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Assessing the Accident-Cost Relationship in Building Construction Projects Using Structural Equation Modeling

Milad Ghanbari [1)*]***, Raad Abed Saadoon*** [2)] ***and Sayed Mohammad Mousavi*** [3)]

[1)] Assistant Professor, Department of Civil Engineering, East Tehran Branch, Islamic Azad University,
Tehran, Iran. * Corresponding Author. E-Mail: Milad.ghanbari@srbiau.ac.ir
[2)] M.Sc. Graduate, Department of Project Management and Construction, South Tehran Branch,
Islamic Azad University, Tehran, Iran. E-Mail: Raada1979@yahoo.com
[3)] M.Sc. Graduate, Department of Project Management and Construction, South Tehran Branch,
Islamic Azad University, Tehran, Iran. E-Mail: Msvi.mhmd@gmail.com

ABSTRACT

This study aimed to evaluate the accident-causing factors affecting the total cost of building construction projects using a structural-equation model (SEM). Through the analysis of 35 identified factors categorized into construction, natural disaster, physical and human and psychological domains, this study examined their effects on project costs. The data collected from 120 construction experts in Iraq was analyzed using the SmartPLS software. This study assessed the fit of the measurement model using the following key criteria: reliability, convergent validity and divergent validity. All latent constructs demonstrated Cronbach's-alpha values of above 0.70 and composite-reliability (CR) values of above 0.70, indicating their reliability. The average variance extracted (AVE) values exceeded the 0.5 threshold, confirming convergent validity. The model also demonstrated acceptable discriminant validity. The results confirmed the significant impact of accident-causing factors on project costs, with "excessive physical activity," "storm," "improper ventilation," "low motivation and low efficiency of the workers," and "fire, explosion and vibration" emerging as the top five influencing factors. These findings emphasized the need for tailored safety measures to mitigate such risks. The study underscored the importance of addressing accident-causing factors to enhance both safety planning and financial outcomes in building construction projects.

KEYWORDS: Accident-causing factors, Project cost, Construction-project management, Safety assessment, Structural-equation modeling.

INTRODUCTION

The construction industry is a vital part of countries' development, directly involving 350 million people around the world (Osei-Asibey et al., 2021). Due to the complexity of construction sites (Gunduz et al., 2017; Wu et al., 2022), construction activities are considered highly hazardous. Therefore, it is essential to plan and prioritize the safety of workers to minimize the risk of accidents and fatalities (Jin et al., 2019).

The dynamic nature of the construction sector makes it prone to accidents and safety hazards (Jin et al., 2019; Tang et al., 2020; Alkaissy et al., 2022). The governments around the world are increasingly concerned about safety in the construction industry (Gurcanli et al., 2015). The problem of safety on construction sites has become more severe in developing countries due to the rapid growth of the construction industry. Therefore, there is a pressing need to focus on safety assessment in construction projects to enhance project performance. Several studies have highlighted the significance of safety in the construction industry, as well as the importance of addressing safety concerns (Zhang et al., 2020; Singh & Misra, 2021; Qi et al., 2022).

Construction sites pose numerous health and safety hazards to workers, including potential accidents and

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injuries (Zhang et al., 2020). The frequency and severity of accidents in construction sites are concerning and can be attributed to various hazards associated with the work environment and processes. These accidents not only affect the workers' well-being, but can also have significant negative effects on the overall organizational and economic health of the construction project (Kim & Cho, 2016; Singh & Misra, 2021). The effects of accidents in construction sites are far-reaching and can lead to fatalities, project delays, increased project costs and decreased productivity (Khalid et al., 2021).

Construction accidents are often overlooked during project phases and the lack of a systematic approach to evaluate and recognize safety risks and their relation to project issues is one reason for their occurrence. Most managers only have one technical perspective to address problems related to their projects, which reduces their awareness of risks and their ability to deal with them effectively. This lack of knowledge increases project costs and delivery delays (Andi, 2006).

Developing countries, which often lack strict regulations on construction safety, are particularly vulnerable to construction accidents. In addition, their officials are often not well informed about construction safety issues (Ahmed, 2019). Iraq is one such developing country with numerous ongoing construction projects most of which involve buildings where the workplace is prone to fatal accidents, leading to financial losses due to project-cost overruns (Hatem, 2017; Ali, 2020).

The construction industry plays an essential role in Iraq's developing economy. However, the effective management of health and safety in this industry poses various challenges, such as low productivity, increased expenses and inadequate safety measures (Buniya et al., 2021). Therefore, it is crucial to analyze the different types of accidents that occur in building-construction sites in Iraq. By doing so, it becomes possible to understand the occurrence likelihood of each factor and take the necessary measures to manage safety. Once the accident-causing factors are known, it is equally important to prioritize them according to their impact on the project costs. Therefore, the aim of the present research is to assess the site accidents that affect the ultimate costs of building-construction projects in Iraq. The present research significantly contributes to construction-project management and safety assessment by investigating the connection between the construction accidents and project costs, particularly in Iraq's developing economy. It introduces a novel approach using a structural-equation model to analyze a number of accident-causing factors in order to reveal their complex relationship with financial issues. By prioritizing these factors based on their cost impact, the study offers practical insights for optimizing resource allocation and improving project outcomes.

The case study is conducted in Maysan governorate located in the southeast of Iraq, bordering Iran. It covers a land area of 16,070 square kilometers with a population of 1,112,673 as of 2018 (https://www.citypopulation.de/en/iraq/cities/). Figure 1 depicts the study area.

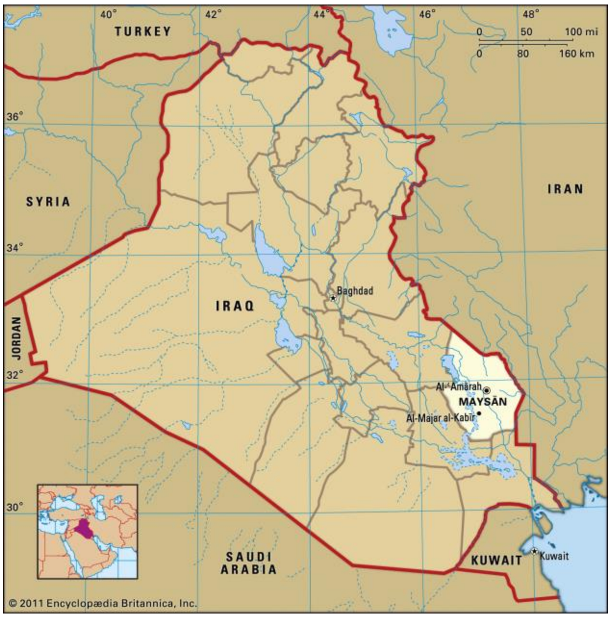

Figure (1): Maysan governorate, Iraq (Britannica, 2015)

Literature Review

According to a research (Haslam et al., 2005), the key causes of accident in construction projects are worker/team issues, workplace problems, equipment shortcomings, unsuitability of materials and risk-management deficiencies. Waehrer et al. (2007) studied the costs of job injuries in the US construction sector. They used national accident data, direct medical expenses, wage losses, productivity impact and quality-of-life costs. Over a half of the total expenses were related to mechanical, electrical and building-construction stages. Chi et al. (2009) studied 255 significant occupational accidents in the construction industry and found that the primary risk to the health of human resources in projects was their lack of familiarity with the leading risks in the implementation of projects.

In the 1970s, research primarily focused on "organizational climate". However, it gradually shifted to "culture" in the 1980s (Guldenmund, 2010). Zohar (2010) introduced safety-climate dimensions, including management attention, work climate and employee perceptions. Organizational culture pertains to senior managers, while job satisfaction concerns lower- and middle-level managers (Obeng et al., 2021). The concept of safety climate highlights how workers view the importance of safety within the organization, which is distinct from the concept of safety culture (Zohar, 2010).

Construction accidents are mainly attributed to human factors, including the efficiency of the workforce. The efficient utilization of human resources aligns with organizational goals, including the minimization of time and cost (Idris & Rahmah, 2010). Human efficiency in projects is affected by safety regulations. Enhancing safety can boost labor efficiency and project profitability (Enshassi et al., 2007; Odesola & Idoro, 2014).

Cheng et al. (2012) explored the impact of safety management on project performance. They identified three key safety management procedures, including safety activities like inspections and training, investigating safety information such as policies and records and establishing safety committees at project and company levels. Their study offered a guidance to construction workers regarding safety checklists and resource management.

Aneziris et al. (2012) assessed the occupational accident risks of workers in the Netherlands. They divided 63 risks into three categories: reversible injuries, permanent injuries and death. Their findings highlighted the chemical and construction industries as the riskiest occupational sectors.

Feng (2013) studied 47 construction projects in Singapore and established a direct link between safety investments and accident prevention. The research also demonstrated that projects with stronger safety cultures had more effective safety investments (Feng, 2013). Asanka and Ranasinghe (2015) explored the impact of accidents on construction projects and showed that human errors were the primary cause. The dynamic and uncertain conditions of the site can contribute to negligence. They emphasized that, due to the nature of the industry, accidents cannot be completely avoided. However, the construction-site safety performance can be enhanced by project-managers' promotion of safety adherence among workers (Asanka & Ranasinghe, 2015).

Awwad et al. (2016) found that around 50% of contractors in Lebanon disregarded safety measures and executed contracts without considering health and safety issues. Limited inspections by the insurance companies due to inadequate resources compounded the issues. Non-compliance with safety laws and insufficient accident data contributed to accidents (Awwad et al., 2016). Kaynak et al. (2016) suggested that employee performance is influenced by factors, such as safety procedures, risk management, safety rules and organizational support for safety. Haupt and Pillay (2016) studied construction-accident costs and analyzed accidents in a high-cost organization. Their research explored the relationship between direct and indirect costs and assessed different types of accidents and their causes. Their findings revealed that indirect costs often surpass direct costs based on the nature of the accident (Haupt & Pillay, 2016).

Safety and productivity are interlinked in construction projects (Choudhry, 2017). Shirali et al. (2017) emphasized that enhancing safety indicators, like assessment, training and risk control, can boost productivity. They stressed that developing safety measures reduces the costs related to accidents and thus enhances the efficiency of the project (Shirali et al., 2017). Ning et al. (2018) emphasized the importance of workshop safety. Their study revealed that pre-construction safety measures, like the proper placement of equipment, substantially reduce risks and ensure later-stage safety of the construction project (Ning et al., 2018).

A recent Australian study by Woolley et al. (2020) revealed that construction-safety issues extend beyond individual organizations and stem from the entire construction system. The researchers emphasized the need for a systematic and dynamic approach to understand the high-level factors influencing accidents and to address safety concerns effectively (Woolley et al., 2020).

Khalid et al. (2021) introduced a safety management system (SMS) framework to address the construction safety factors. The framework comprised around sixty factors categorized into organizational, management, legal, social, environmental and personnel domains. Effective safety performance relies on the implementation of regulations, leadership, planning, protocols, evaluation, risk assessment, inspections and promotion of safety culture (Khalid et al., 2021). Another recent study by Kim et al. (2022) found that deep-learning techniques can be used to predict financial losses resulting from building-construction accidents.

RESEARCH METHODOLOGY

This study aimed to evaluate the factors that cause accidents in Iraqi building-construction projects and their impact on the total cost. The authors developed a structured questionnaire by extracting the accident-causing factors from the background research. The questionnaire was then distributed to the statistical community in Iraq to identify and prioritize the accident-causing factors that affect the total cost of building-construction projects.

The authors conducted a comprehensive review of the existing literature to identify the accident-causing factors that affect the total cost of building-construction projects. Additionally, they conducted interviews with academic and professional experts in the construction industry in Iraq to create a preliminary list of the accident-causing factors. In the present research, the structural-equation model (SEM) was used to analyze the relationship between the accident-causing factors. To collect the input data required for modeling, questionnaire forms were distributed among experienced engineers involved in various building-construction projects in Iraq. The next section of the article analyzes the results obtained from the SEM. Table 1 provides a summary of the accident-causing factors that affect the total cost of building-construction projects in Iraq.

Table 1. The list of the proposed accident-causing factors affecting the total cost of building-construction projects

Component	Code	Accident-causing factors	Reference
Construction	Q1	Construction failure	(Ahmed, 2019); (Woolley et al., 2020); (Khalid et al., 2021); (Wu et al., 2022)
	Q2	Inadequate supervision	(Mohammad et al., 2010); (Zohar, 2010); (Choudhry, 2017); (Zhang et al., 2020)
	Q3	Lack of safety training	(Mohammad et al., 2010); (Zhang et al., 2020); (Singh & Misra, 2021); (Qi et al., 2022)
	Q4	Poor site layout	(Ning et al., 2018); (Ahmed, 2019); (Khalid et al., 2021)
	Q5	Lack of teamwork	(Haslam et al., 2005); (Odesola & Idoro, 2014); (Woolley et al., 2020); (Buniya et al., 2021)
	Q6	Poor maintenance of equipment	(Odesola & Idoro, 2014); (Khalid et al., 2021); (Buniya et al., 2021)
	Q7	Poor site housekeeping	(Gunduz et al., 2017); (Choudhry, 2017); (Jin et al., 2019); (Ahmed, 2019); (Khalid et al., 2021)
	Q8	Inadequate personal protective equipment	(Haslam et al., 2005); (Odesola & Idoro, 2014); (Gunduz et al., 2017); (Khalid et al., 2021)
Natural disasters	Q9	Storm	(Kim et al., 2022)
	Q10	Flood	(Kim et al., 2022)
	Q11	Heavy rain or snow	(Kim et al., 2022)
	Q12	Cold air	(Kim et al., 2022)
	Q13	Intense heat	(Waehrer et al., 2007); (Choudhry, 2017)
Physical factors	Q14	Improper ventilation	(Waehrer et al., 2007); (Odesola & Idoro, 2014)
	Q15	Improper lighting	(Chi et al., 2009); (Gurcanli et al., 2015); (Gunduz et al., 2017); (Choudhry, 2017); (Ahmed, 2019)

	Q16	Exposure to harmful substances	(Odesola & Idoro, 2014); (Asanka & Ranasinghe, 2015); (Ahmed, 2019)
	Q17	Exposure to diesel or lubricating oil	(Purohit et al., 2018); (Ahmed, 2019)
	Q18	Exposure to carbon monoxide	(Gurcanli et al., 2015); (Ahmed, 2019)
	Q19	Fire, explosion and vibration	(Waehrer et al., 2007); (Haupt & Pillay, 2016); (Gunduz et al., 2017); (Khalid et al., 2021); (Kim et al., 2022)
	Q20	Electrical accidents	(Waehrer et al., 2007); (Chi et al., 2009); (Gurcanli et al., 2015); (Gunduz et al., 2017)
	Q21	Falling from heights or scaffolding	(Gurcanli et al., 2015); (Gunduz et al., 2017); (Gunduz et al., 2017); (Islam et al., 2017); (Jin et al., 2019); (Tang et al., 2020); (Khalid et al., 2021)
	Q22	Slipping, tripping or falling on the same surface	(Waehrer et al., 2007); (Asanka & Ranasinghe, 2015); (Ahmed, 2019); (Khalid et al., 2021)
	Q23	Falling object	(Gurcanli et al., 2015); (Gunduz et al., 2017); (Jin et al., 2019); (Khalid et al., 2021)
	Q24	Injury by an animal	(Bhole, 2016); (Purohit et al., 2018)
	Q25	Damage by abrasive/cutting tools	(Odesola & Idoro, 2014); (Gurcanli et al., 2015); (Gunduz et al., 2017)
	Q26	Being caught between objects or substances	(Waehrer et al., 2007); (Odesola & Idoro, 2014); (Asanka & Ranasinghe, 2015)
	Q27	Fall of the crane or the lifting gears	(Gurcanli et al., 2015); (Asanka & Ranasinghe, 2015); (Ahmed, 2019)
	Q28	Vehicle accidents	(Waehrer et al., 2007); (Gurcanli et al., 2015); (Ahmed, 2019); (Khalid et al., 2021)
Human & psychological factors	Q29	Excessive physical activity	(Enshassi et al., 2007); (Odesola & Idoro, 2014); (Khalid et al., 2021)
	Q30	Rework activities	(Odesola & Idoro, 2014); (Khalid et al., 2021)
	Q31	Poor working conditions	(Haslam et al., 2005); (Zohar, 2010); (Odesola & Idoro, 2014); (Zhang et al., 2020); (Osei-Asibey et al., 2021)
	Q32	Lifting heavy objects	(Asanka & Ranasinghe, 2015); (Islam et al., 2017); (Ahmed, 2019)
	Q33	Stress	(Idris & Rahmah, 2010); (Gurcanli et al., 2015); (Jin et al., 2019); (Khalid et al., 2021);
	Q34	Carelessness of the workers	(Idris & Rahmah, 2010); (Woolley et al., 2020); (Khalid et al., 2021)
	Q35	Low motivation and low efficiency of the workers	(Kaynak et al., 2016); (Haupt & Pillay, 2016); (Woolley et al., 2020); (Khalid et al., 2021); (Buniya et al., 2021)

Hypothetical Model

The study model categorized four latent variables and 35 measurable variables as the accident-causing factors. The structural model hypothesized four relationships as follows:

H_1: Accident-causing factors related to construction have a significant and positive impact on the total cost (financial loss) of building-construction projects.

H_2: Accident-causing factors related to natural disasters have a significant and positive impact on the total cost (financial loss) of building-construction projects.

H_3: Accident-causing factors with a physical nature have a significant and positive impact on the total cost (financial loss) of building-construction projects.

H_4: Accident-causing factors with human and psychological origins have a significant and positive impact on the total cost (financial loss) of building-construction projects.

Data Collection

To gather data, a structured questionnaire was prepared using a five-point Likert scale to assess the impact of each accident-causing factor on the total cost (financial loss) of the project. The first part of the questionnaire comprised demographic questions about the respondents. The second part included technical questions related to the impact of accident-causing factors on the total cost of building-construction projects. The response options were: insignificant (1), minor (2), moderate (3), major (4) and catastrophic (5).

Some statistics scholars of SEM have recommended using the ratio of observations to estimated parameters (N:q) as a guide. Specifically, Bentler & Chou (1987) suggested that the N:q ratio be 5 to 1; i.e., 5 observations (participants) for each estimated parameter in the model (Bentler & Chou, 1987). The questionnaire in the present research had 35 parameters. Hence, with a ratio of 5 to 1, the sample size was equal to 175. The questionnaire was sent to 200 experienced building-construction engineers in Iraq and 120 valid responses were collected and analyzed between November and December 2022. The return rate of the questionnaire was 60%. The demographic data of the participants are presented in Table 2.

Table 2. The demographic information of the respondents

Characteristics	Category	Frequency	Percentage%
Age (years)	> 40	72	60
	30-40	40	33.33
	< 30	8	6.67
Specialty	Civil engineering	80	66.67
	Architectural engineering	17	14.17
	Electrical engineering	6	5
	Mechanical engineering	10	8.33
	Other (municipal or urban engineering, surveying engineering, … etc.)	7	5.83
Experience (years)	> 25	26	21.67
	15-25	44	36.67
	10-14	38	31.67
	5-9	12	10
Education level	Doctorate	2	1.67
	Master	90	75
	Bachelor	28	23.33
Affiliation	Client	27	22.5
	Consultant	54	45
	Contractor	39	32.5

Structural-equation Modeling Method

The SmartPLS 3 software was employed in the present study to assess the accuracy of the theoretical model and determine the effects of the coefficients using the Structural-equation modeling (SEM) method. The SmartPLS is a user-friendly software for analyzing the relationships among the variables using SEM and partial least squares (PLS) analysis. It is particularly helpful for researchers working with small sample sizes or exploring new models. SEM is a powerful multi-variate analysis technique that allows researchers to evaluate a set of regression equations simultaneously and enables them to test hypotheses or questions regarding the relationships between the observed and latent variables. The unique feature of SEM is that it uses both multiple-regression analysis and factor analysis simultaneously, making it an essential tool for researchers. One of the advantages of SEM is that it presents a graphical representation of the method. This makes interpretation easier and allows for the calculation of the relationships among the variables simultaneously. Hair et al. (2014) suggested that previous methods were not capable of examining the measurement model and determining the causal relationships of the model simultaneously. Typically, the structural-equation method uses a series of equations similar to multiple regression to demonstrate the internal relationships among the variables. Figure 2 illustrates the four steps of implementing the structural equations in this study, including inputting, processing, evaluating and reporting.

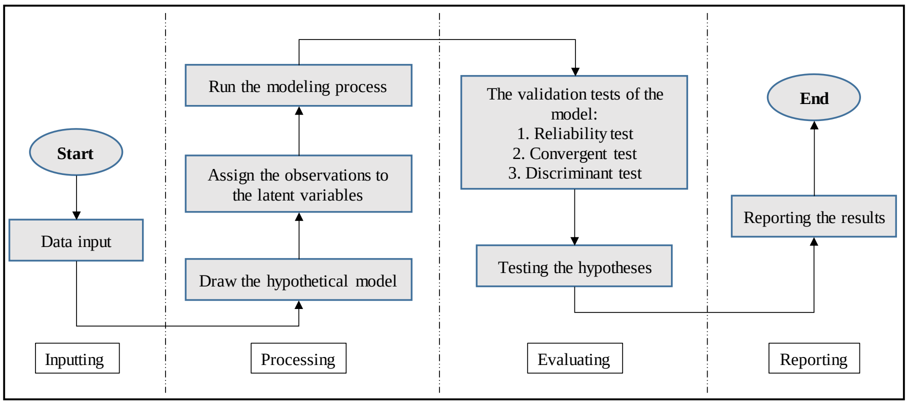

Figure (2): The workflow of SEM using the SmartPLS software

RESULTS AND ANALYSIS

The information collected from the questionnaire was transformed into useful data through the application of statistical methods. The formulated hypotheses were then tested using computer software, such as SPSS 16 and SmartPLS 3, to determine their validity, the level of significance and the strengths and weaknesses of the relationships among the variables. Normality and correlation tests were performed on the data and the validity of the measures was examined through confirmatory factor analysis (CFA) and structural-equation tests. The validity of the research hypotheses was then evaluated. Table 3 shows the descriptive statistics of the variables in the SPSS software.

Table 3. The descriptive statistics of the variables

Variable	N	Mean	Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Construction	120	3.591	1.088	1.185	-0.637	0.221	-0.334	0.438
Natural disasters	120	3.466	1.187	1.411	-0.608	0.221	-0.521	0.438
Physical factors	120	3.650	1.120	1.255	-0.767	0.221	-0.203	0.438
Human & psychological factors	120	3.466	1.208	1.461	-0.472	0.221	-0.819	0.438

Data Normality Test

The normality test of the collected data should be performed prior to any other action. The purpose of this test is to determine the selection of only parametric or non-parametric tests. One of the main criteria for this selection is the Kolmogorov-Smirnov test. If the data distribution is normal, parametric tests are used to test the hypotheses. If the data distribution is non-normal, non-parametric tests are used. To classify the factors affecting the total cost of building-construction projects, four components were identified as the main research variables. The normality of the data was assessed using the Kolmogorov-Smirnov test in the SPSS software. Table 4 shows the one-sample Kolmogorov-Smirnov test in the SPSS software. Since the significance level for all variables was higher than 0.05, the data distribution of all variables was normal. Therefore, parametric statistical techniques that are appropriate for normal data distribution, such as Pearson and structural equation modeling, were employed.

Table 4. The output of the normality test (one-sample Kolmogorov-Smirnov)

		Construction	**Natural disasters**	**Physical factors**	**Human & psychological factors**
N		120	120	120	120
Normal Parameters(a,b)	Mean	3.302	3.276	3.292	3.323
	Std. Deviation	0.791	0.786	0.672	0.589
Most Extreme Differences	Absolute	0.092	0.096	0.062	0.137
	Positive	0.062	0.095	0.040	0.137
	Negative	-0.092	-0.096	-0.062	-0.083
Kolmogorov-Smirnov Z		1.003	1.054	0.679	1.504
Asymp. Sig. (2-tailed)		0.266	0.216	0.746	0.052

a Test distribution is normal.

b Calculated from data.

The Pearson Correlation Test

In statistics, various indices, such as correlation coefficients, are used to show the degree of dependence between two or more variables. The correlation test focuses on assessing the correlation between the four key research variables. If the variables exhibit a normal distribution, the Pearson test is used, while the Spearman test is used if the variables do not follow a normal distribution. To evaluate data correlation, the Pearson test in the SPSS software was employed. Table 5 presents the matrix of Pearson's correlation coefficients in the SPSS software. As Table 5 demonstrates, the p-value (Sig.) for all cases is lower than 0.05, indicating a significant correlation between all variables. In other words, a change in one variable will change the other variables. Correlation coefficients have a value in the range of -1 to 1. The closer the absolute value of these coefficients is to one, the greater is the degree of dependence among the variables.

Table 5. The Pearson correlation matrix

		Construction	**Natural disasters**	**Physical factors**	**Human & psychological factors**
Construction	Pearson Correlation	1	0.715(**)	0.702(**)	0.403(**)
	Sig. (2-tailed)		0.000	0.000	0.000
	N	120	120	120	120
Natural disasters	Pearson Correlation	0.715(**)	1	0.701(**)	0.360(**)
	Sig. (2-tailed)	0.000		0.000	0.000
	N	120	120	120	120
Physical factors	Pearson Correlation	0.702(**)	0.701(**)	1	0.587(**)
	Sig. (2-tailed)	0.000	0.000		0.000
	N	120	120	120	120
Human & psychological factors	Pearson Correlation	0.403(**)	0.360(**)	0.587(**)	1
	Sig. (2-tailed)	0.000	0.000	0.000	
	N	120	120	120	120

** Correlation is significant at the 0.01 level (2-tailed).

The Development and Validation of the Structural-equation Model

Figure 3 presents the SEM model created in the SmartPLS software. It illustrates the measurement model of the research variables as well as the four research hypotheses. Calculated by the SmartPLS software based on factor loadings, the significant t-index and standard path coefficients (values in parentheses) can be seen in Figure 3. Once the measurement model was established, the validation test was performed. The main objectives of this step were examining the conceptual model of the research, verifying the presence or absence of a causal relationship among the research variables and assessing the suitability of the collected data with regard to the conceptual model of the research. To examine the fit of the measurement model, the three criteria of reliability, convergent validity and discriminnat validity are used, as described in the following sub-sections.

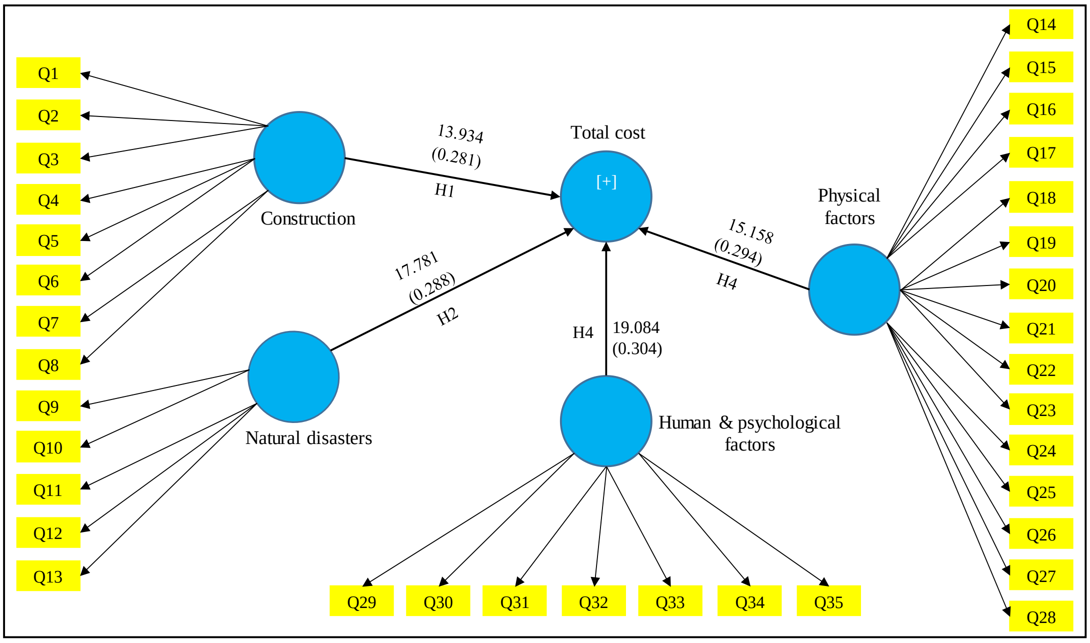

Figure (3): The significant t-index and standard path coefficients (values in parentheses) of the final model

Reliability Check

After computing the factor loadings of the indicators, it is important to calculate and present the composite reliability and Cronbach's alpha. Cronbach's alpha is a measure of internal-consistency reliability that demonstrates the level of positive correlation among the items in a questionnaire. Higher alpha values indicate greater consistency among the items, while lower values indicate the opposite. However, as the average variance of the questions increases, the Cronbach's alpha values often decrease.

The degree of homogeneity of the questions is reflected by the Cronbach's alpha value, with a value closer to 1 indicating a higher internal consistency. The Cronbach's alpha values of 0.7 or higher indicate acceptable internal consistency (Cortina, 1993; Sekaran & Bougie, 2016; Hinton & McMurray, 2017). In addition, to assess the internal consistency of the measurement model, the SmartPLS software employs a more contemporary criterion known as composite reliability (CR). The CR can be calculated using Equation 1 (Netemeyer, 2003; Hair et al., 2014), where λ_i denotes the standardized loading for the ith indicator, $V(\delta_i)$ denotes the variance of the error term for the ith indicator and p refers to the number of indicators.

$$\text{CR} = \frac{(\sum_{i=1}^{p} \lambda_i)^2}{(\sum_{i=1}^{p} \lambda_i)^2 + \sum_{i}^{p} V(\delta)} \qquad \text{(Eq. 1)}$$

In this study, the Cronbach's alpha values of all latent constructs were above the recommended threshold of 0.70 and ranged from 0.765 to 0.798. Similarly, all CR values exceeded 0.70 and ranged from 0.865 to 0.881, as shown in Table 6. Therefore, it can be deduced that the reliability of all research constructs was satisfactory.

Table 6. The Cronbach's-alpha, composite-reliability (CR) and average variance extracted (AVE) values

Variable	Cronbach's alpha	Composite reliability	Average variance extracted
	(α>0.7)	(CR>0.7)	(AVE>0.5)
Construction	0.796	0.881	0.712
Natural disasters	0.765	0.865	0.681
Physical factors	0.798	0.881	0.712
Human & psychological factors	0.791	0.878	0.706
Total cost	0.914	0.927	0.515

Convergent-validity Test

In SEM, the quality of the measurement model is assessed by the value of variance which a construct shares with its indicators and comparing it to those of other constructs in the model. Convergent validity is another criterion for fitting the measurement models used in the SmartPLS software. The average variance extracted (AVE) index indicates the average variance which each construct shares with its indicators. The AVE shows the degree of correlation between a construct and its indicators. The higher the correlation, the better the fit. AVE is considered acceptable when it is 0.5 or higher (Fornell and Larcker, 1981; Hair et al., 2014; Garson, 2016). In addition, to confirm convergent validity, the AVE value should be less than the CR value (Fornell and Larcker, 1981; Qasem Ali et al., 2021).

According to Table 6, all AVE values in this study ranged from 0.681 to 0.712, which were more than the recommended AVE value of >0.5, confirming the convergent validity. Additionally, all constructs met the condition of CR>AVE, indicating the convergent validity of the construct.

Discriminant-validity Test

According to the theory of Fornell and Larcker (1981) in the investigation of discriminant validity, the average root of the AVE for each construct is compared with the correlation coefficients among the constructs. To check the discriminant validity of the model, the Fornell and Larcker-matrix method was used. The results of the discriminant validity are presented in Table 7. The criterion of Fornell and Larcker refers to the issue that the square root of the AVE values of each construct must be greater than the correlation values of that construct with other constructs. In other words, the values on the main diameter of the matrix must be greater than all the values of the latent constructs in the corresponding column. Based on Table 7, the correlations between the constructs ranged from 0.561 to 0.887 and the correlations among the latent constructs were less than the square root of AVE in the corresponding column, indicating that the model had an acceptable level of discriminant validity.

Table 7. The results of the discriminant-validity test

Variable	Construction	Natural disasters	Physical factors	Human & psychological factors	Total cost
Construction	0.844				
Natural disasters	0.599	0.825			
Physical factors	0.561	0.676	0.844		
Human & psychological factors	0.637	0.714	0.673	0.840	
Total cost	0.813	0.873	0.851	0.887	0.717

Results of Statistical Analysis

The SmartPLS software was utilized to analyze the relationships among the variables, as the research data was normally distributed. The path-analysis method was utilized by the software to investigate the causal relationship between the independent and dependent variables and confirm the whole model. In other words, the next step in evaluating the structural model was to examine the research hypotheses through assessing the path coefficients. The path coefficient shows the direct effect of one structure on another structure. The statistical t-value was used to test the hypotheses. To confirm a hypothesis at the 5%, 1% and 0.001 levels, the t-value must be at least 1.96, 2.57 and 3.32, respectively (Hair et al., 2014).

The path analysis showed the direction and intensity of the relationships of the research variables. The values that show the direction and degree of influence between the variables are called path coefficients and are represented by β. Path coefficients are the same as standardized regression coefficients. If the value of β is negative, the relationship is inverse. On the other hand, if it is positive, the relationship is direct. The value of the β coefficient is between 1 and -1. The higher its absolute value, the stronger the effect. If the t-value is greater than 1.96, the relationship is significant.

Table 8 shows the results of testing the hypotheses. According to the results, the path coefficients (β) showed a direct effect. Furthermore, the t-values for all the questions and relationships between the variables were greater than 1.96 and were significant at the confidence level of 95%, verifying the model. This confirmed that all four hypotheses were supported. The standard path coefficients (β) indicate the effect of each of the constructs on the overall structure. According to Table 8, the "human and psychological" factors (path coefficient=0.304) had the greatest effect on the total cost of building-construction projects in the present study.

Table 8. The results of testing the hypotheses

Hypothesis	**Standard path coefficient (β)**	**Significant t-value**	**Result**
H1: Construction	0.281	13.934	Supported
H2: Natural disasters	0.288	17.781	Supported
H3: Physical factors	0.294	15.158	Supported
H4: Human & psychological factors	0.304	13.084	Supported

Ranking the Accident-causing Factors

The Friedman test is a statistical test used to compare several groups and determine their mean ranks. To evaluate the significance and rank of the key components with respect to the total cost (or financial loss) of building-construction projects, the Friedman test was performed using the SPSS software. The findings are presented in Tables 9 and 10. In this test, prioritization is done by the Friedman mean rank. The higher the mean rank, the higher the priority. The results of the Friedman test indicated that human and psychological factors, physical factors, construction and natural disasters were respectively the most to least significant accident-causing components and affected the total cost (financial loss) of building-construction projects. Since the value of chi-square is small and also because the asymp.sig. value is greater than 0.05, all 4 variables have the same distribution or mean. In other words, their ranks are close to each other (Table 9). According to Table 10, the minimum and maximum Friedman mean ranks for accident-causing factors are 13.76 and 20.84, respectively.

Table 9. The output of the Friedman test

Friedman-test statistics	
N	120
Chi-Square	0.734
df	3
Asymp. Sig.	0.865
Ranks	
Components	**Mean Rank**
Construction	2.50
Natural disasters	2.43
Physical factors	2.50
Human & psychological factors	2.57

Table 10. Prioritizing the accident-causing factors affecting the total cost of building-construction projects

Priority	Friedman mean rank	Code	Description
1	20.84	Q29	Excessive physical activity
2	20.73	Q9	Storm
3	20.28	Q14	Improper ventilation
4	20.02	Q35	Low motivation and low efficiency of the workers
5	20.01	Q19	Fire, explosion and vibration
6	19.85	Q20	Electrical accidents
7	19.76	Q2	Inadequate supervision
8	19.46	Q5	Lack of teamwork
9	19.25	Q18	Exposure to carbon monoxide
10	19.25	Q31	Poor working conditions
11	19.15	Q17	Exposure to diesel or lubricating oil
12	19.03	Q28	Vehicle accidents
13	18.95	Q1	Construction failure
14	18.83	Q25	Damage by abrasive/cutting tools
15	18.82	Q10	Flood
16	18.67	Q30	Rework activities
17	18.51	Q3	Lack of safety training
18	18.5	Q33	Stress
19	17.97	Q6	Poor maintenance of equipment
20	17.9	Q15	Improper lighting
21	17.7	Q32	Lifting heavy objects
22	17.69	Q27	Fall of the crane or the lifting gears
23	17.52	Q21	Falling from heights or scaffolding
24	17.35	Q16	Exposure to harmful substances
25	17.25	Q4	Poor site layout
26	17.23	Q8	Inadequate personal protective equipment
27	17.16	Q11	Heavy rain or snow
28	16.91	Q24	Injury by an animal
29	16.03	Q13	Intense heat
30	15.74	Q12	Cold air
31	15.73	Q26	Being caught between objects or substances
32	15.57	Q7	Poor site housekeeping
33	14.66	Q22	Slipping, tripping or falling on the same surface
34	13.94	Q23	Falling object
35	13.76	Q34	Carelessness of the workers

Based on the questionnaire data of 120 building construction experts, excessive physical activity as a human and psychological factor was chosen as the most important cause of accidents, because it leads to worker fatigue paving the way for fatal and financial accidents in building-construction projects. The occurrence of storm as one of the natural disasters is the second cause of accidents that can lead to terrible financial and human losses. Storms can overturn the facilities installed in the construction site. Improper ventilation is the third cause of accidents in construction sites affecting the health of workers. As a human and psychological factor, the low motivation and low efficiency of the workers originating from their weak economic conditions and putting them in a dangerous position in the construction stages occupied the fourth rank. Fire, explosion and vibration comprised the fifth cause of accidents in building-construction sites leading to severe financial and fatal accidents. They mainly result from simple negligence and disregard of simple safety rules by workers.

CONCLUSIONS

A large number of hazardous accidents occur in the construction industry considered as one of the largest industries in the world. These accidents can be classified as safety risks which are often overlooked during the project phases. The occurrence of construction accidents can be attributed to the lack of a systematic approach towards evaluating and identifying safety risks and their association with project issues. In Iraq, construction sites are particularly complex places where accidents are frequently reported. The aim of this study was to identify and classify the accident-causing factors that affected the total cost of building-construction projects in Iraq. A total of 35 accident-causing factors that affected the total cost of building-construction projects were identified and ranked. These factors were categorized into four main groups: 1) construction; 2) natural disasters; 3) physical factors; 4) human and psychological factors.

The study collected data from 120 building-construction engineers in Iraq through a structured questionnaire to obtain their opinions. The statistical analysis of data was carried out using the SPSS software. Additionally, the SmartPLS software was used for structural-equation modeling and the validation of the model. The results of the structural-equation factor analysis confirmed all the 35 identified factors as accident-causing factors affecting the total cost of building-construction projects.

The first accident-causing factor for Iraqi building-construction projects in terms of safety risk management and budget planning was "excessive physical activity". "Storm" and "improper ventilation" were the second and third priorities, respectively. The fourth and fifth priorities were the "low motivation and low efficiency of the workers" and "fire, explosion and vibration", respectively. The sixth priority was "electrical accidents," while the seventh and eighth priorities were "inadequate supervision" and "lack of teamwork", respectively. The ninth and tenth priorities were "exposure to carbon monoxide" and "poor working conditions", respectively. It is crucial to establish and tailor specific safety regulations and protocols for building-construction projects before initiating them. The employers, consulting engineers and project contractors must have a thorough understanding of these factors to develop an effective financial risk-management plan.

Innovative technologies, such as Building Information Modeling (BIM), Internet of Things (IoT) and Artificial Intelligence (AI), have the potential to transform safety management through real-time monitoring and predictive analysis. Using virtual-reality simulations and immersive training can enhance the readiness of human resources. A comprehensive approach to both physical and mental well-being is vital. By embracing these advancements, the construction industry can forge a safer, more efficient and more sustainable future in building projects.

Conflict of Interests

The authors affirm that there are no known competing financial or personal interests that could have affected the work presented in this paper.

Data Availability

The data can be provided upon request.

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REFERENCES

Ahmed, S. (2019). "Causes and effects of accident at construction site: A study for the construction industry in Bangladesh". International Journal of Sustainable Construction Engineering and Technology, 10 (2), 18-40.

Ali, S.J. (2020). "Most common accidents and best safety strategies to reduce accidents in northern Iraq construction projects". International Journal of Advanced Engineering, Sciences and Applications, 1 (3), 30-36.

Alkaissy, M., Arashpour, M., Wakefield, R., Hosseini, R., and Gill, P. (2022). "The cost burden of safety-risk incidents on construction: A probabilistic quantification method". Risk Analysis, 42 (10), 2312-2326.

Andi. (2006). "The importance and allocation of risks in Indonesian construction projects". Construction Management and Economics, 24 (1), 69-80.

Aneziris, O.N., Topali, E., and Papazoglou, I.A. (2012). "Occupational risk of building construction". Reliability Engineering & System Safety, 105, 36-46.

Asanka, W.A., and Ranasinghe, M. (2015). "Study on the impact of accidents on construction projects". In: 6th International Conference on Structural Engineering and Construction Management (pp. 58-67).

Awwad, R., El Souki, O., and Jabbour, M. (2016). "Construction safety practices and challenges in a Middle Eastern developing country". Safety Science, 83, 1-11.

Bentler, P.M., and Chou, C.P. (1987). "Practical issues in structural modeling". Sociological Methods & Research, 16 (1), 78-117.

Bhole, S.A. (2016). "Safety problems and injuries on construction site: A review". International Journal of Engineering and Techniques, 2 (4), 24-35.

Britannica, Editors of Encyclopaedia. (2015, February 13). "Al-ʿAmārah". Encyclopedia Britannica. https://www.britannica.com/place/Al-Amarah

Buniya, M.K., Othman, I., Sunindijo, R.Y., Kashwani, G., Durdyev, S., Ismail, S., ... and Li, H. (2021). "Critical success factors of safety program implementation in construction projects in Iraq". International Journal of Environmental Research and Public Health, 18 (16), 8469.

Cheng, E., Ryan, N., and Kelly, S. (2012). "Exploring the perceived influence of safety-management practices on project performance in the construction industry". Safety Science, 50 (2), 363-369.

Chi, C.F., Yang, C.C., and Chen, Z.L. (2009). "In-depth accident analysis of electrical fatalities in the construction industry". International Journal of Industrial Ergonomics, 39 (4), 635-644.

Choudhry, R.M. (2017). "Achieving safety and productivity in construction projects". Journal of Civil Engineering and Management, 23 (2), 311-318.

Cortina, J.M. (1993). "What is coefficient alpha? An examination of theory and applications". Journal of Applied Psychology, 78 (1), 98.

Enshassi, A., Mohamed, S., Mustafa, Z. A., and Mayer, P. E. (2007). "Factors affecting labour productivity in building projects in the Gaza Strip. Journal of Civil Engineering and Management, 13 (4), 245-254.

Feng, Y. (2013). "Effect of safety investments on safety performance of building projects". Safety Science, 59, 28-45.

Fornell, C., and Larcker, D.F. (1981). "Evaluating structural-equation models with unobservable variables and measurement error". Journal of Marketing Research, 18 (1), 39-50.

Garson, G.D. (2016). "Partial least squares (PLS-SEM): Regression and structural-equation models". North Carolina: Statistical Publishing Associates.

Guldenmund, F.W. (2010). "Understanding and exploring safety culture". Oisterwijk: BOX Press.

Gunduz, M., Birgonul, M.T., and Ozdemir, M. (2017). "Fuzzy structural-equation model to assess construction-site safety performance. Journal of Construction Engineering and Management, 143 (4), 04016112.

Gurcanli, G.E., Bilir, S., and Sevim, M. (2015). "Activity-based risk assessment and safety-cost estimation for residential building construction projects". Safety Science, 80, 1-12.

Hair, J.F., Black, W.C., Babin, B.J., and Anderson, R.E. (2014). "Multivariate data analysis". (7th Edn., Pearson new international edition). Harlow, Essex: Pearson Education.

Haslam, R.A., Hide, S.A., Gibb, A.G., Gyi, D.E., Pavitt, T., Atkinson, S., and Duff, A.R. (2005). "Contributing factors in construction accidents". Applied Ergonomics, 36 (4), 401-415.

Hatem, W. (2017). "Evaluation of safety systems in Iraqi construction projects". International Journal of Applied Engineering Research, 12 (21), 11714-11726.

Haupt, T.C., and Pillay, K. (2016). "Investigating the true costs of construction accidents". Journal of Engineering, Design and Technology, 14 (2), 373-419.

Hinton, P.R., and McMurray, I. (2017). "Presenting your data with SPSS explained". Taylor & Francis.

Idris, J., and Rahmah, I. (2010). "Impact of labour quality on labour productivity and economic growth". African Journal of Business Management, 4 (4), 486-495.

Islam, M.S., Razwanul, I., and Mahmud, M.T. (2017). "Safety practices and causes of fatality in building-construction projects: A case study for Bangladesh". Jordan Journal of Civil Engineering, 11 (2).

Jin, R., Zou, P. X., Piroozfar, P., Wood, H., Yang, Y., Yan, L., and Han, Y. (2019). "A science mapping approach-based review of construction-safety research". Safety Science, 113, 285-297.

Kaynak, R., Toklu, A. T., Elci, M., and Toklu, I. T. (2016). "Effects of occupational health and safety practices on organizational commitment, work alienation and job performance: Using the PLS-SEM approach". International Journal of Business and Management, 11 (5), 146-166.

Khalid, U., Sagoo, A., and Benachir, M. (2021). "Safety management system (SMS) framework development: Mitigating the critical safety factors affecting health and safety performance in construction projects". Safety Science, 143, 105402.

Kim, J.M., Bae, J., Park, H., and Yum, S.G. (2022). "Predicting financial losses due to apartment construction accidents utilizing deep-learning techniques". Scientific Reports, 12 (1), 5365.

Kim, W.Y., and Cho, H.H. (2016). "Unions, health and safety committees and workplace accidents in the Korean manufacturing sector". Safety and Health at Work, 7 (2), 161-165.

Mohammad, S., Al-Smadi, B.M., Hyari, K.H., and Rababeh, S.M. (2010). "Safety management in the Jordanian construction industry". Jordan Journal of Civil Engineering, 4 (1), 47-54.

Netemeyer, R.G., Bearden, W.O., and Sharma, S. (2003). "Scaling procedures: Issues and applications". Sage Publications.

Ning, X., Qi, J., and Wu, C. (2018). "A quantitative safety risk assessment model for construction site layout planning". Safety Science, 104, 246-259.

Obeng, A.F., Zhu, Y., Azinga, S.A., and Quansah, P.E. (2021). "Organizational climate and job performance: Investigating the mediating role of harmonious work passion and the moderating role of leader–member exchange and coaching". Sage Open, 11 (2), 21582440211008456.

Odesola, I.A., and Idoro, G.I. (2014). "Influence of labour-related factors on construction-labour productivity in the south-south geo-political zone of Nigeria". Journal of Construction in Developing Countries, 19 (1), 93.

Osei-Asibey, D., Ayarkwa, J., Acheampong, A., Adinyira, E., and Amoah, P. (2021). "An examination of causes of accidents and hazards in the Ghanaian construction industry". Open Journal of Safety Science and Technology, 11 (2), 66-88. doi:10.4236/ojsst.2021.112006.

Purohit, D.P., Siddiqui, N.A., Nandan, A., and Yadav, B.P. (2018). "Hazard identification and risk assessment in construction industry". International Journal of Applied Engineering Research, 13 (10), 7639-7667.

Qasem Ali, A., Md Sultan, A.B., Abd Ghani, A.A., and Zulzalil, H. (2021). "An empirical investigation of software customization and its impact on the quality of software as a service: Perspectives from software professionals". Applied Sciences, 11 (4), 1677.

Qi, H., Zhou, Z., Li, N., and Zhang, C. (2022). "Construction-safety performance evaluation based on data-envelopment analysis (DEA) from a hybrid perspective of cross-sectional and longitudinal perspectives". Safety Science, 146, 105532.

Sekaran, U., and Bougie, R. (2016). "Research methods for business: A skill-building approach". John Wiley & Sons.

Shirali, G., Savari, R., Ahmadiangali, K., and Salehi, V. (2017). "The effect of safety costs on productivity and quality: A case study of five steel companies in Ahvaz". Jundishapur Journal of Health Sciences, 9 (2).

Singh, A., and Misra, S.C. (2021). "Safety performance and evaluation framework in Indian construction industry". Safety Science, 134, 105023.

Tang, S., Roberts, D., and Golparvar-Fard, M. (2020). "Human-object interaction recognition for automatic construction-site safety inspection". Automation in Construction, 120, 103356.

Waehrer, G.M., Dong, X.S., Miller, T., Haile, E., and Men, Y. (2007). "Costs of occupational injuries in construction in the United States". Accident Analysis & Prevention, 39 (6), 1258-1266.

Wetzels, R., Raaijmakers, J.G., Jakab, E., and Wagenmakers, E.J. (2009). "How to quantify support for and against the null hypothesis: A flexible WinBUGS implementation of a default Bayesian t test". Psychonomic Bulletin & Review, 16, 752-760.

Woolley, M., Goode, N., Salmon, P., and Read, G. (2020). "Who is responsible for construction safety in Australia? A STAMP analysis". Safety Science, 132, 104984.

Wu, S., Hou, L., Zhang, G.K., and Chen, H. (2022). "Real-time mixed reality-based visual warning for construction workforce safety". Automation in Construction, 139, 104252.

Zhang, M., Shi, R., and Yang, Z. (2020). "A critical review of vision-based occupational health and safety monitoring of construction-site workers". Safety Science, 126, 104658.

Zohar, D. (2010). "Thirty years of safety-climate research: Reflections and future directions". Accident Analysis & Prevention, 42 (5), 1517-1522.