A Structural Equation Model to Analyze the Effects of COVID-19 Pandemic Risks on Project Success: Contractors’ Perspective

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**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) focus group session with 11 experts 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 analyze the effects of COVID-19 emerging risks on project success. The results of the SEM analysis show that Financial Market (FM)-related risks, Supply Chain Operations (SCO)-related risks, Health and Safety of Construction Workforce (HSCW)-related risks, Organizational 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, FM-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.

**Keywords:** COVID-19, project success, construction industry, SEM, Iraq

**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 behaviors 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 labor market, and other difficulties experienced by developers, contractors, and vendors (Agyekum et al., 2021). In Iraq, the construction 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 et al. (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). Accordingly, 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). Ultimately, 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 construction 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 construction activities and reconstruction efforts of the country. Thus, instability of oil prices has major impact on other industries, including construction.
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 (BW 2021), 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. In fact, 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 led to shortages of supplies and labor, suspensions, and, in some cases, termination of construction contracts (Alsamarraie and Ghazali 2021).

***Existing challenges facing the success of construction projects in Iraq***

The construction industry in Iraq has faced and continues to face numerous challenges throughout the years. One of the most significant challenges is the issue of funding, as the majority of funds allocated to the sector are public in nature, thus making the role of government and political dynamics vital for the industry's development. Unfortunately, the instability in the government and the insecure security environment have hindered the growth of the sector, as evidenced by the destruction of critical infrastructure and housing projects resulting from internal armed conflicts.

Another challenge is associated with administrative issues, such as faulty leadership, inadequacy of contractor qualifications, and poor team selection, which can contribute to project failure Mahmoud (2020). Furthermore, 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).

Owners may also pose challenges, including delays in payment and excessive interference with the project, which can significantly hinder its successful completion (Aljamee 2020). Corruption is a major concern in Iraq's government system, as the country ranks 157th out of 180 countries in the 2021 Corruption Perceptions Index by Transparency International, making it one of the 23 lowest-ranking countries globally. This corruption discourages economic activity and results in non-compliance with laws and regulations (Al-karawi 2018). Additionally, project management practices in the Iraqi construction industry are generally inadequate, particularly in terms of managing risks. In fact, Iraqi contracting firms are faced with numerous challenges in risk mitigation within an environment that is typified by inadequate suppliers, a lack of investment, unchanged workers, logistical difficulties, and inadequate risk and safety management practices (Al-Mhdawi, 2020; Al-Mhdawi et al., 2020). These are deemed to be among the primary commonalities of the construction industry in developing nations (Darvas and Palmer, 2014; Boadu et al., 2020). To this end, Iraq was selected as a case study due to its representation as a developing country that has been affected by the COVID-19 pandemic and its accessibility to data. This selection provides a unique and valuable perspective in comparison to developed countries and highlights the distinctive characteristics of the COVID-19 pandemic and the related risks posed to a significant number of developing countries.

**Problem Statement**

Emerging research is eagerly exploring the impacts of the COVID-19 pandemic in diverse industries and sectors. 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, 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 generalized 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 (Guerlain et al. 2019). Hence, it is imperative that the impact of the pandemic and its emerging risks on the construction industry 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).

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. Most of the available efforts have investigated the impact of the pandemic on the successful implementation and delivery of construction projects 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), supply chain operations (Alsharef et al. 2022), and contractual implications ([AbdulLateef](https://ascelibrary.org/author/Olanrewaju,%20AbdulLateef) et al. 2022). Additionally, existing studies have primarily examined the impact of the pandemic on the success of construction projects from a broader perspective of construction experts, without paying considerable attention to construction contractors. Although it has been reported that contractors are highly vulnerable to the risks associated with the pandemic (Al-Mhdawi et al. 2022a; Olatunde et al. 2021) resulting in reputational damage and bankruptcy, especially for small contracting companies. Consequently, the current studies fall short in addressing the effects of COVID-19 emerging risks on PS from the perspective of construction 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.

**Research Methodology**

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

**Stage One: Identification of Construction Project Success Indicators**

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 professions, e.g., civil and structural engineers, mechanical and electrical engineers, architects, and quantity surveyors.In this research, a preliminary investigation was conducted with four experienced construction contractors in Iraq to identify the main indicators of construction PS from contractors’ perspective. In the preliminary investigation, the number of expert interviews was established once theoretical saturation was reached. Hennink et al. (2017) argue that there is no set number of interviewees needed for qualitative interviews, and the appropriate number is that required to reach theoretical saturation, after which no substantively novel insights can be derived from interviewees' responses. In this research, the theoretical saturation was reached after two interviews, while the third and fourth interviews confirmed this saturation (i.e., reported similar information), therefore further interviews were not necessary. To this end, the preliminary interviews for this research were concluded with four construction contractors in Iraq.

The selection criteria for the participants of the preliminary investigation required them to have at least 15 years of experience within the construction industry, be registered contracting companies with the Iraqi Ministry of Trade, and be an active member of international professional organizations such as the American Society of Civil Engineering, the Association for Project Management, the Chartered Institute of Building, and the Institution for Civil Engineers.

A detailed profile of the interviewees is provided in Table 2. Ultimately, eight indicators were identified, namely (time, cost, quality, safety, commercial profitability, functionality, client satisfaction, and end-user satisfaction). Each indicator is described as follows:

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 probabilityrefers 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. 2017), 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**

Although some research has been conducted on the impact of COVID-19 on the construction industry, the existing literature does not provide sufficient information to identify the risks associated with the COVID-19 pandemic. A focus group session was conducted with several construction experts in Iraq with the objective of identifying COVID-19 emerging risks. Focus groups refer to a type of group interview that utilizes communication among study participants in order to generate data. Focus groups typically involve small groups of participants, numbering between 6 to 12 individuals per group (Harthi, 2015). In the context of this research, a single focus group session was conducted with 11 experts who work in the Iraqi construction industry. This number of participants was selected based on the need to provide a diverse representation of perspectives within the industry while also ensuring a manageable size for the focus group discussion.

We selected this method due to (1) the lack of international and local (Iraq context) research on COVID-19 risks in the construction industry; and (2) its ability to provide a deeper understanding of phenomena or scenarios (Breen 2006). As part of the participants' selection process, we used a judgmental sampling method, in which participants were selected based on their extensive experience with the topic under investigation (Creswell and Creswell 2017). Capturing the impact of the pandemic and its emerging risks on construction projects is a difficult matter. It is therefore vital that specialists from different professional levels and backgrounds participate in the focus group session. Therefore, we contacted project managers, contractors, and architects. The key COVID-19 risks were discussed in detail during the session. The focus group session was recorded, the recording was reviewed afterward, and further decisive risks were identified. Ultimately, a comprehensive and validated list of COVID19 risks was developed under specific categories/themes.

**Stage Three: 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. Therefore, semi-structured interviews were conducted with construction experts in Iraq to establish the interaction hypotheses between PS and COVID-19 emerging risks that are categorized under five themes, namely: Financial Market (FM)-related risks, Supply Chain Operations (SCO)-related risks, Health and Safety of Construction Workforce (HSCW)-related risks, Organizational Implications (OI)-related risks, and Contractual Implications (CI)-related risks. This method of data collection was selected 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, a purposive sampling method was used whereby the interviewer contacts potential participants who are known to be area experts (Creswell and Clark 2011). Another selection criterion for the interviews is that the experts must possess extensive experience in the construction industry in Iraq. Ultimately, seven semi-structured interviews were conducted with experts working in Iraq's public and private construction sectors and with not less than 15 years of experience in contracting companies, counseling centers, and educational institutions. For data analysis, the interviews outputs were analyzed 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).

As described by Hsieh and Shannon (2005), there are three distinct approaches to content analysis: conventional, directed, and summative. As part of this study, conventional-type content analysis was conducted. This type of analysis is appropriate when identifying factors and is extensively used in the construction risk management literature (see, e.g., Al-Mhdawi 2022).

**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. FM construct compromises 10 items/risks; example items include reduction in labor 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. CI 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). The developed survey is presented in **Appendix A.**

***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. 2022a), and to ensure the suitability and comprehensiveness of the questionnaire (Yang and Shen 2015). In this research, a pilot study was conducted 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 this research, the sample size for the pilot study was determined by taking into account the level of theoretical saturation. In the pilot study, the survey was updated following the first, second, and third interviews. In the fourth and fifth interviews, no comments were received regarding the survey. As a result, four interviews were necessary for theoretical saturation, with the fifth interview being conducted in order to confirm the saturation achieved. The final version was administered to construction contractors working in public and private construction sectors in Iraq. Experts who are involved in the Iraqi construction industry and who are registered contracting companies with the Iraqi Ministry of Trade were invited to answer the survey. Ultimately, the survey was administrated to a total of 250 construction contractors.

***Surveys sample size***

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:

(1)

(2)

Where:

N = Sample size from a finite population; n = Total population number; Sample size from an infinite population; = Standard error variance of population elements; = 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 . Thus N≈100. In order to ensure that the minimum calculated sample size of 100 is met, a total of 250 surveys were distributed to construcion contractors in Iraq.

**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 modeling, structural equation modeling 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 modeling: covariance-based structural equation modeling (CB-SEM) and partial least squares structural equation modeling (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, PLS-SEM was used to (1) test the measurement model’s reliability and validity; and (2) examine the hypothesized relationships among the constructs. The survey output obtained from stage four of the research methodology was analyzed using PLS-SEM by Smart PLS software package V. 3.

**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 Figs. 2 to 4.

**COVID-19 Risks**

Using a focus group session with 11 construction practitioners in Iraq, we identified 46 COVID-19 emerging risks. The identified risks were categorized into five categories, as illustrated in Fig. 5.

**Profiles of the Participants in the Semi-structured Interviews**

As described in step two of the research methodology, semi-structured interviews were conducted with seven Iraqi construction experts to investigate the direct and indirect relationships between COVID-19 related risks and PS. Each interview lasted between 25 and 45 minutes and took place between July 27 and August 30, 2022. 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, three sets of research hypotheses were developed. Hypotheses H1 to H5 examine the direct relationship between COVID-19-emerging risks (e.g., FM-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 FM-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 CI (relationship mediator). These hypotheses are presented in Fig. 6. Additionally, Fig. 7 depicts the SEM hypothesized model used in this study.

**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%). The profiles of the participants are presented in Figs. 8 to 10.

**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 3, 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).

In this research, 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 3.

***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 4, all constructs meet the Fornell-Larckers criterion standard, indicating satisfactory discriminant validity.

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 5 shows this to be the case for all constructs.

**Assessment of Structural Model (Inner Model)**

The Structural Model (SM) examines therelationships among constructs (Le et al. 2022) and is assessed using the coefficient of determination (R2), Cross-validated redundancy (Q2), 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 (R2)***

The coefficient of determinationis 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, R2 values were obtained using the bootstrap algorithm in SMART PLS 3.0 with the recommended iterations of 300. As shown in Table 6, R2 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.

***Cross-validated redundancy (Q2)***

Cross-validated redundancyis 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 *Q2* 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 7, *Q2* 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.

***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. 2014). 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 FM-related risks are positively impacting PS. Results indicated that FM-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 FM-related risks (β=0.518), HSCW-related risks (β=0.485), and SCO-related risks (β=0.462), respectively. Table 8 shows the path coefficient of H1 to H5.

***Mediation analysis***

To assess the mediation role of CI, the research hypotheses H6, H7, H8, and H9 which examine the impact of the constructs on CI were tested. H6 evaluates whether FM-related risks are positively impacting CI. Results indicated that FM-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 FM-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), FM-related risks (β=0.568), and SCO-related risks (β=0.469). The results are presented in Table 9.

Furthermore, the total, direct, and indirect effects of the mediator (i.e., CI) were calculated as presented in Table 10. The total effect refers 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. 2022). The mediator hypotheses of H10 to H13 evaluate whether CI mediates the relationship between FM-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 FM-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%), FM-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 FM, HSCW, OI, and SCO on PS is fully mediated by CI. We, therefore, accept H10, H11, H12, and H13 (see Table 10).

***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**

***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 2022b). These effects can be seen from delays in payment, material price escalation, reduced labor wages, and contractors' bankruptcies. Our SEM analysis support these effects (i.e., **H1:**There is a significant impact of FM-related risks on PS, and H6: There is a significant impact of FM-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; 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](https://ascelibrary.org/author/Pamidimukkala,%20Apurva) et al. 2021). 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 2022b). Ultimately, 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; Rehman et al. 2021; Stiles et al. 2021 and others).

***Organizational 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 organizational 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 FM-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 research 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). Ultimately, the SEM analysis supported H5 (i.e., there is a significant impact of CI-related risks on PS) and is consistentwith the findings of previous research (see, e.g., Olatunde et al. 2021; Salami et al. 2021; Sierra, 2021; Umar 2022 and others).

***Mediator role***

The findings of this study provide useful empirical insight into the indirect impact of FM-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 FM-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. We have (1) identified the indicators of construction project success; (2) identified the key COVID-19 emerging risks; (3) developed hypotheses to capture the impact of the COVID-19 emerging risks on PS; and (3) quantitatively analyzed 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, a focus group session with 11 construction experts in Iraq was conducted to identify and categorize the COVID-19 emerging risks for the construction industry. Third, semi-structured interviews with seven Iraqi construction experts were conducted to develop the impact assessment hypotheses between FM-related risks, SCO-related risks, HSCW-related risks, OI-related risks, CI-related risks, and PS. Fourth, 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 FM-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 FM-related risks (β=0.518), HSCW-related risks (β=0.485), and SCO-related risks (β=0.462), respectively. CI's mediation role between COVID-19 emerging risks and PS revealed the following:

1. OI-related risks had the strongest direct effect on CI (β=0.637), followed by HSCW-related risks (β=0.613), FM -related risks (β=0.568), and SCO-related risks (β=0.469).
2. SCO-related risks had the strongest direct effect on PS (β=0.194), followed by FM-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), FM-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; Puil and Weele 2014; Hamie and Abdul-Malak 2018).

**Contribution and Future Work**

In this research, the effects (total, direct, and indirect) of COVID-19 emerging risks on project success was quantified and statistically validated under SEM environment. The employed model used PLS path modelling to evaluate each latent variable’s attributes and how they impact PS 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). Thus, the modelling outputs constitute a solid foundation for researchers and construction contractors to better understand how the key risks factors emerging from extreme condition like the COVID-19 pandemic affect the successful implementation and delivery of construction projects.

Quantifying risk factors is crucial for practitioners to ensure justified decision-making (Markogiannaki 2019) and determine a response to corresponding risks.Taking into account all risks associated with PS is imperative for practitioners. However, since construction projects typically operate in a dynamic environment involving numerous number of stakeholders and being subject to countless risks and uncertainties, established mitigating strategies must focus on risk factors that have the greatest impact on the success of the project. In fact, Goh and Abdul-Rahman (2013) stressed that the choice of response must correspond to the importance of the risk; it should be financially cost effective and realistic with regard to the project timing; it also must be accepted by other parties. Thus, the reported quantified levels of risk effects on PS are crucial for scholars and construction contractors to understand the required attention (i.e., expertise, and allocated budget) needed to develop appropriate strategies for ensuring the successful delivery of projects by addressing the direct and indirect effects of the key risks with high effects; and identify the root causes for low-level PS.

For future work, the findings of this paper can be used by research scholars to:

1. Compare 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.
2. Integrate the developed SEM with other quantitative-based methods such as fuzzy logic and Bayesian theory in order to improve decision-making by formalizing and addressing human knowledge and uncertainty associated with risk scoring.
3. Establish guidelines and strategies for controlling the impact of pandemic risks on the successful implementation and delivery of construction projects.

**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.

**APPENDIX A: STRUCTURAL EQUATION MODELLING SURVEY**

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

4. 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 Implications | Lack of clarity in the contract language |  |  |  |  |  |
| Claims arising under a construction contract |  |  |  |  |  |
| Change of law |  |  |  |  |  |
| Inappropriate risk Allocation |  |  |  |  |  |
| Contract suspension |  |  |  |  |  |
| Contract termination |  |  |  |  |  |
| Construction 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 construction 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 |  |  |  |  |  |
| Organizational 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 |  |  |  |  |  |

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**Data Availability Statement**

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

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**Table 1.** Summary of existing studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Reference** | **Region** | **Purpose** | **Methods** | **Findings** |
| [Agyekum](https://www.emerald.com/insight/search?q=Kofi%20Agyekum) 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 | 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. |
| 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 |
| 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. |
| King et al. (2021) | Malaysia | Analyzed 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. |
| Kukoyi et al. (2021) | Nigeria | Assessed the risk control systems of construction organizations, as well as the challenges associated with implementing safety measures on construction sites | Open-ended survey | Findings indicated that some construction professionals do not have adequate information regarding the severity of COVID-19 and misapply personal protective equipment. |
| Olanrewaju et al. (2022) | Nigeria, Ghana and South Africa. | Modelled the environmental, economic and social impacts of COVID-19 pandemic on the construction industry | Survey and SEM | Results indicated that the economic impact had the greatest contribution (environmental, economic, and social) to the overall shock caused by the pandemic. Economic impacts were found to be the most significant influence on the construction industry in the region compared to environmental and social impacts. |
| 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. |
| 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. |
| 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. |
| 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. |

**Table 2.** Preliminary investigation experts’ profiles

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| 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 | - | - |

**Table 3.** Results of measurements model – internal consistency reliabilityandconvergent validity

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Constructs** | **Risk code** | **Cronbach's alpha** | **CR** | **Factor**  **Loading** | **AVE** |
| Contractual implications (CI) | C01  C02  C03  C04  C05  C06 | 0.804 | 0.860 | 0.664  0.710  0.749  0.703  0.755  0.681 | 0.506 |
| Financial market | F01  F02  F03  F04  F05  F06  F07  F08  F09  F10 | 0.954 | 0.916 | 0.904  0.890  0.885  0.785  0.871  0.868  0.859  0.720  0.804  0.822 | 0.710 |
| Supply chain operations | S01  S02  S03  S04  S05  S06  S07  S08  S09 | 0.915 | 0.928 | 0.777  0.788  0.765  0.767  0.796  0.674  0.835  0.778  0.720 | 0.590 |
| Health and safety of construction workforce | H01 | 0.932 | 0.941 | 0.620 | 0.555 |
|  | H03  H04  H05  H06  H07  H08  H09  H10  H11  H12  H13 |  |  | 0.768  0.774  0.764  0.738  0.749  0.776  0.821  0.685  0.817  0.792  0.772 |  |
| Organizational implications | O01  O02  O03  O04  O05  O06  O07  O08 | 0.858 | 0.890 | 0.672  0.707  0.775  0.731  0.556  0.778  0.721  0.724 | 0.505 |

**Table 4.** Discriminant validity by Fornell-Larcker criterion

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | FM | HSCW | CI | OI | SCO |
| FM | 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 |

**Table 5**. Discriminant validity by HTMT

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | FM | HSCW | CI | OI | PS | SCO |
| FM | - | - | - | - | - | - |
| 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 | - |

**Table 6.** Structural model’s coefficient of determination values

|  |  |
| --- | --- |
| Construct relation | R2 |
| Effect of COVID-19 risks on CI | 0.670 |
| Effect of COVID-19 risks on PS | 0.792 |

**Table 7.** Structural model’s cross-validated redundancy values

|  |  |  |  |
| --- | --- | --- | --- |
| Endogenous variables | SSO | SSE | Q2(=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 |

**Table 8.** Path coefficient of the research hypotheses H1 to H5

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Hypotheses** | **Path** | **Β** | **Standard Deviation** | ***T***  **Value** | ***P* Value** | **Decision** |
| H1 | FM>>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

**Table 9.** Path coefficient of the research hypotheses H6 to H9

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Hypotheses | Path | Β | Standard Deviation | *T*  Value | *P* Value | Decision |
| H6 | FM>>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 10.** Mediation analysis

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

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