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Impact of safety accidental factors on safety performance for high-rise building projects: EFA-SEM approach

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Abstract:
High-rise building projects face a significant problem with safety mishaps due to insufficient safety performance. This study aims to examine the factors that contribute to safety performance in high-rise building projects by utilising a combined approach of exploratory factor analysis (EFA) and structural equation modelling (SEM). A total of 400 questionnaires were disseminated and as a result, 285 valid replies were obtained, indicating a response rate of 71 %. In order to accomplish the objective of this research study, EFA was used to identify eight safety-related factors that impact the safety performance of high-rise building projects. The results indicated that the factor F8 (mishandling construction material) was eliminated from the final structural equation model because it did not have an adequate statistically significant value. The final structural equation model passed the goodness-of-fit tests and hypothesis testing, indicating the model's validity. Consequently, using EFA and SEM methodologies offers a framework for future researchers to accomplish specific goals in the construction sector and enhance safety management in high-rise building projects. The study's findings will serve as a foundation for numerous industry players to mitigate hazardous situations and enhance the efficiency of high-rise building projects via the application of safety management concepts.

Keywords:
safety performance; high-rise building projects; safety; construction management

1 Introduction

The challenge of safety at work is multifaceted, and there is significant interest in understanding the relationship between safety attitudes and performance in high-rise building projects. The safety of high-rise building projects is regarded as a significant problem because of the high occurrence of accidents and fatalities [1]. Therefore, safety is a fundamental requirement for construction workers. Nevertheless, the participation of several stakeholders, the distinctive characteristics of projects, and the presence of untrained labourers make safety issues particularly difficult to address in high-rise building projects. Thus, safety performance can be evaluated and assessed by analysing performance indicators such as time, cost, quality, client satisfaction, customer changes, business performance, and health and safety. Cost, quality, and time are the three primary safety performance measures. Another method of assessing safety performance involves the oversight of owners, users, and various groups that take a macro perspective, as well as developers and contractors who take a micro perspective [2]. Cost is a crucial factor in high-rise building projects, plays a significant role during the entire construction process, and serves as the main motivator for the project. High-rise building projects involve three distinct cost-related procedures: cost control, cost estimation, and budgeting. These processes are interconnected and mutually influence each other [3].

Compared to other industries, the construction sector is considered a high-risk industry in terms of accidents and fatalities. Falls from heights are the most frequent and severe accidents in high-rise building projects. The construction workers are at risk of experiencing falls from heights, slip and trip falls, being struck by falling objects, improper handling of construction materials, inadequate personal protective equipment (PPE). They also face personal factors such as poor temperament, alcoholism, inconsideration, and lack of knowledge among workers [4]. Consequently, if safety is disregarded, it will have significant consequences on the time, quality, and cost of high-rise building projects, ultimately impacting safety performance. Furthermore, the Department of Occupational Safety and Health (DOSH) in Malaysia reports that the number of high-rise building accidents in Malaysia is rising annually in comparison to 2023 [5]. As an engineering project, high-rise building construction is a complex process with numerous potential hazards that can endanger public safety. For this reason, it is critical to carefully assess the safety factors for public safety in high-rise building projects.

Building site safety is of the utmost importance to safeguard the welfare of workers and reduce the likelihood of accidents. To ensure safer construction, thorough training of all employees regarding safety protocols, proper utilisation of equipment, and the ability to identify potential risks is essential [6]. In addition, it is necessary to utilise suitable PPE, such as helmets, gloves, goggles, and steel-capped footwear. Before commencing high-rise building projects, it is imperative to conduct comprehensive risk assessments, identify potential dangers, establish methods to reduce risks, conduct regular inspections of the site to identify new dangers, and swiftly take action to resolve them [7]. To prevent accidents in high-rise building projects, it is imperative to establish post-accident investigative procedures to ascertain their root causes. Moreover, suggestions for enhancing project safety include reducing financial incentives for project teams, dedicating additional time to address safety issues, augmenting the extent of official safety instruction for supervisors and primary contractors, intensifying the frequency of informal site safety inspections, escalating penalties for workers who demonstrate inadequate safety performance, and implementing other measures [8].

Moreover, improving the organizational framework, acknowledging the importance of organizational safety, taking responsibility and accountability for safety, implementing effective communication, maintaining proper management conduct, involving employees, and ensuring appropriate employee responses and conduct can collectively improve safety performance [9]. Enhanced written safety plans should be created, along with more financing for safety initiatives, additional training for part-time safety coordinators, and greater emphasis on educating new employees about investment requirements and standards [10]. Moreover, corporate safety training and dissemination of safety policies to all parties involved are considered essential for construction safety, together with safety systems, written safety policies, and measurable safety objectives. When considering methods to improve safety during construction, it is important to consider safety rewards or incentive systems, safety training programs, safety committees, and the level of subcontracting [11]. This study aimed to investigate the causal factors that impact safety performance in high-rise building projects, with a particular focus on safety-related accidents. Considering these ideas, we formulated the following research question for this analytical investigation: What are the effects of accidental safety factors on the safety performance of high-rise buildings?

In addition, this study proposes the use of two statistical methods, exploratory factor analysis (EFA) and structural equation modelling (SEM), to uncover and examine the interactions in a hypothetical model. Hence, EFA can be utilised to streamline and distil information by employing a limited set of dimensions to depict the original data and elucidate the intricate relationships between variables. SEM is a flexible statistical method that quantitatively examines the interrelationships between dependent and independent variables sequentially [12]. The use of SEM offers several advantages. First, it enables the effective handling of complex relationships between variables. Second, it enables easy observation of the estimation of all coefficients in the model. Finally, it allows for statistical testing of the hypothesised model to determine its fitness. The main contribution of this study is the enhanced understanding of the safety factors that lead to accidents in high-rise building projects by adopting an integrated approach combining EFA and SEM. In this study, a systematic technique combining EFA and SEM was used to identify, evaluate, and validate safety factors that influence the safety performance of high-rise building projects.

2 Related works and research gaps

Ensuring safe working conditions is fundamental to safety performance. One way to achieve this is to foster an organizational safety culture and promote desirable employee behaviours. Another approach is to minimise the occurrence of accidents and occupational injuries in building projects. According to the literature, safety performance can be enhanced through proactive or reactive measures. Proactive studies have examined several elements of safety management in particular locations, including safety climate, culture, threat identification, and monitoring [13]. The main emphasis of reactive investigations is the analysis of injury frequency rates and compensation expenses. Reactive studies seek to evaluate the safety performance of a product by analysing historical data instead of relying on its current condition [14]. Moreover, they highlight issues without providing practical solutions. A more proactive research approach encompasses topics such as safety-oriented designs and the assessment of potential hazards. Gambatese et al. [15] found that design was a contributing factor in 42% of construction accidents. They recommended that design specialists actively address safety concerns in their design.

Recently, many scholars have made contributions to investigating the safety factors that affect the safety performance of construction projects. However, these studies had notable shortcomings. Choudhry et al. [16] conducted a study that examined the efficacy and deficiencies of safety measures for enhancing the safety performance of construction projects. However, they were able to gather only 54 responses. Lu et al. [17] conducted a study to establish the correlation between safety investments and construction safety performance. However, the data collection was limited to 134 responses. Winge et al. [18] compared safety management and performance. They used qualitative analysis and interviews to acquire data; however, they were only able to gather information from 22 interviewees. Ng et al. [19] introduced a system for evaluating the safety performance of construction projects; however, they were limited to gathering 129 responses. Yap et al. [20] recently conducted a study that examined the safety performance of building projects during production. In total, 157 responses were obtained. Consequently, the present analysis expands the scope of the study by increasing the number of survey respondents to 285. Trinh et al. [21] examined the influence of project complexity on construction safety performance, focusing specifically on 31 safety indicators. Sukamani et al. [22] conducted a study that assessed the inadvertent variables that affect the safety performance of construction sites. However, they were only able to uncover a total of 42 factors. Recently, Buniya et al. [23] examined the safety of construction projects. However, this study identified only 25 safety factors. Moreover, the distinctiveness of this study arises from the limited amount of research conducted on the safety performance of high-rise building projects. Given the available facts, it is imperative to conduct a thorough analysis of the safety aspects associated with accidents in high-rise building projects by combining EFA and SEM methodologies.

3 Methodology

The research methodology consisted of four phases: a) a literature review, b) sampling, c) a questionnaire survey, and d) data analysis. Figure 1 presents a comprehensive flowchart outlining the research approach.

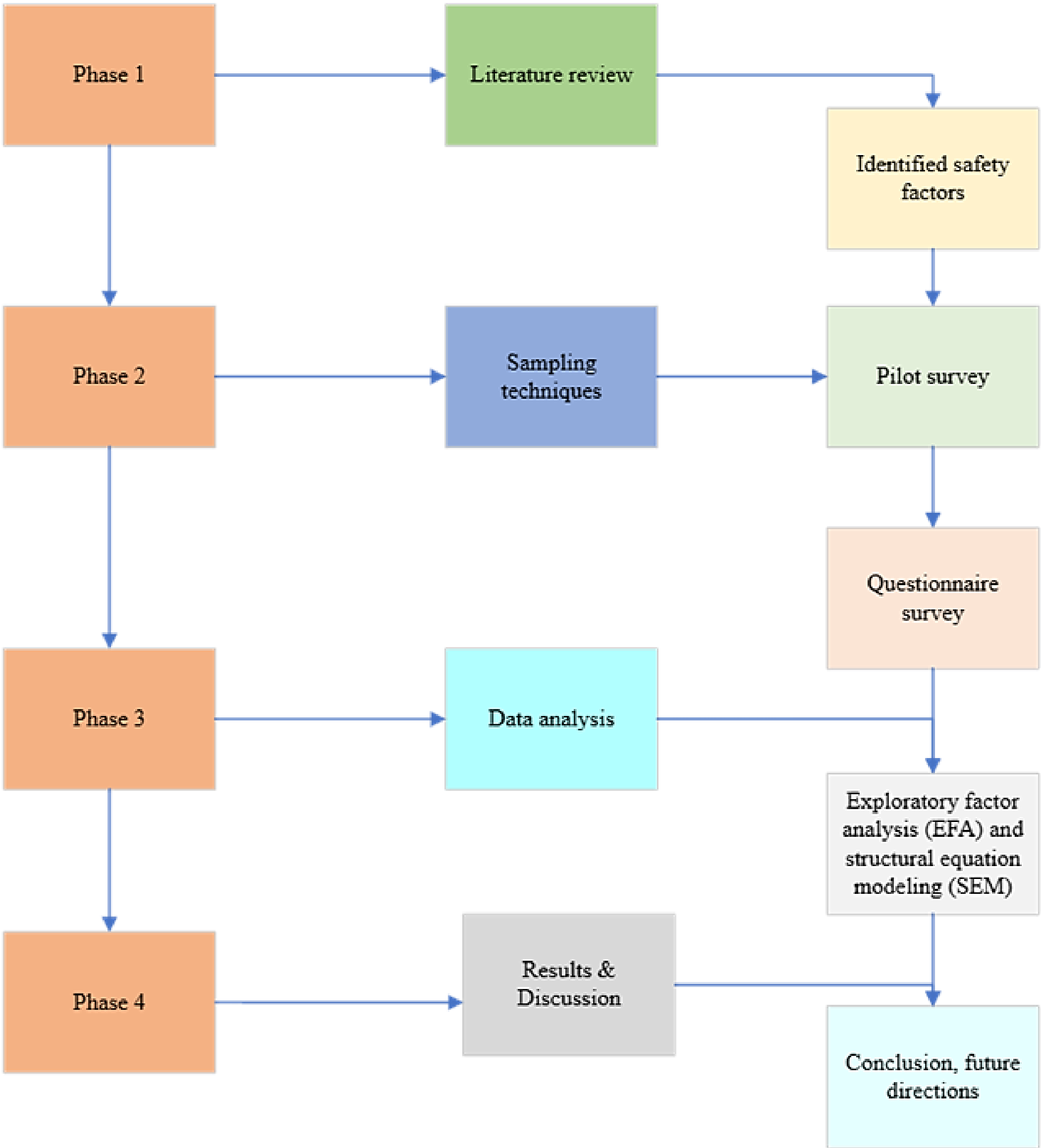

Figure 1. Research methodology flowchart

During the first stage of the study, a comprehensive literature analysis was conducted to identify safety factors using online databases such as Scopus. The Scopus database was chosen because of its comprehensive coverage of a wide range of academic literature, including journals, conference papers, and patents from various fields. This comprehensive coverage ensures that academics have access to diverse choices of materials relevant to their research topics. Scopus employs a rigorous evaluation process to assess the quality of indexed publications, guaranteeing the inclusion of only respectable and peer-reviewed sources. In the second phase, we conducted sampling and a questionnaire survey. A pilot survey was conducted before the questionnaire was administered to ensure its validity. The pilot study involved a group of seven highly qualified people: two assistant professors, two associate professors, two postgraduate researchers, and one professor. A pilot study was essential to improve the design of the questionnaire used to evaluate the impact of accidental safety factors on safety performance in high-rise building projects. A pilot study, which included seven highly competent professionals, aimed to evaluate the clarity, relevance, and comprehensiveness of the survey items.

A validity test for the pilot survey was conducted to ensure the reliability and accuracy of the questionnaire before full-scale data collection. The validity assessment focused on content validity. Content validity was established through expert reviews in which construction safety professionals evaluated whether the survey items adequately covered the key factors influencing safety performance in high-rise building projects. Their feedback led to minor revisions and improved the clarity and relevance of the questions. The pilot study substantially improved the questionnaire by optimising its structure, enhancing its validity, and confirming its efficacy in identifying key safety-related factors affecting the performance of high-rise construction projects. A comprehensive questionnaire was administered after the pilot survey. To achieve this objective, 400 surveys were distributed via email to contractors and clients. The final phase involved conducting a thorough data analysis using EFA and SEM to achieve the research objectives. In the fourth and final part of the paper, the results and discussion are presented, followed by the conclusion, limitations, and future directions.

3.1 Reliability analysis

The most commonly used approach for assessing internal consistency is Cronbach's alpha coefficient, which was used in this study. Cronbach’s alpha ranges from 0 to +1, with higher values indicating greater dependability. In this study, Cronbach's alpha score was 0,976, indicating high reliability and suitability for further analysis [24].

3.2 Exploratory Factor Analysis (EFA)

EFA is a versatile statistical method employed for various purposes. The goal of conducting an EFA is to examine and analyse the correlations between individual variables and identify the underlying latent factors that are represented by the measured variables. Consequently, two tests were conducted to determine the suitability of the data: a) the Kaiser–Meyer–Olkin (KMO) test and b) the Bartlett test.

3.3 KMO and Bartlett tests

To assess the validity of the factor analysis, it was necessary to conduct the KMO and Bartlett tests to establish significant correlations among the initial variables. The KMO test was used to assess the distribution of the values in the factor analysis measurement sample. A minimum KMO coefficient of 0,800 is necessary for sufficient distribution. The KMO test yielded a value of 0,915 in this study, indicating that the data were appropriate for further examination. In addition, the p-value of the Bartlett test was 0,000, which is below the threshold of 0,010. This suggests that the data are suitable for further exploratory factor analyses.

3.4 Analytical approach (SEM)

SEM has been the subject of a significant attention in various domains, particularly in the area of construction research. Several studies focusing on SEM are currently underway in the field of construction safety [25]. In this study, the SEM approach was used to evaluate the acquired data to model the impact of accidental factors on safety performance. This was performed to ensure accuracy of the results. To develop the proposed model, the mathematical strategy used in this research involved measurement and structural model evaluation approaches.

3.5 Questionnaire design and response

The final questionnaire comprised two sections: a) gathering basic information from respondents, and b) assessing the impact of safety accidental factors on the safety performance of high-rise building projects using a Likert scale (1 = Strongly Disagree, 2 = Disagree, 3 = Moderately, 4 = Agree, 5 = Strongly Agree).
A five-point scale offers a well-rounded selection of response possibilities, enabling respondents to convey their level of opinion without feeling overwhelmed by an excessive number of choices or limited by a scarcity of options. The five-point scale enables simple statistical analysis. It offers sufficient diversity to capture slight variations in responses, and enables significant consolidation and comparison of data.
A total of 400 questionnaires were distributed via email, resulting in 285 responses (response rate of 71 %). Figure 2 provides a detailed breakdown of the 285 returned questionnaires, including information on the positions held, work experience, education, and company type.

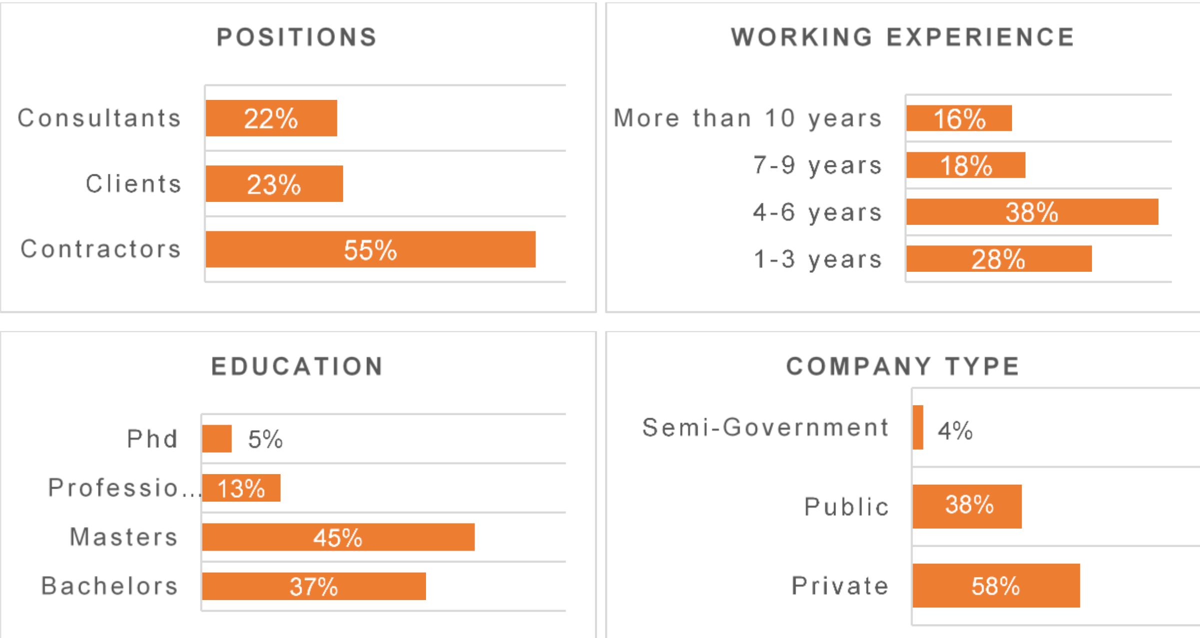

Figure 2. Categorization of 285 returned questionnaires by the a) positions, b) working experience, c) education, and d) company type

The participants were selected based on their professional expertise in high-rise building projects. Table 1 displays a comprehensive overview of the variables that impact the safety performance of high-rise building projects [26-35].

Table 1. List of safety performance variables

No.	Variables
I	Safety signals
SS1	Safety sign location
SS2	Installation of signs when appropriate
SS3	Indicators of potential danger
SS4	Worker surveillance system implemented on location
SS5	Worker location monitoring
SS6	Identification of possible risks to safety

II	Personal protective equipment (PPE)
PPE1	Inadequate quality of PPE utilized.
PPE2	Noncompliance with PPE provision
PPE3	Lack of adherence to the use of hearing protection and safety glasses
PPE4	Failure to use safety belts at high altitudes
PPE5	Failure to use a safety helmet
PPE6	Utilized faulty tool or equipment
III	Fall from floor
FF1	Failure of floor edge protection
FF2	User's inability to perform a task
FF3	Experiencing scaffolding collapse
FF4	Encountering a collapse of the scaffolding structure
FF5	Inadequacy of the safety net system
FF6	Uncovered floor opening
IV	Scaffolding & Ladder Failure
SLF1	Inferior quality of scaffolding material utilized
SLF2	Substandard ladder quality
SLF3	Scaffolds are inadequately secured
SLF4	Concrete formwork failure
SLF5	Inadequate and negligent craftsmanship in the construction of scaffolds
V	Safety clearance
SC1	System for conducting regular safety inspections
SC2	Documentation of safety inspections
SC3	Checking incidences without identification
SC4	For major incidents, listed work is behind schedule
VI	Transportation & Storage
TS1	Inadequate safeguards during the transportation of materials
TS2	Inferior grade of materials utilized in the manufacturing process
TS3	Materials are not wind-resistant
TS4	Storage facility experiences a chemical explosion
TS5	Inadequate management of merchandise
VII	Working circumstances
WC1	Working near flammables
WC2	Encountering dangerous or risky work conditions
WC3	Safe workplace conditions for site-resident workers
WC4	Weather characterized by high temperatures and precipitation
WC5	Intense gusty weather
WC6	Condition characterized by the presence of dust and excessive noise
WC7	Potential risk of fire
WC8	Insufficient or nonexistent protections for moving machinery parts
VIII	Low knowledge and skill level of workers
LKSLW1	Inadequate training of employees
LKSLW2	Lack of adherence to weekly worker meetings
LKSLW3	Insufficient availability of labor with qualified skills
LKSLW4	Insufficient provision of technical advice
LKSLW5	Insufficient presence of seasoned project managers
LKSLW6	Lack of efficient safety communication between workers and supervisor
LKSLW7	Client overestimated project time and cost
LKSLW8	Insecurity and shortcuts among workers
LKSLW9	Insufficient safety training and education infrastructure
IX	Personal Factors
PF1	Workers poor temperament
PF2	Alcoholism among workers
PF3	Workers inconsideration
PF4	Lack of knowledge among workers
PF5	Errors made by humans
PF6	Ignorance
PF7	Workers anxiety and fear
PF8	Excessive workload caused by extra labor, exhaustion, and rework

X	Overload factors
OF1	Crane crashed over
OF2	Operator of a crane without skill
OF3	Controlling machinery without proper authorization
OF4	Inadequate loading or positioning of equipment or supplies
OF5	Inappropriate utilization of apparatus

4 Results and discussion

4.1 Exploratory factor extraction

The principal component factor analysis is crucial for exploratory factor extraction. Principal component factor analysis allows for the identification of common factors by combining variables with high factor loads. Table 2 shows that the eight factors accounted for 68,495 % of the overall variance. To enhance the understanding of the factors, any item with a factor load of less than 0,45 was considered to have a weak index value and could therefore be disregarded. Consequently, the matrix was rotated orthogonally to maximise variance, which enabled the identification of items with factor loadings greater than 0,45 as common factors.

Table 2. Exploratory factor analysis total variance interpretation

Factor	Initial Eigenvalues			After extraction			After rotation		
	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)	Total	Variance (%)	Cumulative (%)
1	22,505	36,298	36,298	22,505	36,298	36,298	10,539	16,998	16,998
2	7,522	12,132	48,430	7,522	12,132	48,430	7,975	12,863	29,861
3	2,987	4,817	53,247	2,987	4,817	53,247	5,825	9,395	39,256
4	2,490	4,016	57,263	2,490	4,016	57,263	4,970	8,016	47,272
5	2,038	3,287	60,550	2,038	3,287	60,550	4,933	7,956	55,228
6	1,825	2,943	63,493	1,825	2,943	63,493	3,065	4,944	60,172
7	1,585	2,556	66,049	1,585	2,556	66,049	2,975	4,798	64,970
8	1,517	2,446	68,495	1,517	2,446	68,495	2,185	3,524	68,495
…	…	…	…	--	--	--	--	--	--
62	0,047	0,035	100,000	--	--	--	--	--	--

The factor load matrix following rotation, together with the extraction of the eight factors, is presented in Table 3.

- Category F1: "Construction workers' safety" contributes the highest percentage of overall variation, accounting for 36,298 %. It includes 18 variables: PPE6, SS2, SS4, SS1, PPE5, FF4, FF6, SS5, PPE4, FF3, PPE3, SS6, FF5, SC2, PPE2, PPE1, SC1, and SS3.
- Category F2: "Construction workers' expertise" describes 12,132 % of the total variance and consists of nine variables, namely LKSLW2, LKSLW5, LKSLW1, LKSLW3, LKSLW4, LKSLW9, LKSLW6, LKSLW7, and LKSLW8.
- Category F3: "Construction workers' attitude" explains 4,817 % of the overall variance. It comprises eight variables: PF1, PF5, PF2, PF3, PF6, PF4, and PF8.
- Category F4: "Overworking" explains 4.016% of the overall variance and is composed of seven variables: SC4, OF2, SC3, OF1, OF4, OF3, and OF5.
- Category F5: "Construction environment" contributes 3,287 % of the overall variance and includes eight variables, namely WC2, WC4, WC6, WC5, WC7, WC3, WC1, and WC8.
- Category F6: "Construction equipment" contributes 2,943 % of the total variance and includes five variables, namely TS5, TS4, TS2, TS1, and TS3.

- Category F7: "Poor workmanship" explains 2,556 % of the total variance and includes five variables: SLF2, SLF5, SLF4, SLF1, and SLF3.
- Category F8: “Mishandling construction materials” contributes 2,446 % of the overall variation and consists of two variables, namely FF1 and FF2.

Table 3. Rotated factor load matrix and eight common factors

Variables	Factors Load Matrix								Extracted common factors
	1	2	3	4	5	6	7	8	
PPE6	0,996	0,098	0,092	0,098	0,021	−0,089	0,004	−0,090	F1: “Construction workers safety”
SS2	0,989	0,089	0,090	0,091	−0,020	0,004	0,009	−0,040	
SS4	0,932	0,089	0,089	0,090	−0,013	0,001	0,009	−0,032	
SS1	0,906	0,083	0,072	0,072	−0,012	0,008	0,010	−0,019	
PPE5	0,902	0,056	0,067	0,045	−0,001	0,009	0,010	−0,010	
FF4	0,892	0,052	0,062	0,040	0,090	0,009	0,012	−0,009	
FF6	0,887	0,043	0,062	0,034	0,087	0,022	0,015	−0,004	
SS5	0,876	0,042	0,051	0,032	0,056	0,022	0,027	−0,001	
PPE4	0,851	0,039	0,045	0,032	0,042	0,098	0,029	0,020	
FF3	0,864	0,034	0,043	0,018	0,034	−0,001	0,030	0,014	
PPE3	0,854	0,034	0,042	0,018	0,032	−0,003	0,032	0,014	
SS6	0,833	0,023	0,034	0,012	0,029	−0,007	0,041	0,012	
FF5	0,831	0,023	0,023	0,012	0,023	−0,007	0,043	0,006	
SC2	0,823	0,015	0,020	0,012	0,023	−0,010	0,076	0,006	
PPE2	0,820	0,012	0,012	0,010	0,014	−0,018	0,089	0,001	
PPE1	0,789	0,012	0,009	0,009	0,012	−0,039	0,098	0,001	
SC1	0,754	0,011	0,009	0,001	0,010	−0,039	−0,090	0,001	
SS3	0,712	0,009	0,008	0,000	0,010	−0,043	0,098	0,001	
LKSLW2	0,090	0,992	0,091	0,129	0,234	0,092	0,055	0,021	F2: “Construction workers expertise”
LKSLW5	0,087	0,923	0,091	0,125	0,234	0,064	0,054	0,020	
LKSLW1	0,070	0,908	0,090	0,120	0,109	0,061	0,043	0,017	
LKSLW3	0,069	0,891	0,067	0,118	0,096	0,046	0,041	0,013	
LKSLW4	0,067	0,885	0,023	0,113	0,090	0,039	0,034	0,011	
LKSLW9	0,055	0,845	0,023	0,101	0,081	0,038	0,029	0,010	
LKSLW6	0,023	0,789	0,012	0,100	0,045	0,031	0,026	0,009	
LKSLW7	0,015	0,768	0,012	0,009	0,012	0,010	0,026	0,005	
LKSLW8	0,012	0,712	0,010	0,002	0,001	0,009	0,100	0,002	
PF1	0,090	0,122	0,971	0,009	0,029	0,012	0,000	0,009	F3: “Construction workers attitude”
PF5	0,012	0,090	0,912	0,034	0,033	0,073	0,081	0,008	
PF2	0,023	0,059	0,892	0,012	0,015	0,000	0,032	0,054	
PF3	0,067	0,071	0,866	0,045	0,006	0,013	0,006	0,023	
PF6	0,054	0,079	0,821	0,023	−0,025	0,002	0,005	0,026	
PF4	0,027	0,023	0,789	0,009	0,022	0,000	0,005	0,000	
PF8	0,080	0,010	0,709	0,050	0,001	0,090	0,068	0,032	
PF7	0,091	0,012	0,091	0,023	0,092	0,022	0,031	0,066	
SC4	0,900	0,045	0,090	0,867	0,090	0,051	0,098	−0,018	F4: “Overworking”
OF2	0,301	0,068	0,082	0,851	0,089	0,002	0,041	−0,015	
SC3	0,223	0,012	0,040	0,823	0,059	0,006	0,031	−0,010	
OF1	0,190	0,086	0,074	0,800	0,040	0,091	0,015	0,060	
OF4	0,123	0,085	0,091	0,791	0,021	0,019	0,006	0,024	
OF3	0,123	0,034	0,090	0,789	0,009	0,012	0,004	0,014	
OF5	0,100	0,090	0,084	0,678	0,004	0,018	0,001	0,002	
WC2	0,190	0,051	0,000	0,047	0,990	0,036	0,032	0,039	F5: “Construction environment”
WC4	0,123	0,065	0,020	0,023	0,905	0,088	0,023	0,049	
WC6	0,192	0,072	0,004	0,023	0,900	0,020	0,023	0,045	
WC5	0,126	0,012	0,000	0,090	0,891	0,012	0,093	0,000	
WC7	0,110	0,052	0,011	0,049	0,867	0,035	0,034	0,036	
WC3	0,123	0,034	0,098	0,000	0,812	0,034	0,000	0,000	
WC1	0,009	0,026	0,014	0,050	0,781	0,033	0,007	0,012	
WC8	0,092	0,067	0,020	0,008	0,761	0,066	0,028	0,014	

TS5	0,034	0,099	0,010	0,011	0,036	0,942	0,011	0,028	F6: "Construction equipment"
TS4	0,090	0,090	0,033	0,036	0,025	0,921	0,012	0,008	
TS2	0,039	0,040	0,031	0,009	0,056	0,891	0,00	0,012	
TS1	0,009	0,006	0,028	0,000	0,023	0,845	0,021	0,030	
TS3	0,012	0,001	0,090	0,026	0,012	0,678	0,002	0,017	
SLF2	0,099	0,012	0,091	0,078	0,031	0,064	0,934	0,046	F7: "Poor workmanship"
SLF5	0,042	0,050	0,077	0,052	0,043	0,063	0,921	0,034	
SLF4	0,015	0,009	0,066	0,038	0,044	0,024	0,823	0,026	
SLF1	0,008	0,067	0,036	0,075	0,057	0,015	0,821	0,010	
SLF3	0,001	0,012	0,034	0,045	0,040	0,009	0,097	0,009	
FF1	0,086	0,007	0,020	0,046	0,044	0,001	0,020	0,821	F8: "Mishandling construction materials"
FF2	0,015	0,028	0,023	0,069	0,057	0,029	0,046	0,808	

Consequently, the following eight groups were developed: construction workers' safety, expertise, attitude, overworking, environment, equipment, poor workmanship, and mishandling construction materials.

4.1.1 Construction workers' safety

The safety features of a construction site are determined by the level of effort required to decrease the probability of accidents, such as safeguarding employees from hazards and implementing necessary safety measures. For efficient safety management, it is crucial to identify dangers in high-rise building projects that have the potential to endanger personnel. An unsafe work environment not only affects the safety of workers, but also has implications for the schedule and budget of the project. The safety of construction workers depends on the presence of safety signs, PPE, safety inspections, and proper scaffolding arrangements [36]. Monitoring construction worker movement onsite is crucial for tracking their activities. Non-compliance with the requirement of wearing a safety helmet on construction sites may lead to severe and devastating consequences. It is essential to wear protective clothes and use PPE to reduce the severity of on-site accidents. Employers are legally obligated to provide safety equipment and protective clothes for all employees. However, employees bear the responsibility of ensuring their personal health and safety [37].

Additionally, it is necessary to have a competent health and safety supervisor to supervise construction site personnel and ensure compliance with safety protocols, including the use of protective gear, to maintain the well-being of workers. Safety planning plays a crucial role in ensuring the well-being of construction workers. The first step in planning construction site safety is to identify the inherent safety factors of the project. This is accomplished through a team meeting that includes a construction manager, a safety manager, and site supervisors. During the meeting, the participants commonly rely on drawings, accident instances, and conceptual understanding as sources of information to develop prevention activities targeting anticipated safety concerns. It is imperative that construction workers receive proper education regarding the safety problems identified during the design phase. To ensure effective teaching and training, it is necessary to customise instructional materials according to the specific requirements of the project site [38].

4.1.2 Construction workers' expertise

Expertise of construction workers is necessary to improve construction safety. A detrimental impact was made on the overall performance of high-rise building projects because of insufficient information and personnel lacking the required skills. To mitigate this, it is crucial to establish efficient and secure communication channels between workers and supervisors, improve technical assistance, organise weekly meetings for construction workers, and prioritise safety training and education. Construction workers benefit from the extensive knowledge and experience of safety specialists, who enable them to identify various situations and take appropriate actions. Conversely, training focuses primarily on job-specific skills as well as the associated standards and procedures. Multiple studies have indicated that literacy and education have substantial impacts on the safety performance of construction workers. Osei et al. [39] argued that a significant obstacle to effective safety management in the construction industry is construction workers' limited literacy. In a study conducted by Tam et al. [40], the factor of "low education level of workers" was evaluated as the 11th most significant influence on construction site safety out of a total of 25 factors. Choudhry et al. [41] interviewed construction workers who were injured during accidents. They found that education was one of the factors influencing worker safety. Lyu et al. [42] found that construction workers with higher levels of education demonstrated superior safety management performance.

Construction workers are motivated to embrace safety measures because of many considerations such as the potential for increased earnings and opportunities for more stable employment. These predictions were confirmed. After accounting for the influence of education and experience, workers who possess competence can earn greater pay per hour. Moreover, the influence of education and experience can result in effective safety management and a reduction in the ratio of fatal accidents to nonfatal injuries in construction projects. Workers lacking proper safety education may struggle to comprehensively understand safety-related information and their ability to perform effectively in safe team settings. Thus, safety education to enhance construction safety is indispensable for ensuring safer construction practices. Ensuring comprehensive safety training for workers with little educational background is crucial to achieve effective safety management and performance.

4.1.3 Construction workers attitude

A good mood is indicative of safer behaviour. A significant number of workplace accidents, especially in high-rise building projects, result from workers' noncompliance with work procedures. Workers must understand that they play a pivotal role in the successful execution of high-rise building projects. Worker comprehension and perception of health, safety, and the working environment are essential components in the process of improving building construction to provide greater benefits for the workers themselves [43]. Physical injuries and hazardous incidents exemplify the tangible components of worker safety outcomes. Furthermore, the stress experienced by construction workers is not a standard or stable condition and can lead to psychological manifestations such as melancholy, anxiety, rage, and tension in the workplace. Construction workers experiencing psychological stress often experience pressure and difficulty in focusing on their tasks, which leads to a decline in their mental well-being. Stress analysis can provide insights for enhancing the collective safety performance of a group. Construction workers are considered one of the most stressful occupational categories because of the dynamics of the labour market and the movement of personnel. Construction workers and managers can experience detrimental effects on their well-being owing to injuries and hazardous incidents [44].

Worker behaviour towards safety management is assessed by evaluating the effectiveness and frequency of safety inspections. The presentation of dangers and safety information, as well as the monitoring of subcontractor safety, is of utmost importance. The continuous focus of management and supervisors on safety concerns, along with the provision of necessary safety infrastructure, clearly communicates to workers that a safe working environment is desired and anticipated. The construction sector is notable for its absence of adequate safety infrastructure. However, by establishing a visible network, workers are motivated to adhere to good work practices. Construction organisations can enhance worker safety by acknowledging the significance of the construction worker's mindset. To achieve this, the construction sector must ensure the continuous development and enhancement of personnel expertise and understanding through training programs, regular skill upgrades, and efficient on-site communication. A safety management system is insufficient to guarantee safety at the site; however, it is essential for cultivating positive connections among construction workers, clients, safety officers, and contractors [45].

4.1.4 Overworking

Excessive activity in high-rise building projects can result in several hazardous situations, such as crane mishaps, incorrect loading or positioning of equipment or materials, and hasty completion of building operations. To enhance the efficiency of construction operations, it is important to motivate construction personnel to fulfil their duties. Encouraging workers is a vital obligation in contemporary construction [46]. Workers' willingness to perform their responsibilities is a crucial factor in the successful completion of any construction project. In addition, highly motivated construction workers positively impact the company's image and increase the probability of achieving strategic objectives. Compensation policies are motivating factors for construction workers, leading to increased performance, discretionary effort, and contribution. Motivation usually arises when an individual recognises a need that has not yet been fulfilled. Subsequently, a specific objective is established to fulfil this requirement. Individuals may be motivated and encouraged to exert greater effort to achieve their goals [47].

4.1.5 Construction environment

An environment dedicated to safety can be used to assess and enhance construction safety. According to a multilevel view, safety conditions at both the organizational and group levels are related to the incidence of injuries [48]. Frontline supervisors played a mediating role in the association between top management opinions on safety and the occurrence of injuries among field workers in a multilevel safety environment. A study utilising a training intervention program found that improving supervisors' safety practices effectively enhanced their self-efficacy and reduced injuries and instances of unfair discordance among construction workers. Unsafe construction settings are commonly acknowledged as major factors contributing to accidents during building construction. Construction workers frequently violate safety protocols and engage in risky job behaviours such as neglecting to secure safety harnesses and helmets, mishandling materials and tools, causing objects to fall from elevated positions, and unintentionally trespassing into restricted areas on construction sites. Engaging in these hazardous behaviours can subject workers and colleagues to heightened safety hazards, leading to both fatal and nonfatal incidents at construction sites [49].

4.1.6 Construction equipment

Safe transportation and storage of construction equipment is absolutely necessary to guarantee construction safety. It is possible for serious accidents to occur during the construction of high-rise buildings if construction equipment is not stored appropriately, and there is a chemical explosion in the storage area [50]. Furthermore, it is imperative to employ proficient and competent construction workers to transport construction equipment efficiently. Consequently, it is crucial to provide detailed information regarding the safety training of construction workers. Safety training is a means of equipping personnel with the requisite expertise and knowledge to perform daily tasks effectively and securely. In addition, safety training can enhance workers' understanding of accident frequency and safety laws while promoting greater safety consciousness. Safety training has been highlighted as an effective method for improving worker safety performance in construction accident prevention studies [51].

4.1.7 Poor workmanship

Most mishaps in high-rise building projects are caused by human error. Regrettably, human mistakes occurred because of inadequate construction work during the building process. The prevalence of construction accidents might be attributed to substandard craftsmanship in building construction and inadequate administration and supervision of building contractors [52]. Furthermore, inadequate craftsmanship includes in adequately fastening or tightening the scaffolding structure, as well as the inept and careless installation of scaffolding. Although workmanship is a paramount factor in ensuring high-quality projects, substandard workmanship can lead to accidents in the construction of tall buildings. Therefore, careful analysis is essential to reduce the consequences of accidents. To minimise such situations, it is advisable to hire construction workers who are highly qualified and well-trained [53].

4.2 Cronbach's α reliability test

Cronbach's α reliability test was conducted to ensure the appropriate grouping of factors, as shown in Table 4. The α values of all common factors fell within the range of 0,982 to 0,812, and all exceeded the minimum requirement of 0,700. Thus, each dimension exhibited strong internal consistency.

Table 4. Cronbach's α reliability test

Extracted common factors	Cronbach's α
F1: "Construction workers safety"	0,982
F2: "Construction workers expertise"	0,975
F3: "Construction workers attitude"	0,970
F4: "Overworking"	0,961
F5: "Construction environment"	0,954
F6: "Construction equipment"	0,948
F7: "Poor workmanship"	0,932
F8: "Mishandling construction materials"	0,812

4.3 Structure equation modelling (SEM)

SEM is a powerful statistical technique that combines mathematical models and computer algorithms to analyse multiple variables simultaneously. SEM is a statistical technique that includes confirmatory factor analysis (CFA). It comprises two main components: a measurement model and a structural model. This study utilised SEM to ascertain the correlation between the safety performances of high-rise building projects. Therefore, model assumptions are regarded as crucial parameters in constructing the SEM [54]. Hence, EFA is crucial for comprehending the connections and constructing the measurement and structural models of SEM. The following hypotheses were formulated:

- H1: Construction workers' safety has a positive and significant effect on safety performance.
- H2: Construction workers' expertise has a positive and significant effect on safety performance.
- H3: Construction workers' attitude has a positive and significant effect on safety performance.
- H4: Overworking has a significant effect on safety performance.
- H5: Construction environment has a positive and significant effect on safety performance.
- H6: Construction equipment has a positive and significant effect on safety performance.
- H7: Poor workmanship has a significant effect on safety performance.
- H8: Mishandling of construction materials has a significant effect on safety performance.

4.3.1 Measurement and structural models

The measurement model comprises the measured variables associated with a latent variable and must be carefully constructed before proceeding with the structural model. Before testing the structural model, it is essential to establish an effective measurement model. To establish the connection between the observed and latent variables, the hypotheses were examined using the data obtained in the AMOS21.0 software package SEM. Table 4 shows that eight measurement models are needed to evaluate the impact of accidental safety factors on safety performance for high-rise building projects; for instance, the measurement model of the latent

variable F5 (construction environment) consists of eight observation variables: working near flammables, encountering dangerous or risky work conditions, safe workplace conditions for site-resident workers, weather characterised by high temperatures and precipitation, intense gusty weather, conditions characterised by the presence of dust and excessive noise, potential risk of fire, and insufficient or non-existent protections for moving machinery parts.
The structural model resembles simultaneous equation regression models [55] because it elucidates the extent of explained and unexplained variance, thus revealing the connections between the latent factors. After establishing the measurement model, a structural equation model was constructed to examine the relationships among the eight latent variables. Different considerations have been suggested for constructing SEM. For instance, the number of samples should be ten times the number of observed variables. Ideally, the sample size should range from 200 to 500 [56; 57]. Hence, it is important to note that the sample size in this research study was 285, and there was a total of 62 variables. Figure 3 shows the structural equation, which represents the parameters that influence the safety performance of high-rise building projects.

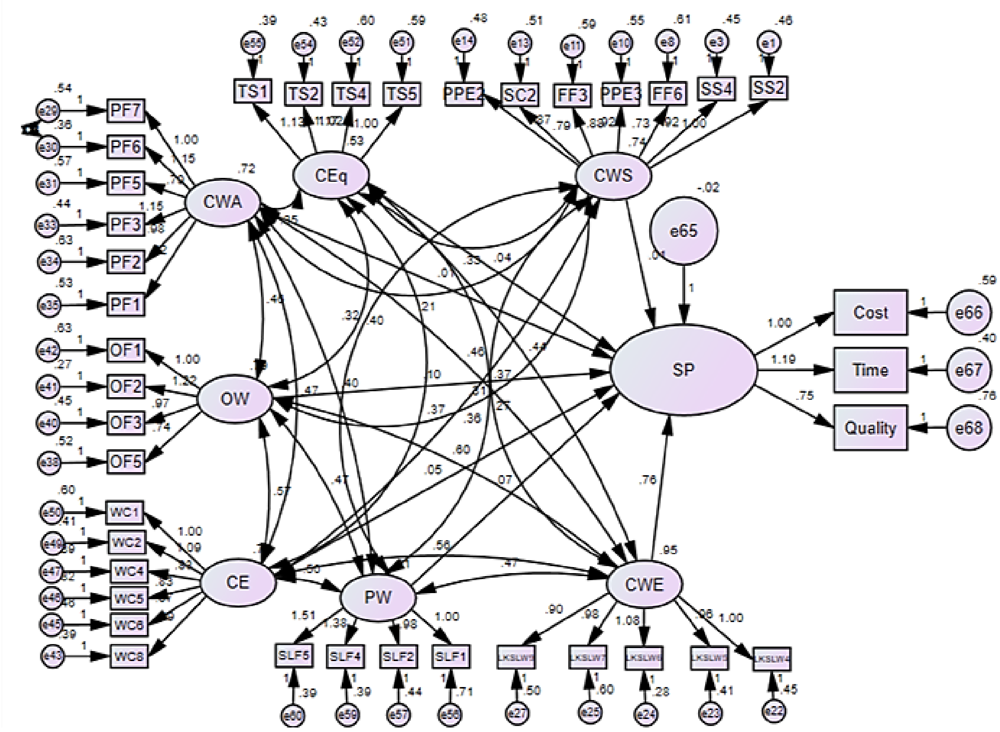

Figure 3. Structural equation model to determine the factors that impact safety performance

SEM demonstrates the relationships among the various factors that influence safety performance in the construction industry. This model incorporates multiple latent variables, each represented by observable indicators, and explores their direct and indirect effects on safety performance. The model suggests a strong and significant relationship between construction workers' attitude (CWA) and safety performance (SP). This finding highlights the fact that workers' personal attributes, such as knowledge, skills, and experience, play a crucial role in determining safety outcomes. The higher the expertise and awareness among workers, the better the safety performance, which is consistent with previous studies emphasising the importance of human factors in workplace safety. The model shows a correlation between overworking (OW) and SP, reinforcing the well-documented idea that fatigue negatively affects safety. Overburdened workers tend to make more errors, have slower reaction times, and are at higher risk of accidents. This result suggests that managing workload and ensuring adequate rest periods are critical for improving safety performance. Construction equipment

(CEq) has a positive and significant impact on SP, indicating that the proper use and maintenance of construction equipment leads to better safety outcomes. Equipment-related hazards are a major concern in construction, and ensuring that tools and machinery are properly maintained and used can substantially reduce workplace accidents. The construction environment (CE) also affects safety performance. A well-organised and hazard-free environment contributes to improved safety conditions. The SEM results confirm that site management, material storage, and worksite layout directly affect the overall safety outcomes. This finding underscores the need for the proper planning and organisation of construction sites to prevent accidents. The model reveals the significant impact of poor workmanship (PW) on SP, indicating that substandard construction practices increase safety risks. Workers who lack proper training or rush through tasks because of tight deadlines may compromise structural integrity and increase the likelihood of safety failures. These findings emphasise the need for continuous training and quality assurance measures. Construction worker safety (CWS) represents adherence to proper personal protective equipment (PPE) use, safety training, and compliance with regulations. The model suggests a strong relationship between CWS and SP, confirming that when workers follow proper safety procedures, overall site safety improves. This result supports the implementation of strict safety policies, frequent inspections, and safety culture initiatives to enhance compliance and reduce risks. The SEM results indicate that SP directly affects key project success criteria: cost, time, and quality. A higher SP score correlates with lower project costs, improved timelines, and better-quality outcomes. This result suggests that prioritising safety is not only a regulatory requirement but also a strategic decision that enhances project efficiency and performance. Figure 4 elaborates the conceptual framework of accidental safety factors on safety performance for high-rise building projects.

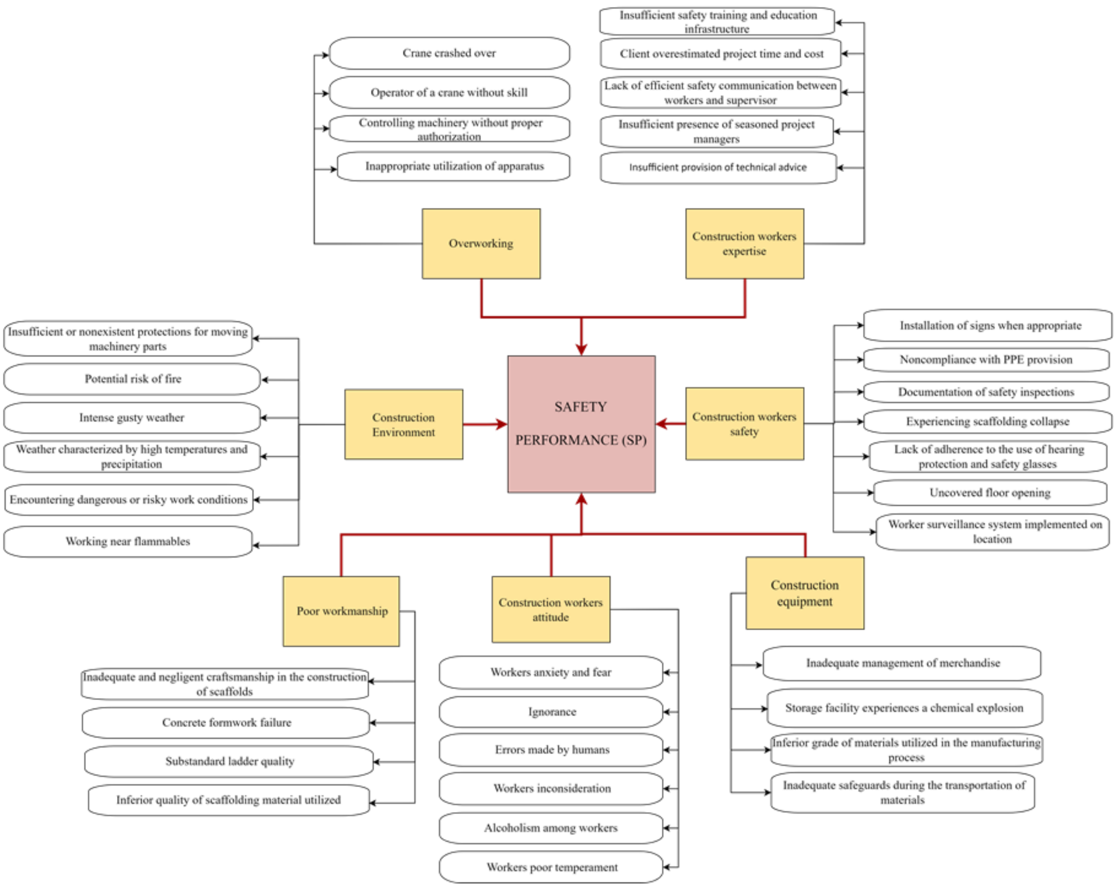

Figure 4. Conceptual framework for safety accidental factors on safety performance for high-rise building projects

4.3.2 Hypothesis test

The hypotheses were deemed valid only when the significance level was set at p < 0,050. Hypothesis 8 was rejected because of its p-value of 0,689; which exceeded the permissible threshold of 0,050. That is, safety factors in high-rise building projects (including the failure of floor edge protection and the user's inability to perform a task) must be excluded. All the remaining eight hypotheses had extremely low significance values and hence were judged valid. Table 5 presents the complete picture of the hypothesis test analysis.

Table 5. Hypothesis test analysis

Hypothesis	p-value	Result
F1 (Construction workers safety) affects safety performance.	0,002	Accepted
F2 (Construction workers expertise) affects safety performance.	0,001	Accepted
F3 (Construction workers attitude) affects safety performance.	0,003	Accepted
F4 (Overworking) affects safety performance.	0,002	Accepted
F5 (Construction environment) affects safety performance.	0,007	Accepted
F6 (Construction equipment) affects safety performance.	0,005	Accepted
F7 (Poor workmanship) affects safety performance).	0,002	Accepted
F8 (Mishandling construction materials) affects safety performance	0,643	Rejected

To attain the required efficacy of the structural equation model, certain variables were omitted from the model. Hypothesis F8 (mishandling of construction materials) was disregarded because the p-value exceeded the predetermined threshold of 0,050. This hypothesis was accepted only if the p-value was < 0,050. To achieve the desired fitness of the model, the structural equation model included F1: “construction workers’ safety” along with the variables “PPE2, SC2, FF3, PPE3, FF6, SS4, and SS2”. F2: “construction workers’ expertise” along with the variables “LKSLW9, LKSLW7, LKSLW6, LKSLW5, and LKSLW4”. F3: “construction workers’ attitude” along with the variables “PF7, PF6, PF5, PF3, PF2, and PF1”. F4: “overworking” along with the variables “OF1, OF2, OF3, and OF5”. F5: “construction environment” along with the variables “WC1, WC2, WC4, WC5, WC6, and WC8”. F6: “construction equipment” along with the variables “TS1, TS2, TS4, and TS5”. F7: “poor workmanship” along with the variables “SLF5, SLF4, SLF2, and SLF1”.

- Significant relationships (accepted hypotheses): Factors F1 (construction workers’ safety), F2 (construction workers’ expertise), F3 (construction workers’ attitude), F4 (overworking), F5 (construction environment), F6 (construction equipment), and F7 (poor workmanship) all had p-values below 0,050; indicating a strong statistical relationship with safety performance.
  - F1 (construction workers’ safety), p = 0,002: This strong relationship suggests that adherence to safety protocols and awareness among workers significantly improves safety performance.
  - F2 (construction workers’ expertise), p = 0,001: Skilled and trained workers contribute positively to safety, reducing the likelihood of accidents.
  - F3 (construction workers’ attitude), p = 0,003: Positive attitudes towards safety, including compliance and responsibility, enhance overall safety outcomes.
  - F4 (overworking), p = 0,002: Fatigue from excessive work negatively affects safety, leading to errors and accidents.
  - F5 (construction environment) p = 0,007: A well-maintained and organised worksite reduces hazards and improves safety.
  - F6 (construction equipment): p = 0,005: Proper maintenance and usage of equipment play crucial roles in accident prevention.
  - F7 (poor workmanship): p = 0,002: Substandard work quality increases risks, emphasising the need for skilled labour and supervision.

- Non-significant relationship (rejected hypothesis): F8 (mishandling construction materials) ($p = 0{,}643$) was rejected, indicating no significant impact on safety performance. This could be due to several reasons: strict material-handling protocols at construction sites may mitigate risks. Moreover, training programmes and site regulations may ensure proper material handling and reduce the impact on safety outcomes. Other factors, such as equipment safety and worker expertise, may have a stronger influence on overall safety and overshadow material mishandling.

4.3.3 Fitness of model

The model fitness is contingent on meeting the standards of absolute, incremental, and parsimonious fit. The absolute fit provides fundamental information regarding the degree of agreement between the model and data sample. The incremental fit suggests that the original form of $\chi 2$ should not be used, and instead, a comparison can be done with the baseline model. Parsimonious fit was regarded as the optimal choice when compared to other goodness-of-fit metrics. Table 6 provides a comprehensive overview of the effectiveness of the structural equation model.

Table 6. Evaluation of the structural equation model's goodness

Category	Rank	Standard level of fitness	Significance
Incremental fit	IFI	> 0,90	0,988
	CFI	> 0,90	0,922
	TLI	> 0,90	0,912
	GFI	> 0,90	0,907
	RFI	> 0,90	0,900
Parsimonious fit	PCFI	> 0,50	0,812
	PNFI	> 0,50	0,709
	PGFI	> 0,50	0,603
Absolute fit	RMSEA	< 0,08	1,902
	CMIN/DF	< 2,00	0,025
	$\chi 2$ test	> 0,05	0,012

4.3.4 Path coefficients analysis

Path coefficient analysis is a statistical technique used to investigate the interrelationships among variables in an intricate system. Route coefficient analysis enables researchers to examine intricate theoretical models and systematically investigate the connections between variables, thereby offering valuable insights into the underlying mechanisms that influence the observed occurrences [58; 59]. It was found that F2, "construction workers' expertise" (CWE), has a maximum path coefficient of 0,76 followed by F7, "poor workmanship" (PW), with a path coefficient of 0,56. F5, "construction environment" (CE), has a path coefficient of 0,56; F4, "overworking" (OW), has path coefficient of 0,47; F6, "construction equipment" (CEq), has a path coefficient of 0,33; F1, "construction workers safety" (CWS), has path coefficient of 0,01; and F3, "construction workers attitude" (CWA), has a path coefficient of 0,01.

5 Limitations

This study provides substantial insights into the impact of accidental safety factors on safety performance in high-rise building projects; however, various limitations must be addressed. The primary drawback is the generalisability of the results across various types of building projects. The primary focus of this study on high-rise buildings may restrict its relevance to low-rise buildings, infrastructure projects, or industrial construction. Variations in safety laws, project complexity, and labour composition among these construction types may affect the impact of accidental safety factors on overall safety performance. Although the questionnaire was carefully designed and refined through a pilot study, there is a possibility of response bias, in which participants may overestimate safety performance or underreport safety incidents owing to social desirability bias. Future research could incorporate objective safety performance data, such as accident reports and site inspections, to enhance the data accuracy. Additionally, the scope of the study was constrained by geographical factors because construction safety regulations and practices varied across regions. These findings may not be applicable to countries with different legal frameworks, safety cultures, or enforcement mechanisms. Future research should explore cross-regional comparisons to enhance the robustness of conclusions. Despite these limitations, this study contributes to the growing body of knowledge on construction safety and provides a foundation for future research and practical improvements in safety management across diverse construction environments.

6 Conclusions and future directions

This study proposes the integration of EFA and SEM to examine the factors affecting the safety performance of high-rise building projects. Questionnaires were developed utilising existing literature to facilitate the survey process. An EFA was conducted to identify shared variables and decrease data dimensionality. Subsequently, SEM was employed to analyse the associations between the variables in the proposed model. EFA identified eight accidental safety factors that impact the safety performance of high-rise building projects: F1: “construction workers’ safety”, F2: “construction workers’ expertise”, F3: “construction workers’ attitude”, F4: “overworking”, F5: “construction environment”, F6: “construction equipment”, F7: “poor workmanship”, and F8: “mishandling construction materials”. Furthermore, F8: “mishandling construction materials” was not included in the final structural equation model because it did not provide statistically significant results when testing the model hypotheses. Consequently, this study offers a platform to enhance safety management. The SEM model highlights weak relationships between two of the constructs towards safety performance (SP), that is, 0,01; this simply indicates a weak positive relationship and indicates that the constructs may not be strongly related. In addition, a path coefficient of 0,01 provides a basis for future investigations. This highlights the need for more nuanced models that explore other dimensions of constructs, such as contextual influences or additional mediators. It also provides guidelines for future research.

In the future, extensive and in-depth assessments should be conducted in other nations with diverse cultural backgrounds. These findings can be compared to achieve the optimal safety outcomes.

Based on the findings of this study, top management and clients should allocate a suitable number of resources towards ensuring the safety of high-rise building projects. This will help in managing and enhancing worker safety behaviour and overall safety performance. Similarly, policymakers should prioritise the promotion of safe workplace conduct among construction workers. Furthermore, it is imperative to enhance the safety culture and implement effective hazard control measures because they significantly contribute to the safe job performance of construction workers.

6.1 Managerial implications

The restructuring of the accidental safety factors will help stakeholders like project owners and contractors develop a "roadmap" for more effectively implementing safety management in high-rise building projects. A beneficial structure for the efficient transformation of construction participants across the stages of safety management may be developed using this reorganisation as a model. This will replace the region's outdated environment and lead to successful outcomes. Because economies are frequently linked to sustainable development, emerging nations must employ safety management to establish a balanced, safe environment. By avoiding problematic scenarios, the suggested "roadmap" will assist Malaysia in achieving its objective of creating a reliable, prosperous, and effective construction business. The "roadmap" developed in this study will also greatly encourage the implementation of safety management in other developing nations, where similar construction programs are carried out. This is crucial in developing nations, where there are many obstacles to overcome, such as the high expenses associated with addressing environmental issues. Safety management will thus provide these nations with the opportunity to successfully incorporate success into all building activity methods. However, this study will have a significant impact in the following ways, all of which have important implications for the construction industry.

It offers a database of safety accident factors and the outcomes that affect them so that their competitiveness and global market success can be assessed through the incorporation of safety management.

It helps decision makers in the construction industry assess and select safety management implementations to guarantee the planning, calibration, and consistency of construction projects.

It presents scientific evidence that could help developing countries in implementing safety management.

This research offers a critical tool that will aid decision-makers in the objective implementation of safety management. For the first time, a prediction process for SEM is proposed in this analysis to address safety management in high-rise building projects. Consequently, this strategy has the potential to be a game-changer in high-rise building projects, especially in developing countries.

The conclusions of this study also provide a roadmap or benchmark for reducing problems related to project execution including risky conditions, objectives, and death. This research also provides owners and employers with knowledge on how to include safety management to boost the effectiveness of their initiatives.

6.2 Theoretical implications

Although the concept of performance has been around for quite some time, it is becoming an increasingly important concept in a wide range of organisations. A precondition for accidental safety management implementation was identified by the suggested prioritisation model, particularly in the construction sector. This analysis describes an accident for the purpose of applying safety management using the provided model and will contribute to resolving difficulties in successfully implementing safety management in the construction sector, specifically in high-rise building projects. This study narrowed the gap between safety management execution and philosophy. However, to the best of the authors' knowledge, no research has been conducted to investigate the accident-related factors that affect safety management performance in high-rise building projects. This study empirically identified a crucial safety management accident that should be eliminated in the implementation of safety management by the construction industry. This finding paves the way for further investigation into the factors that influence safety management in developing nations, particularly in the area of construction management. To accomplish this, the theoretical aspects of this work offer a mathematical foundation for defining safety management accidents that may be used successfully in underdeveloped nations. Thus, this study offers a tool to aid internal authorities in objectively implementing safety management.

References

[1] Lakhiar, M. T.; Lakhiar, M. T.; Abdullah, A. H. Occupational Health and Safety Performance in High-rise Building Projects in Pakistan: A Systematic Literature Review. *Operational Research in Engineering Sciences: Theory and Applications*, 2021, 4 (1), pp. 99-114. https://doi.org/10.31181/oresta2040199l

[2] Dharek, M. S.; Deepak, G. B.; Sughosh, P.; Shalini, G. B. Crucial safety performance indicators in high rise buildings-case study of Bengaluru. *Materials Today: Proceedings*, 2023, In Press. https://doi.org/10.1016/j.matpr.2023.08.184

[3] Li, Y.; Ning, Y.; Chen, W. T. Critical success factors for safety management of high-rise building construction projects in China. *Advances in Civil Engineering*, 2018, 2018 (1), 1516354. https://doi.org/10.1155/2018/1516354

[4] Ansari, R.; Dehghani, P.; Mahdikhani, M.; Jeong, J. A Novel Safety Risk Assessment Based on Fuzzy Set Theory and Decision Methods in High-Rise Buildings. *Buildings*, 2022, 12 (12), 2126. https://doi.org/10.3390/buildings12122126

[5] Jabatan Keselamatan dan Kesihatan Pekerjaan. Accident Statistic. Accessed: May 7, 2025. Available at: https://www.dosh.gov.my/index.php

[6] Arifuddin, R.; Latief, R. U.; Suraji, A. An investigation of fall accident in a high-rise building project. *IOP Conference Series: Earth and Environmental Science*, 2020, 419, 012144. https://doi.org/10.1088/1755-1315/419/1/012144

[7] Mohammadi, A.; Tavakolan, M.; Khosravi, Y. Developing safety archetypes of construction industry at project level using system dynamics. *Journal of Safety Research*, 2018, 67, pp. 17-26. https://doi.org/10.1016/j.jsr.2018.09.010

[8] Tan, S.; Moinuddin, K. Systematic review of human and organizational risks for probabilistic risk analysis in high-rise buildings. *Reliability Engineering & System Safety*, 2019, 188, pp. 233-250. https://doi.org/10.1016/j.ress.2019.03.012

[9] Manzoor, B.; Othman, I.; Pomares, J. C. Digital Technologies in the Architecture, Engineering and Construction (AEC) Industry—A Bibliometric—Qualitative Literature Review of Research Activities. *International Journal of Environmental Research and Public Health*, 2021, 18 (11), 6135. https://doi.org/10.3390/ijerph18116135

[10] Ali, A.; Amin, M.; Husin, A. E. Key success factors for safety programs implementation in Indonesian construction projects. *International Journal of Civil Engineering and Technology (IJCIET)*, 2019, 10 (02), pp. 1385-1394.

[11] Zaini, N. Z. M. et al. Crane Accidents at Construction Sites in Malaysia. *IOP Conference Series: Earth and Environmental Science*, 2020, 498, 012105. https://doi.org/10.1088/1755-1315/498/1/012105

[12] Alaloul, W. S. et al. Structural equation modelling of construction project performance based on coordination factors. *Cogent Engineering*, 2020, 7 (1). https://doi.org/10.1080/23311916.2020.1726069

[13] Zahoor, H.; Chan, A. P. C.; Gao, R.; Utama, W. P. The factors contributing to construction accidents in Pakistan: Their prioritization using the Delphi technique. *Engineering, Construction and Architectural Management*, 2017, 24 (3), pp. 463-485. https://doi.org/10.1108/ECAM-01-2016-0027

[14] Kemei, R.; Nyerere, J. Occupational accident patterns and prevention measures in construction sites in Nairobi County Kenya. *American Journal of Civil Engineering*, 2016, 4 (5), pp. 254-263. https://doi.org/10.11648/j.ajce.20160405.17

[15] Gambatese, J. A.; Behm, M.; Rajendran, S. Design's role in construction accident causality and prevention: Perspectives from an expert panel. *Safety Science*, 2008, 46 (4), pp. 675-691. https://doi.org/10.1016/j.ssci.2007.06.010

[16] Choudhry, R. M.; Zahoor, H. Strengths and weaknesses of safety practices to improve safety performance in construction projects in Pakistan. *Journal of Professional Issues in Engineering Education and Practice*, 2016, 142 (4). https://doi.org/10.1061/(ASCE)EI.1943-5541.0000292

[17] Lu, M.; Cheung, C. M.; Li, H.; Hsu, S.-C. Understanding the relationship between safety investment and safety performance of construction projects through agent-based modeling. *Accident Analysis & Prevention*, 2016, 94, pp. 8-17. https://doi.org/10.1016/j.aap.2016.05.014

[18] Winge, S.; Albrechtsen, E.; Arnesen, J. A comparative analysis of safety management and safety performance in twelve construction projects. *Journal of Safety Research*, 2019, 71, pp. 139-152. https://doi.org/10.1016/j.jsr.2019.09.015

[19] Ng, S. T.; Cheng, K. P.; Skitmore, R. M. A framework for evaluating the safety performance of construction contractors. *Building and Environment*, 2005, 40 (10), pp. 1347-1355. https://doi.org/10.1016/j.buildenv.2004.11.025

[20] Yap, J. B. H.; Rou Chong, J.; Skitmore, M.; Lee, W. P. Rework causation that undermines safety performance during production in construction. *Journal of*

Construction Engineering and Management, 2020, 146 (9). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001902

[21] Trinh, M. T.; Feng, Y. Impact of project complexity on construction safety performance: Moderating role of resilient safety culture. *Journal of Construction Engineering and Management,* 2020, 146 (2). https://doi.org/10.1061/(ASCE)CO.1943-7862.0001758

[22] Sukamani, D.; Wang, J. SEM Model for Investigating Factor of an Accident Affecting Safety Performance in Construction Sites in Nepal. *Engineering Letters*, 2020, 28 (3).

[23] Buniya, M. K. et al. Safety Program Elements in the Construction Industry: The Case of Iraq. *International Journal of Environmental Research and Public Health*, 2021, 18 (2), 411. https://doi.org/10.3390/ijerph18020411

[24] Pallant, J. *SPSS Manual: A step by step guide to data analysis using SPSS for Windows*. 3rd Edition, USA: McGraw Hill/Open University Press, 2007.

[25] Chinda, T.; Mohamed, S. Structural equation model of construction safety culture. *Engineering, Construction and Architectural Management*, 2008, 15 (2), pp. 114-131. https://doi.org/10.1108/09699980810852655

[26] Manzoor, B., Othman, I.; Manzoor, M. Evaluating the critical safety factors causing accidents in high-rise building projects. *Ain Shams Engineering Journal*, 2021, 12 (3), pp. 2485-2492. https://doi.org/10.1016/j.asej.2020.11.025

[27] Wehbe, F.; Al Hattab, M.; Hamzeh, F. Exploring associations between resilience and construction safety performance in safety networks. *Safety Science*, 2016, 82, pp. 338-351. https://doi.org/10.1016/j.ssci.2015.10.006

[28] Nadhim, E. A. et al. Falls from Height in the Construction Industry: A Critical Review of the Scientific Literature. *International Journal of Environmental Research and Public Health*, 2016, 13 (7), 638. https://doi.org/10.3390/ijerph13070638

[29] Harahap, M. I. P.; Othman, I.; Dinata, N. A. M. Investigation on the Nature of Safety Rule Violations in High-Rise Construction Projects. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, 2024, 41 (2), pp. 164-179.

[30] Abas, N. H. et al. Factors Affecting Safety Performance of Construction Projects: A Literature Review. *IOP Conference Series: Materials Science and Engineering*, 2020, 713, 012036. https://doi.org/10.1088/1757-899X/713/1/012036

[31] Hiratkar, T.; Tiwary, A. An Innovative Methodology for Identification of Fall Hazards and Assessment of Risk at High-Rise Construction Site. *International Journal of Recent Engineering Science (IJRES)*, 2023, 10 (2), pp. 29-39. https://doi.org/10.14445/23497157/IJRES-V10I2P105

[32] Awolusi, I.; Marks, E.; Hainen, A.; Alzarrad, A. Incident Analysis and Prediction of Safety Performance on Construction Sites. *CivilEng*, 2022, 3 (3), pp. 669-686. https://doi.org/10.3390/civileng3030039

[33] Shao, B. et al. Fatal accident patterns of building construction activities in China. *Safety Science*, 2019, 111, pp. 253-263. https://doi.org/10.1016/j.ssci.2018.07.019

[34] Masood, R. et al. Investigation for safety performance indicators on construction projects. *Science International*, 2014, 26 (3), pp. 1403-1408.

[35] Ismail, Z.; Doostdar, S.; Harun, Z. Factors influencing the implementation of a safety management system for construction sites. *Safety Science*, 2012, 50 (3), pp. 418-423. https://doi.org/10.1016/j.ssci.2011.10.001

[36] Manzoor, B.; Othman, I.; Pomares, J. C.; Chong, H.-Y. A Research Framework of Mitigating Construction Accidents in High-Rise Building Projects via Integrating Building Information Modeling with Emerging Digital Technologies. *Applied Sciences*, 2021, 11, 8359. https://doi.org/10.3390/app11188359

[37] Manzoor, B.; Othman, I.; Waheed, A. Accidental safety factors and prevention techniques for high-rise building projects–A review. *Ain Shams Engineering Journal*, 2022, 13 (5), 101723. https://doi.org/10.1016/j.asej.2022.101723

[38] Moohialdin, A.; Lamari, F.; Marc, M.; Trigunarsyah, B. A Real-Time Computer Vision System for Workers' PPE and Posture Detection in Actual Construction Site Environment. In: *EASEC16 Proceedings of The 16th East Asian-Pacific Conference on*

Structural Engineering and Construction, Wang, C. M.; Dao, V.; Kitipornchai, S. (eds.). Brisbane, Australia, Springer; 2021, pp. 2169-2181.

[39] Osei-Asibey, D. et al. Stakeholders' Compliance with Existing Construction Health and Safety Related Laws and Regulations in Ghana. *Journal of Building Construction and Planning Research*, 2021, 9 (2), pp. 138-159. https://doi.org/10.4236/jbcpr.2021.92010

[40] Tam, C. M.; Zeng, S. X.; Deng, Z. M. Identifying elements of poor construction safety management in China. *Safety Science*, 2004, 42 (7), pp. 569-586. https://doi.org/10.1016/j.ssci.2003.09.001

[41] Choudhry, R. M.; Fang, D.; Lingard, H. Measuring safety climate of a construction company. *Journal of Construction Engineering and Management*, 2009, 135 (9), pp. 890-899. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000063

[42] Lyu, S. et al. An exploratory study of safety communication networks of ethnic minority crews in the Hong Kong construction industry. *Engineering, Construction and Architectural Management*, 2020, 28 (4), pp. 1156-1175. https://doi.org/10.1108/ECAM-07-2019-0368

[43] Mosly, I. Factors influencing safety performance in the construction industry of Saudi Arabia: an exploratory factor analysis. *International Journal of Occupational Safety and Ergonomics*, 2020, 28 (2), pp. 901-908. https://doi.org/10.1080/10803548.2020.1838774

[44] Abu Aisheh, Y. I.; Alaloul, W. S.; Alhammadi, S. A.; Tayeh, B. A. Safety management implementation drivers for construction projects: a structural equation modelling approach. *International Journal of Occupational Safety and Ergonomics*, 2003, 29 (4), pp. 1358-1367. https://doi.org/10.1080/10803548.2022.2131123

[45] Delpachitra, Y.; Allis, C. Mitigation Practices for Frequent Accidents in High Rise Building Construction. In: *Proceedings of the SLIIT International Conference On Engineering and Technology, Vol. 01*. February 9-11, 2022, Malabe, Sri Lanka; 2022, pp. 91-102.

[46] Sofwan, N. M.; Zaini, A. A.; Mahayuddin, S. A. Preliminary study on the identification of safety risks factors in the high rise building construction. *Jurnal Teknologi (Sciences & Engineering)*, 2016, 78 (5-3), pp. 13-18.

[47] Williams, O. S.; Hamid, R. A.; Misnan, M. S. Analysis of Fatal Building Construction Accidents: Cases and Causes, *Journal of Multidisciplinary Engineering Science and Technology (JMEST)*, 2017, 4 (8), pp. 8030-8040.

[48] Upadhyaya, D.; Malek, M. S. An exploratory factor analysis approach to investigate health and safety factors in Indian construction sector. *Construction Economics and Building*, 2024, 24 (1-2), pp. 29-49.

[49] Ali, A.H. et al. A hybrid model for assessing safety implementation and project success in the construction industry. *Alexandria Engineering Journal*, 2024, 105, pp. 626-639. https://doi.org/10.1016/j.aej.2024.08.040

[50] Thai, H.-T.; Ngo, T.; Uy, B. A review on modular construction for high-rise buildings. *Structures*, 2020, 28, pp. 1265-1290. https://doi.org/10.1016/j.istruc.2020.09.070

[51] Nguyen, V. T. et al. An Analysis of Construction Failure Factors to Stakeholder Coordinating Performance in the Finishing Phase of High-Rise Building Projects. *Advances in Civil Engineering*, 2020, 2020 (1), 6633958. https://doi.org/10.1155/2020/6633958

[52] Zeibak-Shini, R.; Malka, H.; Kima, O.; Shohet, I. M. Analytical Hierarchy Process for Construction Safety Management and Resource Allocation. *Applied Sciences*, 2024, 14 (20), 9265. https://doi.org/10.3390/app14209265

[53] Ali, A. H.; Kineber, A. F. Unveiling and modelling the impact of safety drivers on the overall success of construction projects in developing countries. *International Journal of Construction Management*, 2024, pp. 1-23. https://doi.org/10.1080/15623599.2024.2417562

[54] Wu, X. et al. Prospective safety performance evaluation on construction sites. *Accident Analysis & Prevention*, 2015, 78, pp. 58-72. https://doi.org/10.1016/j.aap.2015.02.003

[55] Wong, P. S. P.; Cheung, S. O. Structural equation model of trust and partnering success. *Journal of Management in Engineering*, 2005, 21 (2), pp. 70-80. https://doi.org/10.1061/(ASCE)0742-597X(2005)21:2(70)
[56] Byrne, B. M. *Structural Equation Modeling with Mplus: Basic Concepts, Applications, and Programming*. 1st Edition, USA: Routledge; 2012.
[57] Thompson, B. Ten commandments of structural equation modeling. In: *Reading and understanding MORE multivariate statistics*, Grimm, L. G.; Yarnold. P. R. (eds.). USA: American Psychological Association; 2000, pp. 261-283.
[58] Shrafat, F. D.; Ismail, M. Structural equation modeling of lean manufacturing practices in a developing country context. *Journal of Manufacturing Technology Management*, 30 (1), pp. 122-145. https://doi.org/10.1108/JMTM-08-2017-0159
[59] Zhang, L.; Liu, Q.; Wu, X.; Skibniewski, M. J. Perceiving interactions on construction safety behaviors: Workers' perspective. *Journal of Management in Engineering*, 2016, 32 (5), 4016012. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000454