A., El-Sayegh, S. and Formaneck, S., 2021. Prioritizing risks in sustainable construction projects using a risk matrix-based Monte Carlo Simulation approach. *Sustainable Cities and Society*, *65*, p.102576.

Rehman, M.S.U., Shafiq, M.T. and Afzal, M., 2021. Impact of COVID-19 on project performance in the UAE construction industry. *Journal of Engineering, Design and Technology*, *20* (1), pp. 245-266.

Research and Markets. 2019. “Construction in Iraq key trends and opportunities to 2023”. Report ID: 4846333. Accessed May 27, 2021. https://www.researchandmarkets.com/reports/4846333/construction-in-iraq-key-trends-and

Ruqaishi, M. and Bashir, H.A., 2015. Causes of delay in construction projects in the oil and gas industry in the gulf cooperation council countries: a case study. *Journal of management in engineering*, *31*(3), p.05014017.

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.

Shahbazi, B., Akbarnezhad, A., Rey, D., Ahmadian Fard Fini, A. and Loosemore, M., 2019. Optimization of job allocation in construction organizations to maximize workers' career development opportunities. *Journal of Construction Engineering and Management*, *145* (6).

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

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), pp.425-437.

Tabish, S.Z.S. and Jha, K.N., 2018. Beyond the iron triangle in public construction projects. *Journal of Construction Engineering and Management*, *144*(8), p.04018067.

Walter, D., 2020. Implications of Covid-19 for labour and employment in India. *The Indian Journal of Labour Economics*, *63*(1), pp.47-51.

Yates, J.K., 2014. Design and construction for sustainable industrial construction. *Journal of construction engineering and management*, *140*(4), p.B4014005.

World Bank. 2020. “Iraq Economic Monitor, fall 2020 : Protecting Vulnerable Iraqis in the Time of a Pandemic, the Case for Urgent Stimulus and Economic Reforms”. Accessed June 25, 2021. https://openknowledge.worldbank.org/handle/10986/34749 License: CC BY 3.0 IGO.”

Zadeh, L.A., 1965. Information and control. *Fuzzy sets*, *8*(3), pp.338-353.

World Bank. 2022. “The world bank in Iraq”. Accessed March 13, 2022. https://www.worldbank.org/en/country/iraq/overview.

Chapter 4. Modelling the Direct and Indirect Effects of the Covid-19 Pandemic Risks on the Success of Iraqi Construction Projects

Abstract

The purpose of this paper is to capture the direct and indirect effects of COVID-19 emerging risks on construction projects' success in developing countries from the contractors' perspective. To achieve this, we collected data from Iraqi construction industry and conducted the following multi-stage research methodology: (1) preliminary investigation with four construction contractors to identify the success indicators of construction projects; (2) literature review to identify the COVID-19 emerging risks for the construction industry; (3) semi-structured interviews with seven construction experts to develop several hypotheses on the effect of COVID-19 emerging risks on project success; (4) survey data collection from 99 construction contractors; and (5) development of a Structural Equation Model (SEM) to analyse the effects of COVID-19 emerging risks on project success.

The results of the SEM analysis show that Construction Financial Market (CFM)-related risks, Supply Chain Operations (SCO)-related risks, Health and Safety of Construction Workforce (HSCW)-related risks, Organisational Implications (OI)-related risks, and Contractual Implications (CI)-related risks have a significant impact on construction projects success. CI-related risks have the strongest total effects on project success, followed by OI-related risks, CFM-related risks, HSCW-related risks, and SCO-related risks, respectively. The results also emphasis the significant mediation role of CI between COVID-19 emerging risks and project success.

This study contributes to the body of knowledge and contracting companies by helping researchers and construction contractors to better understand how the key risk factors emerging from extreme conditions like COVID-19 pandemic affect construction projects' success and may serve as a guideline for developing effective response strategies.

Introduction

Coronavirus disease, caused by severe acute respiratory syndrome, was reported for the first time in Wuhan city, China, in late 2019. In March 2020, the World Health Organization declared the disease a pandemic due to its infectious nature and rapid spread (Singhal, 2020).

In the years preceding the pandemic, the construction sector contributed around 7.7 percent to global employment and was predicted to contribute 13.4 percent of global GDP by 2020 (ILO, 2021). Due to the highly sensitive nature of the construction industry to economic cycles, construction enterprises and workers were particularly affected by the economic downturn caused by the pandemic. In fact, the construction industry suffered from a noticeable reduction in construction jobs (Alsharef *et al*., 2021), materials prices escalation (Al-Mhdawi *et al*., 2022a), delayed contractors' payments (Agyekum *et al*., 2021), supply chain disruption (Khalfan and Ismail 2020; Butt 2021; Rahman *et al*., 2021), reduced demand for construction-related works (King *et al*., 2021), and construction claims and disputes (Salami *et al*., 2021).

COVID-19 has been associated with numerous positive cases and deaths worldwide. The positive cases and mortality rates in developing countries, however, are higher than those in developed countries (Gill and Schellekens, 2021). This is attributed to poor public health and safety awareness (Amoah and Simpeh, 2021), the lack of compliance with global guidelines regarding face masks, and the lack of compliance with social distance measures.

The COVID-19 pandemic has been reported to have similar characteristics and behaviours to the construction industry in developing countries, as indicated by several studies, resulting in changes in laws, business closures, suspension and termination of construction contracts, significant challenges to the labour market, and other difficulties experienced by developers, contractors, and vendors (Agyekum *et al*., 2021). In Iraq, the construcion companies are experiencing major disruptions and difficulties as a result of the impact of the COVID-19 pandemic and its arising risks. Based on OECD (2020), many contracting companies in Iraq are experiencing losses in profits due to the adverse impact of the pandemic's risks. In fact, Al-Mhdawi (2022a) found that construction contractors were the most affected by the pandemic, which adversely affected the successful completion of projects within the agreed budgets, planned schedules, and approved specifications. Several other developing countries have also observed similar adverse effects of the pandemic, including Egypt (Elnaggar and Elhegazy, 2022), Ghana (Agyekum *et al*. 2021); Iran (Rokooei *et al*., 2022), India (Rani *et al*., 2022); and Peru (Bancalari and Molina, 2020), and Vietnam (Nguyen *et al*., 2021).

To this end, it is imperative for the construction industry to clearly understand how the COVID-19 pandemic has affected the success of construction projects, particularly with the lack of evidence on how construction projects survived during past pandemics such as 1918

Pandemic (H1N1 virus), 1957-1958 Pandemic (H2N2 virus), 1968 Pandemic (H3N2 virus), and 2009 Pandemic (H1N1pdm09 virus). Accordingly, the purpose of this research is to quantitatively analyze the direct and indirect effects of the significant risks emerging from the COVID-19 pandemic on Project Success (PS) in developing countries by considering the case of Iraqi construction industry.

The Construcion Industry of Iraq

Pre-2013, the construction industry performed below its potential due to an unstable economic, regulatory, and policy environment, limited financing options, as well as delays in obtaining construction licenses. Iraq's construction sector reached its peak in 2013 with an estimated value of 20.2 trillion IQD (UNESCO 2015). In 2014, the sector experienced a sharp decline, falling to 18.2 trillion IQD (-10%), after which it further declined to 9.1 trillion IQD (-50.2%) in 2015. (UNESCO, 2015). This was due to two key factors:

1. Falling oil prices in 2014. Most of the investment in construction comes from public funds which highly depends on oil production. Oil and Gas revenue in Iraq contributes to around 65% of its gross domestic product (GPD), and over 90% of the public income and most of its foreign exchange revenue (Al-Mhdawi, 2020). It is, therefore, central to the country finical position and critical to the vitality of the country economy and the ongoing construcion activities and reconstruction efforts of the country. Thus, instability of oil prices has major impact on other industries, including construcion.
2. Armed conflicts in 2014. Following the last war in 2014, the Iraqi construction sector was greatly affected in several major cities in the north and west of the country. This resulted in a significant deterioration of Iraq's critical infrastructure and housing projects (Al-Qaicy and Breesam, 2021).

In the period between 2016 and 2019, oil prices substantially increased, resulting in an increase of 13 trillion IQD in the value of the Iraqi construction industry, as a result of the government's investments in the reconstruction of war-damaged property, infrastructure for housing, health care, education, and transportation.

During the period following 2020, the construction industry in Iraq experienced a 40.2% decline in its value as a result of the COVID-19 pandemic and subsequent containment measures implemented to prevent the spread of the disease (BW, 2021). As of March 2020, the Iraqi government declared that the pandemic was an event of force majeure for all projects and contracts. This, however, had a negative impact on the progress and successful delivery of projects. To this end, the effects of COVID-19 emerging risks have resulted in a variety of consequences for construction industry stakeholders, including construction contractors, investors, suppliers, and the construction workforce. This resulted in shortages of supplies and labour, suspensions, and, in some cases, termination of construction contracts (Alsamarraie and Ghazali, 2021).

Existing challenges facing the success of construcion projects in Iraq

Through the years, the construction industry in Iraq has faced and continues to face a variety of challenges. One of these is related to funds. The majority of funds allocated to the construction sector are public funds. Therefore, government and political dynamics play a significant role in the development of this industry. Unfortunately, the unrest in the government and the unstable security environment have hindered the growth of this sector, as evidenced by the destruction of critical infrastructure and housing projects caused by internal armed conflicts. Another challenge is administrative-related issues. For instance, Mahmoud (2020) found that faulty leadership, inadequate contractor qualifications, and poor team selection can all contribute to project failure. Additionally, there are challenges associated with consultants and contractors. Construction project success can also be negatively affected by the quality of consultants' designs and drawings, as well as insufficient specifications (Jahanger, 2013; Bekr, 2015).

A number of project issues may also be attributed to the owners, such as delays in payment and excessive interference with the project, which can significantly hinder the successful completion of the project (Aljamee, 2020). There is also a serious issue of corruption in Iraq's government system, as the country ranks 157 out of 180 in Transparency International's Corruption Perceptions Index for 2021, making it one of the 23 lowest-ranking countries in the world. Economic activity in the sector is strongly discouraged by corruption. In addition, it leads to negligence and non-compliance with laws and regulations (Al-karawi, 2018). Furthermore, project management practices in the construction industry are generally lacking, particularly when it comes to managing risks. In fact, Iraqi contracting companies face a number of challenges in mitigating risks in an environment characterized by poor suppliers, absence of investment, unskilled workers, logistical difficulties, and poor risk and safety management practices (Al-Mhdawi, 2020; Al-Mhdawi *et al*., 2020). This is considered to be one of the key commonalities of the construction industry in developing countries (Darvas and Palmer, 2014; Boadu *et al*., 2020).

To this end, the authors chose the construcion industry of Iraq as a case study in this research which reflects the unique characteristics of the COVID-19 pandemic and the risks it poses to the vast majority of developing countries.

Knowledge gap

Table 1 summarizes the existing body of research work. To the best of the authors knowledge, very limited research captured the impact of the COVID-19 pandemic on construction projects success. Most of the available efforts have investigated the impact of the pandemic on the construction industry either in general (see e.g., Salami *et al*., 2021; Umar, 2022; Al-Mhdawi *et al*., 2022a; and others), or on a specific construction operation such as health and safety (see e.g., Kukoyi *et al*., 2021; Chigara and Moyo, 2021; and others). Furthermore, the existing studies focused mainly on the impact of the pandemic on the construction industry from a broader perspective of construction experts rather than focusing on construction contractors, despite the fact that literature indicates that contractors are significantly vulnerable to the risks associated with the pandemic (Olatunde *et al*., 2021). To this end, the current studies fall short in addressing the direct and indirect effects of COVID-19 emerging risks on PS from the perspective of construcion contractors in terms of meeting project delivery deadlines within the agreed budget and specified quality while maintaining a high safety profile, commercial profitability, functionality, and client/end-user satisfaction. This research, therefore, fills this knowledge gap by considering the case of the Iraqi construction contractors.

Table 24. *Summary of existing studies (source: author)*
(COVID-19 and project success paper, Table 1)

Reference	Region	Purpose	Methods	Findings
Agyekum *et al*. (2021)	Ghana	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.	Interviews	Findings indicated that the impact of the COVID-19 pandemic had resulted in a significant reduction in productivity, increased materials costs, and delayed payments. In addition to providing personal protective equipment, construction companies have implemented a number of other measures, including regular and effective screenings at entrances and exits from the job site and educating the workers about the virus.
Alsharef *et al*. (2021)	United States	Investigated the early adverse effects and opportunities of the COVID-19 pandemic on the construction industry in the United States	Interviews	The results indicated that the COVID-19 pandemic had caused material price escalation, reduced productivity rates, delayed project delivery, and supply chain disruption. On the other hand, the new emerging opportunities included recruiting skilled workers and constructing medical facilities on a fast-track basis.

Table 24. *Continued.*

Chigara and Moyo (2021)	Zimbabwe	Investigated the perceptions of construction professionals in relation to factors that affect the delivery of optimal health and safety on construction projects during the COVID-19 pandemic.	Survey and factor analysis	Findings indicated that the delivery of optimum health and safety during the COVID-19 pandemic were affected by job security and funding-related, production-related, access to information and health service-related, on-site facilities and welfare-related, risk assessment and mitigation-related, the change and innovation-related, cost-related, and COVID-19 risk perception-related, and monitoring and enforcement related factors.
Umar (2022)	Gulf Cooperation Council	Examined the effect of the COVID-19 pandemic on the construction industry in the Gulf Cooperation Council (GCC) members countries and provided recommendations on how to help the industry survive during this period of crisis.	Interviews	Findings indicated that the impact of the COVID-19 pandemic had caused project delays, workforce management disruption, health and safety issues, and legal implications.
King *et al*. (2021)	Malaysia	Analysed the interrelationships between the COVID-19 pandemic and the architectural, engineering, and construction organizations.	Literature review and interviews	Findings indicated that small- and medium-sized enterprises are significantly impacted by a disruption in the supply chain, reduced demand for construction-related works, reduced number of public projects, reduced demand for construction-related works, reduced construction productivity, reduced foreign investment in the construction industry, and reduced foreign investment in the construction industry. In addition, the decline in foreign investment in the construction sector was moderately correlated with decreased demand for construction works, disruptions in the supply chain, and reduced productivity.
Olukolajo *et al*. (2021)	Nigeria	Examined the level of compliance of construction site workers with various Covid-19 protocols while working on construction sites.	Survey	Findings indicated that although the workers were aware of the Covid-19 pandemic, their attitudes about preventive measures on construction sites were concerning.

Table 24. *Continued.*

Olatunde *et al*. (2021)	Nigeria	Investigated the impact of the Coronavirus Disease 2019 (COVID-19) on indigenous contractors in a developing economy in order to enhance their performance.	Interviews	Findings of the study indicated that indigenous contractors experienced a loss of profit and the creation of disputes, time overruns, increased local material prices, and disruption in supply chains due to COVID-19.
Rehman *et al*. (2021)	United Arab Emirate	Studied the impact of COVID-19 on construction project performance in the UAE	Interviews	Findings indicated that the performance of construction projects was adversely affected by several challenges, including delayed permits, disrupted cashflows, material and equipment shortages, serious health and safety concerns, travel restrictions, and schedule delays.
Salami *et al*. (2021)	United Kingdom	Investigated the adopted methodologies and practices implemented by construction companies in the United Kingdom to mitigate litigation risks arising from potential contract breaches resulting from COVID-19.	Descriptive statistics, exploratory factor analysis, and reliability analysis.	Findings indicated a number of effective strategies, such as establishing and maintaining good relations with contractual partners, timely reporting of potential disputes, collaborating with parties for goodwill, making early decisions on-site closures, and reviewing contractual provisions for information about notice periods.
Araya (2021)	General	Modeled the potential impact of COVID-19 on construction workers	Agent-based simulation	Findings indicated that the workforce involved in a construction project might decline by 30% to 90% as a result of COVID-19 impact

Methodology

This paper follows a multi-stage research methodology, as shown in Figure 1. Details of each stage are described in the following sub-sections.

Stage One: Identification of Construction Project Success Indicators

In this research, the authors conducted a preliminary investigation with four experienced construction contractors in Iraq to identify the main indicators of construction PS. To this end, the authors identified eight indicators, namely (time, cost, quality, safety, commercial profitability, functionality, client satisfaction, and end-user satisfaction). Each indicator is described as follows:

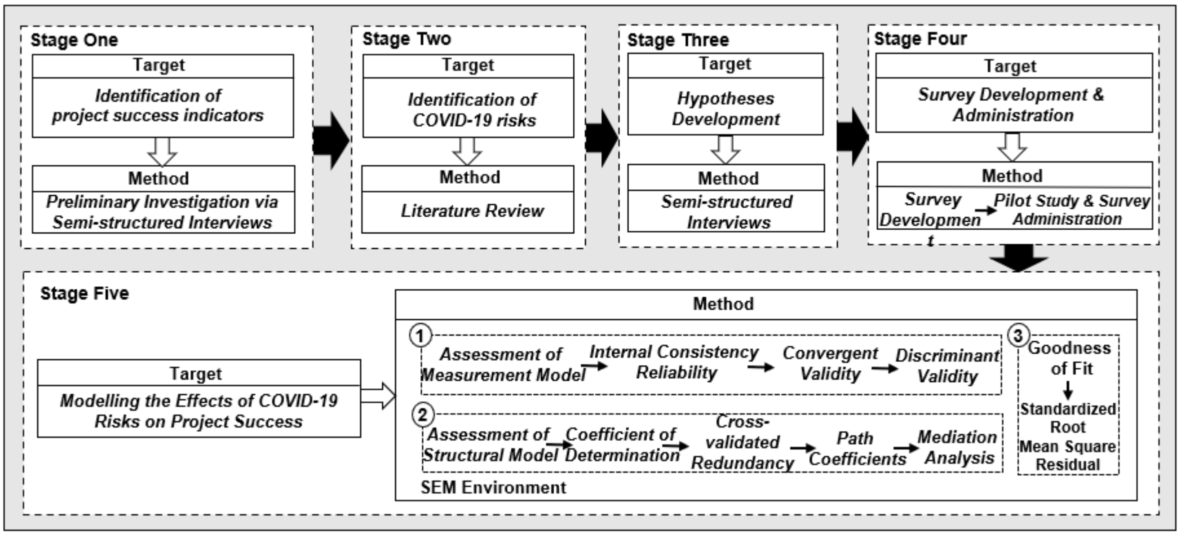

***Figure 31**. Research methodology (source: author)*

(COVID-19 and project success paper, Figure 1)

1. **Time.** Time refers to the degree to which the general conditions promote the completion of a project within the allocated duration (Chan and Chan, 2004; Hughes *et al*., 2004), and it can be measured by construction duration (Czarnigowska and Sobotka, 2013) and time overrun (Shehu *et al*., 2014).
2. **Cost.** Cost refers to the extent to which the general conditions enable a project to be completed within the estimated budget (Ali and Rahmat, 2010), and it can be measured by cost overrun (Durdyev *et al*., 2014), as well as unit cost (Chan and Chan, 2004).
3. **Quality.** Quality refers to the extent to which the general conditions promote the meeting of the project's established requirements for workmanship and materials (Chan and Chan, 2004), and it can be expressed in terms of technical specifications, appearance, and function (Ab Sani and Othman, 2012).
4. **Safety.** Safety is an aspect of construction-related activities that is concerned with preventing death, personal injury, disease, or any other health-related risks from occurring (Ferrett, 2015).
5. **Commercial Profitability.** Commercial probability refers to the degree to which a project yields profit or financial success, and it is calculated as the difference between the total revenue and the processing costs (Majer *et al*., 2020).
6. **Functionality.** Functionality refers to the purpose of a building or structure, its operation, process, or performance. Based on Chan *et al*. (2002), this indicator correlates with the expectations of project participants, which can be best evaluated by assessing the degree of conformance to technical performance specifications.

7. **Client satisfaction.** Client satisfaction refers to the extent to which the project requirements have been met. Many factors contribute to client satisfaction, including successful work performance (Saunders *et al*., 2016), the number of complaints issued to project managers, and the ability of these managers to resolve them (Sarhan *et al*., 2017), effective relationship, leadership, and communication skills (Wu *et al*., 2016), effective waste management (Onubi and Hassan, 2020), honesty, maintaining trusting relationships (Jiang, 2016), as well as ensuring that quality raw materials and effective processes are utilized, and all work is performed within budget and in compliance with standards and agreed specifications (Zhou *et al*., 2015).
8. **End-user satisfaction.** End-user satisfaction refers to the extent to which a contractor fulfils the customer's expectations. End-user satisfaction is crucial to the development of the construction process. With increasing competition, construction companies pay more attention to end-user relationships and satisfaction (Karna *et al*., 2004). End-user satisfaction can be evaluated by serval factors such as structure accessibility, materials quality, and the use of technology.

Stage Two: Identification of COVID-19 Risks

This research utilized the COVID-19 risks that were identified by Al-Mhdawi *et al*. (2022b). In their work, the authors conducted a focus group session with 11 Iraqi construction experts and identified a comprehensive list of 46 risks impacting the construction industry market, supply chain operations, health and safety of the construction workforce, and contractual and organisational aspects. These risks are presented in Table 2.

Table 25. *COVID-19 risks for construction projects (source: Al-Mhdawi et al., 2022b)*

(COVID-19 and project success paper, Table 2)

Theme	**COVID-19 risks**
Construction Financial Market	**C01.** Increase` insurance rates
	C02. Increase of tax rate
	C03. Fluctuation in currency rates of exchange
	C04. Materials prices escalation
	C05. Equipment prices escalation
	C06. Reduction in labour wages
	C07. Lack of fiscal headroom for local Government.
	C08. Contractors' bankruptcy
	C09. Delayed in payments **C10.** Suppliers' bankruptcy

Table 25. *Continued.*

Theme	COVID-19 risks
Supply chain operations	**S01.** Scarcity of manpower
	S02. Lack of construction sub-contractors
	S03. Skills shortage
	S04. Machine failure
	S05. Damaged materials*
	S06. Construction materials shortage
	S07. Material delivery delays
	S08. Cargo theft
	S09. Monopolization of construction materials
Health and safety of construction workforce	**H01.** Non-compliance with social distancing guidelines
	H02. Increased subsidy rates
	H03. Psychological stress
	H04. Poorly ventilated spaces
	H05. Delays caused by workforce self-isolating
	H06. Virus spreading due to poor hygiene and lack of sanitizing stations
	H07. Virus spreading in commonly used or high traffic construction area
	H08. Lack of cleanliness and sterilization of commonly used surfaces, tools, and workstations by construction workers.
	H09. Contracting or spreading the virus when traveling to work
	H10. Contracting or spreading the virus in changing rooms, showers, and toilets facilities.
	H11. Contracting or spreading the virus during site meetings and training.
	H12. Lack of face masks or coverings
	H13. Re-using face masks or covering
Organisational Implications	**O01.** Delays caused by confusion arising out of the status or effect of government guidance.
	O02. Delayed due to Municipalities' prolonged procedures and routine
	O03. Delayed work inspection and approval.
	O04. Poor site and virtual communication
	O05. Restricted site access
	O06. Delayed contractor mobilization to the site.
	O07. Delay of work progress and reporting
	O08. Delayed design submission

Table 25. *Continued.*

Legal Implications	**L01.** Lack of clarity of the contract language
	L02. Claims arising under a construction contract
	L03. Change of law
	L04. Inappropriate risk allocation
	L05. Contract suspension
	L06. Contract termination

*****Damaged construction materials are due to forced prolonged time in storage, and poor storage of materials on construction sites.

Stage 3: Hypotheses Development

Until recently, few studies have examined the impact of the COVID-19 pandemic and its emerging risks on the construction industry. However, the current literature lacks empirical evidence to assess the extent to which COVID-19 emerging risks may impact construction PS. To this end, the authors conducted semi-structured interviews with construction experts in Iraq to establish the interaction hypotheses between PS and COVID-19 emerging risks that are categorized under five themes, namely: Construction Financial Market (CFM)-related risks, Supply Chain Operations (SCO)-related risks, Health and Safety of Construction Workforce (HSCW)-related risks, Organisational Implications (OI)-related risks, and Contractual Implications (CI)-related risks. The authors chose this method of data collection since there were few studies on COVID risks in the construction industry conducted internationally and locally (in the context of Iraq). Further, this method is effective in exploring and gaining a deeper understanding of phenomena and situations (Cachia and Millward, 2011), and it has been extensively used in previous research to identify the risks and barriers associated with engineering management (Hasanzadeh *et al*., 2020).

In order to select the interview participants, the authors used a purposive sampling method whereby the interviewer contacts potential participants who are known to be area experts (Creswell and Clark, 2011). The authors, therefore, approached experts working as general contractors and risk management academics. Another selection criterion for the interviews is that the experts must possess extensive experience in the construction industry in Iraq.

Ultimately, the authors conducted seven semi-structured interviews with experts working in Iraq's public and private construction sectors and with not less than 15 years of experience in contracting companies, counselling centres, and educational institutions. For data analysis, the authors analysed the interviews outputs manually using the content analysis technique. Content analysis refers to a technique of identifying, either quantitatively or qualitatively, the most significant patterns in verbal, written, or communication messages (Krippendorff, 2013).

Stage Four: Survey Development and Administration

Survey Development

The purpose of the survey was to examine the effects of COVID-19 related risks on the success of construction projects in Iraq. There were three sections in the questionnaire survey. The first section precedes the main body of the survey, and it sets forth the objectives of this study. In the second section, respondents provided demographic information, which comprised information about their working sector, their experience, and their educational background. The third section examined the respondents' perceptions about the effects of COVID-19 risk factors on PS. CFM construct compromises 10 items/risks; example items include reduction in labour wages. SCO construct has a total of nine items; example items include construction materials shortage. HSCW construct has a total of 13 items; example items include delays caused by workforce self-isolating. OI construct has a total of 8 items; example items include delays caused by confusion arising out of the status or effect of government guidance. LI construct has six items; example items include *inappropriate risk allocation.* Finally, the PS construct has a total of eight items; example items include client satisfaction. This section consisted of questions that solicited the perceived agreement of the risk factors that influenced PS and its indicators on a five-point Likert scale ranging from “1” referring to “strongly disagree” to “5” referring to “strongly agree." The Likert scale is commonly used with SEM research (see, e.g., Krajangsri and Pongpeng, 2017).

Pilot Study and Survey Administration

Prior to administering a questionnaire survey to a large-scale sample size, conducting a pilot study can help to provide more response choices, more questions relevant to the characteristics of the sample, identify potential for misunderstanding of instructions, and remove redundant questions (Al-Mhdawi *et al*., 2022c), and to ensure the suitability and comprehensiveness of the questionnaire (Yang and Shen, 2015). In this research, the authors conducted a pilot study with five contractors who work in the private and public construction sectors in Iraq. Further, all the respondents who participated in the pilot study had worked in the construction industry for more than 15 years. As part of the pilot study, respondents were asked to provide comments and feedback on the survey in terms of adding or removing questions, clarifying the language required to ensure consistency in understanding among all respondents; and correcting typographical errors within the survey.

In the end, the authors modified the survey in accordance with the comments of the pilot study respondents; the final version was administered to construction contractors working in public and private construction sectors in Iraq. The authors targeted experts who are involved in the Iraqi construction industry and who are registered contracting companies with the Iraqi Ministry of Trade. Ultimately, the authors administered the survey to a total of 250 construction contractors.

Stage Five: Modelling the Effects of COVID-19 Emerging risks on Project Success using Structural Modelling Equation

Structural Modelling Equation (SEM) is a tool that can analyze the relationships between dependent and independent variables in a measurable manner (Alaloul *et al*., 2020). In contrast to other techniques like least square regression, logistic regression, and log-linear modelling, structural equation modelling has many advantages, such as estimating and evaluating the entire conceptual model instead of just testing individual hypotheses (Shackman, 2013). This is in addition to the capability to estimate measurement error. There are two types of structural equation modelling: covariance-based structural equation modelling (CB-SEM) and partial least squares structural equation modelling (PLS-SEM). The CB-SEM is commonly used when testing, confirming or comparing theories (Zhang *et al*., 2021).

On the other hand, the PLS-SEM is used for exploratory research or an extension of an existing structural theory (Hair *et al*., 2011). Due to the exploratory nature of this research that aims to assess the effects of COVID-19 emerging risks on PS, the authors used PLS-SEM to (1) test the measurement model's reliability and validity; and (2) examine the hypothesized relationships among the constructs. To this end, the survey output obtained from stage four of the research methodology was analysed using PLS-SEM by Smart PLS software package V. 3.

Results and analysis

Participants' Profiles in the Preliminary Investigation

As mentioned previously in Stage One of the research methodology, the authors conducted preliminary investigation with four experienced construction contractors in Iraq to identify the main PS indicators. The profiles of the participants are presented in Table 3.

Table 26. *Preliminary investigation experts' profiles (source: author)*

(COVID-19 and project success paper, Table 3)

Interviewee's code	Working Sector	Years of experience	Education level		
			BSc	**MSc**	**PhD**
Contractor 1	Public	24	1	-	-
Contractor 2	Public	20	1	-	-
Contractor 3	Private	17	1	-	-
Contractor 4	Private	15	1	-	-

Profiles of the Participants in the Semi-structured Interviews

The authors conducted semi-structured interviews with seven Iraqi construction experts to investigate the direct and indirect relationships between COVID-19 related risks and PS, as described in step two of the research methodology. Each interview lasted between 25 and 45 minutes and took place between August 27 and September 30, 2021. The questions were grouped into two themes. The first theme focused on the respondents' role in construction, their working experience, and their educational background. On the other hand, the second theme's questions investigated the respondents' perceptions about the impact of COVID-19 risks on PS.

The interviewees chosen were as follows: first, a contractor with 26 years of construction experience and a BSc degree in civil engineering, who is currently employed as the director for a contracting firm within the public construction sector. Second, a contractor with 23 years of construction experience and a BSc degree in civil engineering, who is a general construction contractor. Third, a contractor with 19 years of construction experience and a BSc degree in mechanical engineering, who is a general construction contractor. Fourth, a contractor with 17 years of experience in construction and a BSc in architectural engineering who is a piling contractor. Fifth, a contractor with 15 years of experience in construction and an MSc in transportation engineering, who is an asphalt paving contractor. Sixth, a professor of risk management with 21 years of industry and academic experience in risk and uncertainty management for construction projects. Finally, an associate professor of risk management with 18 years of industry and academic experience in project risk management.

Hypotheses Development

On the basis of expert interviews' outputs, the authors developed three sets of research hypotheses. Hypotheses H1 to H5 examine the direct relationship between COVID-19-

emerging risks (e.g., CFM-related risks, HSCW-related risks, OI-related risks, SCO-related risks, and CI-related risks) and PS. Hypotheses H6 to H9 examine the direct relationship between CFM-related risks, HSCW-related risks, OI-related risks, and SCO-related risks on CI. Furthermore, hypotheses H10 to H13 examine the indirect relationship between COVID-19-emering risks and PS through C.I (relationship mediator). These hypotheses are presented in Figure 2.

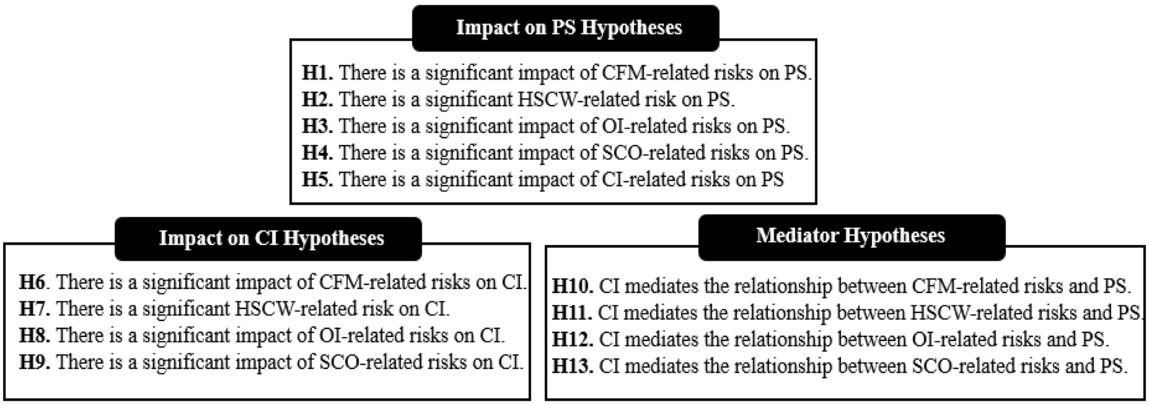

Figure 32. *Research Hypotheses (source: author)*

(COVID-19 and project success paper, Figure 2)

Profiles of the Survey Respondents

In total, 250 survey forms were administrated online to contractors working in Iraq's public and private construction sectors. Out of the 250 administrated surveys, 113 were returned. However, only 99 responses out of the 113 were completed and considered for further analysis. As such, the response rate for the survey is 39.6%, exceeding the acceptable response rate for survey-based research in construction-related studies of 20% (Tan *et al*., 2014), 30% (Liu *et al*., 2016; Assaad *et al*., 2020), and 35% (Fellows and Liu, 2015).

The distribution of the survey respondents between the construction public and private sectors was as follows: 81% from the private sector and 19% from the public sector. In addition, the average experience of the survey respondents was 17.8 years, and most of the respondents (about 86%) had more than ten years of construction experience. Moreover, approximately 3% of the respondents had 1 to 5 years of experience; 42% had 6 to 15 years; 37% had 16 to 25 years, and 18% had over 25 years of experience. Furthermore, many of the survey participants held different levels of academic attainment, including a bachelor's degree (77%), a master's degree (19%), and a doctoral degree (4%). A detailed profile of the respondents is provided in Table 4.

Table 27. *Profile of survey respondents (source: author)*

(COVID-19 and project success paper, Table 4)

Interviewees Profile	**Category**	**Distribution (%)**
Working Sector	Public Sector	19
	Private Sector	81
Construction Role	Contractors	100
Range of Experience	1-5 Years	3
	6-15 Years	42
	16-25 Years	37
	>25 Years	18
Educational qualifications	Bachelor's degree	77
	Masters' Degree	19
	Doctorate degree	4

Assessment of Measurements Model (Outer Model)

The Measurement Model (MM) specifies the rules of correspondence between measured and latent variables (Hair *et al*., 2010) and is assessed using Internal Consistency Reliability (ICR), Convergent Validity (CV), and Discernment Validity (DV) (Hair, 2014a). The following sub-sections provide details on each assessment criterion for the MM.

Internal Consistency Reliability

Internal consistency reliability refers to the degree to which test measurements remain consistent when performed under similar conditions repeatedly (Revicki, 2014). PLS-SEM uses two criteria to measure the internal consistency reliability of the inputs, namely Cronbach's alpha and composite reliability. Cronbach's alpha is commonly used as an indicator of internal consistency since it provides an estimate of the correlations between the observed indication variables (Taber, 2018). However, the reliability of Cronbach's alpha is affected by the number of items on the scale, and it generally underestimates the internal consistency reliability (Thorsen and Bjorner, 2010). It may thus be considered as a more conservative measure of internal consistency reliability.

Composite reliability (sometimes called construct reliability), on the other hand, is a measure of internal consistency in scale items, and it incorporates the different outer loadings of the indicator variables (Cho, 2016).

As it can be seen in columns 3 and 4 in Table 5, the Cronbach's Alpha values ranged between 0.804 and 0.954, as well as composite reliability (CR), which ranged between

0.860 and 0.916 both measures exceeded the threshold of 0.707, indicating accepted construct reliability (Nunnaly and Bernstein, 1994). Therefore, the results indicated that the structural model has strong reliability both in the Cronbach's α and composite reliability.

Convergent Validity

Convergent validity refers to the degree to which the new scale is related to other measures and variables of the same construct (Freson, 2015). PLS-SEM uses two criteria to examine the convergent validity i.e., outer loading of indicators and Average Variance Extracted (AVE) (Hair *et al*., 2013). Generally, a construct with a high outer loading indicates that its associated indicators are closely related, which are captured by the construct (Hair *et al*., 2021). The AVE, on the other hand, measures the amount of variance captured by a construct as compared to the amount of variance caused by measurement error (Fornell and Larcker, 1981).

To this end, the factor loadings for the constructs' indicators were ranged from 0.620 to 0.904, exceeding the minimum threshold of 0.60 for item reliability (Gefen and Straub, 2005). It is important to mention that only one item (H02) was excluded from the analysis as it had a low factor loading (<0.60).

Ultimately, the CV values were deemed adequate ranging from 0.505 to 0.710, exceeding the recommended threshold of 0.5 (Ringle *et al*., 2018). The calculated loading factors and CV values are presented in columns 5 and 6 of Table 5.

Table 28. *Measurement model results– internal consistency reliability and convergent Validity (source: author)*

(COVID-19 and project success paper, Table 5)

Constructs	**Risk code**	**Cronbach's alpha**	**CR**	**Factor Loading**	**AVE**
Contractual implications (CI)	C01	0.804	0.860	0.664	0.506
	C02			0.710	
	C03			0.749	
	C04			0.703	
	C05			0.755	
	C06			0.681	

Table 28. *Continued.*

Constructs	Risk code	Cronbach's alpha	CR	Factor Loading	AVE
Construction financial market	C01	0.954	0.916	0.904	0.710
	C02			0.890	
	C03			0.885	
	C04			0.785	
	C05			0.871	
	C06			0.868	
	C07			0.859	
	C08			0.720	
	C09			0.804	
	C10			0.822	
Supply chain operations	S01	0.915	0.928	0.777	0.590
	S02			0.788	
	S03			0.765	
	S04			0.767	
	S05			0.796	
	S06			0.674	
	S07			0.835	
	S08			0.778	
	S09			0.720	
Health and safety of construction workforce	H01	0.932	0.941	0.620	0.555
	H03			0.768	
	H04			0.774	
	H05			0.764	
	H06			0.738	
	H07			0.749	
	H08			0.776	
	H09			0.821	
	H10			0.685	
	H11			0.817	
	H12			0.792	
	H13			0.772	

Table 28. *Continued.*

Constructs	**Risk code**	**Cronbach's alpha**	**CR**	**Factor Loading**	**AVE**
Organisational implications	O01	0.858	0.890	0.672	0.505
	O02			0.707	
	O03			0.775	
	O04			0.731	
	O05			0.556	
	O06			0.778	
	O07			0.721	
	O08			0.724	

Discriminant validity

Discriminant or Divergent validity refers to the degree of differentiation and independence between a set of factors (Buniya *et al*., 2021). PLS-SEM uses two criteria to measure the discriminant validity of a construct i.e., Fornell-Larcker criterion and Heterotrait-monotrait Ratio of Correlations (HTMT). For the Fornel-larcker criterion, the discriminant validity of a construct is tested by comparing the square root of the AVE with the off-diagonal correlations (Li *et al*., 2021). If the square root of the AVE is larger, then the construct is considered to have discriminate vakidity (Bagozzi, 1981). As shown in Table 6, all constructs meet the Fornell-Larckers criterion standard, indicating satisfactory discriminant validity.

Table 29. *Discriminant validity by Fornell-Larcker criterion (source: author)*

(COVID-19 and project success paper, Table 6)

	CFM	HSCW	CI	OI	SCO
CFM	0.843	-	-	-	-
HSCW	0.246	0.745	-	-	-
LI	0.335	0.567	0.711	-	-
OI	0.213	0.515	0.669	0.711	-
SCO	0.223	0.345	0.250	0.214	0.768

Finally, the HTMT measures similarity between latent variables (Suzuki and Pheng, 2019). HTMT values equal to or smaller than 0.90 can be considered indicative of discriminant validity (Henseler *et al*., 2015); Table 7 shows this to be the case for all constructs.

***Table 30**. Discriminant validity by HTMT (source: author)*

(COVID-19 and project success paper, Table 7)

	CFM	**HSCW**	**CI**	**OI**	**PS**	**SCO**
CFM	-	-	-	-	-	-
HSCW	0.251	-	-	-	-	-
LI	0.373	0.653	-	-	-	-
OI	0.244	0.573	0.803	-	-	-
PS	0.141	0.603	0.828	0.800	-	-
SCO	0.249	0.357	0.274	0.225	0.341	-

Assessment of Structural Model (Inner Model)

The Structural Model (SM) examines the relationships among constructs (Le *et al*., 2021) and is assessed using the coefficient of determination (R^2), Cross-validated redundancy (Q^2), path coefficients(β), and Standardized Root Mean Square Residual (SRMR) which indicate the degree to which the data support the research mode (Chin, 2010; Hair *et al*., 2017). The following sub-sections provide details on each assessment criterion for the SM.

Coefficient of determination (R^2)

The coefficient of determination is a measure of the model's predictive accuracy (Hair *et al*., 2017). This coefficient indicates the proportion of variation in the dependent variable(s) that can be accounted for by one or more predictor variables (Elliott and Woodward, 2007). In this research, R^2 values were obtained using the bootstrap algorithm in SMART PLS 3.0 with the recommended iterations of 300. As shown in Table 8, R^2 values for the effects of COVID-19 risks on CI and PS, were 0.670 and 0.792, respectively, exceeding the minimum acceptable level of 0.1 as recommended by (Falk and Miller, 1992). Hence, indicating a satisfactory predicting capability.

***Table 31.** Structural model's coefficient of determination values (source: author)*

(COVID-19 and project success paper, Table 8)

Construct relation	**R^2**
Effect of COVID-19 risks on CI	0.670
Effect of COVID-19 risks on PS	0.792

Cross-validated redundancy (Q^2)

Cross-validated redundancy is a measure of the predictive relevance of the inner model (Perry *et al*., 2014). This method is one of the most used data resampling techniques for predictive models to assess their generalizability and avoid overfitting. In this research, the Q^2 values were obtained using the blindfolding algorithm in SMART PLS 3.0 with the recommended iterations of 300 and an omission distance of seven. As presented in Table 9, Q^2 values for the effects of COVID-19 risks on CI and PS, were 0.231 and 0.314, respectively, exceeding the minimum acceptable level of 0.00 as recommended by (Hair *et al*., 2017). Hence, indicating a satisfactory predicting relevance level.

Table 32. *Structural model's cross-validated redundancy values (source: author)*

(COVID-19 and project success paper, Table 9)

Endogenous variables	SSO	SSE	Q^2(=1-SSE/SSO)
Effect of COVID-19 risks on LI	594.000	457.002	0.231
Effect of COVID-19 risks on PS	891.000	611.387	0.314

Path coefficients(β)

A path coefficient is a standardized version of a linear regression weight that can be applied in the context of SEM to evaluate the hypothesized relationship between constructs (Hair *et al*., 2014b). Based on Hair *et al*. (2017), to accept the hypothesis, the *T*-value must be greater than 1.96, and the *p*-value must be less than 5%.

In this research, H1 evaluates whether CFM-related risks are positively impacting PS. Results indicated that CFM-related risks had a significant impact on PS (β =0.518, *T* =6.167, *P<1%*). Hence, H1 was supported. In addition, H2 evaluates whether HSCW-related risks are positively impacting PS. Results revealed that HSCW related risks had a significant impact on PS (β =0.485, *T* =6.382, *P<1%*). Consequently, H2 was supported. H3 evaluates whether OI-related risks are positively impacting PS. Results showed that OI-related risks had a significant impact on PS (β =0.561, *T* =6.164, *P<1%*). In light of this, H3 was supported. H4 evaluates whether SCO-related risks are positively impacting PS. Results revealed that SCO-related risks had a significant impact on PS (β =0.462, *T* =4.278, *P<1%*). Accordingly, H4 was supported. Moreover, H5 evaluates whether CI-related risks are positively impacting PS. Results found that LI-related risks had a significant impact on PS (β =0.573, *T* =8.552, *P<1%*). Therefore, H5 was supported.

Considering the strength between exogenous (i.e., COVID-19 risks under the five categories) and endogenous latent constructs (i.e., PS and its indicators), which is measured by beta coefficient (β) values (Sarstedt *et al*., 2021), CI-related risks had the strongest total effects on PS (β=0.573), followed by OI-related risks (β=0.561), followed by CFM-related risks (β=0.518), HSCW-related risks (β=0.485), and SCO-related risks (β=0.462), respectively. Table 10 shows the path coefficient of H1 to H5.

Table 33. *Path coefficient of the research hypotheses H1 to H5 (source: author) (COVID-19 and project success paper, Table 10)*

Hypotheses	**Path**	**B**	**Standard Deviation**	***T* Value**	***P* Value**	**Decision**
H1	CFM>>PS	0.518	0.084	6.167	0.00**	Supported
H2	HSCW>>PS	0.485	0.076	6.382	0.00**	Supported
H3	OI>>PS	0.561	0.091	6.164	0.00**	Supported
H4	SCO>>PS	0.462	0.108	4.278	0.00**	Supported
H5	CI>>PS	0.573	0.067	8.552	0.00**	Supported

Note(s): * $p < 0.05$; ** $p < 0.01$

Mediation analysis

To assess the mediation role of CI, the authors first tested the research hypotheses H6, H7, H8, and H9 that examine the impact of the constructs on CI. H6 evaluates whether CFM-related risks are positively impacting CI. Results indicated that CFM-related risks significantly impacted CI (β =0.511, *T* =6.604, *P*<1%). As a result, H6 was supported. H7 evaluates whether HSCW-related risks are positively impacting CI. The results showed that HSCW-related risks had a significant impact on CI (β =0.613, T =11.57, P<1%). The hypothesis was therefore supported. H8 evaluates whether OI-related risks are positively impacting CI. Based on the results, OI-related risks had a significant impact on CI (β =0.637, T =8.847, P<1%). The hypothesis was thus supported. Finally, H9 evaluates whether SCO-related risks are positively impacting CI. According to the results, SCO-related risks had a significant impact on CI (β =0.469, T =4.989, P<1%). Consequently, H9 was supported.

Considering the strength of CFM-related risks, HSCW-related risks, OI-related risks, and SCO-related risks CI, OI-related risks had the strongest direct effect on PS (β=0.637), followed by HSCW-related risks (β=0.613), CFM-related risks (β=0.568), and SCO-related risks (β=0.469). The results are presented in Table 11. Furthermore, the authors calculated the total, direct, and indirect effects of the mediator (i.e., CI) as presented in Table 12. Total effects refer to the sum of direct and indirect effects, which can be used to examine the influences of mediating variables on latent variables (Le *et al*., 2021). The mediator hypotheses of H10 to H13 evaluate whether CI mediates the relationship between CFM-related risks, HSCW-related risks, OI-related risks, SCO-related risks, and PS. Considering the strength between exogenous (i.e., COVID-19 risks under the five categories) and endogenous latent constructs (i.e., PS and its indicators), which is measured by beta coefficient (β) values (Sarstedt *et al*., 2021), SCO-related risks had the strongest direct effect on PS (β=0.194, *T*=2.662, *P*< 1%), followed by CFM-related risks (β=0.189, *T*=2.517, *P*< 1%), HSCW-related risks (β=0.134**,** *T*=2.183, *P*< 5%), and OI-related risks (β=0.121, *T*=3.011, *P*< 1%). Furthermore, the indirect effects with the inclusion of mediator into the analysis was found significant for OI-related risks with a strongest indirect effect (β=0.440, *T*=4.834, *P*< 1%), followed with HSCW-related risks (β=0.351, *T*=4.195, *P*< 1%), CFM-related risks (β=0.329, *T*=4.336, *P*< 1%), and SCO-related risks (β=0.268, *T*=3.276, *P*< 1%), respectively. Thus, the effect of CFM, HSCW, OI, and SCO on PS is fully mediated by CI. We, therefore, accept H10, H11, H12, and H13 (see Table 12).

Table 34. *Path coefficient of the research hypotheses H6 to H9 (source: author)*

(COVID-19 and project success paper, Table 11)

Hypotheses	**Path**	**Β**	**Standard Deviation**	***T* Value**	***P* Value**	**Decision**
H6	CFM>>CI	0.568	0.086	6.604	0.00**	Supported
H7	HSCW>>CI	0.613	0.053	11.57	0.00**	Supported
H8	OI>>CI	0.637	0.072	8.847	0.00**	Supported
H9	SCO>>CI	0.469	0.094	4.989	0.00**	Supported

Note(s): * p < 0.05; **p < 0.01

Table 35. *Mediation analysis (source: author)*

(COVID-19 and project success paper, Table 12)

	Total effects			**Direct effects**				**Indirect effects**		
	β	***T* value**	***P* value**	**Β**	***T* value**	***P* value**	**Hypotheses**	**β**	***T* value**	***P* value**
CFM>>PS	0.518	6.167	0.000	0.193	2.517	0.013	CFM>>CI>>PS	0.325	4.336	0.000
HSCW>>PS	0.485	6.382	0.000	0.134	2.183	0.031	HSCW>>CI>>PS	0.351	4.195	0.000
OI>>PS	0.561	6.164	0.000	0.121	3.011	0.003	OI>> CI >>PS	0.440	4.834	0.000
SCO>>PS	0.462	4.278	0.000	0.194	2.662	0.009	SCO>> CI >>PS	0.268	3.276	0.001

Note(s): * p < 0.05; **p < 0.01

Standardized Root Mean Square Residual (SRMR)

Hisseler *et al*. (2014) introduce the SRMR as a measure of the goodness of fit for PLS-SEM, which can be used to avoid model misspecification. According to Hu and Bentler (1999), a SRMR value of less than 0.10 indicates a good fit. In this research, the model's SRMR value was 0.074, indicating a satisfactory level of goodness of fit.

Discussion

Construction Financial Market-related Risks.

The pandemic has been regarded as the greatest threat to the global economy since the Great Recession (Ibn-Mohammed, 2021). According to the World Bank, the global economy experienced a 4.3% decline, ranking it among the top four recessions in the past 150 years (World Bank 2021). In Iraq, the COVID-19 pandemic has profoundly affected the construction market, with the industry experiencing its most severe slump since the Iraq war in 2003 (Al-Mhdawi *et al*., 2022c). These effects can be seen from delays in payment, material price escalation, reduced labour wages, and contractors' bankruptcies. Our SEM analysis support these effects (i.e., H1: There is a significant impact of CFM-related risks on PS, and H6: There is a significant impact of CFM-related risks on CI, are supported). Our result is consistent with the findings of previous studies (see, e.g., Amoah *et al*., 2021; Rehman *et al*., 2021; Sierra, 2021; Al-Mhdawi *et al*., 2022c and others).

Health and Safety of construction workforce-related risks

The COVID-19 pandemic has severely affected workers and workplaces around the world (Matli, 2020). This has significantly altered the workplace environment, causing concerns related to economic insecurity, remote working, isolation, and returning to work safely (Pamidimukkala *et al*., 2021b). In Iraq, despite extensive guidance from governmental authorities, there is an increased risk for infection and the COVID-19 disease, especially in a profession that is already hazardous, resulting in significant losses of productivity. This is being compounded by a number of factors, including poor Personal Protective Equipment (PPE) practices and mental health-related factors due to lockdown and reduced working hours (Al-Mhdawi, 2022a). To this end, our SEM analysis supported H2 (i.e., there is a significant impact of OI-related risks on PS) and H7 (i.e., there is a significant HSCW-related risk on CI), and is aligned with the results of previous research (see, e.g., Agyekum *et al*., 2021; Alsharef *et al*., 2021; Araya, 2021; Chigara and Moyo, 2021; Pamidimukkala *et al*., 2021a; Rehman *et al*., 2021; Stiles *et al*., 2021 and others).

Organisational implication-related risks

In the pre-COVID era, the construction industry of developing countries found a considerable number of challenges to mitigate the risks of poor organisational management (Boadu, 2020). The impact of the pandemic has raised the ceiling of management challenges. For instance, the pandemic in Iraq has caused numerous disruptions and delays due to restricted site access, poor site, and virtual communication, delayed work inspection and approval (Al-Mhdawi, 2022b). Based on the results of the SEM analysis, it was found that CFM-related risks have a significant impact on the PS (i.e., H3: there is a significant impact of OI-related risks on PS, and H8: there is a significant impact of OI-related risks on CI are supported). This finding is in line with the results of previous research (see, e.g., Ogunnusi *et al*., 2021; Rehman *et al*., 2021 and others).

Supply chain operations-related risks

Construction projects were negatively affected by the COVID-19 pandemic on all levels, and the most severe disruption was to supply chain operations (Jallow, 2020). In Iraq, the construction industry relied heavily on imported resources (i.e., construction materials and equipment). Consequently, due to the constant lockdowns, travel bans, and other measures taken to curtail implications associated with the outbreak, all construction projects encountered significant delays caused by lack of resources, workforce shortage, and other SCO factors. These observations are confirmed by our SEM analysis (H4: There is a significant impact of OI-related risks on PS, and H9: There is a significant impact of SCO-related risks on CI, are supported). Previous studies are consistent with our finding (see, e.g., Butt, 2021; King *et al*., 2021; Ogunnusi *et al*., 2021; Olatunde *et al*., 2021 and others).

Contractual implications-related risks

In the construction industry, the interactions between the different parties are determined by the contractual relationships between them (Assaad *et al*., 2020), and thus contractual and legal aspects are of particular importance in this industry. A number of contract-related challenges in construction projects include poor contract communication, unclear scope, and vagueness and contradictions in the contract document (Ashmawi *et al*., 2018). Contract-related challenges often have legal implications, including penalties and lawsuits for non-compliance with contract terms. In Iraq, the pandemic has caused numerous disruptions and delays due to the curfews on the one hand and the government's strict safety policies and regulations, on the other hand, leading to projects experiencing significant contractual implications, including claims, legal lawsuits, contracts' suspension and termination (Al-Mhdawi *et al*., 2022a). To this end, the SEM analysis supported the H5 (i.e., there is a significant impact of CI-related risks on PS) and is consistent with the findings of previous research (see, e.g., Olatunde *et al*., 2021; Salami *et al*., 2021; Sierra, 2021; Al-Mhdawi *et al*., 2022b; Umar, 2022 and others).

Mediator Role

The findings of this study provide useful empirical insight into the indirect impact of CFM-related risks, HHSCW-related risks, OI-related risks, and SCO-related risks on PS through the mediation of CI. These findings suggest that CI plays an important role in mediating the relationship between the mentioned risk categories and PS. To this end, H10: CI mediate the relationship between CFM-related risks and PS, H11: CI mediate the relationship between HSCW-related risks and PS, H12: CI mediate the relationship between OI-related risks and PS, and H13: CI mediate the relationship between SCO-related risks and PS

Conclusion

In order for a project to be successful, a thorough examination of the major risks affecting the project is imperative (Adeleke *et al*., 2021). An understanding of their characteristics and effects helps decision-makers to propose the most appropriate and practical mitigation measures. This research thus offers a better understanding of the direct and indirect effects of COVID-19 pandemic emerging risks on construction PS in developing countries by considering the case of Iraqi construction industry.

The authors have (1) identified the indicators of construction project success; (2) developed hypotheses to capture the impact of the COVID-19 emerging risks that were identified and classified in the available literature on PS; and (3) quantitatively examined how construction contractors in Iraq perceive the impact of these risk factors. First, a preliminary investigation with four construction contractors in Iraq was conducted to identify the indicators of project success. Second, semi-structured interviews with seven Iraqi construction experts were conducted to develop the impact assessment hypotheses between CFM-related risks, SCO-related risks, HSCW-related risks, OI-related risks, CI-related risks, and PS. Third, a survey was administrated and answered by 99 contractors. Last, a SEM model was developed to test the relationship between the COVID-19 emerging risks and PS in terms of project cost, time, quality, safety, commercial profitability, and functionality, client satisfaction, and end-user satisfaction).

The results of the SEM analysis indicated that CFM-related risks, SCO-related risks, HSCW-related risks, OI-related risks, and CI-related risks significantly impact construction projects' success. CI-related risks had the strongest total effects on PS (β=0.573), followed by OI-related risks (β=0.561), followed by CFM-related risks (β=0.518), HSCW-related risks (β=0.485), and SCO-related risks (β=0.462), respectively. Furthermore, the authors mediated the relationship between the COVID-19 emerging risks and PS through CI. The results indicated that:

A) OI-related risks had the strongest direct effect on CI (β=0.637), followed by HSCW-related risks (β=0.613), CFM -related risks (β=0.568), and SCO-related risks (β=0.469).
B) SCO-related risks had the strongest direct effect on PS (β=0.194), followed by CFM-related risks (β= β=0.193), HSCW-related risks (β=0.134), and OI-related risks (β=0.121). Moreover, the indirect effects with the inclusion of mediator into the analysis were found significant for OI-related risks with a strongest indirect effect (β=0.440), followed with HSCW-related risks (β=0.351), CFM-related risks (β=0.329), and SCO-related risks (β=0.268), respectively.

This highlights the need to establish an integrated contract management system for construction projects under extreme conditions that captures the main risk categories and their sources. This can help in controlling conflicts on schedule, reducing disputes, protecting the financial interest of the key stakeholders, maintaining relevant records, controlling changes, managing roles and responsibilities, resolving discrepancies or inconsistencies among the several contract documents, and safeguarding entities' rights (Oluka and Basheka, 2014; Van Weele, 2014; Hamie and Abdul-Malak, 2018).

Research and Practical Implications

This research offers one of the first attempts to develop and test an integrated model that links COVID-19 emerging risks to the success of construction projects. This study contributes to the body of knowledge and contracting companies by helping researchers and construction contractors to better understand how the key risk factors emerging from extreme conditions affect construction projects' success. According to Al-Mhdawi *et al*. (2022a), construction contractors were exposed to a high level of bankruptcy risk, and this led to the failure of several projects. Thus, understanding the nature of the relationship between the risks emerging from extreme conditions and PS will help construction contractors to (1) identify the root causes of low-level PS, and (2) develop appropriate strategies for improving PS levels by addressing the direct and indirect effects of extreme conditions risks.

Research Limitations

The findings of this research are based on the perspectives of construction contractors in Iraq. However, the perspectives of other construction stakeholders (e.g., project managers, consultants, etc.) may differ on the impact of extreme conditions on the success of projects. In addition, PS was defined based on eight indicators (i.e., time, cost, quality, safety, client satisfaction, end-user satisfaction, commercial profitability, and functionality). Other indicators such as environmental impact and performance were not captured in this research which might be identified based on other stakeholders' group focus. Lastly, only five construction themes were examined. Other themes such as governmental implications may be considered for future research based on the developed methodology in this research.

References

Ab Sani, J. and Othman, N., 2012. Quality standard and specification for soft-scape construction in Malaysia. *Procedia-Social and Behavioral Sciences*, *35*, pp.260-266.

Adeleke, A.Q., Ajibike, W.A., Muuka, G.N., Darun, M.R. and Moshood, T.D., 2021. Managing External Risk Factors on Oil and Gas Project Success: A Dream for All Firms. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, *7*(4), p.04021063.

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*, *20*(1), pp.222-244.

Alaloul, W.S., Liew, M.S., Zawawi, N.A.W., Mohammed, B.S., Adamu, M. and Musharat, M.A., 2020. Structural equation modelling of construction project performance based on coordination factors. *Cogent engineering*, *7*(1), p.1726069.

Ali, A.S. and Rahmat, I., 2010. The performance measurement of construction projects managed by ISO-certified contractors in Malaysia. *Journal of Retail & Leisure Property*, *9*(1), pp.25-35.

Aljamee, H., Naeem, S. and Bell, A., 2020. The causes of project delay in Iraqi petroleum industry: A case study in Basra Oil Company. *Journal of Transnational Management*, *25*(1), pp.57-70.

Al-karawi, S.N., 2018. Challenges Facing Construction Contracts in Iraq. *Journal of Engineering and Sustainable Development*, *22*(4), pp.192-201.

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., 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.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. 2022b (In press). Risk Management of Construction Projects Under Extreme Conditions: A Case Study of Iraq. (In Press). PhD Thesis. University of Southampton, UK.

Al-Mhdawi, M.K.S., Brito, M.P., and Onggo, B.S. 2022c (In press). Analyzing the Impact of COVID-19 Pandemic Risks on Construction Projects in Developing Countries: Case of Iraq. In *Construction Research Congress 2022: Computer Applications*. ASCE: USA.

Al-Qaicy, S.T. and Breesam, H.K., 2021, February. An Analytical Study to Evaluate Iraqi Construction Sector Readiness to Manage Post-Disaster Reconstruction. In *Journal of Physics: Conference Series* (Vol. 1804, No. 1, p. 012014). IOP Publishing.

Alsamarraie, M.M. and Ghazali, F., 2021. The Impact of COVID-19 and Control Strategies Adoptionin the Construction Sector. *Annals of the Romanian Society for Cell Biology*, *25*(6), pp.19524-19531.

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*, *9*(1). https://doi.org/10.1080/23311916.2022.2044575

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

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.

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

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.

Buniya, M.K., Othman, I., Sunindijo, R.Y., Kineber, A.F., Mussi, E. and Ahmad, H., 2021. Barriers to safety program implementation in the construction industry. *Ain Shams Engineering Journal*, *12*(1), pp.65-72.

Butt, A.S., 2021. Understanding the implications of pandemic outbreaks on supply chains: an exploratory study of the effects caused by the COVID-19 across four South Asian countries and steps taken by firms to address the disruptions. *International Journal of Physical Distribution & Logistics Management*, *52*(4), pp. 370-392.

BW (Business Wire). 2022. Iraq Construction Market Trends and Opportunities". Accessed Sep 01, 2022. Iraq Construction Market Trends and Opportunities Report, H1 2021 - ResearchAndMarkets.com | Business Wire

Cachia, M. and Millward, L., 2011. The telephone medium and semi-structured interviews: a complementary fit. *Qualitative Research in Organizations and Management: An International Journal*, *6*(3), pp. 265-277.

Chan, A.P C. and Chan, A.P., 2004. Key performance indicators for measuring construction success. *Benchmarking: an international journal*,*11*(2), pp. 203-221.

Chan, A.P., Scott, D. and Lam, E.W., 2002. Framework of success criteria for design/build projects. *Journal of management in engineering*, *18*(3), pp.120-128.

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.

Czarnigowska, A. and Sobotka, A., 2013. Time–cost relationship for predicting construction duration. *Archives of Civil and Mechanical Engineering*, *13*(4), pp.518-526.

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

Durdyev, S., Ismail, S. and Bakar, N.A., 2012. Factors causing cost overruns in construction of residential projects: case study of Turkey. *International Journal of Science and Management*, *1*(1), pp.3-12.

Elliott, A.C. and Woodward, W., 2007. *Statistical Analysis Quick Reference Guidebook: With SPSS Example*. Sage Publications.

Elnaggar, S.M. and Elhegazy, H., 2022. Study the impact of the COVID-19 pandemic on the construction industry in Egypt. In *Structures*, *35*, pp.1270-1277

Falk, R.F. and Miller, N.B., 1992. *A primer for soft modeling*. University of Akron Press.

Fellows, R.F. and Liu, A.M., 2021. *Research methods for construction*. John Wiley & Sons.

Ferrett, E., 2015. *Health and Safety in Construction Revision Guide: For the NEBOSH National Certificate in Construction Health and Safety*. Routledge.

Fornell, C., & Larcker, D. F. (1981), Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research*, *18*(3), pp. 328-388. https://doi.org/10.2307/3150980

Freson, T.S., 2015. *Invariance, convergent and discriminant validity across occasions for the Male Body Image Disturbance Scale*. Washington State University.

Gefen, D. and Straub, D., 2005. A practical guide to factorial validity using PLS-Graph: Tutorial and annotated example. *Communications of the Association for Information systems*, *16*(1), p.5.

Hair Jr, J.F., Hult, G.T.M., Ringle, C.M. and Sarstedt, M., 2021. *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage publications.

Hair Jr, J.F., Hult, G.T.M., Ringle, C.M. and Sarstedt, M., 2021. *A primer on partial least squares structural equation modeling (PLS-SEM)*. Sage publications.

Hair Jr, J.F., Sarstedt, M., Hopkins, L. and Kuppelwieser, V.G., 2014b. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European business review*, *26*(2), pp.106-121

Hair, J. F., JR., Black, W. C.,Babin, B. J., and Anderson, R. E., (2010). *Multivariate data analysis (7th ed.)*. Upper Saddle River, NJ: Pearson Prentice Hall.

Hair, J. F., Ringle, C. M., and Sarstedt, M. 2011. PLS-SEM: Indeed a Silver Bullet. *Journal of Marketing Theory and Practice 19(*2), pp.139-151.

Hair, J.F., 2014a. A Primer on Partial Least Squares Structural Equations Modeling (PLS-SEM) SAGE. *Newcastle upon Tyne, UK*.

Hair, J.F., Ringle, C.M. and Sarstedt, M., 2013. Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long range planning, 46*(1-2), pp.1-12.

Hamie, J.M. and Abdul-Malak, M.A.U., 2018. Model language for specifying the construction contract's order-of-precedence clause. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *10*(3), p.04518011.

Hasanzadeh, S., de la Garza, J.M. and Geller, E.S., 2020. How sensation-seeking propensity determines individuals' risk-taking behaviors: Implication of risk compensation in a simulated roofing task. *Journal of Management in Engineering*, *36*(5), p.04020047.

Henseler, J., Ringle, C.M. and Sarstedt, M., 2015. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science*, *43*(1), pp.115-135.

Hu, L.T. and Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), pp.1-55.

Hughes, S.W., Tippett, D.D. and Thomas, W.K., 2004. Measuring project success in the construction industry. *Engineering Management Journal*, *16*(3), pp.31-37.

Ibn-Mohammed, T., Mustapha, K.B., Godsell, J., Adamu, Z., Babatunde, K.A., Akintade, D.D., Acquaye, A., Fujii, H., Ndiaye, M.M., Yamoah, F.A. and Koh, S.C.L., 2021. A critical analysis of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies. *Resources, Conservation and Recycling*, *164*, p.105169.

ILO (International Labour of Organization). 2021. Impact of COVID-19 on the construction sector. ILO Sectoral Brief. Switzerland.

Isa, C.M.M., Nusa, F.N.M., Ishak, S.Z. and Fam, S.F., 2021, June. Impacts of COVID-19 Pandemic on the Road and Transport Sectors using Relative Importance Index. In *2021 IEEE International Conference on Automatic Control & Intelligent Systems (I2CACIS)* (pp. 305-310). IEEE.

Jahanger, Q.K., 2013. Important causes of delay in construction projects in Baghdad city. *Australian Journal of Basic and Applied Sciences*, *7*(4), pp.14-23.

Jallow, H., Renukappa, S. and Suresh, S., 2020. The impact of COVID-19 outbreak on United Kingdom infrastructure sector. *Smart and Sustainable Built Environment*, *10*(4), pp. 581-593.

Jiang, W., Lu, Y. and Le, Y., 2016. Trust and project success: A twofold perspective between owners and contractors. *Journal of Management in Engineering*, *32*(6), p.04016022.

Karna, S., Junnonen, J.M. and Kankainen, J., 2004, August. Customer satisfaction in construction. In *Proceedings of the 12th Annual Conference on Lean Construction* (pp. 476-488). Helsingøv.

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. https://doi: 10.1109/IEEE-CONF51154.2020.9319948.

King, S.S., Rahman, R.A., Fauzi, M.A. and Haron, A.T., 2021. Critical analysis of pandemic impact on AEC organizations: The COVID-19 case. *Journal of Engineering, Design and Technology*.

Krajangsri, T. and Pongpeng, J., 2017. Effect of sustainable infrastructure assessments on construction project success using structural equation modeling. *Journal of Management in Engineering*, *33*(3), p.04016056.

Kukoyi, P.O., Simpeh, F., Adebowale, O.J. and Agumba, J.N., 2021. Managing the risk and challenges of COVID-19 on construction sites in Lagos, Nigeria. *Journal of Engineering, Design and Technology*, *20*(1), pp. 99-144. https://doi.org/10.1108/JEDT-01-2021-0058

Le, A.T.H., Domingo, N., Rasheed, E. and Park, K., 2022. Maturity model of building maintenance management for New Zealand's state schools. *Building Research & Information*, *50*(4), pp.438-451.

Li, B., Gao, Y., Zhang, S. and Wang, C., 2021. Understanding the Effects of Trust and Conflict Event Criticality on Conflict Resolution Behavior in Construction Projects: Mediating Role of Social Motives. *Journal of Management in Engineering*, *37*(6), p.04021066.

Mahmoud, A.H., 2020. Factors affecting performance at the Iraqi Construction Projects, Ministry of Construction, and Housing and Municipalities and Public Works of Iraq as a case study. *Asian Journal of Civil Engineering*, *21*(1), pp.105-118.

Majer, R., Ellingerová, H. and Gašparík, J., 2020. Methods for the calculation of the lost profit in construction contracts. *Buildings*, *10*(4). https://doi:10.3390/buildings10040074.

Matli, W., 2020. The changing work landscape as a result of the Covid-19 pandemic: insights from remote workers life situations in South Africa. *International Journal of Sociology and Social Policy*, *40*(9/10), pp. 1237-1256.

McKibbin, W. and Fernando, R., 2021. The global macroeconomic impacts of COVID-19: Seven scenarios. *Asian Economic Papers*, *20*(2), pp.1-30.

Ogunnusi, M., Omotayo, T., Hamma-Adama, M., Awuzie, B.O. and Egbelakin, T., 2021. Lessons learned from the impact of COVID-19 on the global construction industry. *Journal of engineering, design and technology*, *20*(1), pp. 299-320.

Olatunde, N.A., Awodele, I.A. and Adebayo, B.O., 2021. Impact of COVID-19 pandemic on indigenous contractors in a developing economy. *Journal of Engineering, Design and Technology*, *20*(1), pp. 267-280.

Oluka, P.N. and Basheka, B.C., 2014. Determinants and constraints to effective procurement contract management in Uganda: A practitioner's perspective. *International journal of logistics systems and management*, *17*(1), pp.104-124.

Olukolajo, M.A., Oyetunji, A.K. and Oluleye, I.B., 2021. Covid-19 protocols: assessing construction site workers compliance. *Journal of Engineering, Design and Technology*, *20*(1), pp. 115-131.

Onubi, H.O. and Hassan, A.S., 2020. How environmental performance influence client satisfaction on projects that adopt green construction practices: The role of economic performance and client types. *Journal of Cleaner Production*, *272*, p.122763.

Pamidimukkala, A. and Kermanshachi, S., 2021b. Impact of Covid-19 on field and office workforce in construction industry. *Project Leadership and Society*, p.100018.

Pamidimukkala, A., Kermanshachi, S. and Jahan Nipa, T., 2021a. Impacts of COVID-19 on Health and Safety of Workforce in Construction Industry. In *International Conference on Transportation and Development 2021* (pp. 418-430).

Parasher, A., 2021. COVID-19: Current understanding of its pathophysiology, clinical presentation and treatment. *Postgraduate Medical Journal*, *97*(1147), pp.312-320

Perry, C.M., Álvarez, J.C. and López, J.F., 2014, July. Manufacturing and continuous improvement areas using partial least square path modeling with multiple regression comparison. In *CBU International Conference Proceedings* (Vol. 2, pp. 15-26).

Rehman, M.S.U., Shafiq, M.T. and Afzal, M., 2021. Impact of COVID-19 on project performance in the UAE construction industry. *Journal of Engineering, Design and Technology*, *20* (1), pp. 245-266.

Revicki, D., 2014. Internal consistency reliability. *Encyclopedia of quality of life and well-being research*. https://doi.org/10.1007/978-94-007-0753-5_1494

Ringle, C.M., Sarstedt, M., Mitchell, R. and Gudergan, S.P., 2020. Partial least squares structural equation modeling in HRM research. *The International Journal of Human Resource Management*, *31*(12), pp.1617-1643.

Rokooei, S., Alvanchi, A. and Rahimi, M., 2022. Perception of COVID-19 impacts on the construction industry over time. *Cogent Engineering*, *9*(1), p.2044575.

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.

Sarhan, J.G., Xia, B., Fawzia, S. and Karim, A. 2017. Lean construction implementation in the Saudi Arabian construction industry. Construction Economics and Building, *17*(1), pp. 46- 69.

Sarstedt M., Ringle C.M., Hair J.F. 2017. *Partial Least Squares Structural Equation Modeling*. In: Homburg C., Klarmann M., Vomberg A. (eds) Handbook of Market Research. Springer, Cham. https://doi.org/10.1007/978-3-319-05542-8_15-1

Saunders, L.W., McCoy, A.P., Kleiner, B.M., Lingard, H., Cooke, T., Mills, T., Blismas, N. and Wakefield, R. 2016. International Benchmarking for Performance Improvement in Construction Safety and Health. *Benchmarking: An International Journal, 23*(4), pp. 916-936.

Shackman, J.D., 2013. The use of partial least squares path modeling and generalized structured component analysis in international business research: A literature review. *International Journal of Management*, *30*(3), p.78

Shehu, Z., Endut, I.R. and Akintoye, A., 2014. Factors contributing to project time and hence cost overrun in the Malaysian construction industry. *Journal of Financial Management of Property and Construction*, *19*(1), pp. 55-75.

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.

Singhal, T., 2020. A review of coronavirus disease-2019 (COVID-19). *The indian journal of pediatrics*, *87*(4), pp.281-286.

Stiles, S., Golightly, D., & 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.

Suzuki, K. and Pheng, L.S., 2019. *Japanese Contractors in Overseas Markets: Bridging Cultural and Communication Gaps*. Springer.

Taber, K.S., 2018. The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, *48*(6), pp.1273-1296.

Tan, Y., Shen, L., Langston, C., Lu, W. and Yam, M.C., 2014. Critical success factors for building maintenance business: a Hong Kong case study. *Facilities*, *32*(5/6), pp.208-225.

Thorsen, S.V. and Bjorner, J.B., 2010. Reliability of the Copenhagen psychosocial questionnaire. *Scandinavian journal of public health*, *38*(3_suppl), pp.25-32.

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), pp.1-17.

UNESCO. 2015. "UNESCO Iraq Office newsletter". Accessed Sep 20, 2022. https://unesdoc.unesco.org/ark:/48223/pf0000245107

Van Weele, A., 2014. *International contracting: Contract management in complex construction projects*. World Scientific.

Viscusi, W.K., 2020. Pricing the global health risks of the COVID-19 pandemic. *Journal of Risk and Uncertainty*, *61*(2), pp.101-128.

Yang, R.J. and Shen, G.Q., 2015. Framework for stakeholder management in construction projects. *Journal of Management in Engineering*, *31*(4), p.04014064.

Zhong, B., Li, H., Luo, H., Zhou, J., Fang, W. and Xing, X., 2020. Ontology-based semantic modeling of knowledge in construction: classification and identification of hazards implied in images. *Journal of construction engineering and management*, *146*(4), p.04020013.

Zhou, Z., Goh, Y.M. and Li, Q., 2015. Overview and analysis of safety management studies in the construction industry. *Safety science*, *72*, pp.337-350.

Chapter 5. Summary and Conclusions

5.1. Introduction

This chapter provides details on the methodological approaches and the main findings of each of the research objectives under the three PhD papers. Moreover, it provides a summary of key concussions, research contributions, limitations, and recommendations.

5.2. The first paper: risk management implementation challenges, barriers, and practices efficacy

The main aim of the first paper is to assess the main challenges and barriers to risk management implementation, and the level of risk management practices in relation to risk management challenges and barriers in the construction of developing countries by considering the case of the Iraqi construction industry. The associated objectives are to: (1) investigate and quantitatively analyse the challenges and barriers to construction risk management implementation during COVID-19 pandemic using AHP; and (2) quantify the level of efficacy of risk management practices during COVID-19 pandemic in relation to risk management implementation challenges and barriers using a novel multi-dimensional assessment model under fuzzy environment. As mentioned in Chapter One, the first and second objectives of the first paper represent the first and second objectives of this thesis. The following sub-sections provide details on the methodological approaches used to achieve these objectives and highlight the significant findings.

5.2.1. The first thesis objective

The first objective of the thesis was to investigate and quantitatively analyse the level of significance of the challenges and barriers to risk management implementation in the construction industry during the COVID-19 pandemic. A mixed-method approach was employed to achieve this objective, including (1) semi-structured interviews with 30 construction experts in Iraq (i.e., project managers, contractors, safety engineers, and academics) to identify the main challenges and barriers to construction risk management implementation; (2) AHP-based questionnaire survey to 200 construction experts in Iraq (i.e., project managers, contractors, consultants, and safety engineers) to rank the identified challenges and barriers to construction risk management implementation based on Saaty's 9-point scale (i.e., 1: equal importance, 3: moderate importance, 5: strong importance, 7: very strong importance, and 9: extreme importance); and (3) development of risk management implementation challenges and barrerites assessment model under AHP environment.

Overall, 34 risk management implementation challenges and barriers were identified and grouped under four main categories, namely: analytical approaches-related challenges and barriers, behaviour-related challenges and barriers, management-related challenges and barriers, and team-related challenges and barriers.

The first category (i.e., *analytical approaches-related challenges and barriers*) consisted of seven challenges and barriers, including: difficulty to estimate the risks' probabilities of occurrence and their level of severity; complexity of quantitative-based risk assessment tools; time-consuming process; a lack of historical data for the analysis and modelling of risk trends; ineffectiveness of the cost of risk management analytical approaches; inability to comprehend and interpret results; and insufficiency of good data to ensure reliability.

The second category (i.e., *behaviour-related challenges and barriers*) consisted of four challenges and barriers, including lack of willingness to change the current project management practices; bribery; lack of commitment; and lack of willingness for collaboration among stakeholders.

The third category (i.e., *management-related challenges and barriers*) consisted of 15 challenges and barriers, including lack of awareness of risk management potential benefits; insufficient risk management resources; lack of continuation and coordination among risk management activities at various stages of the project lifecycle; lack of continuation and coordination among risk management activities at various stages of the project lifecycle; lack of unified risk management framework for construction projects; time constraints and commercial pressures; inadequate integration of risk management with other project management processes; insufficient support from the upper management; the difficulty of determining the risk-return trade-off; inadequate organisational structure; ineffective risk communication; the absence of government legislation; sluggish decision-making process; limited participation of contractors during the design process; failure to document and/or share lessons learned; and poor risk management training system.

Finally, the fourth category (i.e., *team-related challenges and barriers*) consisted of eight challenges and barriers, including lack of expertise and experience; lack of awareness and consciousness of risks among the project management team; lack of specialised risk management role; insufficient familiarity with risk management process; lack of clarity regarding individual responsibilities; doubts regarding the suitability of risk management techniques; poor interaction among the project parties; and the conflict between the subjectivity of risk assessment.

Furthermore, the identified challenges and barriers were assessed based on three criteria that were obtained from the semi-structured interviews. These assessment criteria were (1) challenges and barriers level of probability of occurrence (i.e., how likely or how often these challenges and barriers occur on average in the construction industry during COVID-19 era); (2) their level of impact on cost (i.e., the expected impact of these challenges and barriers on the project's cost); and (3) their impact on the project schedule (i.e., the anticipated impact of these challenges and barriers on the project schedule). A novel six-step assessment model was developed to assess the level of significance of risk management implementation challenges and barriers, as detailed in Chapter Three. In total, three hierarchies were developed in accordance with each assessment criteria. Each hierarchy consisted of three levels, namely the target level (i.e., the assessment criteria for risk management implementation challenges and barriers), the factor level (i.e., the classification of risk management implementation challenges and barriers), and the sub-factor level (i.e., the identified risk management implementation challenges and barriers).

The model outputs indicated that the top three challenges and barriers to risk management implementation during COVID-19 era in each category era were as described below.

a. Analytical approaches-related challenges and barriers

The complexity of quantitative-based risk assessment tools was ranked first in the analytical approaches-related category, and second overall, with a Challenges and Barriers Priority Number (CB-PN) of 0.3443. Moreover, time-consuming process was ranked second in this category, and fourth overall (CB-PN = 0.2015). The ineffectiveness of the cost of RM analytical approaches was ranked third in this category, and tenth overall (CB-PN = 0.0995).

b. Behaviour-related challenges and barriers

Bribery was ranked first in the behaviour-related category, and first overall, with a CB-PN value of 0.4215. lack of willingness for collaboration among stakeholders was ranked second in this category, and third overall (CB-PN = 0.2218). Moreover, lack of willingness to change the current project management practices was ranked third in this category, and 12th overall (CB-PN = 0.0728).

c. Management-related challenges and barriers

Ineffective risk communication was ranked first in the management-related category, and fifth overall, with a CB-PN value of 0.1415. Lack of unified risk management framework for construction projects was ranked second in this category and seventh overall (CB-PN =

0.1300). Additionally, inadequate integration of risk management with other project management processes was ranked third in this category, and ninth overall (CB-PN = 0.1060).

d. Team-related challenges and barriers

Insufficient familiarity with risk management processes was ranked first in the team-related category, and sixth overall (CB-PN = 0.1368). Moreover, poor interaction among the project parties was ranked second in this category, and eighth overall, with a CB-PN value of 0.1218. Furthermore, lack of expertise and experience was ranked third in this category, as well as 13th overall (CB-PN = 0.1060).

5.2.2. The second thesis objective

The second objective of the thesis was to quantify the level of efficacy of risk management practices during COVID-19 pandemic in relation to the significant risk management implementation challenges and barriers using a novel multi-dimensional assessment model under fuzzy environment. A mixed-method approach was employed to achieve this objective. Semi-structured interviews were held with 30 construction professionals in Iraq (i.e., project managers, contractors, safety engineers, and academics) to identify the main indicators of effective risk management practices for construction projects. A fuzzy-based questionnaire survey was administered to 200 public- and private-sector construction experts in Iraq (i.e., project managers, contractors, consultants, and safety engineers), who were asked to rank each factor of the risk management practices in relation to each significant barrier and challenge to construction risk management implementation using a five-point Likert scale (ranging from 1 “very low” to 5 “very high”). A risk management practices assessment model was developed in relation to the challenges and barriers to construction risk management implementation using fuzzy sets theory.

To this end, 12 factors related to risk management practices measurement were identified and grouped into six categories of indicators, namely stakeholders’ involvement, organisational communication, risk culture, risk management training, risk management policies, and continuous risk monitoring. The main factors for the first indicator (i.e., stakeholders’ involvement) were relative to the perceived significance of each stakeholder to the others, and the level of interest the stakeholders have in the project. In addition, the main factors for the second indicator (i.e., organisational communication) were organisational communication culture, and usability of the communication tools. Moreover, the main factors for the third indicator (i.e., risk culture) were willingness to collaboration and knowledge sharing, and conflict in values. For the fourth indicator (i.e., risk management training), the main factors were the availability of expertise for training, and availability of resources. The main factors for the fifth indicators (i.e., risk management policies) were upper management support and openness to adopt risk management policies; and risk management potential benefits. Finally, the main factors for the sixth indicator (i.e., continuous risk monitoring) were risk management integration with other management processes, and project partiers integration.

The researcher used these indicators and their factors to assess the construction risk management practices against the most significant challenges and barriers to risk management implementation in each identified category under fuzzy environment. The assessment model consisted of 13 inputs, 900 IF-THEN conditional statements, and one output. The inputs represented the factors of the risk management practices indicators (12 inputs) with respect to each risk management implementation challenges and barriers (the 13th input). On the other hand, the output of the model represented the Risk Management Quantified Practices (RM-QP).

Ultimately, the resulted indicated that the RM-QP the Av. RM-QP for the identified categories and their significant risk management implementation challenges and barriers were as follows.

a. Analytical approaches-related challenges and barriers

The analytical approaches-related challenges and barriers category was ranked third, with an Av. RM-QP of 0.3393. The ranking and quantified values of the practices with regard to the significant challenges and barriers to risk management implementation were as follows (from high to low overall rank): (1) time-consuming process (ranked fourth), with an RM-QP value of 0.3594; (2) the complexity of quantitative-based risk assessment tools (ranked 11th, with an RM-QP value of 0.3265); and (3) ineffectiveness of the cost of risk management analytical approaches (ranked eighth with an RM-QP value of 0.3321).

b. Behaviour-related challenges and barriers

The behaviour-related challenges and barriers were ranked fourth, with an Av. RM-QP value of 0.3282. The ranking and quantified values of the practices with regard to the significant challenges and barriers to risk management implementation were as follows (from high to low overall rank): (1) lack of willingness for collaboration among stakeholders (ranked seventh, with an RM-QP value of 0.3386); (2) lack of willingness to change the current project management practices (ranked ninth, with an RM-QP value of 0.3292); and (3) bribery (ranked 12th, with an RM-QP value of 0.3168).

c. Management-related challenges and barriers

The management-related challenges and barriers were ranked fourth, with an Av. RM-QP value of 0.4033. The ranking and quantified values of the practices with regard to the significant challenges and barriers to risk management implementation were as follows (from high to low overall rank): (1) inadequate integration of risk management with other project management processes (ranked first, with an RM-QP value of 0.4960); (2) ineffective risk communication (ranked third, with an RM-QP value of 0.3683); and (3) lack of unified RM framework for construction projects (ranked sixth, with an RM-QP value of 0.3458).

d. Team-related challenges and barriers

The management-related challenges and barriers were ranked fourth, with an Av. RM-QP value of 0.3766. The ranking and quantified values of the practices with regard to the significant challenges and barriers to risk management implementation were as follows (from high to low overall rank): (1) conflicts in subjective assessment by risk assessors (ranked second, with an RM-QP value of 0.4519); (2) lack of expertise and experience (ranked tenth, with an RM-QP value of 0.3271); and (3) insufficient familiarity with risk management processes (ranked fifth, with an RM-QP value of 0.3508).

Thus, the findings of the risk management practice assessment using fuzzy sets theory revealed a low level of risk management practices in relation to the significant challenges and barriers to construction risk management implementation during the COVID-19 pandemic, which provide warning signs regarding the effects of risk management challenges and barriers, and the level of risk management practices during the pandemic.

5.3. The second paper: COVID-19 risk assessment

The aim of this paper is to develop a risk assessment model for construction projects under extreme conditions by considering the case of Iraqi construction industry during the COVID-19 pandemic era. The associated objectives are to: (1) identify and classify the risk factors emerging from the COVID-19 pandemic in the construction industry; and (2) quantify the riskiness level of the COVID-19 identified risks using a novel multi-criteria risk analysis model under fuzzy environment. As mentioned in Chapter One, the first and second objectives of the second paper represent the third and fourth objectives of this thesis. The following sub-sections provide details on the methodological approaches used to achieve these objectives and highlight the significant findings.

5.3.1. The third thesis objective

The third objective of this thesis was to identify and categorise the risk factors emerging from the COVID-19 pandemic in the Iraqi construction industry. In order to achieve this objective, a literature review and focus group session were used. To analyse the related COVID-19 and construction literature, a four-stage process was employed, including journal selection, keywords identification, article screening and selection criteria, and qualitative content analysis. Furthermore, a focus group session was conducted with 11 construction experts in Iraq (i.e., project managers, contractors, and architects). Participants in the focus group session added to and validated the list of emergent COVID-19 risks for the construction industry.

A total of 16 papers were initially retrieved from the literature search, and further scrutiny of their content led to selecting eight relevant works. Analysis of these studies and the focus group discussion output resulted in the identification of 46 Emergent COVID-19 risks, which were categorised under five themes: contractual/legal implications, construction financial market, supply chain operations, health and safety of construction workforce, and organisational implications themes.

The first theme of risks (i.e., contractual implications) included six emergent COVID-19 risks, namely lack of clarity of the contract language; claims arising under a construction contract; change of law; inappropriate risk allocation; contract suspension; and contract termination.

The second theme of risks (i.e., construction financial market) included ten risks, namely increased insurance premiums; increased taxes; fluctuation in currency exchange rates; escalation in the prices of materials; escalation in the prices of equipment; reduction in labour wages; lack of fiscal headroom for local government; contractors' bankruptcy; delayed payments; and suppliers' bankruptcy

The third theme of risks (i.e., supply chain operations) included nine risks, namely scarcity of manpower; lack of construction contractors; skills shortage; machine failure; damaged materials; construction materials shortage; material delivery delays; cargo theft; and monopoly of construction materials.

The fourth theme of risks (i.e., health and safety of construction workforce) included 13 risks, namely non-compliance with social distancing guidelines; increased subsidy rates; psychological stress; poorly ventilated spaces; delays caused by workforce self-isolating; virus spreading due to poor hygiene and lack of sanitised stations; virus spreading in commonly used or high-traffic construction areas; lack of cleanliness and sterilisation of commonly used surfaces, tools, and workstations by construction workers; contracting or spreading the virus when travelling to work; contracting or spreading the virus in changing, shower, and toilet facilities; contracting or spreading the virus during site meetings and training; lack of face masks or coverings; and re-using face masks or covering.

Lastly, the fifth theme of risks (i.e., organisational implications) included nine risks, namely delays caused by confusion arising out of the status or effect of government guidance; delays due to municipalities' prolonged procedures and routine; delayed work inspection and approval; poor site and virtual communication; restricted site access; delayed contractor mobilisation to the site; delay of work progress and reporting; and delayed design submission.

5.3.2. The fourth thesis objective

The fourth objective of the thesis was to quantify COVID-19 emerging risk levels using a novel multi-criteria risk analysis model under fuzzy environment. A mixed-method approach was adopted to achieve this objective, including (1) a focus group session with 11 construction experts (i.e., project managers, contractors, and architects) to identify the main dimensions/criteria for risk analysis and their decision components and discuss the COVID-19 risk assessment model's outputs and highlight their importance; (2) a questionnaire survey administered to 450 construction experts in Iraq (i.e., architects, project managers, contractors, and safety engineers); (3) interviews with a panel of six experts (i.e., five project managers and one risk professor) to establish the conditional statements between the components of each analysis criterion and between the analysis criteria; and (4) fuzzy-based risk analysis model development.

A three criteria-based analysis model was developed to analyse COVID-19 risks for the construction industry under fuzzy environment. These criteria were organisational level of readiness, risk probability of occurrence, and risk impact or severity. The decision components for the first risk analysis criteria (i.e., organisational level of readiness) were: (1) available expertise (e.g., assessor's level of technical experience in design, construction and project management, their contractual, legal, and financial experience, and their health and safety); and (2) company's level of contingencies. In addition, the decision components for the second risk analysis criteria (i.e., risk probability of occurrence) were: (1) organisational level of readiness; (2) political and security factors; and (3) out of control factors (e.g., adverse weather conditions, pandemics). Finally, the decision components for the third risk analysis criteria (risk impact or severity) comprised impacts on project cost, project time, and project quality.

Emergent COVID-19 risks for the construction industry were analysed using these criteria and their decision components. The fuzzy-based analysis model included seven inputs, four fuzzy controllers, and one output. Accordingly, the model inputs (i.e., the decision components) were evaluated within the fuzzy inference engine in order to determine the estimated level of each analysis criterion and the overall level of riskiness of each COVID-19 risk based on 350 IF-THEN conditional statements. The output of the model represented the fuzzy risk number (F-RN).

Ultimately, the results indicated that the F-RN for the identified emergent COVID-19 risks was significant. The F-RM and the ranking of the risks were as described below, in ranking order from high to low.

a. Contractual/legal implications theme

In this theme of risks, contract suspension was ranked first, with an F-RN value of 0.8104, followed by claims arising under a construction contract (F-RN = 0.7350; ranked fourth), inappropriate risk allocation (F-RN = 0.6966; ranked fifth), lack of clarity of the contract language (F-RN = 0.6617; ranked ninth), contract termination (F-RN = 0.5983; ranked 25th), and change of law (F-RN = 0.5302; ranked 38th).

b. Construction financial market theme

In this theme of risks, contractors bankruptcy was ranked second, with an F-RN value of 0.8098, followed by materials price escalation (F-RN = 0.7520; ranked third), equipment price escalation (F-RN = 0.6587; ranked tenth), increased taxation (F-RN = 0.6471; ranked 13th), increase insurance rates (F-RN = 0.6346; ranked 16th), fluctuation in currency rates of exchange (F-RN = 0.6353; ranked 17th), reduction in labour wages (F-RN = 0.6165 ranked 22nd), delayed payments (F-RN = 0.6020; ranked 24th), lack of fiscal headroom for local government (F-RN = 0.5223; ranked 40th), and suppliers' bankruptcy (F-RN = 0.4751; ranked 42nd).

c. Supply chain operations theme

In this theme of risks, skills shortage was ranked seventh, with an F-RN value of 0.6681, followed by material delivery delays (F-RN = 0.6038; ranked 23rd), damaged materials (F-RN = 0.5938; ranked 27th), cargo theft (F-RN = 0.5651; ranked 33rd), scarcity of manpower (F-RN = 0.5631; ranked 34th), monopoly of construction materials (F-RN = 0.5598; ranked 35th), lack of construction contractors (F-RN = 0.5507; ranked 36th), construction materials shortage (F-RN = 0.5263; ranked 39th), and machine failure (F-RN = 0.3912; ranked 46th).

d. Health and safety theme

In this theme of risks, non-compliance with social distancing guidelines was ranked sixth with an F-RN value of 0.6755, followed by virus spreading due to poor hygiene and lack of sanitised stations (F-RN = 0.6439; ranked 14th); increased subsidy rates (F-RN = 0.6504; ranked 11th); contracting or spreading the virus when travelling to work (F-RN = 0.6433; ranked 15th); lack of cleanliness and sterilisation of commonly used surfaces, tools, and workstations by construction workers (F-RN = 0.6279; ranked 19th); lack of face masks or coverings (F-RN = 0.6218; ranked 20th); psychological stress (F-RN = 0.5918; ranked 29th); re-using face masks or covering (F-RN = 0.5822; ranked 30th); poorly ventilated spaces (F-RN = 0.5817; ranked 31st); contracting or spreading the virus during site meetings and training (F-RN = 0.5506; ranked 37th); delays caused by workforce self-isolating (F-RN = 0.5183; ranked 41st); contracting or spreading the virus in changing; showers; and toilets facilities (F-RN = 0.4680; ranked 43rd); and virus spreading in commonly used or high-traffic construction areas (F-RN = 0.4017; ranked 45th).

e. Organisational implications

In this theme of risks, poor site and virtual communication was ranked eighth, with an F-RN value of 0.6677, followed by delayed due to municipalities' prolonged procedures and routine (F-RN = 0.6489; ranked 12th), delays caused by confusion arising out of the status or effect of government guidance (F-RN = 0.6319; ranked 18), delayed work inspection and approval (F-RN = 0.6172; ranked 21st), delayed design submission (F-RN = 0.5951; ranked 26th), delayed contractor mobilisation to the site (F-RN = 0.5927; ranked 28th), delay of work progress and reporting (F-RN = 0.5654; ranked 32nd), and restricted site access (F-RN = 0.4561; ranked 44th).

5.4. The third paper: The effects of COVID-19 pandemic risks on project success

The purpose of this research is to quantitatively analyse the direct and indirect effects of the significant risks emerging from the COVID-19 pandemic on project success (PS) in developing countries by considering the case of Iraqi construction industry. As mentioned in Chapter One, the third paper seeks to address the fifth objective of this thesis. The following sub-sections provide details on the methodological approaches used to achieve this objective and highlight the significant findings.

5.4.1. The fifth thesis objective

As mentioned previously, the fifth objective of this thesis was to model the effects of the significant risks emerging from the COVID-19 pandemic on construction project success. This objective captures the perceptions of construction contractors in Iraq, as the previous results of objective four indicated that the contractors were facing high levels of financial loss, including bankruptcy. As a result of the emergency financial crisis which was caused by the COVID-19 pandemic, construction companies have not been able to find sufficient manpower, materials, and equipment to continue their progress based on the planned activities and the projected completion date (Assaad and El-adaway, 2021), resulting in the filing of bankruptcy by many companies worldwide (Strickland, 2020).

In the context of Iraq, the Iraqi Contract Conditions for Civil Engineering Works (ICCCEW, 1987) stipulates that contracting companies are only entitled to time extensions without cost reimbursements during crises that may lead to the collapse of many contracting companies. Accordingly, the perceived impact on project success from the perspective of the contractor was considered in this objective. To this end, the fifth thesis objective was achieved using a mixed research methodology, including: (1) preliminary investigation with four construction contractors to identify the success indicators of construction projects; (2) literature review to identify the emergent COVID-19 risks for the construction industry; (3) semi-structured interviews with seven construction experts to develop several hypotheses on the effect of emergent COVID-19 risks to project success; (4) survey data collection from 250 construction contractors in Iraq to assess the perceived agreement of the COVID-19 emerging risk factors that influence construction project success and its indicators on a five-point Likert scale (ranging from 1 “strongly disagree” to 5 “strongly agree”); and (5) development of a structural equation model to analyse the effects of emergent COVID-19 risks to project success.

Ultimately, eight indicators of project success were identified, namely time, cost, quality, safety, commercial profitability, functionality, client satisfaction, and end-user satisfaction. Moreover, a hypothetical framework for emergent COVID-19 risks and project success was established under three sets of hypotheses.

The first set of hypotheses examines the direct relationship between risks to project success related to contractual implications (CI), construction financial market (CFM), supply chain operations (SCO), health and safety of construction workforce (HSCW), and organisational implications (OI).

The second set of hypotheses examines the direct relationship between CFM related risks, HSCW related risks, OI related risks, SCO related risks on contractual implications.

The third set of hypotheses examines the indirect relationship between the emergent COVID-19 risks and the success of the construction project through the role of the mediator (i.e., contractual implications).

The SEM findings are summarised below.

a. The first set of hypotheses

For the first set of hypotheses, the results indicated that risks related to CI, CFM, SCO, HSCW, and OI had variety of adverse impacts on the successful delivery of the construction projects during COVID-19 pandemic. CI-related risks had the strongest total effects on PS (β = 0.573, T = 8.552, P<1%), followed by OI-related risks (β = 0.561, T = 6.164, P<1%), then CFM-related risks (β = 0.518, T = 6.167, P<1%), HSCW-related risks (β = 0.485, T = 6.382, P<1%), and SCO-related risks (β = 0.462, T = 4.278, P<1%).

b. The second set of hypotheses

For the second set of hypotheses, the results indicated that OI-related risks had the strongest direct effect on CI (β = 0.637, T = 8.847, P<1%), followed by HSCW-related risks (β = 0.613, T = 11.57, P<1%), CFM -related risks (β = 0.568, T = 6.604, P<1%), and SCO-related risks (β = 0.469, T = 4.989, P<1%).

c. The third set of hypotheses

For the third set of hypotheses, the results indicated the SCO-related risks had the strongest direct effect on project success (β = 0.194, T = 2.662, P<1%), followed by CFM-related risks (β = 0.193, T = 2.517, P<1%), HSCW-related risks (β = 0.134, T = 2.183, P<1%), and OI-related risks (β = 0.121, T = 3.011, P<1%). On the other hand, the indirect effects with the inclusion of mediator into the analysis were found significant for OI-related risks with the strongest indirect effect (β = 0.440, T = 4.834, P<1%), followed by HSCW-related risks (β = 0.351, T = 4.195, P<1%), CFM-related risks (β = 0.325, T = 4.336, P<1%), and SCO-related risks (β = 0.268,T = 3.276, P<1%)

These findings emphasise the need for an integrated contract management system for construction projects under extreme conditions that comprehensively captures the main risk categories and their sources. This may aid in managing conflicts on schedule, reducing disputes, protecting the financial interests of key stakeholders, maintaining relevant records, controlling changes, managing roles and responsibilities, resolving discrepancies or inconsistencies among several contractual documents, and safeguarding entities' rights (Oluka and Basheka, 2014; Van Weele, 2014; Hamie and Abdul-Malak, 2018).

5.5. Key conclusions

The thesis conclusions can be summarised as follows:

1. Unlike other 21st-century outbreaks (e.g., SARS1, MERS2, or H1N1pdm09), the COVID-19 pandemic is of unprecedented scale and intensity for the construction industry worldwide, causing supply chain disruptions, workforce restrictions, and legislative changes. However, the construction industry in developing countries like Iraq is perceived to be more vulnerable to the challenges associated with the pandemic. Moreover, the ongoing challenges facing the construction industry in developing countries, such as the limited use of technology, skills shortages, lack of training, lack of investment, lack of culturally appropriate procurement methods, poor health and safety systems, and a lack of government support, have played a significant role in amplifying the risk of COVID-19 pandemic (and public health measures), causing an adverse effect on the success of construction projects.

2. COVID-19 and its emerging risks for the construction industry have received a lack of literature attention, and there is a lack of research assessing emergent COVID-19 risks, as well as risk management challenges, barriers, and RM practices during the pandemic in the construction industry of developing countries, particularly for the case of Iraq. Put simply, it can be concluded that existing literature does not address contracting companies' best RM practices for managing COVID-19 risks.

3. Risk management 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. In extreme conditions such as the COVID-19 pandemic, RM becomes even more crucial, particularly in developing countries that are characterised by a poor latent project management culture. 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 developing countries with the poorest construction risk management practices.

4. Based on the findings of this study, it can be concluded that 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.
5. Identifying, analysing, 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.
6. Considering the complexity of mathematical methodologies for assessing and forecasting risks, as well as the costs associated with the use of RM analytical approaches, such as purchasing software licenses and conducting training sessions outside of Iraq, decision-makers find it difficult to adopt and employ these methodologies. Consequently, decision-makers continue to rely on their own engineering experience, judgment, and intuition to make decisions.
7. Managing construction project risks under unprecedented 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.
8. The majority of construction companies in Iraq view the implementation of a structured risk management approach, whether it is qualitatively-based, quantitatively-based or a combination of both, as an unnecessary expense.
9. 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.

10. The risk practices assessment model based on FST developed in this thesis 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.

11. 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.

12. Despite the popularity of risk matrices and their inclusion in standards and professional guidelines (e.g., ISO 31000:2009, NIST800-30: 2012, etc.), as well as their visual appearance, simplicity, and ease of use, they have some limitations, such as poor resolution and ambiguous inputs and outputs, and continue to undergo continuous development processes.

13. Incorporating organisational readiness level as a new assessment dimension when analysing extreme conditions risks helps capture new underestimated decision components (e.g., the availability of resources and expertise), and aligns with the actual practice of assessing construction risk during extreme circumstances such as the COVID-19 pandemic. Additionally, it is perceived to align with the construction risk assessment practices carried out during extreme conditions, such as the pandemic.

14. Using the risk analysis model based on FST developed in this thesis, industry experts in developing countries like Iraq can effectively assess the unique characteristics of the risks arising from extreme conditions such as the COVID-19 pandemic based on the level of available expertise (i.e., assessors' level of technical

experience in design, construction and project management; their contractual, legal, and financial experience; and their health and safety); companies' levels of contingencies; political and security factors; and out of control factors (e.g., adverse weather conditions) impacts on project cost, schedule, and quality.

15. The risk analysis results suggest that most bankruptcies during the COVID-19 era in Iraq were recorded among small and new contracting companies, which resulted in a void in the market that could not be filled by large contracting companies.

16. The poor insurance mechanism for contracting companies affected by the COVID-19 pandemic and its emerging risks in Iraq has resulted in numerous construction-related claims that have not yet been resolved, due to a lack of clarity from courts and arbitration institutions regarding the resolution of these disputes.

17. SEM modelling results indicate that SCO-related risks have the greatest direct effect on the success of Iraqi construction projects. A number of factors contributed to this, including constant lockdowns, travel bans, and other measures implemented to control the effects of the outbreak, which led to significant delays in the completion of construction projects as a result of a lack of resources, a shortage of construction workforce, and other factors related to the outbreak and public health measures.

18. SEM modelling outputs suggest that CI plays a vital role in mediating the relationship (modelling the indirect effects) between the COVID-19 risk categories (i.e., CFM-related risks, HHSCW-related risks, OI-related risks, and SCO-related risks). Consequently, it is imperative that an integrated contract management system be established for construction projects under extreme conditions that addresses the main risk categories and their sources. Such a system can assist in controlling scheduling conflicts, reducing disputes, protecting the financial interests of key stakeholders, maintaining relevant records, controlling changes, and managing roles and responsibilities.

19. The results of the five sets of interviews and one focus group session 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, as well as the key risks arising from the COVID-19 pandemic and how they affect the successful implementation of construction projects. Additionally, these insights helped validate the developed models' methodological aspects and the analysis outcomes. Furthermore, the statistically valid and reliable outputs of the four sets of

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 the construction industry of developing countries that share similar characteristics.

5.6. Research contributions

5.6.1. Contribution to knowledge

In any doctoral 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 thesis, the literature review disclosed a lack of research on construction project management in developing countries during the COVID-19 pandemic. This research makes an original contribution to the body of knowledge in the field of construction risk management research during extreme conditions like the pandemic (and analogous situations such as public order emergencies or natural disasters). In fact, this research is the first to examine the effects of risk management challenges and practices during the COVID-19 pandemic, as well as how these risks impact construction project success, in the context of developing countries in general, and Iraq in particular. 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 emergent COVID-19 risks for the construction industry.
2. Developing an integrated assessment methodology based on AHP and FST to assess risk management implementation challenges and barriers, as well as the effectiveness of current risk management practices. In fact, the overall developed assessment methodology considered the level of importance (weight) of each challenge and barrier that resulted from the AHP analysis as well as 12 inputs (i.e., the relative significance of each stakeholder to others; the level of interest the stakeholders have in the project; organisational communication culture; usability of communication tools; willingness to collaborate and knowledge sharing; conflict in values; availability of expertise for training and availability of resources; upper management support and openness to adopt risk management policies; risk management potential benefits; risk management integration with other management processes; and project parties integration) under six main risk

management indicators (i.e., stakeholders' involvement; organisational communication; risk culture; risk management training; risk management policies; and continuous risk monitoring).

3. Developing a risk analysis model for extreme conditions based on FST that determines COVID-19 emerging risk levels based on three assessment criteria (i.e., organisational level of readiness; risk probability of occurrence; and risk impact) and six decision components (i.e., organisational level of readiness; political and security factors; out of control factors, impact on project cost; impact on project time; and impact on project quality).
4. Developing a risk impact on project success assessment model that utilised PLS-SEM to elucidate the structural correlation among the identified COVID-19 risks and project success. The employed model used PLS path modelling to evaluate each latent variable's attributes and how they impact process success and its indicators through the assessment of measurement model (i.e., internal consistency reliability, convergent validity, and discriminant validity), and the assessment of the structural model (i.e., coefficient of determination, cross validated redundancy, path coefficient, and mediation analysis).
5. Providing proposals for responses to the related parties in the form of recommendations, in order to eradicate or alleviate poor risk management practices and extreme conditions risks.

5.6.2. Contribution to managerial practices

The findings of this research can help construction practitioners to better understand the challenges and barriers hindering the effective implementation of risk management strategies for construction projects during the COVID-19 period and analogous crises. In addition, it provides valuable information to decision makers regarding the efficacy of current construction risk management practices in developing countries such as Iraq. Moreover, it provides a better understanding of the significant risks emerging from the COVID-19 pandemic and to what extent these significant risks affect construction projects' success in terms of time, cost, quality, safety, end-user satisfaction, client satisfaction, commercial profitability, and functionality.

To this end, the outcomes of this research can therefore serve as a baseline for construction companies and government to develop effective strategies for addressing risk management implementation's main challenges and barriers, and ultimately enhance risk management practices for the construction industry. In addition, it should enhance the effectiveness of risk assessment in the construction industry of developing countries and minimise project losses by capturing the importance of the organisational level of readiness and incorporating into the risk analysis process the components of risk analysis criteria, which are crucial when projects are subject to high levels of uncertainty during extreme conditions. Furthermore, understanding the nature of the relationship between the risks emerging from extreme conditions and project success should assist construction contractors in identifying the root causes of low-level project success; and in developing appropriate strategies for improving project success levels by addressing the direct and indirect effects of extreme conditions risks.

5.7. Research limitations

Despite its contributions, this study has some limitations. First, the scope of this research is limited to COVID-19 risks for the construction industry, without particular consideration of other major potential disruptions (e.g., earthquakes, hurricanes, or conflicts).

Second, this research depends on experts' judgment via interviews, focus group sessions, and questionnaire surveys. Other methods like case studies should be applied to complement the results obtained.

Third, only five construction themes were examined in this research (i.e., contractual implications, financial market, supply chain operations, health and safety of construction workforce, and organisational implications). Other themes such as governmental implications may be considered for future research based on the developed methodology in this research.

Fourth, the research identified only 34 risk management implementing challenges and barriers under four categories. Other challenges and barriers to risk management implementation should be identified and categorised.

Fifth, the research considered only 12 factors under four risk management practices for efficacy measurement. New indicators should be investigated to increase the scope of risk management practices by captures the perception of other stakeholders' groups.

Sixth, the research identified only 46 risks that were classified under five main construction themes. Other risks emerging from the COVID-19 pandemic should be identified and classified under the study existing themes or under new construction themes.

Seventh, not all of the stakeholder groups were involved in the COVID-19 risk identification and analysis. Other stakeholders such as suppliers and end-users should be invited to conduct follow up studies.

Eighth, the direct and indirect effects of emergent COVID-19 risks on construction project success was modelled based on the perspectives of contractors in Iraq. However, the perspectives of other construction stakeholders (e.g., project managers, consultants, etc.) may differ on the impact of extreme conditions on the success of projects.

Finally, project success was measured using eight indicators (i.e., time, cost, quality, safety, client satisfaction, end-user satisfaction, commercial profitability, and functionality). Other indicators such as environmental impact and performance were not captured in this research, which might be identified based on other stakeholders' group focus.

5.8. Recommendations

5.8.1. Recommendations for construction practitioners

The following recommendations may assist construction practitioners and decision-makers to minimise and control the risks of extreme conditions:

1. Contacting parties should use the best practices in identifying, analysing, responding and controlling extreme conditions risks (e.g., COVID-19 emerging risks), and maintaining an updated risk register.
2. It is necessary to select the right set of effective and efficient tools and techniques that will assist with the assessment of extreme conditions risks. Failure to use the appropriate tools and techniques during the identification or analysis of risks could result in miscalculations during the risk assessment process and negatively affect the construction firm resources.
3. Construction companies should comply with the standards and general guidelines of the risk management 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 risk management process, and establish a risk management information and reporting system for each project.
4. Governmental bodies such as the Iraqi Engineers Association should provide training, education, and awareness for project managers and contractors on how to manage the risks arising from extreme conditions.
5. It is imperative that construction companies consider whether their construction site hazard and risk assessments indicate a need for more than the standard personal protective equipment (e.g., face masks, gloves, and vests), including equipment not

traditionally considered necessary for sites (e.g., to prevent viral transmission during pandemics).

6. The safety management team should ensure that objects and surfaces that are touched regularly (such as buckets, site equipment, and control panels) are cleaned frequently; dispose of cleaning products properly; and encourage hand-washing and sanitisation in a more frequent and systematic manner.
7. The safety management team should ensure that cleaning products are properly disposed of, especially for buckets, site equipment, and control panels that are continually touched.
8. The safety management team should provide additional non-recycling bins for workers and visitors to dispose of single-use face coverings and personal protective equipment.

5.8.2. Recommendations for future studies

Future studies can utilise and build upon the findings of this research by:

1. Implementing the developed risk management challenged and barriers assessment (i.e., the AHP-based model) and risk management practices assessment (i.e., fuzzy-based model) in various case studies and within different stages of project life cycle, and examining their impacts on project success and related indicators.
2. Developing risk management best practices guidelines and response strategies to address implementation challenges and barriers.
3. Investigating risk management implementation challenges and barriers and the level of risk management practices in developing versus developed countries.
4. Applying the developed risk assessment model to examine the impact of other extreme conditions (e.g., natural disasters).
5. Comparing the results of the structural equation model that captures the effects of emergent COVID-19 risks on construction success from the contractors' perspective with the viewpoints of other key stakeholders in the construction industry.

5.9. Challenges encountered during the research execution

It is unrealistic to expect not to encounter some difficulties when conducting a research project. During the course of conducting this research, the following three main difficulties were encountered:

1. The lack of a theoretical foundation for COVID-19 and construction. Because of the scarcity of relevant literature, the researcher faced significant challenges in understanding theoretically the impact of COVID-19 pandemic on construction projects. As a matter of fact, the only available resources were some online technical notes from key construction companies in Europe and North America. This actually formed the departure point for the researcher to investigate what was known and what was unknown more deeply, which contributed to the subsequent formulation of the aim and objectives of this thesis.
2. Data collection difficulties. Obtaining responses to the questionnaires from the research respondents was a challenging task. Furthermore, the researcher spent considerable time arranging the interviews with the research participants. There was a delay in this process due to the fact that some respondents had missed their appointments or wished to reschedule them. Additionally, given the varying work schedules and availability of the experts involved in the focus groups, it was difficult to get them all to agree to meet at the same time. This was exacerbated by intermittent lockdown and social distancing measures applied in Iraq during the period of fieldwork.
3. Data analysis and processing difficulties. The analysis of the qualitative and quantitative data from the construction experts who participated in this study took considerable time. Nevertheless, the interviews and surveys presented in this study were crucial to developing the theoretical basis of construction RM during extreme conditions like COVID-19.

Appendix A: The First Survey

My name is Mohamed Al-Mhdawi and I am a PhD student at the University of Southampton. As part of my study for my degree, I will examine risk management for construction projects during the COVID-19 era. The purpose of this survey is to rank the risk management implementation challenges and barriers based on three key assessment criteria (i.e., the level of probability, the level of impact on project cost, and the level of impact on project schedule).

I would like to invite you to participate in this survey by completing the questionnaire, as you have been recognized as a highly credible contractor, project manager, safety engineer, construction academic, architect, and consultant with experience in the construction industry in Iraq. The questionnaire will take approximately 45 to 90 minutes to complete. Participation is entirely voluntary, and all responses will be treated as anonymous. If published, the results will summarise the responses of the entire sample; individual responses will not be identified. Please note that by returning this questionnaire you are giving your informed consent to participate in this study. I greatly appreciate your participation. Thank you for taking the time to complete the survey.

Yours sincerely,

Mohammed Al-Mhdawi

M.K.S-Al-Mhdawi@Southampton.ac.uk

***Section One: Sample Characteristics*:**

1. Working Sector:

☐ Public ☐ Private

2. Profession

☐ Project manager ☐ Contractors ☐ Consultant

☐ Safety engineer ☐ Other

3. Years of experience

☐ 1-5 years ☐ 6-15 years ☐ 16-25 years

☐ >25 years

4. Educational qualifications

☐ Diploma ☐ MSc

☐ BSc ☐ PhD

Section Two:

Please specify the relative importance of each criterion or sub criterion with respect to the other criterion or sub criterion in pairwise comparison to compare all of the criteria to each other, knowing that the relative importance should be based on AHP according to the numerical rating as shown in **Table A.** Please refer to **Table B** which provides guiding questions regarding the analysis criteria that reflect the interdependence between the analysis criteria related to risk management implementation challenges and barriers. Please also use **Table C** as a reference when completing Q4 to Q15.

Table A: 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 a strong importance than risk *y*)
1/3, 1/5, 1/9	Values of inverse comparison

Table B: 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?*

Where *K* and *Y* are the risk management implementation challenges and barriers and their categories with respect to the assessment criteria (i.e., probability of occurrence, impact on cost, and impact on schedule).

Table C: Risk management implementation challenges and barriers

Category	Challenges and barriers
Analytical Approaches-related challenges and barriers	**A01.** Difficulty to estimate the risks' probabilities of occurrence and their level of severity
	A02. Complexity of quantitative-based risk assessment tools (e.g., Monte Carlo simulation)
	A03. Time-consuming process
	A04. A lack of historical data for the analysis and modelling of risk Trends
	A05. Ineffectiveness of the cost of RM analytical approaches (e.g., expenses associated with licensing and training).
	A06. Inability to comprehend and interpret results
	A07. Insufficiency of good data to ensure reliability
Behaviours-related challenges and barriers	**B01.** Lack of willingness to change the current project management practices
	B02. Bribery
	B03. Lack of commitment
	B04. Lack of willingness for collaboration
Management-related challenges and barriers	**M01**. Lack of awareness of RM potential benefits
	M02. Insufficient RM resources (e.g., budget)
	M03. Lack of continuation and coordination among RM activities at various stages of the project lifecycle
	M04. Lack of unified RM framework for construction projects
	M05. Time constraints and commercial pressures
	M06. Inadequate integration of RM with other project management Processes

	M07. insufficient support from the upper management
	M08. The difficulty of determining the risk-return trade-off
	M09. Inadequate organisational structure
	M10. Ineffective risk communication
	M11. The absence of government legislation
	M12. Sluggish decision-making process
	M13. Limited participation of contractors during the design process
	M14. Failure to document and/or share lessons learned
	M15. Poor risk management training system
Team-related related challenges and barriers	**T01**. Lack of expertise and experience
	T02. Lack of awareness and consciousness of risks among the project management team
	T03. A lack of specialized RM role
	T04. Insufficient familiarity with RM processes
	T05. Lack of clarity regarding individual responsibilities
	T06. Doubts regarding the suitability of RM techniques
	T07. Poor interaction among the project parties
	T08. Conflicts in subjective assessment by risk assessors

Q1) Please determine the weight of the main risk management implementation challenges and barriers categories when assessing the level of probability of occurrence.

	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers
Analytical approaches-related challenges and barriers				
Behaviours-related challenges and barriers				
Management-related challenges and barriers				
Team-related challenges and barriers				

Q2) Please determine the weight of the main risk management implementation challenges and barriers categories when assessing the level of impact on cost.

	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers
Analytical approaches-related challenges and barriers				
Behaviours-related challenges and barriers				
Management-related challenges and barriers				
Team-related challenges and barriers				

Q3) Please determine the weights of the main risk management implementation challenges and barriers categories when assessing the level of impact on schedule.

	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers	Analytical approaches-related challenges and barriers
Analytical approaches-related challenges and barriers				
Behaviours-related challenges and barriers				
Management-related challenges and barriers				
Team-related challenges and barriers				

Q4) Please determine the weights of the main risk management implementation challenges and barriers with respect to the probability of occurrence creation.

	A01	A02	A03	A04	A05	A06
A01						
A02						
A03						
A04						
A05						
A06						

Q5) Please determine the weights of the main risk management implementation challenges and barriers with respect to impact on project cost creation.

	A01	A02	A03	A04	A05	A06
A01						
A02						
A03						
A04						
A05						
A06						

Q6) Please determine the weights of the main risk management implementation challenges and barriers with respect to impact on project schedule creation.

	A01	A02	A03	A04	A05	A06
A01						
A02						
A03						
A04						
A05						
A06						

Q7) Please determine the weights of the main risk management implementation challenges and barriers with respect to the probability of occurrence creation.

	B01	B02	B03	B04
B01				
B02				
B03				
B04				

Q8) Please determine the weights of the main risk management implementation challenges and barriers with respect to the impact on cost creation.

	B01	B02	B03	B04
B01				
B02				
B03				
B04				

Q9) Please determine the weights of the main risk management implementation challenges and barriers with respect to the impact on schedule creation.

	B01	B02	B03	B04
B01				
B02				
B03				
B04				

Q10) Please determine the weights of the main risk management implementation challenges and barriers with respect to the probability of occurrence creation.

	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15
M01															
M02															
M03															
M04															
M05															
M06															
M07															
M08															
M09															
M10															
M11															
M12															
M13															
M14															
M15															

Q11) Please determine the weights of the main risk management implementation challenges and barriers with respect to the impact on cost creation.

	M01	M02	M03	M04	M05	M06	M07	M08	M09	M10	M11	M12	M13	M14	M15
M01															
M02															
M03															
M04															
M05															
M06															
M07															
M08															
M09															
M10															
M11															

M12															
M13															
M14															
M15															

Q12) Please determine the weights of the main risk management implementation challenges and barriers with respect to the impact on schedule creation.

	M01	**M02**	**M03**	**M04**	**M05**	**M06**	**M07**	**M08**	**M09**	**M10**	**M11**	**M12**	**M13**	**M14**	**M15**
M01															
M02															
M03															
M04															
M05															
M06															
M07															
M08															
M09															
M10															
M11															
M12															
M13															
M14															
M15															

Q13) Please determine the weights of the main risk management implementation challenges and barriers with respect to probability of occurrence creation.

	T01	T02	T03	T04	T05	T06	T07	T08
T01								
T02								
T03								
T04								
T05								
T06								
T07								
T08								

Q14) Please determine the weights of the main risk management implementation challenges and barriers with respect to the impact on cost creation.

	T01	T02	T03	T04	T05	T06	T07	T08
T01								
T02								
T03								
T04								
T05								
T06								
T07								
T08								

Q15) Please determine the weights of the main risk management implementation challenges and barriers with respect to the impact on schedule creation.

	T01	T02	T03	T04	T05	T06	T07	T08
T01								
T02								
T03								
T04								
T05								
T06								
T07								

Appendix B: The Second Survey

My name is Mohamed Al-Mhdawi and I am a PhD student at the University of Southampton. As part of my study for my degree, I will examine risk management for construction projects during the COVID-19 era. The purpose of this survey is to assess the level of efficacy of the risk management practices in relation to the significant risk management challenges and barriers. I would like to invite you to participate in this survey by completing the questionnaire, as you have been recognized as a highly credible contractor, project manager, safety engineer, construction academic, architect, and consultant with experience in the construction industry in Iraq. The questionnaire will take approximately 45 to 90 minutes to complete. Participation is entirely voluntary, and all responses will be treated as anonymous. If published, the results will summarise the responses of the entire sample; individual responses will not be identified. Please note that by returning this questionnaire you are giving your informed consent to participate in this study. I greatly appreciate your participation. Thank you for taking the time to complete the survey.

Yours sincerely,

Mohammed Al-Mhdawi

M.K.S-Al-Mhdawi@Southampton.ac.uk

Section One: Sample Characteristics:

5. Working Sector:

☐ Public ☐ Private

6. Profession

☐ Project manager ☐ Contractors ☐ Consultant

☐ Safety engineer ☐ Other

7. Years of experience

☐ 1-5 years ☐ 6-15 years ☐ 16-25 years

☐ >25 years

4. Educational qualifications

☐ Diploma ☐ MSc

☐ BSc ☐ PhD

Section Two:

Please rate the following criteria to assess the risk management practices in relation to the main challenges and barriers to risk management implementation using a five-point Likert's quintet scale (1: very low) to (5: very high). Please use Table A as a ranking reference. Please refer to Table B which summarizes the assessment criteria and Table C which lists the significant challenges and barriers.

Table A: Ranking reference

Value	**Description**
1	Very low
2	Low
3	Moderate
4	High
5	Very high

Table B: The assessment Criteria

Abbreviation	Description
LS	The relative significance of each stakeholder to other
LI	The level of interest the stakeholders have in the project
OCC	Organization Communication Culture
CT	The level of usability of the communication tools
AET	Availability of Expertise for Training
AR	Availability of Resources
WCKS	Willingness to Collaboration and Knowledge Sharing
CV	Conflict in Values

Table C: The significant challenges and barriers to risk management implementation

Code	Description
A02	Complexity of quantitative-based risk assessment tools (e.g., Monte Carlo simulation)
A03	Time-consuming process
A05	Ineffectiveness of the cost of RM analytical approaches (e.g., expenses associated with licensing and training
B01	Lack of willingness to change the current project management practices
B02	Bribery
B04	lack of willingness for collaboration among stakeholders
M04	Lack of unified RM framework for construction projects
M06	Inadequate integration of RM with other project management processes
M10	Ineffective risk communication
T01	Lack of expertise and experience
T04	Insufficient familiarity with RM processes
T08	Conflicts in subjective assessment by risk assessors

Please use **Tables A, B and C** to rate the following criteria:

Challenges and barriers	**Stakeholders' involvement**		**Communication level**		**Risk management training**		**Risk culture**	
	LS	**LI**	**OCC**	**CT**	**AET**	**AR**	**WCKS**	**CV**
A02								
A03								
A05								
B01								
B02								
B04								
M04								
M06								
M10								
T01								
T04								
T08								

Appendix C: the Third Survey

My name is Mohamed Al-Mhdawi and I am a PhD student at the University of Southampton. As part of my study for my degree, I will examine risk management for construction projects during the COVID-19 era. The purpose of this survey is to assess covid-19 emerging risks for the construction industry. I would like to invite you to participate in this survey by completing the questionnaire, as you have been recognized as a highly credible contractor, project manager, safety engineer, construction academic, architect, and consultant with experience in the construction industry in Iraq. The questionnaire will take approximately 45 to 90 minutes to complete. Participation is entirely voluntary, and all responses will be treated as anonymous. If published, the results will summarise the responses of the entire sample; individual responses will not be identified. Please note that by returning this questionnaire you are giving your informed consent to participate in this study. I greatly appreciate your participation. Thank you for taking the time to complete the survey.

Yours sincerely,

Mohammed Al-Mhdawi

M.K.S-Al-Mhdawi@Southampton.ac.uk

Section One: Sample Characteristics:

1. **Working Sector:**

☐ Public ☐ Private

2. **Profession**

☐ Project manager ☐ Contractors ☐ Consultant

☐ Safety engineer ☐ Other

3. **Years of experience**

☐ 1-5 years ☐ 6-15 years ☐ 16-25 years

☐ >25 years

4. **Educational qualifications**

☐ Diploma ☐ MSc

☐ BSc ☐ PhD

Section Two:

Please rate each of the COVID-19 risks in terms of the components of the analysis criteria, i.e., AE and CLC (for the organization level of readiness), PSF and OCF (for the probability of risk occurrence), and IPC, IPT, and IPC (for risk impact on project set objectives) using a five-point Likert's quintet scale (1: very low) to (5: very high) for the assessment of the analysis criteria (please refer to **Table A).** Please also refer to **Table B** which summarizes the assessment criteria and **Table C** which lists the significant COVID-19 emerging risks for the construction industry.

Table A: Ranking scale

Numerical value	Description
1	Very low
2	Low
3	Moderate
4	High
5	Very high

Table B: The assessment Criteria

Abbreviation	Description
PSF	Political and Security Factors
OCF	Out of Control Factors
IPC	Impact on Project Cost
IPT	Impact on Project Time
IPQ	Impact on Project Quality
AE	Available Expertise
CLC	Company's Level of Contingencies

Table C: COVID-19 emerging risks for the construction industry

Theme	**COVID-19 risks**
Construction Financial Market	**C01.** Increase` insurance rates
	C02. Increase of tax rate
	C03. Fluctuation in currency rates of exchange
	C04. Materials prices escalation
	C05. Equipment prices escalation
	C06. Reduction in labour wages
	C07. Lack of fiscal headroom for local Government.
	C08. Contractors' bankruptcy
	C09. Delayed in payments **C10.** Suppliers' bankruptcy
Supply chain operations	**S01.** Scarcity of manpower
	S02. Lack of construction sub-contractors
	S03. Skills shortage
	S04. Machine failure
	S05. Damaged materials*****
	S06. Construction materials shortage
	S07. Material delivery delays
	S08. Cargo theft
	S09. Monopolization of construction materials
Health and safety of construction workforce	**H01.** Non-compliance with social distancing guidelines
	H02. Increased subsidy rates
	H03. Psychological stress
	H04. Poorly ventilated spaces
	H05. Delays caused by workforce self-isolating
	H06. Virus spreading due to poor hygiene and lack of sanitizing stations
	H07. Virus spreading in commonly used or high traffic construction Area
	H08. Lack of cleanliness and sterilization of commonly used surfaces,

	tools, and workstations by construction workers.
	H09. Contracting or spreading the virus when traveling to work
	H10. Contracting or spreading the virus in changing rooms, showers, and toilets facilities.
	H11. Contracting or spreading the virus during site meetings and training.
	H12. Lack of face masks or coverings
	H13. Re-using face masks or covering
Organisational Implications	**O01.** Delays caused by confusion arising out of the status or effect of government guidance.
	O02. Delayed due to Municipalities' prolonged procedures and Routine
	O03. Delayed work inspection and approval.
	O04. Poor site and virtual communication
	O05. Restricted site access
	O06. Delayed contractor mobilization to the site.
	O07. Delay of work progress and reporting
	O08. Delayed design submission
Legal Implications	**L01.** Lack of clarity of the contract language
	L02. Claims arising under a construction contract
	L03. Change of law
	L04. Inappropriate risk allocation
	L05. Contract suspension
	L06. Contract termination

***Damaged construction materials are due to forced prolonged time in storage, and poor storage of materials on construction sites.

Please use Tables A, B and C to rate the following criteria:

Risk ID	**Probability Level**		**Impact Level**			**Readiness Level**	
	PSF	**OCF**	**IPC**	**IPT**	**IPQ**	**ALTE**	**CLC**
C01							
C02							
C03							
C04							
C05							
C06							
C07							
C08							
C09							
C10							
C11							
C12							
C13							
C14							
C15							
C16							
C17							
C18							

C19							
C20							
C21							
C22							
C23							
C24							
C25							
C26							
C27							
C28							
C29							
C30							
C31							
C32							
C33							
C34							
C35							
C36							
C37							
C38							
C39							
C40							
C41							
C42							
C43							
C44							
C45							
C46							

Appendix D: The Fourth Survey

My name is Mohamed Al-Mhdawi and I am a PhD student at the University of Southampton. As part of my study for my degree, I will examine risk management for construction projects during the COVID-19 era. The purpose of this survey is to rate the level of effect of COVID-19 emerging risks on construction projects' success in the developing countries. I would like to invite you to participate in this survey by completing the questionnaire, as you have been recognized as a highly credible contractor with experience in the construction industry in Iraq. The questionnaire will take approximately 30 to 45 minutes to complete. Participation is entirely voluntary, and all responses will be treated as anonymous. If published, the results will summarise the responses of the entire sample; individual responses will not be identified. Please note that by returning this questionnaire you are giving your informed consent to participate in this study. I greatly appreciate your participation. Thank you for taking the time to complete the survey.

Yours sincerely,

Mohammed Al-Mhdawi

M.K.S-Al-Mhdawi@Southampton.ac.uk

***Section One: Sample Characteristics*:**

1- Working Sector:

☐ Public ☐ Private

2. Years of experience

☐ 1-5 years ☐ 6-15 years ☐ 16-25 years

☐ >25 years

3. Educational qualifications

☐ Diploma ☐ MSc

☐ BSc ☐ PhD

Section Two:

Please rate the perceived level of agreement for each factor in Tables A and B.

Where: 1 refers to strongly disagree; 2 refers to disagree; 3 refers to neutral; 4 refers to agree; and 5 refers to strongly agree.

Table A: COVID-19 emerging risks

Category	COVID-19 risks	1	2	3	4	5
Contractual/ Legal Implications	Lack of clarity in the contract language					
	Claims arising under a construction contract					
	Change of law					
	Inappropriate risk Allocation					
	Contract suspension					
	Contract termination					
Construcion financial market	Increase insurance rates					
	Increase of tax rate					
	Fluctuation in currency rates of exchange					
	Materials prices escalation					
	Equipment prices escalation					
	Reduction in labour wages					
	lack of fiscal headroom for local Government					
	Contractors’ bankruptcy					
	Delayed in payments					

	Suppliers' bankruptcy					
Supply chain operations	Scarcity of manpower					
	Lack of construction contractors					
	Skills shortage					
	Machine failure					
	Damaged materials*					
	Construction materials shortage					
	Material delivery delays					
	Cargo theft					
	Monopoly of construction materials					
Health and safety of the construcion workforce	Non-compliance with social distancing guidelines					
	Increased subsidy rates					
	Psychological stress					
	Poorly ventilated spaces					
	Delays caused by workforce self-isolating					
	Virus spreading due to poor hygiene and lack of sanitizing stations					
	Virus spreading in commonly used or high traffic construction area					
	Lack of cleanliness and sterilization of commonly used surfaces, tools, and workstations by construction workers.					
	Contracting or spreading the virus when travelling to work					
	Contracting or spreading the virus in changing, showers, and toilets facilities					
	Contracting or spreading the virus during site meetings and training					
	Lack of face masks or coverings					
	Re-using face masks or covering					
Organisational implications	Delays caused by confusion arising out of the status or effect of government guidance					
	Delays due to Municipalities' prolonged procedures and routine					
	Delayed work inspection and approval					
	Poor site and virtual communication					
	Restricted site access					
	Delayed contractor mobilization to the site					
	Delay of work progress and reporting					
	Delayed design submission					

***Damaged construction materials are due to forced prolonged time in storage, and poor storage of materials on construction sites.

Table B: Project Success indicators

Project success indicators	1	2	3	4	5
Time					
Cost					
Quality					
Safety					
Commercial Profitability					
Functionality					
Client satisfaction					
End user satisfaction					

List of References

Abdelgawad, M. and Fayek, A.R., 2010. Risk management in the construction industry using combined fuzzy FMEA and fuzzy AHP. *Journal of Construction Engineering and management*, *136*(9), pp.1028-1036.

Abdulhussein, H. and Shibaani, A., 2016. Risk management in construction projects in Iraq: contractors' perspective. *International Journal of Engineering Research*, *4*(3), pp.114-130.

Adams, F.K., 2008. Construction contract risk management: a study of practices in the United Kingdom. *Cost Engineering*, *50*(1), pp.22-33.

Adeleke, A.Q., Bahaudin, A.Y., Kamaruddeen, A.M., Bamgbade, J.A. and Ali, M.W., 2019. An empirical analysis of organizational external factors on construction risk management. *Int J Suppl Chain Manag*, *8*(1), pp.932-940.

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*, *20*(1), pp.222-244.

Ahadzie, D.K., Proverbs, D.G. and Olomolaiye, P.O., 2008. Critical success criteria for mass house building projects in developing countries. *International Journal of project management*, *26*(6), pp.675-687.

Ahamed, N.U., Benson, L., Clermont, C., Osis, S.T. and Ferber, R., 2017. Fuzzy inference system-based recognition of slow, medium and fast running conditions using a triaxial accelerometer. *Procedia Computer Science*, *114*, pp.401-407.

Ahmadi-Javid, A., Fateminia, S.H. and Gemünden, H.G., 2020. A method for risk response planning in project portfolio management. *Project Management Journal*, *51*(1), pp.77-95.

Akhtaruzzaman, M., Boubaker, S., Chiah, M. and Zhong, A., 2021. COVID− 19 and oil price risk exposure. *Finance research letters*, *42*, p.101882.

Al Khayat, A. 2019. *Assessment of the Labour Market and Skills Analysis Iraq and Kurdistan Region-Iraq*. United Nations Educational, Scientific and Cultural Organization, France.

Alaloul, W.S., Liew, M.S., Zawawi, N.A.W., Mohammed, B.S., Adamu, M. and Musharat, M.A., 2020. Structural equation modelling of construction project performance based on coordination factors. *Cogent engineering*, *7*(1), p.1726069.

Alase, A., 2017. The interpretative phenomenological analysis (IPA): A guide to a good qualitative research approach. *International Journal of Education and Literacy Studies*, *5*(2), pp.9-19.

Alhumaidi, H.M., 2015. Construction contractors ranking method using multiple decision-makers and multiattribute fuzzy weighted average. *Journal of Construction Engineering and Management*, *141*(4), p.04014092.

Ali, A.S. and Rahmat, I., 2010. The performance measurement of construction projects managed by ISO-certified contractors in Malaysia. *Journal of Retail & Leisure Property*, *9*(1), pp.25-35.

Al-Mhdawi, M.K., 2020. Proposed risk management decision support methodology for oil and gas construction projects. *Lecture Notes in Mechanical Engineering*, pp.407-420.

Al-Mhdawi, M.K., 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., Brito, M.P., Abdul Nabi, M., El-Adaway, I.H. and Onggo, B.S., 2022. 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.

Alsaawi, A., 2014. A critical review of qualitative interviews. *European Journal of Business and Social Sciences*, *3*(4). SSRN: https://ssrn.com/abstract=2819536 or http://dx.doi.org/10.2139/ssrn.2819536

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.

Al-Tmeemy, S.M.H.M., Abdul-Rahman, H. and Harun, Z., 2011. Future criteria for success of building projects in Malaysia. *International journal of project management*, *29*(3), pp.337-348.

Amoah, C. and Simpeh, F., 2020. Implementation challenges of COVID-19 safety measures at construction sites in South Africa. *Journal of Facilities Management*, *19*(1). https://doi.org/10.1108/JFM-08-2020-0061.

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*, *9*(1). https://doi.org/10.1080/23311916.2022.2044575

Anthoine, E., Moret, L., Regnault, A., Sébille, V. and Hardouin, J.B., 2014. Sample size used to validate a scale: a review of publications on newly-developed patient reported outcomes measures. *Health and quality of life outcomes*, *12*(1), pp.1-10.

APM (Association for Project Management) 2006. APM Body of Knowledge 5th Ed. UK.

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

Arthur. W. and Richard. H., 1995. *Risk management and insurance*. Mcgraw-hill, New York, USA.

Ashurst. 2020. “COVID-19: Impact on the construction sector.” Accessed Jan 12, 2022. https://www.ashurst.com/en/news-and-insights/legal -updates/covid-19-impact-on-the-construction-sector.

Assaad, R. and 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), p.06021001.

Avlijas, G., 2019. Examining the value of Monte Carlo simulation for project time management. *Management: Journal of Sustainable Business and Management Solutions in Emerging Economies*, *24*(1), pp.11-23.

Babbie, E.R., 2010. *The practice of social research*. 12th ed. Belmont, USA: Wadsworth Publishing.

Bagozzi, R.P., Yi, Y. and Phillips, L.W., 1991. Assessing construct validity in organizational research. *Administrative science quarterly*, *36*(3), pp.421-458.

Bahrami, M., Bazzaz, D.H. and Sajjadi, S.M., 2012. Innovation and improvements in project implementation and management; using FMEA technique. *Procedia-Social and Behavioral Sciences*, *41*, pp.418-425.

Baker, B. N., Murphy, D. C. and Fisher, D., 1988. Factor affecting success. In: Cleland, D. L. and King, W. R. (Eds), *Project Management Handbook*. New York: Van Nostrand Reinhold.

Ballad, B., Ballad, T. and Banks, E., 2010. *Access control, authentication, and public key infrastructure*. Jones & Bartlett Publishers.

Banaitiene, N. and Banaitis, A., 2012. Risk management in construction projects. *Risk Management–Current Issues and Challenges. In N. Banaitiene (Ed.), Risk Management–Current Issues and Challenges*, pp.429-448.

Banaitiene, N., Banaitis, A. and Norkus, A., 2011. Risk management in projects: peculiarities of Lithuanian construction companies. *International Journal of strategic property Management*, *15*(1), pp.60-73.

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

Barua, A., Mudunuri, L.S. and Kosheleva, O., 2013. Why trapezoidal and triangular membership functions work so well: Towards a theoretical explanation. Department technical reports, University of Texas at El Paso, USA.

Baumann, S., Erber, I. and Gattringer, M., 2016. Selection of risk identification instruments. *ACRN Oxford Journal of Finance and Risk Perspectives*, *5*(2), pp.27-41.

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

Bernard, H.R., 2011. *Research Methods in Anthropology: Qualitative and Quantitative Approaches*. Rowman and Littlefield.

Bhat, S., 2008. *Financial management: Principles and practice*. Excel Books India.

Bhattacherjee, A., 2012. Social science research: Principles, methods, and practices.Textbooks Collection. 3. http://scholarcommons.usf.edu/oa_textbooks/3

Bilsel, R.U. and Lin, D.K., 2012. Ishikawa cause and effect diagrams using capture recapture techniques. *Quality Technology & Quantitative Management*, *9*(2), pp.137-152.

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.

Boateng, A., Ameyaw, C. and Mensah, S., 2020. Assessment of systematic risk management practices on building construction projects in Ghana. *International Journal of Construction Management*, pp.1-10. https://doi:10.1080/15623599.2020.1842962

Borgonovo, E., 2017. Sensitivity analysis. *An Introduction for the Management Scientist. International Series in Operations Research and Management Science (ISOR, volume 251).* Cham, Switzerland: Springer.

Brewer, G., Gajendran, T. and Le Goff, R., 2012. Building information modelling (BIM): Australian perspectives and adoption trends. *Centre for Interdisciplinary Built Environment Research (CIBER).*

Brockett, P.L., Golden, L.L. and Betak, J., 2019. Different market methods for transferring financial risks in construction. In *Risk Management in Construction Projects*. IntechOpen.

Bryman, A., 2006. Paradigm peace and the implications for quality. *International journal of social research methodology*, *9*(2), pp.111-126.

Bryman, A., 2016. *Social research methods*. Oxford university press.

Buniya, M.K., Othman, I., Durdyev, S., Sunindijo, R.Y., Ismail, S. and Kineber, A.F., 2021. Safety program elements in the construction industry: the case of Iraq. *International journal of environmental research and public health*, *18*(2), p.411.

Buniya, M.K., Othman, I., Sunindijo, R.Y., Karakhan, A.A., Kineber, A.F. and Durdyev, S., 2022. Contributions of safety critical success factors and safety program elements to overall project success. *International journal of occupational safety and ergonomics*, pp.1-36.

Buniya, M.K., Othman, I., Sunindijo, R.Y., Kashwani, G., Durdyev, S., Ismail, S., Antwi-Afari, M.F. and Li, H., 2021. Critical success factors of safety program implementation in construction projects in Iraq. *International journal of environmental research and public health*, *18*(16), p.8469.

Buniya, M.K., Othman, I., Sunindijo, R.Y., Kineber, A.F., Mussi, E. and Ahmad, H., 2021. Barriers to safety program implementation in the construction industry. *Ain Shams Engineering Journal*, *12*(1), pp.65-72.

Bu-Qammaz, A.S., Dikmen, I. and Birgonul, M.T., 2009. Risk assessment of international construction projects using the analytic network process. *Canadian Journal of Civil Engineering*, *36*(7), pp.1170-1181.

Burcar, I. and Radujkovic, M., 2005. Risk breakdown structure for construction projects. In *Proc., 3rd Int. Conf. on Construction in the 21st Century - Advancing Engineering, Management and Technology*. National Technical University of Athens.

Burney, A., 2008. Inductive and deductive research approach. Accessed Jan 12, 2022. http://www. drburney. net. *INDUCTIVE% 20&% 20DEDUCTIVE% 20RESEARCH% 20A PPROACH, 2006032008*.

Calas, M.B. and Smircich, L., 1999. Past postmodernism? Reflections and tentative directions. *Academy of management review*, *24*(4), pp.649-672.

Chan, A.P. and Chan, A.P., 2004. Key performance indicators for measuring construction success. *Benchmarking: an international journal*, *11*(2), pp.203-221

Chan, A.P., Scott, D. and Lam, E.W., 2002. Framework of success criteria for design/build projects. *Journal of management in engineering*, *18*(3), pp.120-128.

Chapman, R.J., 1998. The effectiveness of working group risk identification and assessment techniques. *International Journal of Project Management*, *16*(6), pp.333-343.

Chen, L.J. and Hung, H.C., 2016. The indirect effect in multiple mediators model by structural equation modeling. *European Journal of Business, Economics and Accountancy*, *4*(3), pp.36-43.

Chenail, R.J., 2011. Interviewing the investigator: Strategies for addressing instrumentation and researcher bias concerns in qualitative research. *Qualitative Report*, *16*(1), pp.255-262.

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. https://doi.org/10.1108/JEDT-01-2021-0053

Chileshe, N. and Kikwasi, G.J., 2014. Critical success factors for implementation of risk assessment and management practices within the Tanzanian construction industry. *Engineering, Construction and Architectural Management*, *21*(3), 291-319. https://doi.org/10.1108/ECAM-01-2013-0001

Chileshe, N. and Yirenkyi-Fianko, A.B., 2012. An evaluation of risk factors impacting construction projects in Ghana. *Journal of Engineering, Design and Technology*, *10*(3), pp.306-329.

Chileshe, N., Hosseini, M.R. and Jepson, J., 2016. Critical barriers to implementing risk assessment and management practices (RAMP) in the Iranian construction sector. *Journal of construction in developing countries*, *21*(2), p.81.

Cho, E., 2016. Making reliability reliable: A systematic approach to reliability coefficients. *Organizational Research Methods*, *19*(4), pp.651-682.

Chovichien, V. and Nguyen, T.A., 2013, October. List of indicators and criteria for evaluating construction project success and their weight assignment. In *4th International Conference on Engineering Project and Production* (pp130-150). Pingtung, Taiwan.

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

Cleden, D., 2017. *Managing project uncertainty*. Routledge.

Collis, J. and Hussey, R., 2014. Business research: A practical guide for undergraduate and postgraduate students. London: Palgrave Macmillan.

Cox, A., 2008. What's wrong with risk matrices?. *Risk Analysis: An International Journal*, *28*(2), pp.497-512.

Creswell, J.W. and Clark, V.L.P., 2017. *Designing and conducting mixed methods research*. Sage publications.

Creswell, J.W. and Creswell, J.D., 2017. *Research design: Qualitative, quantitative, and mixed methods approaches.* Sage publications.

Crockford, G.N., 1982. The bibliography and history of risk management: Some preliminary observations. *Geneva Papers on Risk and Insurance*, *7*(23), pp.169-179.

Daniels, W., M. Griffith, and R. Shreve. 2020. “The coronavirus effect on construction projects.” Accessed Nov 20, 2021. https://www.jdsupra .com/legalnews/the-coronavirus-effect-on-construction-13000/.

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

De Vaus, D., 2001. Research design in social research. *Research design in social research*, pp.1-296.

Derakhshanalavijeh, R. and Teixeira, J.M.C., 2017. Cost overrun in construction projects in developing countries, gas-oil industry of Iran as a case study. *Journal of Civil Engineering and Management*, *23*(1), pp.125-136.

Derrida, J., 2016. Of grammatology. Baltimore: Johns Hopkins University Press

Dickinger, A., Arami, M. and Meyer, D., 2006, January. Reconsidering the adoption process: enjoyment and social norms-antecedents of hedonic mobile technology use. In *Proceedings of the 39th Annual Hawaii International Conference on System Sciences (HICSS'06)* (Vol. 1, pp. 23a-23a). IEEE.

Dinu, A.M., 2012. Modern methods of risk identification in risk management. *International journal of academic research in economics and management sciences*, *1*(6), p.67.

Diop, M. 2020. "What can AI tell us about COVID-19's impact on infrastructure?" Accessed Dec 10, 2021. https://blogs.worldbank.org/ppps /what-can-ai-tell-us-about-covid-19s-impact-infrastructure.

Doskocil, R., 2016. An evaluation of total project risk based on fuzzy logic. *Verslas: teorija ir prak-tika*, *17*(1), pp.23-31.

Dryhurst, S., Schneider, C.R., Kerr, J., Freeman, A.L., Recchia, G., Van Der Bles, A.M., Spiegelhalter, D. and Van Der Linden, S., 2020. Risk perceptions of COVID-19 around the world. *Journal of Risk Research*, *23*(7-8), pp.994-1006.

Dumbravă, V. and Iacob, V.S., 2013. Using probability–impact matrix in analysis and risk assessment projects. *Descrierea CIP/Description of CIP–Biblioteca Națională a României Conferința Internațională Educație și Creativitate pentru o Societate Bazată pe Cunoaștere–ŞTIINŢE ECONOMICE*, *42*.

Duncan, O.D., 1975. *Introduction to structural equation models*. Academic Press

Ehsan, N., Mirza, E., Alam, M. and Ishaque, A., 2010, July. Notice of Retraction: Risk management in construction industry. In *2010 3rd International Conference on Computer Science and Information Technology* (Vol. 9, pp. 16-21). IEEE.

Elbarkouky, M.M., Fayek, A.R., Siraj, N.B. and Sadeghi, N., 2016. Fuzzy arithmetic risk analysis approach to determine construction project contingency. *Journal of construction engineering and management*, *142*(12), p.04016070.

Elmontsri, M., 2014. Review of the strengths and weaknesses of risk matrices. *Journal of Risk Analysis and Crisis Response*, *4*(1). pp.49-56.

El-Sayegh, S.M., 2014. Project risk management practices in the UAE construction industry. *International Journal of Project Organisation and Management*, *6*(1-2), pp.121-137.

Ennouri, W., 2013. Risks management: new literature review. *Polish Journal of Management Studies*, *8*, pp.288-297.

Erford, B., 2014. *Research and Evaluation in Counselling*, 2nd edition., Brooks Cole.

Erlingsson, C. and Brysiewicz, P., 2017. A hands-on guide to doing content analysis. *African journal of emergency medicine*, *7*(3), pp.93-99.

Falk, R.F. and Miller, N.B., 1992. *A primer for soft modeling*. University of Akron Press.

Fan, Y., Chen, J., Shirkey, G., John, R., Wu, S.R., Park, H. and Shao, C., 2016. Applications of structural equation modeling (SEM) in ecological studies: an updated review. *Ecological Processes*, *5*(1), pp.1-12.

Fang, L. and Zhang, W., 2013. Numerical Simulation of Thrust Line Off-set of Solid Rocket Motor Based on Monte-Carlo Method. *Journal of Projectiles, Rockets, Missiles and Guidance*, *33*(3), pp.109-111.

Fetters, M.D., Curry, L.A. and Creswell, J.W., 2013. Achieving integration in mixed methods designs—principles and practices. *Health services research*, *48*(6pt2), pp.2134-2156.

Flanagan, R., Jewell, C., & Johansson, J. (2007). Riskhantering i praktiken. Byggnadsekonomi, Institutionen för bygg- och miljöteknik, Centrum för management i byggsektorn (CMB) . Göteborg: Chalmers Repro.

Fleetwood, S., 2005. Ontology in organization and management studies: A critical realist perspective. *Organization*, *12*(2), pp.197-222.

Fornell, C. and Larcker, D.F., 1981. Structural equation models with unobservable variables and measurement error: Algebra and statistics. *Journal of Marketing Research, 18*(3), pp. 328-388. https://doi.org/10.2307/3150980

Franzese, N.P., 2020. Potential impacts of the coronavirus pandemic on construction projects. *The National Law Review*, *10*(78).

Freson, T.S., 2015. *Invariance, convergent and discriminant validity across occasions for the Male Body Image Disturbance Scale*. Washington State University.

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

Garrido, M.C., Ruotolo, M.C.A.A.E., Ribeiro, F.M.L. and Naked, H.A., 2011. Risk identification techniques knowledge and application in the Brazilian construction. *Journal of Civil Engineering and Construction Technology*, *2*(11), pp.242-252.

Gefen, D. and Straub, D., 2005. A practical guide to factorial validity using PLS-Graph: Tutorial and annotated example. *Communications of the Association for Information systems*, *16*(1), pp.91-109.

Giannakis, M. and Louis, M., 2011. A multi-agent based framework for supply chain risk management. *Journal of Purchasing and Supply Management*, *17*(1), pp.23-31.

Gong, Z., Lin, Y. and Yao, T., 2012. *Uncertain fuzzy preference relations and their applications* (Vol. 281). Springer.

Gonzalez, O., O'Rourke, H.P., Wurpts, I.C. and Grimm, K.J., 2018. Analyzing monte carlo simulation studies with classification and regression trees. *Structural Equation Modeling: A Multidisciplinary Journal*, *25*(3), pp.403-413.

Govan, P. and Damnjanovic, I., 2016. The resource-based view on project risk management. *Journal of Construction Engineering and Management*, *142*(9), p.04016034.

Guba, E.G. and Lincoln, Y.S., 1982. Epistemological and methodological bases of naturalistic inquiry. *Ectj*, *30*(4), pp.233-252.

Gubrium, J.F. and Holstein, J.A., 2002. From the individual interview to the interview society. *Handbook of interview research: Context and method*, pp.3-32.

Guerlain, C., Renault, S. and Ferrero, F., 2019. Understanding construction logistics in urban areas and lowering its environmental impact: A focus on construction consolidation centres. *Sustainability*, *11*(21), p.6118.

Gunduz, M., Nielsen, Y. and Ozdemir, M., 2015. Fuzzy assessment model to estimate the probability of delay in Turkish construction projects. *Journal of Management in Engineering*, *31*(4), p.04014055.

Gunzler, D., Chen, T., Wu, P. and Zhang, H., 2013. Introduction to mediation analysis with structural equation modeling. *Shanghai archives of psychiatry*, *25*(6), p.390.

Haigh, R., 2008. Interviews: A negotiated partnership. *Advanced research methods in the built environment*, pp.111-121.

Hair Jr, J.F., Sarstedt, M., Hopkins, L. and Kuppelwieser, V.G., 2014. Partial least squares structural equation modeling (PLS-SEM): An emerging tool in business research. *European business review, 26*(2), pp.106-121

Hair, J. F., JR., Black, W. C.,Babin, B. J., and Anderson, R. E., (2010). *Multivariate data analysis (7th ed.)*. Upper Saddle River, NJ: Pearson Prentice Hall.

Hair, J.F., Ringle, C.M. and Sarstedt, M., 2011. PLS-SEM: Indeed a silver bullet. *Journal of Marketing theory and Practice*, *19*(2), pp.139-152.

Hair, J.F., Ringle, C.M. and Sarstedt, M., 2013. Partial least squares structural equation modeling: Rigorous applications, better results and higher acceptance. *Long range planning*, *46*(1-2), pp.1-12.

Hakansson, A., 2013. Portal of research methods and methodologies for research projects and degree projects. In *The 2013 World Congress in Computer Science, Computer Engineering, and Applied Computing WORLDCOMP 2013; Las Vegas, Nevada, USA, 22-25 July* (pp. 67-73). CSREA Press USA.

Hamie, J.M. and Abdul-Malak, M.A.U., 2018. Model language for specifying the construction contract's order-of-precedence clause. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *10*(3), p.04518011.

Hansen, S., 2020, May. Does the COVID-19 outbreak constitute a force majeure event? A pandemic impact on construction contracts. *Journal of the civil engineering forum*, *6*(1), pp. 201-214.

Harinarain, N., 2020. Despair during the COVID-19 lockdown for the South African construction industry. *Journal of Construction*, *13*(1), pp.52-63.

Harthi, B.A.A., 2015. *Risk management in fast-track projects: A study of UAE construction projects* (Doctoral dissertation, University of Wolverhampton).

Heidary D, J., Vanaki, A.S., Firoozfar, H.R., Zavadskas, E.K. and Čereška, A., 2020. An extension of the failure mode and effect analysis with hesitant fuzzy sets to assess the occupational hazards in the construction industry. *International journal of environmental research and public health*, *17*(4), p.1442.

Hekmatpanah, M., 2011. The application of cause and effect diagram in the oil industry in Iran: The case of four liter oil canning process of Sepahan Oil Company. *African Journal of Business Management*, *5*(26), pp.10900-10907.

Henjewele, C., 2010. *Modelling Client's Value for Money Uncertainties in PFI Projects* (Doctoral dissertation, University of the West of England, Bristol).

Hennink, M. and Kaiser, B.N., 2021. Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science & Medicine*, p.114523.

Hennink, M.M., Kaiser, B.N. and Marconi, V.C., 2017. Code saturation versus meaning saturation: how many interviews are enough?. *Qualitative health research*, *27*(4), pp.591-608.

Henseler, J., Dijkstra, T.K., Sarstedt, M., Ringle, C.M., Diamantopoulos, A., Straub, D.W., Ketchen, D.J., Hair, J.F., Hult, G.T.M. and Calantone, R.J., 2014. Common beliefs and reality about partial least squares. *Organizational Research Methods*, *17*(2), pp.182-209.

Henseler, J., Ringle, C.M. and Sarstedt, M., 2015. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the academy of marketing science*, *43*(1), pp.115-135.

Hillson, D., 2006. Integrated risk management as a framework for organisational success. In *Proceedings of the PMI Global Congress*.

Ho, R., 2006. *Handbook of univariate and multivariate data analysis and interpretation with SPSS*. Chapman and Hall/CRC.

Hopkin, P., 2018. *Fundamentals of risk management: understanding, evaluating and implementing effective risk management*. Kogan Page Publishers.

Hosny, H.E., Ibrahim, A.H. and Fraig, R.F., 2018. Risk management framework for Continuous Flight Auger piles construction in Egypt. *Alexandria engineering journal*, *57*(4), pp.2667-2677.

Hu, L.T. and Bentler, P.M., 1999. Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural equation modeling: a multidisciplinary journal*, *6*(1), pp.1-55.

Hwang, B.G., Zhao, X. and Toh, L.P., 2014. Risk management in small construction projects in Singapore: Status, barriers and impact. *International journal of project management*, *32*(1), pp.116-124.

Ilie, G. and Ciocoiu, C.N., 2010. Application of fishbone diagram to determine the risk of an event with multiple causes. *Management research and practice*, *2*(1), pp.1-20.

IOM (International Organization for Migraiton). 2020. "Impact of COVID19 on small and medium-sized enterprises in Iraq." Accessed January 4, 2021. https://www.iom.int/.

IRMS (Information Resources Management Association). 2015. Transportation Systems and Engineering: Concepts, Methodologies, Tools, and Applications, IGI Global.

Isa, C.M.M., Nusa, F.N.M., Ishak, S.Z. and Fam, S.F., 2021, June. Impacts of COVID-19 Pandemic on the Road and Transport Sectors using Relative Importance Index. In *2021 IEEE International Conference on Automatic Control & Intelligent Systems (I2CACIS)* (pp. 305-310). IEEE.

Isaac, S. and Navon, R., 2008. Feasibility study of an automated tool for identifying the implications of changes in construction projects. *Journal of Construction Engineering and Management*, *134*(2), pp.139-145.

Islam, M.S. and Nepal, M., 2016. A fuzzy-Bayesian model for risk assessment in power plant projects. *Procedia Computer Science*, *100*, pp.963-970.

Ivankova, N.V., Creswell, J.W. and Stick, S.L., 2006. Using mixed-methods sequential explanatory design: From theory to practice. *Field methods*, *18*(1), pp.3-20.

Jamshidi, A., Yazdani-Chamzini, A., Yakhchali, S.H. and Khaleghi, S., 2013. Developing a new fuzzy inference system for pipeline risk assessment. *Journal of loss prevention in the process industries*, *26*(1), pp.197-208.

Jia, G., Ni, X., Chen, Z., Hong, B., Chen, Y., Yang, F. and Lin, C., 2013. Measuring the maturity of risk management in large-scale construction projects. *Automation in Construction*, *34*, pp.56-66.

Joshi, G. and Joshi, H., 2014. FMEA and alternatives v/s enhanced risk assessment mechanism. *International Journal of Computer Applications*, *93*(14).

Jung, Y. and Choi, M., 2012. Survey-Based Approach for Hydrological Vulnerability Indicators Due to Climate Change: Case Study of Small-Scale Rivers 1. *JAWRA Journal of the American Water Resources Association*, *48*(2), pp.256-265.

Kablan, M.M., 2004. Decision support for energy conservation promotion: an analytic hierarchy process approach. *Energy policy*, *32*(10), pp.1151-1158.

Karimpour, K., Zarghami, R., Moosavian, M.A. and Bahmanyar, H., 2016. New fuzzy model for risk assessment based on different types of consequences. *Oil & Gas Science and Technology–Re-vue d'IFP Energies nouvelles*, *71*(1), pp.1-15.

Kassem, M.A., Khoiry, M.A. and Hamzah, N., 2020. Assessment of the effect of external risk factors on the success of an oil and gas construction project. *Engineering, Construction and Architectural Management*, *27*(9), pp.2767-2793.

Kaur, A. and Kaur, A., 2012. Comparison of Mamdani-type and Sugeno-type fuzzy inference systems for air conditioning system. *International Journal of Soft Computing and Engineering (IJSCE)*, *2*(2), pp.323-325.

Kaushik, V. and Walsh, C.A., 2019. Pragmatism as a research paradigm and its implications for social work research. *Social sciences*, *8*(9), p.255.

Ke, Y., Wang, S., Chan, A.P. and Cheung, E., 2011. Understanding the risks in China's PPP projects: ranking of their probability and consequence. *Engineering, Construction and Architectural Management*, *18*(5), pp.481-496.

Keeney, S., Hasson, F. and McKenna, H., 2017. *The Delphi technique in nursing and health research*. Chichester, West Sussex :Wiley-Blackwell.

Kelemen, M.L. and Rumens, N., 2008. *An introduction to critical management research*. SAGE Publications Ltd.

Kendrick, T., 2015. *Identifying and managing project risk: essential tools for failure-proofing your project*. Amacom.

Khalaj, M., Makui, A. and Tavakkoli-Moghaddam, R., 2012. Risk-based reliability assessment under epistemic uncertainty. *Journal of Loss Prevention in the Process Industries*, *25*(3), pp.571-581.

Khaldi, K., 2017. Quantitative, qualitative or mixed research: which research paradigm to use?. *Journal of Educational and Social Research*, *7*(2), pp.15-15.

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. https://doi: 10.1109/IEEE-CONF51154.2020.9319948.

Khamooshi, H. and Cioffi, D.F., 2009. Program risk contingency budget planning. *IEEE Transactions on Engineering Management*, *56*(1), pp.171-179.

Khosravi, S. and Afshari, H., 2011, July. A success measurement model for construction projects. In *International Conference on Financial Management and Economics IPEDR* (Vol. 11, pp. 186-190). IACSIT Press Singapore.

Kikwasi, G.J., 2011. An assessment of risk management practices by consultants in Tanzania. *Proceedings of the 6th Built Environment. Johannesburg, South Africa*, *31*, pp.302-314.

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.

King, S.S., Rahman, R.A., Fauzi, M.A. and Haron, A.T., 2021. Critical analysis of pandemic impact on AEC organizations: The COVID-19 case. *Journal of Engineering, Design and Technology*, *20* (1), pp.358-383. https://doi.org/10.1108/JEDT-04-2021-0225.

Kirchberger, M. 2018. *The role of the construction sector*. Library in Kiel, Germany: Econstor

Kotb, M.H. and Ghattas, M.M., 2017. An overview of risk identification barriers with implementation of PMI standards in construction projects. *PM World Journal, VI (X)*, pp.1-12.

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

Krechowicz, M., 2020. Comprehensive risk management in horizontal directional drilling projects. *Journal of construction engineering and management*, *146*(5), p.04020034.

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

Kukoyi, P.O., Simpeh, F., Adebowale, O.J. and Agumba, J.N., 2021. Managing the risk and challenges of COVID-19 on construction sites in Lagos, Nigeria. *Journal of Engineering, Design and Technology*, *20*(1), pp. 99-144. https://doi.org/10.1108/JEDT-01-2021-0058

Kululanga, G. and Kuotcha, W., 2010. Measuring project risk management process for construction contractors with statement indicators linked to numerical scores. *Engineering, Construction and Architectural Management*, *20* (1), pp. 99-144. https://doi.org/10.1108/JEDT-01-2021-0058.

Kwak, Y.H. and Ingall, L., 2009. Exploring Monte Carlo simulation applications for project management. *IEEE Engineering Management Review*, *37*(2), pp.83-91.

Le, A.T.H., Domingo, N., Rasheed, E. and Park, K., 2022. Maturity model of building maintenance management for New Zealand's state schools. *Building Research & Information*, *50*(4), pp.438-451.

Lechler, T. and Gao, T., 2012. *Explaining project success with client expectation alignment: an empirical study.* Project Management Institute, USA.

Lee, C.F., Tzeng, G.H. and Wang, S.Y., 2005. A fuzzy set approach for generalized CRR model: An empirical analysis of S&P 500 index options. *Review of Quantitative Finance and Accounting*, *25*(3), pp.255-275.

Lee, J. J., Park, J. S., and Rhee, K. H. (2014). “Development and application of hydrological safety evaluation guidelines for agricultural reservoir with AHP.” J. Wetlands Res., 16(2), 235–243 (in Korean language).

Lee, M.C., 2014. Information security risk analysis methods and research trends: AHP and fuzzy comprehensive method. *AIRCC's International Journal of Computer Science and Information Technology*, *6*(1), pp.29-45.

Ling, F.Y., Zhang, Z. and Yew, A.Y., 2022. Impact of COVID-19 Pandemic on Demand, Output, and Outcomes of Construction Projects in Singapore. *Journal of Management in Engineering*, *38*(2), p.04021097.

Lipol, L.S. and Haq, J., 2011. Risk analysis method: FMEA/FMECA in the organizations. *International Journal of Basic & Applied Sciences*, *11*(5), pp.74-82.

Liu, H., Deng, X. and Jiang, W., 2017. Risk evaluation in failure mode and effects analysis using fuzzy measure and fuzzy integral. *Symmetry*, *9*(8), p.162.

Liyanage, C. and Villalba-Romero, F., 2015. Measuring success of PPP transport projects: a cross-case analysis of toll roads. *Transport reviews*, *35*(2), pp.140-161.

Lodico, M.G., Spaulding, D.T. and Voegtle, K.H., 2010. *Methods in educational research: From theory to practice* (Vol. 28). John Wiley & Sons.

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

Lowry, P.B. and Gaskin, J., 2014. Partial least squares (PLS) structural equation modeling (SEM) for building and testing behavioral causal theory: When to choose it and how to use it. *IEEE transactions on professional communication*, *57*(2), pp.123-146.

Lune, H. and Berg, B.L., 2017. *Qualitative research methods for the social sciences*. Pearson.

Mamdani, E.H. and Assilian, S., 1975. An experiment in linguistic synthesis with a fuzzy logic controller. *International journal of man-machine studies*, *7*(1), pp.1-13.

Mandal, H.K., 2014. Brainstorming approach and mind mapping in synergy creating activity. *Global Journal of Finance and Management*, *6*(4), pp.333-338.

Mariajayaprakash, A., Senthilvelan, T. and Gnanadass, R., 2015. Optimization of process parameters through fuzzy logic and genetic algorithm–A case study in a process industry. *Applied Soft Computing*, *30*, pp.94-103.

Market Research Iraq. 2021. “Construction and Infrastructure.” Accessed June 18, 2021. https://www.marketresearchiraq.com/industry/construction-infrastructure.

Martin, P., 2009. *The recession and migration: alternative scenarios*. International Migration Institute, University of Oxford.

Matsunaga, H., 2019. *The reconstruction of Iraq after 2003: learning from its successes and failures*. World Bank Publications.

Maxwell, J.A., 2013. Applied social research methods series: Vol. 41. *Qualitative research design: An interactive approach*, *3*.

Mazher, K.M., Chan, A.P., Zahoor, H., Khan, M.I. and Ameyaw, E.E., 2018. Fuzzy integral–based risk-assessment approach for public–private partnership infrastructure projects. *Journal of Construction engineering and Management*, *144*(12), p.04018111.

McElwee, N., 2013. *At-risk children and youth: Resiliency explored*. Routledge.

McFadden, P., Russ, E., Blakeman, P., Kirwin, G., Anand, J., Lähteinen, S., Baugerud, G.A. and Tham, P., 2020. COVID-19 impact on social work admissions and education in seven international universities. *Social Work Education*, *39*(8), pp.1154-1163.

McMillan, S.S., King, M. and Tully, M.P., 2016. How to use the nominal group and Delphi techniques. *International journal of clinical pharmacy*, *38*(3), pp.655-662.

Mehr R. I., and Hedges. B. A., 1963. Risk Management in the Business Enterprise. Irwin, Homewood, Illinois.

Meredith, J.R., Shafer, S.M. and Mantel Jr, S.J., 2017. *Project management: a strategic managerial approach*. John Wiley & Sons.

Mohamed, M. and Tran, D.Q., 2021. Risk-Based Inspection Model for Hot Mix Asphalt Pavement Construction Projects. *Journal of Construction Engineering and Management*, *147*(6), p.04021045.

Morgan, D.L., 2013. *Integrating qualitative and quantitative methods: A pragmatic approach*. Sage publications.

Motaleb, O., 2021. Risk Response Development in Construction Projects Delay: Multiple Case Studies from UAE. *ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part A: Civil Engineering*, *7*(3), p.05021004.

Mubin, S. and Mannan, A., 2013. Innovative approach to risk analysis and management of oil and gas sector EPC contracts from a contractor's perspective. *Journal of Business & Economics*, *5*(2), p.149.

Nayak, S., Pattanayak, S., Choudhury, B.B. and Kumar, N., 2020. Selection of industrial robot using fuzzy logic approach. In *Computational Intelligence in Data Mining* (pp. 221-232). Springer, Singapore.

NCCMT (National Collaborating Centre for Methods and Tools) 2015. *Appraising qualitative, quantitative and mixed methods studies included in mixed studies reviews: The MMAT*. Hamilton, ON: McMaster University. Retrieved from http://www.nccmt.ca/resources/search/232.

Nieto-Morote, A. and Ruz-Vila, F., 2011. A fuzzy approach to construction project risk assessment. *International Journal of Project Management*, *29*(2), pp.220-231.

Nunnally, J.C., 1994. The assessment of reliability. *Psychometric theory, 3*, 248-292.

Nyumba, T., Wilson, K., Derrick, C.J. and Mukherjee, N., 2018. The use of focus group discussion methodology: Insights from two decades of application in conservation. *Methods in Ecology and evolution*, *9*(1), pp.20-32.

O'Connor, R., J. Scott, and A. Scott. 2020. "COVID-19 impact on UK construction contracts." Accessed Jan 17, 2022. https://www.lexology .com/library/detail.aspx?g=dbbde91c-7e7f-417a-bac9-a20394c06ee2.

OECD (Organisation for Economic Co-operation and Development). 2020a. "Coronavirus (COVID-19): SME policy responses." Accessed Feb 09, 2022. https://www.oecd.org.

OECD (Organization for Economic Co-operation and Development). 2020b. "The world economy on a tightrope." Accessed Feb 03, 2022. http:// www.oecd.org/OECE.

Olsson, R., 2007. In search of opportunity management: Is the risk management process enough?. *International journal of project management*, *25*(8), pp.745-752.

Oluka, P.N. and Basheka, B.C., 2014. Determinants and constraints to effective procurement contract management in Uganda: A practitioner's perspective. *International journal of logistics systems and management*, *17*(1), pp.104-124.

Olukolajo, M.A., Oyetunji, A.K. and Oluleye, I.B., 2021. Covid-19 protocols: assessing construction site workers compliance. *Journal of Engineering, Design and Technology*, *20*(1), pp. 115-131.

Othman, I., 2010, December. Safety management practices at construction site. In *Proceeding 3rd International Conference on Environment*. IOP Conference Series Materials Science and Engineering, *291*(1):012018

Paape, L. and Speklé, R.F., 2012. The adoption and design of enterprise risk management practices: An empirical study. *European Accounting Review*, *21*(3), pp.533-564.

Papke-Shields, K.E., Beise, C. and Quan, J., 2010. Do project managers practice what they preach, and does it matter to project success?. *International journal of project management*, *28*(7), pp.650-662.

Parr, S., Wolshon, B., Renne, J., Murray-Tuite, P. and Kim, K., 2020. Traffic impacts of the COVID-19 pandemic: statewide analysis of social separation and activity restriction. *Natural hazards review*, *21*(3). https://doi.org/10.1061/(ASCE)NH.1527-6996.0000409

Pathuri, R.T., Killingsworth, J. and Mehany, M.S.H.M., 2022. Knowledge, skills, and abilities for senior-level construction managers: A US Industry-based Delphi study. *International Journal of Construction Education and Research*, *18*(3), pp.234-250.

Perminova, O., Gustafsson, M. and Wikström, K., 2008. Defining uncertainty in projects–a new perspective. *International journal of project management*, *26*(1), pp.73-79.

Perry, C.M., Álvarez, J.C. and López, J.F., 2014, July. Manufacturing and continuous improvement areas using partial least square path modeling with multiple regression comparison. In *CBU International Conference Proceedings* (Vol. 2, pp. 15-26).

Pirzadeh, P. and Lingard, H., 2021. Working from Home during the COVID-19 Pandemic: Health and Well-Being of Project-Based Construction Workers. *Journal of Construction Engineering and Management*, *147*(6), p.04021048.

PMI (Project Management Institute), 2009. Practice standard for project risk management. Project Management Institute.

PMI (Project Management Institute), 2013. A guide to the Project Management Body of Knowledge. Project Management Institute.

Ponto, J., 2015. Understanding and evaluating survey research. *Journal of the advanced practitioner in oncology*, *6*(2), pp.168–171.

Porter, R. 2020. "3 ways to manage the impact of COVID-19 in the construction industry." Accessed Dec 16, 2021. https://exclusive.multibriefs .com/content/3-ways-to-manage-the-impact-of-covid-19-in-theconstruction-industry/business-management-services-risk-management.

Prosper Bright, M., Terrence Kudzai, N. and Ngavaite, C., 2021. The impact of COVID-19 on agricultural extension and food supply in Zimbabwe. *Cogent Food & Agriculture*, *7*(1), p.1918428.

PWC (Price Waterhouse Coopers). 2020. "Navigate the tax measures in response to COVID-19." Accessed Nov 15, 2021. https://www.pwc .com/sk/en/tax-news/navigate-the-tax-measures-in-response-to-Covid-19 .html

Quang, T.D., Tran, T.C., Tran, V.H., Nguyen, T.T. and Nguyen, T.T., 2022. Is Vietnam ready to welcome tourists back? Assessing COVID-19's economic impact and the Vietnamese tourism industry's response to the pandemic. *Current Issues in Tourism*, *25*(1), pp.115-133.

Radhika, C. and Parvathi, R., 2016. Intuitionistic fuzzification functions. *Global Journal of Pure and Applied Mathematics*, *12*(2), pp.1211-1227.

Ramona, S.E., 2011. Advantages and disadvantages of quantitative and qualitative information risk approaches. *Chinese Business Review*, *10*(12).

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.

Raoufi, M. and Fayek, A.R., 2022. New Modes of Operating for Construction Organizations during the COVID-19 Pandemic: Challenges, Actions, and Future Best Practices. *Journal of Management in Engineering*, *38*(2), p.04021091.

Rashvand, P. and Majid, M.Z.A., 2014. Critical criteria on client and customer satisfaction for the issue of performance measurement. *Journal of management in engineering*, *30*(1), pp.10-18.

Raychaudhuri, S., 2008, December. Introduction to monte carlo simulation. In *2008 Winter simulation conference* (pp. 91-100). IEEE.

Razavi, S., Jakeman, A., Saltelli, A., Prieur, C., Iooss, B., Borgonovo, E., Plischke, E., Piano, S.L., Iwanaga, T., Becker, W. and Tarantola, S., 2021. The future of sensitivity analysis: an essential discipline for systems modeling and policy support. *Environmental Modelling & Software*, *137*, p.104954.

Rehman, M.S.U., Shafiq, M.T. and Afzal, M., 2021. Impact of COVID-19 on project performance in the UAE construction industry. *Journal of Engineering, Design and Technology*, *20*(1), pp.245-266.

Renault, B.Y. and Agumba, J.N., 2016. Risk management in the construction industry: A new literature review. In *MATEC web of conferences* (Vol. 66, p. 00008). EDP Sciences.

Renuka, S.M., Umarani, C. and Kamal, S., 2014. A review on critical risk factors in the life cycle of construction projects. *Journal of Civil Engineering Research*, *4*(2A), pp.31-36.

Research and Markets. 2019. "Construction in Iraq key trends and opportunities to 2023. Report ID: 4846333." Accessed May 27, 2021. https://www.researchandmarkets.com/reports/4846333/construction-in-iraq-key-trends-and

Revicki, D., 2014. Internal consistency reliability. *Encyclopedia of quality of life and well-being research*, https://doi.org/10.1007/978-94-007-0753-5_1494

Reynold, J. and Santos, A., 1999. Cronbach's alpha: A tool for assessing the reliability of scales. *The journal of extension*, *37*(7), pp.35-36.

Rezakhani, P., 2012. Classifying key risk factors in construction projects. *Buletinul Institutului Politehnic din lasi. Sectia Constructii, Arhitectura*, *58*(2), pp. 27-38.

Ringle, C.M., Sarstedt, M., Mitchell, R. and Gudergan, S.P., 2020. Partial least squares structural equation modeling in HRM research. *The International Journal of Human Resource Management*, *31*(12), pp.1617-1643.

Russo, D. and Stol, K.J., 2021. PLS-SEM for software engineering research: An introduction and survey. *ACM Computing Surveys (CSUR)*, *54*(4), pp.1-38.

Saaty, T. L. 1982. *Decision making for leaders*, Lifetime Learning Publications, Belmont, USA.

Saaty, T.L., 1985. Decision making for leaders. *IEEE transactions on systems, man, and cybernetics*, (3), pp.450-452. https://doi:10.1109/TSMC.1985.6313384.

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.https://doi.org/10.1080/15623599.2021.1963561

Saltelli, A., Ratto, M., Andres, T., Campolongo, F., Cariboni, J., Gatelli, D., Saisana, M. and Tarantola, S., 2008. *Global sensitivity analysis: the primer*. John Wiley & Sons.

Saunders, M., Lewis, P. and Thornhill, A., 2009. *Research methods for business students*. Pearson education.

Saunders, M., Lewis, P. and Thornhill, A., 2012. *Research methods for business students*. Essex, England: Pearson Education Limited.

Saunders, M., Lewis, P. and Thornhill, A., 2016. *Research methods for business students*. *Nueva York: Pearson Education*.

Saunders, M.N., Lewis, P., Thornhill, A. and Bristow, A., 2019. *Understanding research philosophy and approaches to theory development.* Pearson Education Limited.

Schilling, D.R., 2013. *Global construction expected to increase by $4.8 trillion by 2020*. Industry Tap. ACESS Global Construction Expected to Increase by $4.8 Trillion by 2020 - Industry Tap

Scott S. H. and Gregory R. N., 1964. *Risk management and Insurance*. Irwin/McGraq-Hill, USA.

Scott S. H. and Gregory R. N., 2003. *Risk management and Insurance*. Irwin/McGraq-Hill, USA.

Serrador, P. and Turner, R., 2015. The relationship between project success and project efficiency. *Project management journal*, *46*(1), pp.30-39.

Shackman, J.D., 2013. The use of partial least squares path modeling and generalized structured component analysis in international business research: A literature review. *International Journal of Management*, *30*(3), pp.78-85.

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

Sheard, J., 2018. Quantitative data analysis. In *Research Methods: Information, Systems, and Contexts, Second Edition* (pp. 429-452). Elsevier.

Sherif, M.S.E., 2009. Towards developing an improved methodology for evaluating performance and achieving success in construction projects. *Scientific Research and Essays*, *4*(6), pp.549-554.

Shipley, B., 2016. *Cause and correlation in biology: a user's guide to path analysis, structural equations and causal inference with R*. Cambridge University Press.

Siang, L.C. and Ali, A.S., 2012. Implementation of risk management in the Malaysian construction industry. *Journal of Surveying, Construction and Property*, *3*(1), pp.1-15.

Sierra, F., 2021. "COVID-19: main challenges during construction stage". *Engineering, Construction and Architectural Management*. https://doi:10.1108/ECAM-09-2020-0719

Silva, E.S., Wu, Y. and Ojiako, U., 2013. Developing risk management as a competitive capability. *Strategic Change*, *22*(5-6), pp.281-294.

Simmons and Simmons. 2020. "COVID-19: Impact on construction proj ects in the Middle East." Accessed October 26, 2021. https://www.simmons -simmons.com/en/publications/ck7yjeifa0r1m0951yvoqlc49/covid-19 -impact-on-construction-projects-in-the-middle-east.

Siraj, N.B. and Fayek, A.R., 2019. Risk identification and common risks in construction: Literature review and content analysis. *Journal of Construction Engineering and Management*, *145*(9), p.03119004.

Smith, D.J. and Simpson, K.G., 2020. *The Safety Critical Systems Handbook: A Straightforward Guide to Functional Safety: IEC 61508 (2010 Edition), IEC 61511 (2015 Edition) and Related Guidance*. Butterworth-Heinemann.

Smith, N.J., Merna, T. and Jobling, P., 2014. *Managing risk in construction projects*. John Wiley & Sons.

Soni D., Chowdhary A. K., and Chowdhary K. 2017. *A study of factors affecting construction projects By Delphi Technique*. LAP LAMBERT Academic Publishing.

Stamatis, D.H., 2019. *Risk management using failure mode and effect analysis (FMEA)*. Quality Press.

Steyn, J.W. 2018. "Quantitative risk analysis for projects." Accessed 11 January 2022. https://www.ownerteamconsult.com/wp-content/uploads/2020/03/Insight-Article-050-Quantitative-Risk-Analysis.

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), pp.425-437.

Sugeno, M., 1985. *Industrial applications of fuzzy control*. Elsevier Science Inc.

Sumner, M., 2009. Information security threats: a comparative analysis of impact, probability, and preparedness. *Information Systems Management*, *26*(1), pp.2-12.

Suzuki, K. and Pheng, L.S., 2019. *Japanese Contractors in Overseas Markets: Bridging Cultural and Communication Gaps*. Springer.

Szymanski, P., 2017. Risk management in construction projects. *Procedia engineering*, *208*, pp.174-182.

Taber, K.S., 2018. The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in science education*, *48*(6), pp.1273-1296.

Tashakkori, A. and Creswell, J.W., 2007. The new era of mixed methods. *Journal of mixed methods research*, *1*(1), pp.3-7.

Taylan, O., Bafail, A.O., Abdulaal, R.M. and Kabli, M.R., 2014. Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies. *Applied Soft Computing*, *17*, pp.105-116.

Tengan, C. and Aigbavboa, C., 2021. Validating factors influencing monitoring and evaluation in the Ghanaian construction industry: a Delphi study approach. *International Journal of Construction Management*, *21*(3), pp.223-234.

The Institute of Risk Management (IRM), The Association of Insurance and Risk Manager (AIRMIC) and The Public Risk Management Association (Alarm), (2010) "A structured approach to Enterprise Risk Management (ERM) and the requirements of ISO 31000", UK

Trochim, W. and Donnelly, J.P., 2007. The research methods knowledge base 3rd Ed: Mason. *OH: Thompson Publishing Group*.

Tymvios, N. and Gambatese, J.A., 2016. Direction for generating interest for design for construction worker safety—A Delphi study. *Journal of Construction Engineering and Management*, *142*(8), p.04016024.

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), pp.1-17.

Van Steenkiste, E., Schoofs, J., Gilis, S. and Messiaen, P., 2022. Mental health impact of COVID-19 in frontline healthcare workers in a Belgian Tertiary care hospital: A prospective longitudinal study. *Acta Clinica Belgica*, *77*(3), pp.533-540.

Van Weele, A., 2014. *International contracting: Contract management in complex construction projects*. World Scientific.

Vasile, V., Comes, C.A., Ştefan, B.A. and Munteanu, A., 2015. Emerging Markets Queries in Finance and Business. *Procedia Economics and Finance*, *32*, pp.1-3.

Viswanathan, S.K., Tripathi, K.K. and Jha, K.N., 2020. Influence of risk mitigation measures on international construction project success criteria–a survey of Indian experiences. *Construction Management and Economics*, *38*(3), pp.207-222.

Wan, A.H. and Chiu, T.T., 2019. Risk Avoidance. *Journal: Encyclopedia of Gerontology and Population Aging*, pp.1-8. https://doi.org/10.1007/978-3-319-69892-2_870-1

Wang, W., Fu, Y., Gao, J., Shang, K., Gao, S., Xing, J., Ni, G., Yuan, Z., Qiao, Y. and Mi, L., 2021. How the COVID-19 outbreak affected organizational citizenship behavior in emergency construction megaprojects: Case study from two emergency hospital projects in Wuhan, China. *Journal of Management in Engineering*, *37*(3), p.04021008.

Wehbe, F.A. and Hamzeh, F.R., 2013, July. Failure mode and effect analysis as a tool for risk management in construction planning. In *21st Annual Conference of the International Group for Lean Construction* (pp. 685-694).

Wibowo, A. and Taufik, J., 2017. Developing a self-assessment model of risk management maturity for client organizations of public construction projects: Indonesian context. *Procedia engineering*, *171*, pp.274-281.

Willet, A., 1951. *The Economic Theory of Risk Insurance*, University of Pennsylvania, Press, Philadelphia, USA.

World Bank. 2020. *Global economic prospects*. Washington, DC: World Bank.

World Bank. 2020. Iraq Economic Monitor, fall 2020 : Protecting Vulnerable Iraqis in the Time of a Pandemic, the Case for Urgent Stimulus and Economic Reforms". Accessed June 25, 2021. https://openknowledge.worldbank.org/handle/10986/34749 License: CC BY 3.0 IGO."

Wu, Z., Nisar, T., Kapletia, D. and Prabhakar, G., 2017. Risk factors for project success in the Chinese construction industry. *Journal of manufacturing technology management*. *28*(7), pp. 850-866.

Wulan, M. and Petrovic, D., 2012. A fuzzy logic based system for risk analysis and evaluation within enterprise collaborations. *Computers in Industry*, *63*(8), pp.739-748.

Xia, N., Zou, P.X., Griffin, M.A., Wang, X. and Zhong, R., 2018. Towards integrating construction risk management and stakeholder management: A systematic literature review and future research agendas. *International Journal of Project Management*, *36*(5), pp.701-715.

Yager, R.R., 1980. On a general class of fuzzy connectives. *Fuzzy sets and Systems*, *4*(3), pp.235-242.

Yazdi, M., Daneshvar, S. and Setareh, H., 2017. An extension to fuzzy developed failure mode and effects analysis (FDFMEA) application for aircraft landing system. *Safety science*, *98*, pp.113-123.

Yoon, Y., Tamer, Z. and Hastak, M., 2015. Protocol to enhance profitability by managing risks in construction projects. *Journal of Management in Engineering*, *31*(5), p.04014090.

Zalaghi, H. and Khazaei, M., 2016. The role of deductive and inductive reasoning in accounting research and standard setting. *Asian Journal of Finance & Accounting*, *8*(1), pp.23-37.

Zayed, T., Amer, M. and Pan, J., 2008. Assessing risk and uncertainty inherent in Chinese highway projects using AHP. *International journal of project management*, *26*(4), pp.408-419.

Zhang, L., Xu, X. and Tao, L., 2013. Some similarity measures for triangular fuzzy number and their applications in multiple criteria group decision-making. *Journal of Applied Mathematics*, https://doi.org/10.1155/2013/538261

Zhang, M.F., Dawson, J.F. and Kline, R.B., 2021. Evaluating the use of covariance-based structural equation modelling with reflective measurement in organizational and management research: A review and recommendations for best practice. *British Journal of Management*, *32*(2), pp.257-272.

Zhao, X., Hwang, B.G. and Low, S.P., 2013. Developing fuzzy enterprise risk management maturity model for construction firms. *Journal of construction engineering and management*, *139*(9), pp.1179-1189.

Zohrabi, M., 2013. Mixed Method Research: Instruments, Validity, Reliability and Reporting Findings. *Theory & practice in language studies*, *3*(2).

Zou, P.X., Chen, Y. and Chan, T.Y., 2010. Understanding and improving your risk management capability: Assessment model for construction organizations. *Journal of Construction Engineering and Management*, *136*(8), pp.854-86

Zou, T.F. and Zhao, L.X., 2013. A Method for Estimating Sample Size of Monte Carlo Method in Accident Reconstruction. *Journal of China Safety Science*, *5*, pp.22-26.