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High risk and impact factors on construction management process – case study of COVID-19 of a hospital in Iraq

Mustafa Al-Saffar*, Abdul Salam K. Darwish, and Peter Farrell

University of Bolton, Bolton, UK

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Abstract. The pandemic of COVID-19 crisis suddenly appeared worldwide, and there were no proper crisis management procedures taken in advance to contain such a problem. Moreover, it has had harmful and unmeasured consequences on most life sectors, including construction, which has been severely impacted during the pandemic. This paper aims to review factors with a high-risk impact on hospitals' construction projects during the outbreak of COVID-19 in developing countries by considering the case of Iraq's construction sector. A mixed methodology of qualitative and quantitative research approaches was used. The qualitative method involved (1) a literature review and (2) semi-structured interviews to identify high-risk factors that affect construction projects during the outbreak of COVID-19. The quantitative method involved (1) collecting survey data from 205 industry professionals and experts to determine each risk factor's importance and influence. Cronbach's alpha test to check the reliability of the collected data set, and (3) a fuzzy inference system method was used to assess the impact of each factor on construction projects during the pandemic. The findings of this study indicate that the construction industry has been hit severely during the COVID-19 in Iraq. Moreover, 17 high-risk sub-factors under six main construction factors involve health and safety, risk management, management deficiency, financial, supply chain management and contractual impact hospital construction projects. Furthermore, the most significant risk factors had impacted hospital construction projects by calculating their means were (1) commitment to safety and health recommendations with a level of impact equal to 4.81; (2) risk management procedures with a level of impact equal to 4.63; (3) equipment delivery delays with a level of impact equal to 4.54; (4) worker acceptance of COVID-19 vaccination with a level of impact equal to 4.36; (5) increase of price material with a level of impact equal to 4.18; (6) lack of use of the latest technology with a level of impact equal to 4.09; (7) delay in payments with a level of impact equal to 3.90; and (8) lack of training to deal with the pandemic with a level of impact equal to 3.81. As such, this paper contributes by providing effective policies and measures to mitigate the impact of COVID-19 on hospital construction projects in Iraq.

Keywords: Risk management / COVID-19 / crisis / hospital construction projects / Iraq

1 Introduction

The construction industry is the backbone of economic growth and development for any country. It plays a pivotal role in national growth, as it directly impacts the economy [1]. Indeed, developing infrastructures, such as buildings, hospitals, bridges, tunnels, and roads, is an indicator of countries' economic growth [2]. Furthermore, the construction industry constitutes a significant portion of different countries' gross domestic product (GDP). For instance, 7.4% in Iraq, 3.2% in Jordan, 7% in the United Kingdom, and 6.4% in the United Arab Emirates [3–5]. However, construction, like other industries, has challenges and risks and may be affected by risks that may occur during project life cycles [6]. Risk is "a combination of the probability of an event occurring and its consequences for project objectives" [7]. One such aspect is the construction industry, where risks associated with construction are uncertain incidents or situations which have negative or positive impacts on achieving project objectives if they happen. Moreover, there are different types of risks, such as financial, supply chain management, health and safety and contractual. Supply chain management and contractual risk factors substantially impact the success of construction projects in developing countries [8]. Consequently, risks may cause schedule delays, cost overruns, and safety and quality problems. Since 2020, construction projects have faced one of the biggest challenges represented by COVID-19. In fact, COVID-19 resulted in suspending all business

* e-mail: maa1res@bolton.ac.uk

activities of many industries, including the construction industry. Also, many countries experienced recession and economic downturns due to measures implemented to control the spread of COVID-19. The world bank indicated that COVID-19 has triggered the most significant recession since World War II. Additionally, the income per capita will remain below pre-COVID-19 levels in about 40% of developing countries, and growth in middle-income countries will substantially decrease in 2023 [9]. During the outbreak of COVID-19, the construction industry was influenced worldwide and faced many challenges and a variety of risks, such as health and safety risks, financial and economic risks, supply chain management, etc., which caused delays in project delivery and cost overruns. However, some studies have attempted to assess the impact of COVID-19 on the construction industry. For instance, Al-Mhdawi et al. [10] discussed the impact of COVID-19 risks on construction projects in developing countries. A study by Umar [11] investigated the impact of COVID-19 on the construction industry in Gulf Cooperation Council (GCC) countries in terms of project delays, health and safety management, workforce management, and legal issues. However, this paper aims to overview the factors with high risk and impact on hospital construction management processes through COVID-19 on construction project risk management. Also, the objectives of this research are (1) to highlight management challenges facing construction projects during the outbreak of the pandemic crises, (2) identify risk factors with a high impact on the construction project management from the lesson learned from COVID-19, and (3) develop effective policies and practices for effective risk management for construction projects pre-pandemic.

2 Literature review

In this paper, the authors discussed the risk factors that affected construction projects, considering two phases. The first phase is the period before the appearance of the pandemic COVID-19 in our world, where numerous common risk factors may occur at any stage of the project life cycle, such as financial risks, contractual risks, operational risks, and political and environmental. A study by Bahamid et al. [12] highlighted the risk factors that substantially impact the construction industry in developing countries; the critical risk factors identified were inflation and increases in material prices, accidents and safety, delays in approvals, changes in laws and regulations, labour productivity, and clients' financial failure. References [13,14] revealed that the most significant risk factors that impact construction projects in Iraq were material price increases, political change, delays in payment, and unofficial holidays. Al-Turfi et al. [15] agreed with these studies but also identified further other important risk factors, which were the regulatory changes, inappropriate organisational structure, lack of motivation, encouragement, and slow decision-making, which have all had a significant impact on Iraq's construction projects. Moreover, Al-Hazim et al. [16] indicated in their study that the critical risk factors that affected Jordan's public and private construction projects were design changes, poor risk management and weather conditions. The second phase is the period of the outbreak of the pandemic of COVID-19, where the construction industry was experiencing one of the biggest challenges that have affected the performance of several success factors of performing construction projects. Alsharef et al. [17] discussed the adverse effect of the pandemic of COVID-19 on USA construction projects. They identified the most critical risk factors for construction projects, including delays on projects, productivity reductions, inability to secure materials on time and price material increases. Jallow et al. [18] points out that it was challenging to manage construction projects in the UK during the pandemic of COVID-19 since team members worked remotely and could not physically attend sites. In addition, Sierra [19] reported that the UK's construction industry confronted several challenges due to the pandemic, including skill shortages, legal exposures, financial difficulties, and supply chain issues, which had a significant impact on all parties involved in construction projects. On the other hand, the construction industry in Ghana has been hit severely during the pandemic COVID-19, with significant risk factors including a decrease in work rate, delays in payments and an increase in the cost of materials arising from border closure [20]. Also, A recent study by Al-Mhdawi et al. [21], found that the most significant COVID-19 risks in Iraq are fluctuation of price materials, contractor bankruptcy, commitment to health and safety procedures, skills shortage, management expertise, and interpretation of the contracts.

Based on the aforementioned information and studies, it was found that: (1) most studies focused on the diverse effects of COVID-19 on construction projects in various countries. However, few studies have highlighted the impact of COVID-19 on different types of construction, particularly the construction of hospitals, which is one of the most important types of construction during the pandemic. (2) Most studies focused on factors that affected construction projects during COVID-19, using a qualitative approach (systematic literature review and semi-structured interview). In this paper, the authors focused on important factors that affected the construction projects, particularly the construction hospital projects, by using mixed methods, both qualitative and quantitative. The qualitative method includes a literature review of relevant studies and semi-structured interviews with experts in construction projects. The quantitative method includes developing a survey to rate the factors in terms of their high importance. In addition, a fuzzy inference system to evaluate the effect of COVID-19 on construction hospital projects, and (3) no previous studies highlighted the significant factors that affect management processes in construction projects for hospitals, which this paper focuses on.

3 Iraq's hospital construction industry

Iraq's construction industry, especially for infrastructure projects, has continued to grow since 2003, where the domestic demand for construction projects has increased significantly due to rapid population growth in the country; this has been consistent with the expansionary economic policies [22]. According to Iraqi Central Statistical Organization [23], the population of Iraq is estimated to increase to 51.21 million in 2030. This will lead to an increase in demand for construction projects such as (Hospitals, Housing, Schools, and Buildings). In this paper, the authors focused on construction hospital projects during the outbreak of COVID-19. Before the pandemic, one of the critical objectives of the Iraqi government was to build hospitals to provide healthcare to their citizens and address the shortage of hospitals caused by the growing population. According to Iraqi Ministry of Planning [24], the estimation of the population for the year 2022 was 42.24 million. Also, the numbers of hospitals are 290 public hospitals and 155 private hospitals throughout Iraq [25]. Therefore, the Iraqi government has spent a considerable budget on building hospitals, as the current number of hospitals cannot accommodate the population growth. However, many of these projects have been suspended or delayed for different reasons, including financial, supply chain management, risk management, and contractual and legal factors [15]. During COVID-19, Iraq was severely impacted due to an increase in positive cases and high death rates. The main causes of this increase were a lack of commitment to safety and health recommendations issued by the Ministry of Health, including too little social distancing and wearing masks. On February 2020, the Iraqi Ministry of Health announced the first case of infection by COVID-19 in Iraq. Three weeks later, the Iraqi government imposed a nationwide lockdown from March to the end of May 2020 and shut down most industries, including the construction industry, to control the spread of the virus [26]. Nevertheless, a study by Al-Mhdawi et al. [27] pointed out that the Iraqi government has lifted the lockdown gradually and implemented strict safety and conducted vaccine awareness campaigns for workers, but the vaccination rate was still very low. However, many hospital construction projects suspended their works or were delayed for various reasons. For instance, Ibn Cena Hospital with 600 beds, Al-Huryia hospital with 400 beds, and the Armed Forces with 400 beds in Baghdad province, Turkish Hospital with 600 beds in Maysan [28]. In fact, these hospitals construction projects have faced several risks during COVID-19, such as (1) shortage in workers, (2) increases in price materials, (3) material availability, (4) delay in payment, (5) currency exchange rate, (6) risk management practice, (7) low productivity of labour, (8) interpretation of contract language and (9) safety and health management [10,17,29]. Ultimately, it found that Iraq's construction projects, particularly hospitals, have encountered a series of challenges that directly affected this sector, which requires the development of appropriate plans to avoid such a situation in the future.

4 The pandemic of COVID-19

Coronavirus disease (COVID-19) is an infectious airborne disease caused by the SARS-CoV-2 virus; it is principally transmitted through respiratory droplets and aerosols. It was first discovered in December 2019 in Wuhan, People's Republic of China, following a report among a cluster of patients with viral pneumonia [30]. Later, it became a worldwide concern because it spread quickly worldwide, and the World Health Organization declared the disease a pandemic on 11 March 2020. However, two years after the outbreak of COVID-19 as it has become part of our lives with the appearance of vastly different versions of the virus emerging with new properties of the infections. For instance, the ease of its spread, the degree and severity of the disease, the effectiveness of vaccines, therapeutic drugs, diagnostic tools, and other public health and social measures. Therefore, the only way to prevent the spreading of the disease in indoor settings is to open as many windows and doors as possible and mandate mask use [31]. According to the statistics of the World Health Organization [32], the number of infections with COVID-19 since the beginning of the pandemic is estimated at 623.98 million, and the death 6.55 million at the time of the initial draft of this publication.

5 Crises impact on construction projects during COVID-19

Crises are unplanned events that happen outside the normal scope of operations for top management [33]. Since the World Health Organization declared that a pandemic is a health crisis, it has spread worldwide and has not only affected lives but also substantially impacted various sectors such as medicine, health care, architecture, education, transportation engineering and construction. In response to this crisis, many countries have closed their borders and implemented a lockdown policy with restrictions on gatherings and the movement of people. Thus, these measures imposed by the explored consequences of COVID-19 have minimised industrial operations and affected the economy of countries [34]. A study by Fernandes [35] attempted to assess the impact of COVID-19 on different countries; the study found that the economy of some countries plummeted by 3–6% while other countries fell by 15% in the first quarter of 2020, and lost jobs and fell in the GDP for countries that are mainly dependent on foreign trade. Like other industries, COVID-19 has hit construction projects severely. Alsharef et al. [17] identified the adverse impacts of COVID-19 on the economy and construction projects. The study found that COVID-19 has brought significant challenges to the growth and development of construction projects. Also, a study by Jallow et al. [18] attempted to assess the impact of COVID-19 on construction projects. The study revealed that COVID-19 forced construction companies and their staff and workers to work remotely, which has caused delays in many projects. Table 1 shows the pandemic crisis's impact on the

Table 1. The pandemic crisis impacted on the construction industry in developed and developing countries.

	UK	Australia	UAE	Iraq
Population	67.44 million	25.69 million	10.206 million	40.22 million
Unemployment Rates	4.47%	6.8%	5%	13.74%
Lockdown period	24-March-2020 to 4 Jul 2020	23 March 2020 to May 2020	26 March 2020 to 17 April 2020	15 March 2020 to April 2020
Estimated loss	£301 million per day.	Approx. £4.42 billion due to COVID-19 pandemic.	shrinkage by 10.4% in 2020	£88.46 million per day
COVID-19 impact on construction industry	In the first quarter of 2020, the construction sector of UK lost 2.1% towards the contribution to GDP and fell 5.9% in March due to COVID-19 as well as the output of construction shrunk 25% in 2020.	76500 workers lost their jobs from March to May.	The construction industry faced costly pressures, and productivity has declined due to lack of labour	Disruptions and difficulties. Many Iraqi construction firms witnessed loss of profits and faced challenges, which are prevented growth and development
Reference	Preston [36]	Biswas et al. [37]	Biswas et al. [37]	[38]

construction industry in various developed and developing countries.

6 Research methodology

A mixed qualitative and quantitative methodology is adopted to meet the research goals. According to Farrell et al. [33], the best studies should involve analysis of both qualitative and quantitative data. Figure 1 demonstrates the research methodology used.

6.1 Literature review analysis

Initially, the authors conducted an extensive search using textbooks, academic and peer-reviewed journals, conference and seminar proceedings, dissertations, theses, and government reports focused on the impact of the pandemic COVID-19 on construction projects as primary sources of data [39]. Following the approach of [40,41], the search was carried out using Google Scholar and Scopus to find relevant publications. The keywords used in the search engine were COVID-19, health crisis, construction industry, risk assessment in construction projects, critical risk factors affecting construction projects, and challenges encountered during COVID-19. Ultimately, the database search led to 50 reports and papers. However, after selecting and screening, it can be included a total of 30 of them in our study.

6.2 Semi-structured interview

In this step, the authors conducted 45 semi-structured face-to-face interviews. According to Alsaawi [42] open-ended questions are used to conduct semi-structured interviews before the interview. As a result, the authors prepared the questions based on the literature review analysis. This method was used because it is an effective method of explaining or exploring complicated phenomena or situations [43] and enables the authors to gather more in-depth opinions and insights from industry experts about the issue beforehand [44]. The sample that we focused on was semi-structured interviews representing senior-level construction industry practitioners and academics based in Iraq.

6.3 Survey development

The third step was to develop a survey to assess the impact of COVID-19 on hospital construction projects and to obtain the ranking of all risks in construction projects in Iraq. The survey involved two sections. The first section involved respondents' general information, including education degree, the extent of experience, and job positions in their organisations. The second part of the survey aims to quantify the level of importance and severity of construction factors during COVID-19 in Iraq. The authors adopted a five-point Likert scale to measure the importance of factors and the severity of each factor as follows: 1 = very high, 2 = high, 3 = moderate, 4 = low, and 5 = very low.

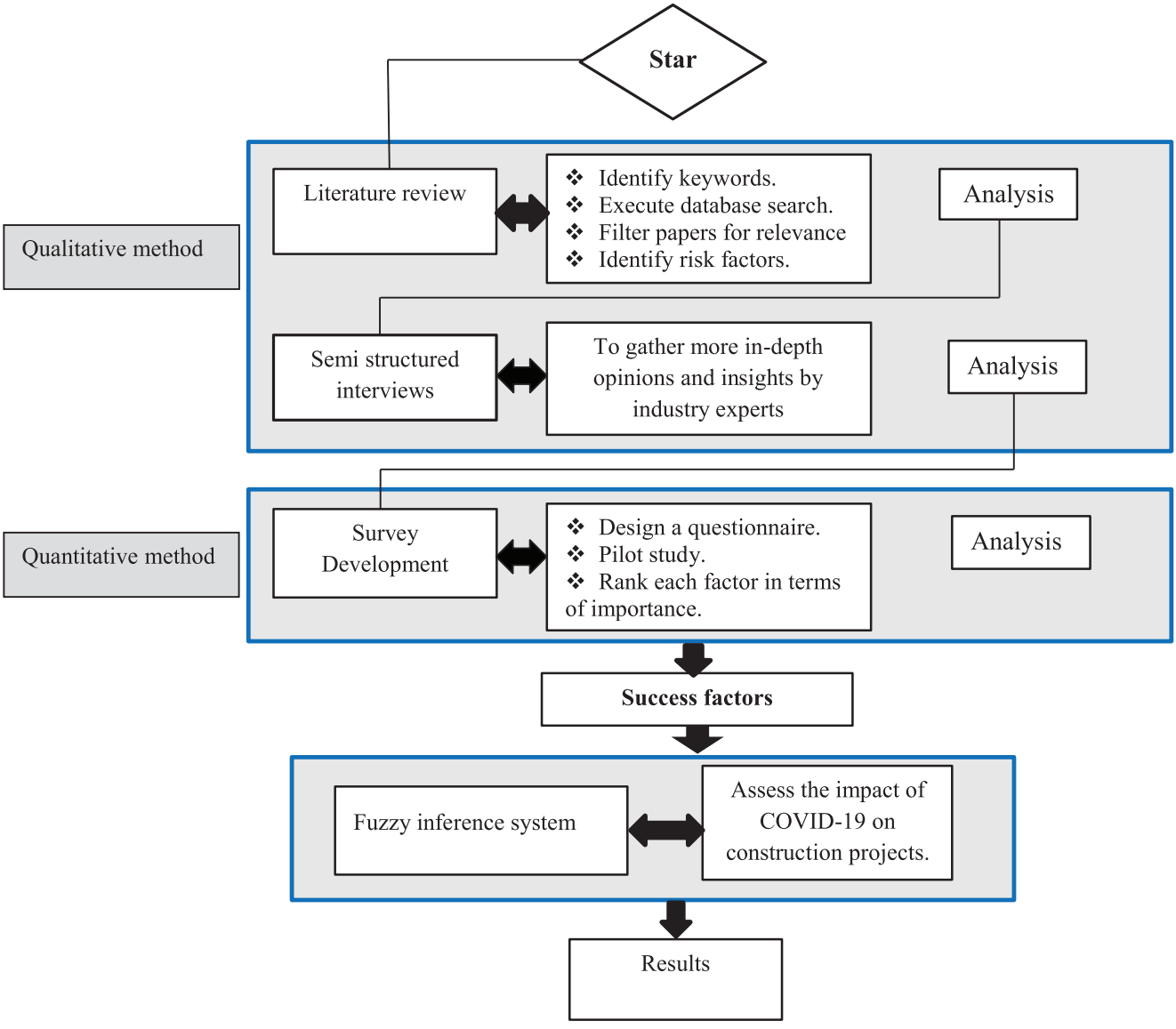

Fig. 1. Research plan.

6.3.1 Pilot study

A pilot study of the survey was conducted to determine its effectiveness and problems (Evans et al., 2022). The survey was piloted to six construction industry practitioners and four consultants who specialised in construction management in Iraq. The respondents suggested some amendments for some questions and added some others. Therefore, based on the respondents' feedback, the authors updated the questionnaire accordingly, and the survey was ready for formal testing [33]. The pilot study helps to reduce the likelihood of respondents having problems with answering the questions, thus creating data recording problems. Furthermore, to assess weaknesses by getting feedback from experts in the construction industry on the questions that need to be improved, refined, added, or deleted.

6.4 Fuzzy inference system

The authors adopted a fuzzy inference system (FIS) approach to assess the impact of the pandemic of COVID-19 on hospital construction projects in Iraq. The FIS is a system that provides a precise approach with a clear understanding of how to deal with ambiguity and uses information based on the knowledge of experts. This system interprets values in the input variables and based on if-then rules, assigns values to the output variables. According to Alhumaidi [45] the inputs of FIS are objectively associated with linguistic terms. The advantage of using FIS is (1) its ability to use linguistic terms to provide an inference framework to deal with complex and poorly defined problems due to imprecise and complete information [46], and (2) its ability to formalize and address human knowledge and uncertainties in decision making [47,48]. In this paper, the authors selected this

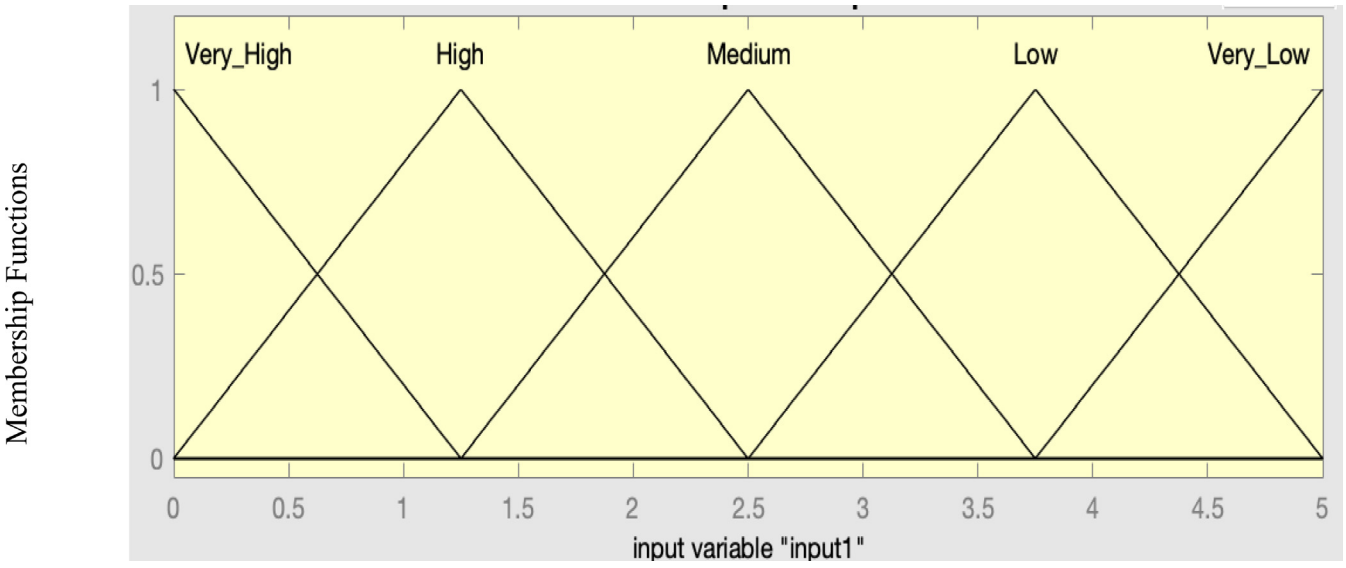

Fig. 2. Importance of the factor (IF) input variable.

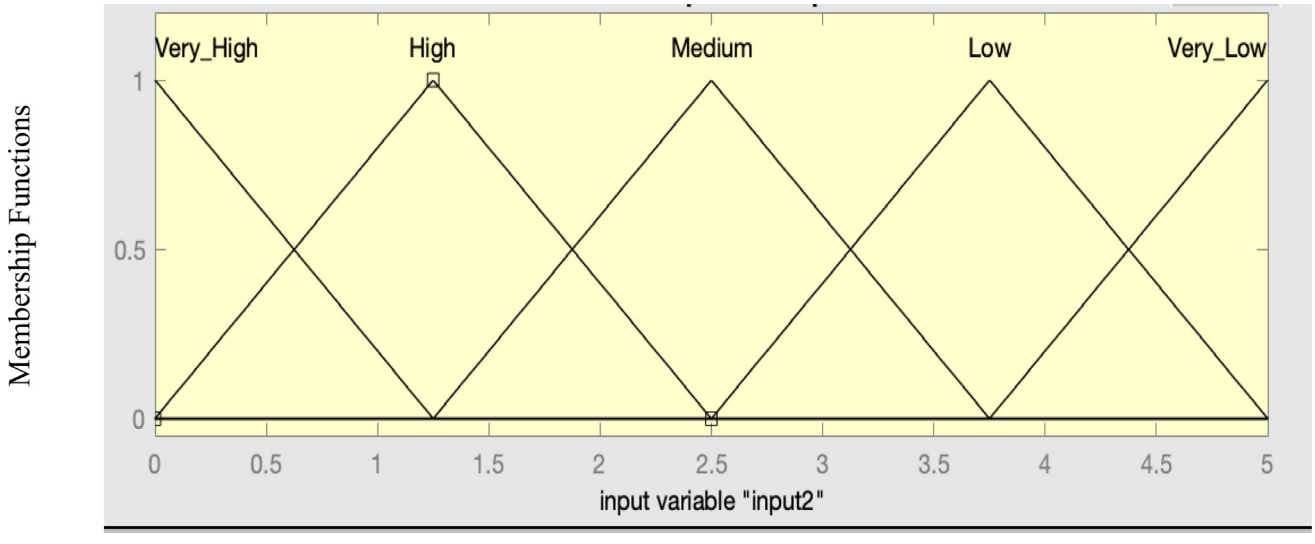

Fig. 3. Severity (S) input variable.

approach because its inputs consist of linguistic and not numerical and are based on the knowledge of experts. It also deals with cases that are ambiguous and complex, and since COVID-19 is a complex and vague phenomenon that has not been witnessed before. Thus, this is the best method to assess the impact of COVID-19 on Iraq construction projects.

6.4.1 Fuzzy inference system process

The authors describe the proposed model in this paper in six stages:

Stage 1: Inputs:

At this stage, there are two input variables, the importance of factors (IF) and severity (S), where IF refers to the extent of the importance of the factor, and S refers to the level of impact of the pandemic COVID-19 on construction projects in terms of performance and quality. In addition, one output ICCP refers to the effect of COVID-19 on construction projects.

Stage 2: Define Membership Functions

Membership function (MF) is usually used to quantify linguistic terms and represents a fuzzy set graphically. According to Adil et al. [49], MF is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the "universe of discourse". For this paper, five fuzzy sets of membership functions are applied for both inputs and outputs of the FIS system. The fuzzy sets in the form of linguistic variables for inputs and output of Stage 1 include "very high", "high", "moderate", "low", and "very low", as shown in Figures 2–4. Furthermore, the most common type of membership functions triangular, trapezoidal, and Gaussian, Generalized bell MFs

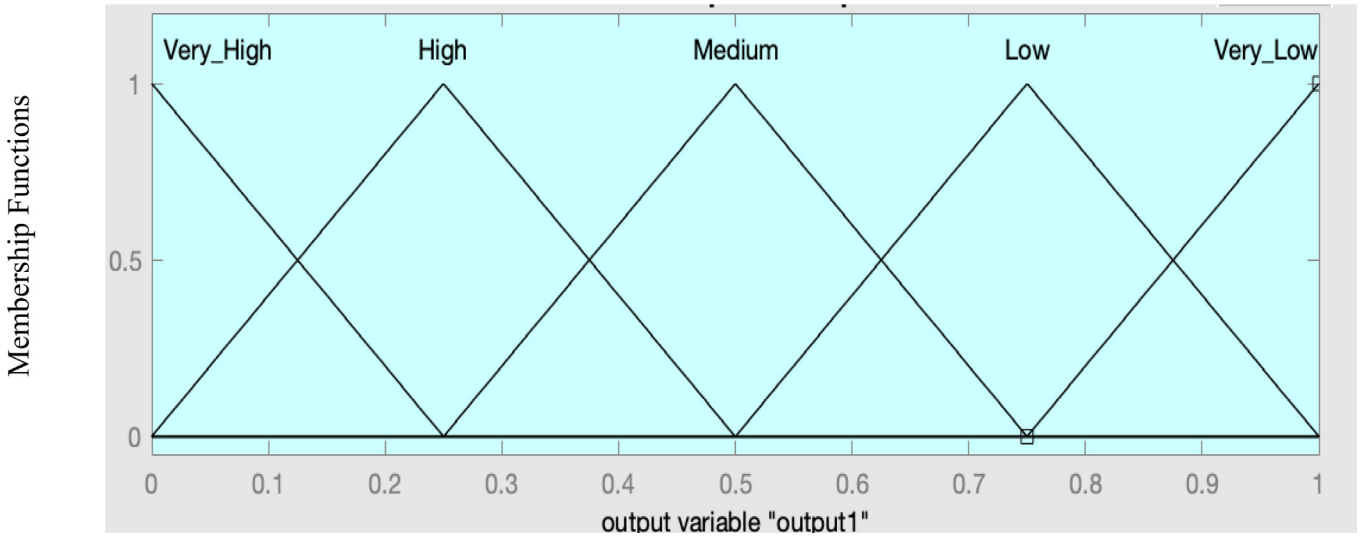

Fig. 4. The COVID-19 impact on construction projects (ICCP) output variable.

π- Shaped Membership Function and S- Shaped Membership Function [49]. In fact, the authors used triangular membership functions because of (1) an efficient method to gather vague information, (2) an effective solution to the optimisation of fuzzy modelling, and (3) simplicity in terms of arithmetic computation.

Stage 3: Establish if-then rules

At this stage, to assess the impact of the pandemic COVID-19 on Iraq hospital construction projects, the authors adopted the Mamdani fuzzy inference system. It was first introduced by Ebrahim Mamdani [50]. It is an often-known method for forecasting and evaluating various engineering and construction projects [51]. The concept of Mamdani's method is synthesising a set of linguistic control rules based on the experience of human operators. The If-then format is used to define the relationship between inputs and outputs. In other words, Rule 1 shows the conjunction of the "if" part or antecedent—using, for instance, an "AND" method such as Product or Minimum—leads to a specific then part-or consequence. For instance,

$$\text{If } x1 \text{ is } A \text{ and } x2 \text{ is } B; \quad \text{then } y \text{ is } C. \quad \text{Rule 1}$$

where A, B, and C are linguistic terms and membership functions of $x1$, $x2$, and y, respectively. As mentioned above, the alternative options for the inputs (i.e., the five linguistic terms for each input variable). Thus, 25 "if-then" rules have been developed to incubate all the input variables as shown in Table 2.

Stage 4: Fuzzification

There are multiple definitions of Fuzzification. It is a process in which a mapping is established from crisp input values to fuzzy sets [52]. Further, it is a process in which crisp values are transformed into degrees of membership for linguistic terms of fuzzy sets. Thus, the authors used the triangular membership functions, as shown in equation (1), to fuzzify the inputs.

$$\mu A(z) = \begin{cases} 0, & 1 \\ \dfrac{x-a}{b-1} & a \le x \le b \\ 1, & x = b \\ \dfrac{c-x}{c-b} & b \le x \le c \\ 0, & x \ge c \end{cases}, \tag{1}$$

where a, b, and c = lower, modal, and upper values, respectively.

To end this, the values of (IF) and (S) rated by respondents were considered inputs for evaluating COVID-19 impact. By using equation (1) and Figures 2–4 to get membership of values fuzzicated of IF and S from each survey

Stage 5: Aggregation

After fuzzifying the inputs (i.e. IF and S), the if-then rules are used to obtain the membership function for the output variable (i.e. ICCP) impact. Aggregation is the process through which the fuzzy sets representing the outputs of each rule obtained at the implication step are combined into a single fuzzy set. Aggregation occurs once for each output variable before the final defuzzification stage [53]. For Mamdani's fuzzy inference system, the min-max composition is used for aggregation and obtaining each factor's output function, as shown in equation (2)

$$\mu(y) = \max\{\min(\mu Ar(\chi 1), \mu \beta 1(\chi 2)r\}. \tag{2}$$

Stage 6: Defuzzification

According to the membership functions of the output, the defuzzification process is the aggregate fuzzy set, and the output is a single crisp (nonfuzzy) value for each factor [53]. There are different defuzzification techniques, including the centroid method, bisector of area, and middle of

Table 2. Construction main factors and sub-risk factors.

Main factors	Sub −Risk factors	References
Health and Safety	F1: Commitment of safety & health recommendation F2: Personal protect equipment & hands sterilizing. F3: Workers acceptance of Covid-19 vaccination F4: Lack of training to deal with pandemic	[11,17,27,29,55–57] and Research findings
Risk Management	F5: Risk management procedures	[10,17,29,55,57]
Management deficiency	F6: Lack of the use latest technology F7: Time management F8: Difficulty in controlling behaviour of workers	Research findings
Financial and economic	F9: Currency exchange rate F10: Material price increases F11: Labor wages F12: Delay in payment F13: Inflation	[10,11,17,29,58,59]
Operational	F14: Low productivity of labour F15: Delay in equipment delivery	[10,11,27,29,59,60]
Contractual	F16: Legal disputes F17: Interpretation of contract language	[10,11,17,29,61]

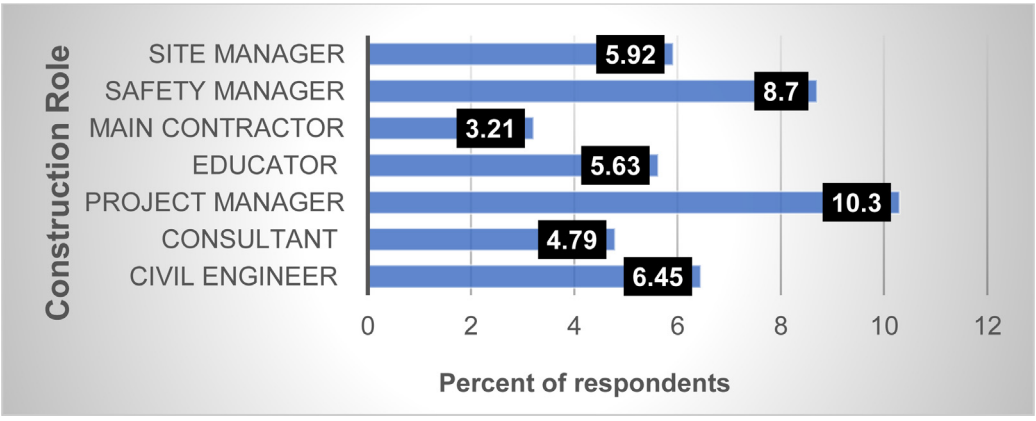

Fig. 5. Distribution of respondents according to their employment role.

maximum, as well as the largest of maximum and smallest of maximum methods [54]. For this paper, the authors used the centroid method, which returns the centre of the area under the membership curve. This technique finds the centroid of the area under the output membership function, as shown in equation (3).

$$y* = \frac{\int y\mu s(y)dy}{\int \mu s(y)dy}. \quad (3)$$

7 Analysis

7.1 Literature review

Through the literature review conducted, the authors identified the main risk factors that impacted construction projects during COVID-19.

7.2 Semi-structured interviews

The authors conducted 45 Interviews to assess the impact of COVID-19 on Iraq's hospital construction projects. Figures 5–7 show the respondents' profile and distribution. A total of 17 critical risk factors were considered during the interview and supported by the literature review conducted, as shown in Table 2.

7.3 Survey development

In this step, the authors developed a survey which consisted of two sections. The first section was used to collect the general information of respondents, such as current position at organisations, years of experience and level of education. The second section included 17 risk factors from the literature and interviews to quantify the level of importance and severity of all construction factors. 250 surveys were sent to experts and professionals in the

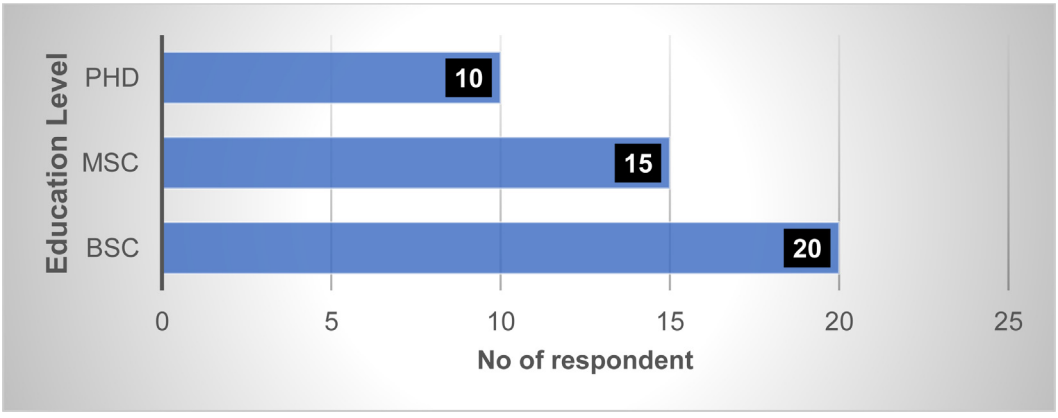

Fig. 6. Distribution of respondents according to their highest achievement education.

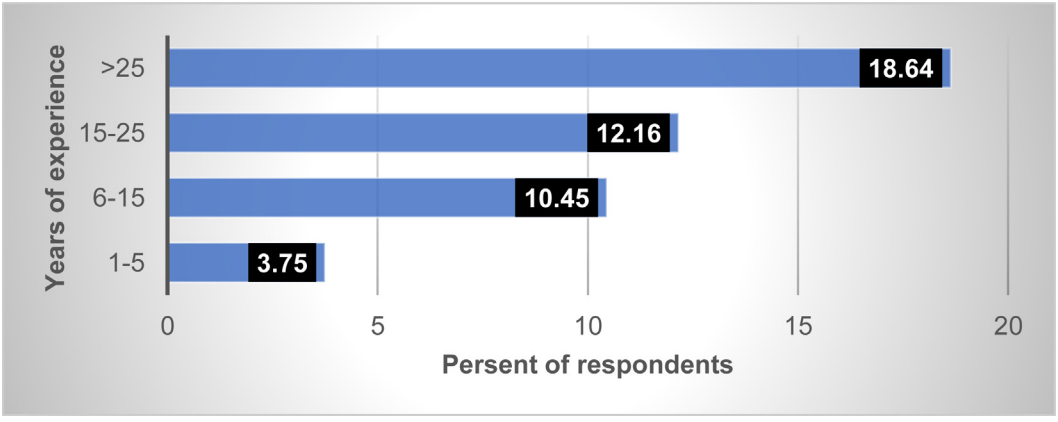

Fig. 7. Distribution of respondents according to their experience.

construction industry. 205 surveys were received and used in the analysis, with a response rate for the survey of 82%. The authors calculated the mean of ICCP from the collected survey response to introduce each factor's average level of impact on construction projects, as shown in Table 3.

7.4 Fuzzy inference system

The fuzzy logic toolbox was used in MATLAB to develop a FIS model. The development model process consists of four steps:

- There are two Inputs (IF) and (S) and outputs (ICCP).
- Membership functions for inputs and outputs were presented in Figures 2–4.
- If-then rules: Using the Mamdani method, there are 25 rules based on the knowledge base, as shown in Table 4.
- The output surface of FIS, as shown in Figure 8, illustrates that the more input values increase, the more output value (More impact on construction projects).

8 Discussion

From the results obtained, it can be observed that the COVID-19 pandemic has hit severely Iraq's construction sector, including hospital construction. Based on the quantitative assessment, F1: commitment to safety & health recommendations factor were the first high-risk factors impacted by COVID-19, followed by F5: risk management procedures, F15: delay in equipment delivery, F10: increases of price material, and F6: lack of use the latest technology and F17: interpretation of contract language.

8.1 Health and Safety

The health and safety factor ranked first among other high-risk factors which COVID-19 impacted. The health and safety consist of four factors, F1: commitment to safety & health recommendations, F2: personal protection equipment & hand sterilising, F3: worker's acceptance of

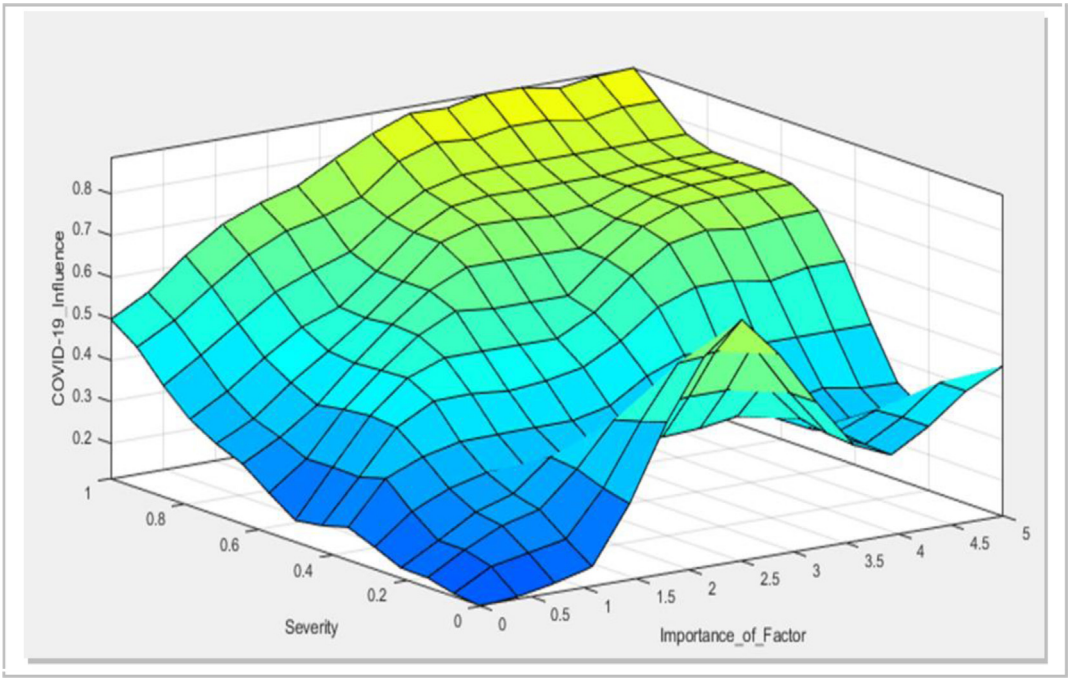

Fig. 8. The output surface.

Table 3. Construction factors impacted by COVID-19.

Construction main factors	Sub-Factors	Means	Rank
Health and safety	F1: Commitment of safety & health recommendations	4.81	1
	F2: Personal protect equipment & hands sterilizing	3.63	12
	F3: Workers acceptance of Covid-19 vaccination	4.36	4
	F4: Lack of training to deal with pandemic	3.81	8
Risk management	F5: Risk management procedures	4.63	2
Management Deficiency	F6: Lack of the use latest technology	4.09	6
	F7: Time management	3.63	10
	F8: Difficulty in controlling behaviour of workers	3.09	14
Financial	F9: Exchange currency rate	2.09	15
	F10: Increase of price materials	4.18	5
	F11: Labour wages	2.81	16
	F12: Delays in payment	3.90	7
	F13: Inflation	3.72	9
Supply chain management	F14: Low productivity of labour	3.18	13
	F15: Delay in equipment delivery	4.54	3
Contractual	F16: Legal disputes	2.54	17
	F17: Interpretation of contract language	3.45	11

Covid-19 vaccination and F4: lack of training to deal with the pandemic with an average level of impact equal to 4.81, 3.36, 4.36 and 3.81 respectively.

One of the interviewees, who is a civil engineer working in the Maysan Governorate office, stated that one of the most significant risk factors faced by construction projects was health and safety during the outbreak of COVID-19. Based on his viewpoint, there are two phases that they experienced during the pandemic. The first phase was the period of the lockdown imposed by the Iraqi government, which led to the suspension of all construction activities. The second phase was the period after lifting the lockdown in May 2020.

Table 4. If- then fuzzy rules.

Rule No.	If	AND	Then
1	IF is very low	S is very low	COVID-19 impact is very low
2	IF is very low	S is low	COVID-19 impact is very low
3	IF is very low	S is medium	COVID-19 impact is very low
4	IF is very low	S is high	COVID-19 impact is low
5	IF is very low	S is very high	COVID-19 impact is medium
6	IF is low	S is very low	COVID-19 impact is very low
7	IF is low	S is low	COVID-19 impact is low
8	IF is low	S is medium	COVID-19 impact is medium
9	IF is low	S is high	COVID-19 impact is medium
10	IF is low	S is very high	COVID-19 impact is high
11	IF is medium	S is very low	COVID-19 impact is high
12	IF is medium	S is low	COVID-19 impact is low
13	IF is medium	S is medium	COVID-19 impact is medium
14	IF is medium	S is high	COVID-19 impact is high
15	IF is medium	S is very high	COVID-19 impact is very high
16	IF is high	S is Very Low	COVID-19 impact is low
17	IF is high	S is low	COVID-19 impact is low
18	IF is high	S is medium	COVID-19 impact is high
19	IF is high	S is high	COVID-19 impact is high
20	IF is high	S is very high	COVID-19 impact is very high
21	IF is very high	S is very low	COVID-19 impact is medium
22	IF is very high	S is low	COVID-19 impact is low
23	IF is very high	S is medium	COVID-19 impact is low
24	IF is very high	S is high	COVID-19 impact is high
25	IF is very high	S is very high	COVID-19 impact is very high

However, The Iraqi Ministry of Health in line with the World Health Organization, issued guidance and safety recommendations. But the weak commitment of the workforce and the vaccination rate were still very low, causing an increase in positive cases in Maysan province.

Another interviewee, who is working in the engineering office of the Maysan Health Department and is responsible for hospital construction projects, including a Turkish hospital with 600 beds, agreed with the aforementioned. Also, he added that there is still no training program to deal with the pandemic, although it has been three years since its outbreak on construction sites. In addition, it can be noted that workers in developed countries on construction sites wear protective clothing to prevent infection and continue their work. Therefore, the construction of the Turkish hospital was delayed, although there was an urgent need to complete the hospital to accommodate the increase in patients.

As such, construction firms in Iraq must be committed to health and safety recommendations to avoid site closure and disruption. Additionally, workers must wear masks, keep their hands sterilised, maintain social distance between workers, and employers must conduct daily tests on workers and visitors.

8.2 Risk management practice

The risk management practice factor ranked second in terms of high importance among those impacted by the pandemic of COVID-19 in construction hospitals, with a level of impact equal to 4.63. Many interviewees mentioned that there is no framework and actual practice for risk management on construction projects, particularly in hospital construction. Therefore, many hospitals, including the Turkish hospital in Maysan Province, suspended their construction work during COVID-19. Furthermore, no standards and techniques are followed in managing and mitigating risk, which is considered one of the critical success factors of projects. One interviewee, an employee in the Iraq Ministry of Health/Engineering office, stated that no official department in the Ministry of Health specialised in risk management that is concerned with studying and assessing risks that may occur throughout project life cycles. Moreover, most contractors must follow a formal approach to assessing and managing risks. Therefore, there are approximately 20 hospitals that suspended construction works. Based on the interviews and literature review analysis. To end this, during COVID-19, a lack of required risk management knowledge for all construction project

partners (contractor, expert, and consultant) suspended several hospital construction projects. Therefore, it is recommended that the Iraqi government adopt risk management in all construction projects by (1) establishing a formal risk management department in all ministries; (2) adopting British or American standards that specialise in managing or mitigating risks in construction projects.

8.3 Supply chain management

Supply chain management ranked third among the six main factors in terms of high importance, which were impacted severely by COVID-19 in construction hospitals. In the context of Iraq, most raw materials and equipment for construction are imported from outside the country, such iron, steel, cement, and equipment. However, the supply chain was disrupted in all countries during COVID-19 due to government lockdown policies, which had an immediate and negative impact on the construction sector. Furthermore, all vehicles transporting raw materials and equipment could not move between countries, resulting in delays in raw materials needed to continue construction hospital work. Supply chain management consists of two factors; F14: delay in equipment delivery, and F15: low productivity of labour, which are highly impacted by COVID-19, with a level of impact equal to 4.54 and 3.18.

One of the interviewees, a local consultant in the civil engineering department at the University of Baghdad, stated that COVID-19 infected many workforces and employees on construction sites during the first, second, and third waves; thus, the productivity of labour decreased.

However, a comprehensive plan and strategy must be developed for the implementation of construction projects, particularly hospitals, and consider all potential problems they may face during the life cycle of projects and develop solutions to overcome them. Therefore, risk management plays a significant role in the success of construction projects, as mentioned earlier.

8.4 Financial and economic factors

Financial and economic factors ranked fourth in quantitative analysis, which was highly impacted by COVID-19 on construction hospitals. The financial and economic consists of four factors, including F10: exchange of currency rate, F11: increase of price material, F11: labour wages, F12: delay in payments and F13: inflation with an average level of impact 2.09, 4.18, 2.81, 3.90 and 3.72.

According to the interviews and literature review conducted, most interviewees agreed that the delay in payment factor was the most important among all financial and economic factors for different reasons such as the Iraqi economy was affected severely by COVID-19, instability of the political situation in Iraq, which led to a delay in approving the country's general budget. Furthermore, the fluctuation of oil prices, which is considered the primary source of income for the Iraqi economy, also affected the country's financial status. Consequently, most contractors declared bankruptcy and their construction work was suspended. However, financial and economic factors are one of the causes of the suspension of the Turkish hospital project in Maysan Province. Therefore, one of the solutions to address this problem is to rely on domestic investment and enable the private sector, with government support, to allocate an appropriate budget for hospital construction projects; also to plan and predict the worst-case scenarios the country may face, diversify the country's sources of income to develop the Iraqi economy, including the construction sector, to provide financial strength to overcome force majeure conditions and epidemics.

8.5 Management deficiency

According to the quantitative analysis, the average level of impact of management deficiency sub-factors (F6: lack of use of latest technology, F7: time management and F8: difficulty in controlling worker behaviour) are 4.09, 3.63, and 3.09.

The use of technology has increased during COVID-19 worldwide because it helps reduce risks associated with construction projects by moving from high-risk to low-risk zones. Using technology allows knowledge sharing and better teamwork, cooperation, improved information retrieval, enhanced productivity rates, and time and cost savings. Furthermore, it also introduces a better understanding of projects. Most interviewees mentioned a slow adoption and use of technology in the construction sector in Iraq. Moreover, based on the literature review and interviews, it was found that there needs to be more organising and planning in managing time between different activities in construction projects and prioritising tasks to ensure enough time is available to complete every project. Therefore, some construction projects suspended their construction work during COVID-19 because it exceeded the time specified for implementation. Also, many contractors have confirmed that controlling workers' behaviour in the workplace is very difficult. For example, some workers were infected by COVID-19. They continued their work and did not inform their managers or take the required procedures to prevent virus transmission between other workers; this happened in the Turkish hospital. Adopting and using the latest technology for the construction sector, such as artificial intelligence, building information modelling, laser screening, virtual reality, and wearables, is necessary. For the time management factor, managers should organise, plan, and prioritise tasks and use applications such as time tracking and connecteam software. Managers should also maintain control over workers' behaviour by following the Ministry of Health and Safety's guidelines, such as checking the worker's temperature daily and isolating workers who exhibit symptoms.

8.6 Contractual factors

Contractual factors are least impacted by COVID-19, which ranked sixth among other factors in the quantitative analysis. Contractual factors consist of legal disputes and interpretations of contract language, with a level of impact equal to 2.54 and 3.45, respectively.

The interviewee, who was an employee in the Ministry of Construction and Housing/Municipalities and public works/contract department, stated that there is a "Force Majeure" clause in government contracts, and COVID-19 falls within. There are many sub-clauses as a part of force majeure to guarantee parties' rights, and they must clearly understand it.

However, several construction companies were involved in legal disputes and faced financial penalties during the outbreak of COVID-19 as a result of not understanding contract clauses. As such, the contract must be written in plain language. Each contract paragraph must be explained in detail, outlining the contract party's obligations andrights.

9 Conclusion and future work

The paper results indicate six main factors: health and safety, risk management, management deficiency, operational and contractual, with 17 sub-factors. Health and safety were the most significant factors impacted by COVID-19. Also, the pandemic has the greatest impact on the following eight sub-risk factors: (1) F1: Commitment to safety and health recommendations; (2) F:5 Risk management procedures; (3) F15: Equipment delivery delays; (4) F3: Worker acceptance of COVID-19 vaccination; (5) F10: Material price increases; (6) F6: Lack of using latest technology, and (7) F12: Delay in payments; and (8) F4: Lack of training to deal with a pandemic. In summary, some studies highlighted the most significant risk factors that are impacted by the COVID-19 pandemic using different approaches and methods. For instance, health and safety and risk management factors are the greatest risk factors affecting construction projects [10,20]. In contrast, other studies identified other risk factors, such as financial and economic, supply chain contractual, operational and risk management [17,21]. In this study, the results reached the same results as other studies. However, the authors found other risk factors that are greatly impacted, such as lack of training to deal with the pandemic, slow adoption of the latest technology, risk management practice code and worker's acceptance and time management COVID-19 vaccination, using mixed methodology qualitative and quantitative. The qualitative method involved a literature review and semi-structured interviews to identify high-risk factors that affect construction projects during the outbreak of COVID-19. The quantitative method involved collecting survey data to determine each risk factor's importance and influence. Cronbach's alpha test to check the reliability of the collected data set and a fuzzy inference system method was used to assess the impact of each factor on construction projects during the pandemic.

As such, this paper contributes to the knowledge by providing policies and measures on how to mitigate the impact of a pandemic on hospital construction projects in Iraq. For future work, it can be used the results of this study by search scholars (1) compare the impact of COVID-19 on hospitals construction projects with housing construction projects, (2) use artificial intelligence methods in order to assess the impact of risk on the construction sector, (3) study the impact of COVID-19 on housing projects quality and performance. For future research can be used the findings of this study to (1) compare the impact of COVID-19 on hospitals construction projects with housing construction projects, (2) use artificial intelligence methods to assess the impact of risk on the construction sector, and (3) examine the impact of COVID-19 on housing projects quality and performance.

Appendix: Semi-structured interview questions

Subject	Interview questions
General	What are the critical risk factors that impact the construction projects during COVID-19?
Health and Safety	What do you think about the construction companies' commitment to the Iraq Ministry of health rules and guidelines? How do you see the level of vaccination among the worker in construction projects? Are there any procedures conducted on the site, such as random daily tests, wearing masks, and wearing unique clothing? How the construction companies manage delays caused by COVID-19 worker absences.
Risk management	Are there any standards for risk management practice in the construction sector? Do the construction companies have a professional team to manage risk in construction projects?
Management deficiency	How do you see the process of adopting the latest technology in the construction sector in Iraq? Does time management have any impact on the project schedule during COVID-19? Do construction companies face difficulties in controlling their worker behaviour during COVID-19? Do construction companies face difficulties in controlling their worker behaviour during COVID-19?
Financial	Does the currency exchange rate impact construction projects? What do you think about the increase in material prices during COVID-19? Does it affect the cost of construction projects? Does the labour wages factor impact the construction companies during COVID-19? How do you see the inflation happening around the world during COVID-19? Does it affect the construction industry?
Operational	What is the impact of COVID-19 on the productivity of labour? Does the delay in the equipment delivery during COVID-19 have any impact on the implementation of construction projects?
Contractual	Do the contracts (terms of conditions) include the clause of force majeure? If so, do you think both parties of the contract completely understand the terms of the conditions? How do you see the procedures for resolving the legal dispute during COVID-19?

References

1. A. Dakhil, The contribution of the construction industry to economic development in Libya, PhD Thesis, Liverpool John Moores University (2013)
2. A. Oke, A. Ogungbile, L. Oyewobi, C. Tengan, Economic development as a function of construction project performance, J. Constr. Project Manag. Innov. **6**, 1447–1459 (2016)
3. Central Bank of Jordan, Annual Report – The Central Bank of Jordan (2021). Available at: https://www.cbj.gov.jo/Pages/viewpage.aspx?pageID=337 [Accessed: 17 August 2022]
4. GT, Construction Sector Contributes around 6.4% to Dubai's GDP – GulfToday (2019). Available at: https://www.gulftoday.ae/business/2019/11/27/construction-sector-contributes-around-6-4-to-dubai-gdp [Accessed: 9 August 2022]
5. Kapita, Building and Construction in Iraq (2021). Available at: https://kapita.iq/content/issue/building-and-construction-iraq [Accessed: 9 August 2022]
6. M.F.F. Siu, W.Y.J. Leung, W.M.D. Chan, A data-driven approach to identify-quantify-analyse construction risk for Hong Kong NEC projects, J. Civil Eng. Manag. **24**, 592–606 (2018)
7. BSI, BSI IEC 62198:2001 Project Risk Management Application Guidelines (2001). Available at: https://www.bsigroup.com/en-GB/search-results/?q=project%20risk%20management%20&Page=1&tab=Standards [Accessed: April 30, 2023]
8. Y. Badran, Analysis of Construction and Stakeholder Risks for Public Private Partnership Projects in Developing Countries. A Comparative Analysis Using Artificial Neural Networks to Determine the Effect of Poor Stakeholder Management and Construction Risks on the Project's Schedule (PPP vs. Traditional Projects)., PhD Thesis, University of Salford (2020)
9. The World Bank, Global Economic Prospects – June 2022; Foreword by The World Bank (2022). Available at: https://thedocs.worldbank.org/en/doc/18ad707266f7740bced755498ae0307a-0350012022/related/Global-Economic-Prospects-June-2022-Foreword.pdf [Accessed: April 2, 2023]

10. M.K.S. Al-Mhdawi, M.P. Brito, M. Abdul Nabi, I.H. El-Adaway, B.S. Onggo. Capturing the impact of COVID-19 on construction projects in developing countries: a case study of Iraq, J. Manag. Eng. **38**, 05021015 (2021)
11. T. Umar, The impact of COVID-19 on the GCC construction industry, Int. J. Serv. Sci. Manag. Eng. Technol. **13**, 1–17 (2022)
12. R.A. Bahamid, S.I. Doh, M.A. Al-Sharaf, Risk factors affecting the construction projects in the developing countries, IOP Conf. Ser.: Earth Environ. Sci. **244**, 012040 (2019)
13. H. Abdulhussein, A. Shibaani, Risk management in construction projects in Iraq: contractors perspective, Int. J. Eng. Res. **4**, 114–130 (2016)
14. F.K. Jaber, Establishing risk management factors for construction projects in Iraq, Int. J. Eng. Res. Eng. Tec. **6**, 35–48 (2015)
15. S. Al-Turfi, Best Practice Project management for the Sustainable Regeneration of Holy Karbala Province in Iraq, PhD thesis, University of Bolton (2017)
16. N. Al-Hazim, Z.A. Salem, H. Ahmad, Delay and cost overrun in infrastructure projects in Jordan, Proc. Eng. **182**, 18–24 (2017)
17. A. Alsharef, S. Banerjee, S.M.J. Uddin, A. Albert, E. Jaselskis, Early impacts of the COVID-19 pandemic on the United States construction industry, Int. J. Environ. Res. Public Health **18**, 1–21 (2021)
18. H. Jallow, S. Renukappa, S. Suresh, The impact of COVID-19 outbreak on United Kingdom infrastructure sector, Smart Sustain. Built Environ. **10**, 581–593 (2021)
19. F. Sierra, COVID-19: main challenges during construction stage, Eng. Constr. Arch. Manag. **29**, 1817–1834 (2022)
20. K. Agyekum, A.S. Kukah, J. Amudjie, The impact of COVID-19 on the construction industry in Ghana: the case of some selected firms, J. Eng. Des. Technol. **20**, 222–244 (2022)
21. M.K.S. Al-Mhdawi, M. Brito, B.S. Onggo, A. Qazi, A. O'Connor, COVID-19 emerging risk assessment for the construction industry of developing countries: evidence from Iraq, Int. J. Construc. Manag. 1–14 (2023)
22. F. Nasser, M. Rachid, Estimation of the total demand gap in the activities of the construction industries, Baghdad College of Economic Sciences University Journal. **64**, 147–173 (2021)
23. Iraqi Central Statistical Organization, Iraqi Central Statistical Organization (2013). Available at: https://cosit.gov.iq/ar/?option=com_content&view=article&layout=edit&id=174&jsn_setmobile=no [Accessed: 13 August 2022]
24. Iraqi Ministry of Planning, Iraqi Ministry of planning announced the number of population in 2022 (2022). Available at: https://mop.gov.iq/news/view/details?id=841 [Accessed: 13 August 2022]
25. Iraqi Ministry of Health, Iraqi Ministry of Health-Annual statistic report (2020). Available at: https://moh.gov.iq/?page=46 [Accessed: 23 October 2022]
26. UNICEF, UNICEF Iraq Covid-19 Situation Report | UNICEF Iraq (2020). Available at: https://www.unicef.org/iraq/reports/unicef-iraq-covid-19-situation-report-0 [Accessed: 15 September 2022]
27. M.K.S. Al-Mhdawi, M.P. Brito, B.S. Onggo, H.A. Rashid, Analyzing the impact of the COVID-19 pandemic risks on construction projects in developing countries: case of Iraq, International Construction Research Congress, American Society of Civil Engineers (ASCE) **2-B**, 1013–1023 (2022)
28. Independent Arabia, Number of stopped hospitals in Iraq (2021). Available at: https://www.independentarabia.com [Accessed: 13 August 2022]
29. M.K. Buniya, I. Othman, R.Y. Sunindijo, G. Kashwani, S. Durdyev, S. Ismail, M.F. Antwi-Afari, H. Li, Critical success factors of safety program implementation in construction projects in Iraq, Int. J. Env. Res. Public Health **18**, 8469 (2021)
30. T.A.N. Alenezi, The impact of Covid-19 on construction projects in Kuwait, Int. J. Eng. Res. General Sci. **8**, 6–9 (2020)
31. WHO, Coronavirus disease (COVID-19) by World Health Organisation, (2020). Available at: https://www.who.int/health-topics/coronavirus#tab=tab_1 [Accessed: 18 August 2022]
32. WHO, Coronavirus (2020). Available at: https://www.who.int/health-topics/coronavirus#tab=tab_1 [Accessed: 10 August 2022]
33. P. Farrell, M. Evans, E. Elbeltagi, H. Dion, Competency framework to integrate lean construction and integrated project delivery on construction megaprojects: towards a future of work global initiatives in multinational engineering organizations, Benchmarking: An Int. J. **29**, 1913–1956 (2022)
34. Y.O. Kaied, A.S.K. Darwish, P. Farrell, COVID-19 impact on air quality and associated elements: knowledge data of the Emirate of Ajman − UAE, Renew. Energy Environ. Sustain. **6**, 15 (2021)
35. N. Fernandes, Economic effects of coronavirus outbreak (COVID-19) on the world economy (2020). Available at: https://ssrn.com/abstract=3557504 [Accessed: 18 August 2022]
36. D. Preston, Covid-19 recovery plan for the UK construction sector | Fieldfisher (2020). Available at: https://www.fieldfisher.com/en/insights/covid-19-recovery-plan-for-the-uk-construction-sec [Accessed: 19 August 2022]
37. A. Biswas, A. Ghosh, A. Kar, T. Mondal, B. Ghosh, P.K. Bardhan, The impact of COVID-19 in the construction sector and its remedial measures, J. Phys.: Conf. Ser. **1797**, 12054 (2021)
38. Statista, Iraq − Unemployment rate 2021 | Statista (2021). Available at: https://www.statista.com/statistics/327328/unemployment-rate-in-iraq/ [Accessed: 19 August 2022]
39. W. Aarseth, T. Ahola, K. Aaltonen, A. Økland, B. Andersen, Project sustainability strategies: A systematic literature review, Int. J. Proj. Manag. **35**, 1071–1083 (2016)
40. A.J.G. Silvius, R.P.J. Schipper, Sustainability in project management: A literature review and impact analysis, Social Business. **4**, 63–96 (2014)
41. A. Khalifeh, P. Farrell, M. Al-edenat, The impact of project sustainability management (PSM) on project success: a systematic literature review, J. Manag. Dev. (2020)
42. A. Alsaawi, A critical review of qualitative interviews, Eur. J. Bus. Social Sci. **3**, 149–156 (2014)
43. A. Galletta, W. Cross, Mastering the Semi-Structured Interview and Beyond: From research design to analysis and publication (New York Univ., New York, 2013). Available at: https://muse.jhu.edu/book/22815/ [Accessed: 19 August 2022]
44. L.R. Harris, G.T.L. Brown, Mixing interview and questionnaire methods: Practical problems in Aligning Data, Practical Assess. Res. Eval. **15** (2010)
45. H.M. Alhumaidi, Construction contractors ranking method using multiple decision-makers and multiattribute fuzzy weighted average, J. Construc. Eng. Manag. **141**, 04014092 (2014)

46. D. Singh, R.L.K. Tiong, A fuzzy decision framework for contractor selection, J. Constr. Eng. Manag. **131**, 62–70 (2005)
47. M.K. Al-Mhdawi, Proposed risk management decision support methodology for oil and gas construction projects, The 10th International Conference on Engineering, Project, and Production Management, 407–420 (2020)
48. M.S. Islama, M. Nepal, A Fuzzy-Bayesian Model for Risk Assessment in Power Plant Projects, Procedia Computer Science, **100**, 936–970 (2016)
49. O. Adil, A. Ali, M. Ali, Y. Ali, S. Sumait, Comparison between the effects of different types of membership functions on fuzzy logic controller performance, Int. J. Emerg. Eng. Res. Technol. **3**, 76-83 (2015)
50. T. Hoang, E.H. Mamdani, S. Assilian, An experiment in linguistic synthesis with a fuzzy logic controller, J. Man-Machine Studies **7**, 1–13 (1975)
51. P.H.D. Nguyen, D.Q. Tran, B.C. Lines, Empirical Inference System for Highway Project Delivery Selection Using Fuzzy Pattern Recognition, J. Constr. Eng. Manag. **146**, (2020)
52. R. Doskočil, An Evaluation of Total Project Risk Based on Fuzzy Logic, Verslas: teorija ir praktika **17**, 23–31 (2015)
53. B.C. Arabacioglu, Using fuzzy inference system for architectural space analysis, Appl. Soft Comput. J. **10**, 926–937 (2010)
54. K. Karimpour, R. Zarghami, M.A. Moosavian, H. Bahmanyar, New Fuzzy Model for Risk Assessment Based on Different Types of Consequences, Oil Gas Sci. Technol. – Rev. IFP Energies nouvelles. **71** (2016)
55. S.U.M. Rehman, M.T. Shafiq, M. Afzal, Impact of COVID-19 on project performance in the UAE construction industry, J. Eng. Des. Technol. **20**, 245–266 (2022)
56. F.R. Nabil, M. Namian, J. Shukes, D. Batie, M.K.S. Al-Mhdawi, COVID-19 Vaccine Acceptance Among Construction Workers, EPiC Series in Built Environment **3**, 56–64 (2022)
57. F. Simpeh, E. Bamfo-Agyei, C. Amoah, Barriers to the implementation of COVID-19 safety regulations: insight from Ghanaian construction sites, J. Eng. Des. Technol. **20**, 47–65 (2022)
58. R. Assaad, I.H. El-adaway, Guidelines for responding to COVID-19 pandemic: best practices, impacts, and future research directions, J. Manag. Eng. **37**, 06021001 (2021)
59. F.Y.Y. Ling, Z. Zhang, A.Y.R. Yew, Impact of COVID-19 pandemic on demand, output, and outcomes of construction projects in Singapore, J. Manag. Eng. **38**, 04021097 (2021)
60. Y. Gamil, A. Alhagar, The impact of pandemic crisis on the survival of construction industry: a case of COVID-19, Mediterr. J. Social Sci. **11**, 122 (2020)
61. S.H. Zamani, R.A. Rahman, M.A. Fauzi, L.M. Yusof, Effect of COVID-19 on building construction projects: Impact and response mechanisms, IOP Conf. Ser.: Earth Environ. Sci. **682** (2021)
62. P. Farrell, F. Sherratt, A. Richardson, Writing Built Environment Dissertations and Projects (2016)
63. Statista, United Arab Emirates − unemployment rate 2020 | Statista (2020). Available at: https://www.statista.com/statistics/297778/uae-unemployment-rate/ [Accessed: 23 August 2022]

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