Journal of Mechanical, Civil and Industrial Engineering
ISSN: 2710-1436
DOI: 10.32996/jmcie
Journal Homepage: www.al-kindipublisher.com/index.php/jmcie

JMCIE
AL-KINDI CENTER FOR RESEARCH AND DEVELOPMENT

| RESEARCH ARTICLE

Safety Analysis of Construction Projects in Kabul Using the FMEA Method with a Worker Behavioral–Psychological Approach

Mohammad Ali Qazi Zada[1], MOHAMMAD ARIF KOSHYAR[2] ✉ and AHMAD JAWEED TAFAKUR[3]
[1]Under graduate student in Civil and Industrial Department, Kabul Polytechnic University, Kabul-Afghanistan
[23]Assistant Professor in Civil and Industrial Department, Kabul Polytechnic University, Kabul-Afghanistan
Corresponding Author: MOHAMMAD ARIF KOSHYAR, **E-mail**: arifkoshyar@kpu.edu.af and koshyar1363@gmail.com

| ABSTRACT
Construction safety in developing countries such as Afghanistan is a major concern due to weak regulations and cultural influences that significantly increase risks. This field-based study employed the Failure Modes and Effects Analysis (FMEA) method to identify hazards, with particular emphasis on both technical and behavioral aspects.An analytical investigation was conducted across ten construction projects, including governmental, residential, and commercial buildings, to identify, assess, and prioritize hazards. Initially, the primary risk factors within the projects were identified. For each hazard, three parameters—severity, occurrence probability, and detectability—were determined. Subsequently, prioritization criteria were applied, and hazards were ranked based on the Risk Priority Number (RPN).The findings revealed that the highest RPN value (560) was associated with work at heights. Contributing factors included discomfort caused by personal protective equipment (PPE), lack of safety harnesses, rushing, and a culture of indifference, along with managerial negligence driven by cost reduction and underestimation of worker health. Conversely, the lowest RPN value (180) was linked to disregard for PPE, stemming from weak work culture, lack of incentive and penalty systems, and insufficient training. The results also highlighted significant risks posed by crane operations, temporary electrical work, and the absence of a reporting culture. The RPN findings suggest that Afghan authorities should implement supervisory controls, enforce regulations, provide crane operation training, ensure the use of PPE, and strengthen the reporting culture to mitigate critical hazards and enhance the culture of construction safety in Kabul.

| KEYWORDS

Construction Safety, FMEA, RPN, PPE, Kabul.

| ARTICLE INFORMATION

ACCEPTED: 01 October 2025 **PUBLISHED:** 20 October 2025 **DOI:** 10.32996/jmcie.2025.6.4.1

1. Introduction

Construction safety remains one of the most pressing global challenges, particularly in developing countries such as Afghanistan, where rapid urban growth, weak legal oversight, and cultural perspectives exacerbate workplace hazards (International Labour Organization [ILO], 2021, 2022). Kabul, the capital of Afghanistan, has experienced a significant increase in infrastructure and construction projects over the past two decades due to population growth, urban renewal efforts, and international investments (Afghanistan National Development Strategy [ANDS], 2020). However, these projects have been accompanied by safety incidents, including falls from heights, crane accidents, fires, and electrocutions (Behm, 2005). According to the International Labour Organization (ILO, 2021), the construction industry is among the most hazardous sectors globally, accounting for nearly 30% of work-related fatalities. In Afghanistan, particularly in Kabul, this risk is intensified by weak enforcement of safety standards, insufficient protective equipment, and the absence of a safety-oriented culture among workers and managers (Choudhry, 2009; Mearns, Whitaker, & Flin, 2003; Choudhry & Fang, 2008).

While technical aspects of construction safety, such as equipment design, scaffold stability, and access to protective devices, are well recognized, psychological and behavioral factors also play a critical but less studied role (Zou & Sunindijo, 2014; Wu et al., 2022). Workplace vulnerability is influenced by workers' perception of risk, peer pressure, fatigue, cultural beliefs, and managerial attitudes toward safety, all of which shape actual compliance with safety practices (Hinze & Gambatese, 2003; Hinze, 1997; Gibb, 2003). Studies have shown that even when personal protective equipment (PPE) is available, workers may refrain from using it due to discomfort, peer ridicule, or time pressure (Lingard & Rowlinson, 2005; Abdelhamid & Everett, 2000). Likewise, managers often tend not to allocate resources for safety, which frequently leads to cost reduction, productivity pressures, and systemic hazards (Stamatis, 2003). These behavioral and managerial dimensions highlight the need for integrated safety assessment methods that incorporate both technical and human factors (Albasyouni, Abotaleb, & Nassar, 2023).

Failure Modes and Effects Analysis (FMEA) has proven to be a powerful tool for identifying, analyzing, and prioritizing hazards in construction projects (Song & Kim, 2007; Rajput & Jha, 2018; Abreu, 2019; Ahmed & Azhar, 2017). Originally developed in industries such as aerospace, military, and automotive, FMEA provides a systematic approach to risk assessment, enabling the identification of critical hazards through the calculation of the Risk Priority Number (RPN), which considers severity (S), occurrence (O), and detectability (D) (Albasyouni, Abotaleb, & Nassar, 2023; Mohamed, 2002). Although FMEA has predominantly been applied in engineering domains, its application in construction—particularly emphasizing psychological and behavioral factors—remains limited, especially in developing countries (Abreu, 2019; Ahmed & Azhar, 2017). In Kabul's construction projects, where technical and non-technical hazards coexist, FMEA offers a robust framework to address these gaps.

Therefore, this study applies FMEA to construction projects in Kabul to systematically assess both technical and behavioral hazards, thereby addressing an important gap in the literature and contributing to improved construction safety practices in developing contexts.

2. Literature Review

A recent field study on ten construction projects, including governmental, residential, and commercial sites, revealed that hazards such as working at heights, weak managerial supervision, and crane operations are among the most critical safety risks. The data revealed that falls from scaffolds and platforms (RPN = 560) represented the highest risk, followed by weak managerial supervision (RPN = 420) and crane operations (RPN = 378). This suggests the dual impact of technical deficiencies (e.g., lack of guardrails or unqualified crane operators) and behavioral issues (e.g., rushing, negligence, distrust of PPE, and overconfidence) on increasing risk levels.

The importance of psychological and behavioral dimensions is further highlighted when examining factors that increase occurrence and reduce detectability of hazards. For instance, peer pressure and ridicule may prevent workers from using PPE, while managerial negligence creates an environment in which near-misses go unreported due to fear of consequences (Cooper, 2001; Flin, Mearns, O'Connor, & Bryden, 2000). Hazard occurrence is particularly high on Kabul construction sites, where informal labor and hierarchical structures are predominant (Clarke, 2006). Therefore, integrating safety and behavioral strategies—such as engineer supervision, visual and narrative-based training, incentive mechanisms for PPE compliance, and technical interventions like electrical lockout systems and guardrails—is deemed essential (Reader & O'Connor, 2013; Sunindijo & Zou, 2013).

Multiple global studies have shown that determinants for reducing construction accidents include safety culture, leadership commitment, and worker participation (Zou & Sunindijo, 2014; Alkilani, Jupp, & Sawhney, 2013). For example, projects in China and India with strong safety culture systems and managerial commitment reported significantly fewer accidents (Zou & Sunindijo, 2014; Kheni, Gibb, & Dainty, 2008). Similarly, studies in the Middle East emphasize the role of migrant worker psychology, cultural barriers, and limited supervision in influencing accident rates (Hale, Borys, & Else, 2012; Glendon & Stanton, 2000). Applying these insights to Kabul reveals that any sustainable safety strategy must combine technical controls with psychological and behavioral interventions.

Field observations in Kabul indicate that severity levels (S, mean ≈ 8.6) remain consistently high across most hazards, suggesting that potential incidents often have fatal or near-fatal consequences. Therefore, reducing RPN requires a focus on occurrence (O) and detectability (D). Factors increasing occurrence include time pressure, overconfidence, and PPE discomfort, while fear of punishment, insufficient reporting systems, and weak supervision reduce detectability (Zohar, 2010; Molenaar, Park, & Washington, 2009). Effective approaches, consistent with international studies, suggest behavioral safety programs that encourage open reporting, reward safe behaviors, and reduce negative labeling (Seo, Lee, Kim, & Jee, 2002).

This study contributes to the existing knowledge on construction safety by demonstrating the applicability of FMEA in Kabul's construction industry, with a particular focus on often-overlooked psychological and behavioral factors. By analyzing a diverse set of projects, this research covers a wide spectrum of hazards and cultural variability. The findings not only inform local stakeholders, such as contractors, government regulatory agencies, and international development organizations, but also contribute to the global body of literature on construction safety in developing regions.

3. Methodology

The present study employs a field-based and statistical research design to assess safety hazards in construction projects in Kabul, Afghanistan, with an emphasis on both technical and psychological/behavioral factors among workers. One of the main methods used in this research is Failure Modes and Effects Analysis (FMEA), which systematically identifies hazards, evaluates their potential consequences, and prioritizes them based on quantitative criteria.

The study was conducted on ten buildings, including four governmental projects, four residential projects, and two commercial projects. The FMEA form was completed for each building, and a sample of a completed form is presented in Table 1.

Table 1: Risk Priority Number (RPN) for each type of hazard in the buildings

No.	Building Type	Work Location	Failure Mode	Consequence	Causes	S	O	D	RPN	Corrective Actions	Action Level
1	All	Working at height	Not using harness / incomplete guardrail	Fall – serious injury/death	Lack of harness, rushing, careless safety culture	10	8	7	560	Proper harness, complete guardrail, daily training, checklist	Very Critical
2	All	Management	Lack of supervision and support	Increased overall risks	Budget saving, undervaluing safety	10	6	7	420	Allocate budget for safety leadership training for managers	Very Critical
3	Commercial / Government	Crane/Lift	Improper loading	Falling load – serious injury/death	Untrained operator, unbalanced load	9	7	6	378	Operator training, load labeling, checklist	High Risk
4	Commercial / Government	Temporary electricity	Exposed/badly connected cables	Electrocution – burn/death	Temporary wiring, poor maintenance	9	7	6	378	Rewiring, proper insulation, regular inspection	High Risk
5	All	Reporting culture	Hidden errors	Serious future incident	Fear of blame	9	5	8	360	Non-punitive reporting system (Just Culture)	High Risk
6	All	Working conditions	Fatigue and stress	Injury/fall	Overtime, mental fatigue	7	8	6	336	Regular shifts, mental health counseling	High Risk
7	All	Welding/ Hot Work	Welding without protection	Fire, severe burns	No protection, flammable materials	8	6	5	240	Work area isolation, fire extinguisher, training	Medium

8	Residential/ Commercial	Scaffolding/ Ladders	Improper use	Fall – injury	Worn ladder, improper installation	7	6	5	210	Scaffold inspection, ladder training, safety tagging	Mediu m

The study population consisted of 40 individuals, including construction workers and site engineers. To ensure representation of different project types, purposive sampling was employed. Participants directly involved in technical operations and managerial actions were included to provide a comprehensive assessment of safety hazards. Participants' age and work experience were also recorded as part of the data collection process Table 2.

Table 2: Age and work experience of the participants in the study

Age	**20–30 years**	**30–40 years**	**More than 40 years**
Number of participants	10	17	13
Work Experience	**Less than 10 years**	**10–20 years**	**More than 20 years**
Number of participants	8	22	10

Step 1: Hazard Severity Assessment

The FMEA technique was implemented through a series of steps. First, hazard severity was determined based on participants' awareness of hazards and their potential consequences. Hazards were classified according to severity levels as shown in Table 3 (Hallowell & Gambatese, 2010; Hallowell, 2010).

Table 3: Ranking of hazards based on severity of consequences

No.	**Severity of Effect**	**Construction Examples**
1	No significant effect; superficial scratch	Minor scratch
2	Very slight injury; simple first aid	Small cut, eye irritation
3	Minor injury; work stoppage < 1 day	Mild sprain, superficial burn
4	Moderate injury; work stoppage 1–3 days	Minor fracture (e.g., finger)
5	Significant injury; work stoppage 3–7 days	Injury requiring a few stitches
6	Serious non-fatal injury; short hospitalization	Second-degree burn
7	Very serious injury; partial disability	Partial amputation (e.g., finger)
8	Risk of death/permanent disability of one person	Fall from moderate height (2–3 m)
9	Death or permanent disability of several people	Fire in section of the building
10	Public/organizational catastrophe	Fall from great height, large explosion

Step 2: Likelihood of Occurrence

The probability of occurrence for each hazard was determined using Table 4. To obtain a more accurate evaluation, face-to-face interviews were conducted with relevant engineers and workers (Behm, 2005; Hallowell & Gambatese, 2009).

Table 4: Ranking of hazards based on likelihood of occurrence

No.	**Probability Level**	**Psychological/Behavioral Factors (Construction Examples)**
1	Almost impossible	High awareness, strong safety culture
2	Very rare	Awareness + good supervision
3	Rare	Regular safety meetings, intrinsic motivation
4	Low	Reluctant acceptance of PPE
5	Medium to low	Manageable time pressure
6	Medium	Occasional fatigue/boredom (e.g., dropping a tool from hand)
7	High	Obligation-driven rather than ownership-driven
8	Very high	Ridiculing PPE use, normalizing unsafe behaviors
9	Extremely high	Lack of training/resources, unawareness of hazards (e.g., working at height without a safety belt)
10	Permanent	General indifference, absence of effective supervision

Step 3: Hazard Detectability Evaluation

The system's ability to detect the cause or mechanism of a hazard was examined, and the detectability rank for each hazard was assigned based on Table 5 (Albasyouni, Abotaleb, & Nassar, 2023; Dhillon, 2004).

Table 5: Ranking of hazards based on likelihood of detection (traceability)

No.	Detection Level	Psychological/Behavioral Factors (Construction Examples)
1	Very easy to detect	Positive reporting culture
2	Highly detectable	Proactive safety observers
3	Relatively detectable	Immediate constructive feedback
4	Normally detectable	Behavioral reminders (e.g., a colleague's warning on site)
5	Medium	Average motivation
6	Relatively hard to detect	Group inaction (everyone notices but remains silent)
7	Hard to detect	Underreporting (minor incidents not reported)
8	Very hard to detect	Distraction (e.g., when operating a crane or cutting machine)
9	Extremely hard to detect	Lack of trust in management
10	Almost undetectable	Blame culture (fear of punishment prevents reporting)

Step 4: Risk Priority Number (RPN) Assignment

In the FMEA method, the Risk Priority Number is calculated by multiplying severity, occurrence probability, and detectability scores. Each factor is rated on a scale from 1 to 10, resulting in an RPN range of 1–1000. Higher RPN values indicate more severe hazards with significant consequences. If at least one factor scores above 6, preventive measures are recommended; if at least two factors exceed 6, immediate corrective actions are necessary (Huang & Hinze, 2006; Ghosh & Jintanapakanont, 2004).

Step 5: Corrective Actions Implementation

Practical measures to mitigate or eliminate hazards were recorded in the FMEA form. These corrective actions were determined based on the researcher's knowledge, legal requirements, and hazard prioritization. Implementation focused on construction management and site supervision, addressing equipment deficiencies and other safety issues. The types of hazards observed across the buildings are presented in Table 6, including cases such as work at heights, managerial negligence, and crane/lifting operations, along with their corresponding RPN values determined using this methodology (Mitropoulos & Cupido, 2009; Kartam & Bouz, 1998) (Figure 1).

Figure 1 Field observation of unsafe work at height during concrete casting in Kabul, used as evidence in the FMEA process.

Table 6: Types of hazards in the buildings

No.	Type of Hazard
1	Working at heights (scaffolding/platforms)
2	Management negligence / weak safety governance
3	Crane and lift operations
4	Electricity (risk of electrocution)
5	Falling objects
6	Fire hazard

4. Results

The FMEA method (Failure Modes and Effects Analysis) was applied in the context of construction safety to examine potential hazards that workers and managers may encounter. In this approach, each hazard is quantified using the Risk Priority Number (RPN), which is derived from the combination of three factors: 1. the likelihood of hazard occurrence, 2. the severity of its consequences, and 3. the detectability or difficulty of identifying it. This allows hazards to be systematically identified and prioritized, enabling safety officers to make informed decisions on which areas require immediate intervention and which preventive measures should be implemented to reduce accidents.

Among the analyzed hazards, three exhibited the highest RPN values, indicating the need for urgent risk mitigation policies. Working at heights received the highest RPN of 560, making it the most critical concern in construction sites. This high score emphasizes the severe potential consequences of falls, which, if protective measures such as safety harnesses and guardrails are not properly enforced, could result in serious injury or even death. The next critical hazard was managerial negligence/oversight with an RPN of 420, highlighting that insufficient supervision, failure to implement safety procedures, and delayed decision-making substantially increase accident likelihood. Finally, crane operations and lifting activities were identified with an RPN of 378, reflecting the inherent risks associated with handling heavy loads and operating complex machinery, where technical errors, human slips, or lack of coordination among workers or managers can lead to incidents.

These three primary hazards demonstrate that construction safety cannot be achieved by focusing on a single factor; rather, optimal outcomes require the integration of both technical and human factors. Risk reduction must simultaneously address strong managerial oversight, adherence to operational protocols, and compliance by workers. Figure 2 illustrates the distribution of RPN values for these hazards, providing a visual representation of their relative severity and priority. By systematically addressing technical and behavioral factors, construction projects can achieve more comprehensive safety management and reduce the overall likelihood of workplace incidents.

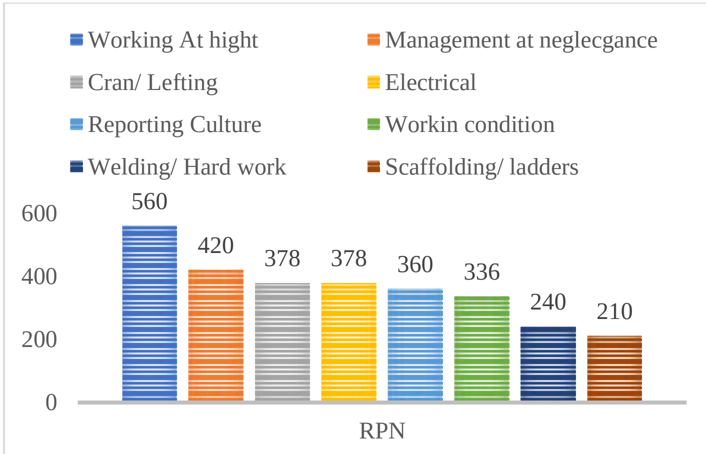

Figure 2: Working at height, management negligence, and crane/lifting are the top-ranked risks by RPN.

Working at heights received the highest risk score in the FMEA evaluation, with the maximum severity (10). This indicates that associated incidents can result in very serious injuries or fatalities, making it the primary concern in construction safety. This hazard arises from a combination of technical, behavioral, and managerial factors, all contributing to the probability and consequences of incidents.

Several key factors contributed to this high RPN: First, the availability and proper use of personal protective equipment (PPE) were often inadequate. In some cases, PPE was unavailable, poorly maintained, or unsuitable for the task, reducing its effectiveness in preventing injuries. Second, improper fitting of safety harnesses was frequently observed, compromising fall protection systems and substantially increasing injury risk. Third, tight project schedules and deadlines forced workers to prioritize speed over safety, leading to neglect of safety protocols. Finally, non-compliance with safety regulations—by both workers and management—reflects gaps in training and supervision.

These factors indicate that the hazard of working at heights is not solely a technical issue but is also influenced by worker and management behavior. Risk reduction requires a comprehensive approach, including proper equipment, sufficient training, continuous supervision, and strict enforcement of safety regulations. Figure 3 presents an example of an unsafe scaffold, highlighting the consequences of inadequate protection and the importance of simultaneously addressing technical and behavioral aspects.

Figure 3: Unsafe scaffolding work at height without proper fall protection

FMEA evaluation also identified managerial negligence as one of the most influential factors in construction hazards, with an RPN of 420. This underscores the significant role of management decisions and practices in safety outcomes. Key reasons include excessive focus on cost reduction, which often leads management to prioritize financial savings over safety. This approach results in insufficient investment in PPE, the use of worn-out tools, and inadequate inspections, creating serious risks for workers and ultimately increasing accidents and injuries. Additionally, limited attention to worker health can lead to neglect of critical aspects such as health monitoring, fatigue management, and regular training. Another major factor is weak managerial accountability, which delays responses to safety incidents. Supervisors often fail to enforce protocols effectively, allowing unsafe practices to persist. This demonstrates that even well-designed systems can pose serious risks if managerial oversight is inadequate.

Crane operations and lifting tasks were identified as serious hazards with an RPN of 378. This score reflects the risks associated with moving heavy loads and operating lifting machinery in confined or high-traffic areas. Three primary causes were identified: 1) operator inexperience and insufficient training, where inexperienced operators may make errors in controlling heavy equipment; 2) poor signaling and communication, where unclear instructions between operators and ground personnel can result in confusion and unsafe maneuvers; 3) unsafe load management practices, including overloading cranes or improper securing of suspended materials, which can be hazardous. These factors significantly increase the likelihood of serious or even fatal incidents.

In addition to the three main hazards, the analysis indicated other factors affecting construction safety. These include electrical hazards (e.g., faulty wiring or inadequate insulation), falling objects (from scaffolds or during load lifting), and fire hazards (from flammable materials and poor emergency planning). These findings highlight the diversity of risks present in construction and the need for a comprehensive safety program that addresses not only technical and operational aspects but also leadership, supervision, and regulatory enforcement.

Figure 4 illustrates an example of hazardous lifting work on a rooftop, where workers are positioned close to a suspended load without maintaining a safe distance. This image demonstrates how insufficient managerial attention to safety protocols and work organization increases the risks identified in the FMEA analysis.

Figure 4: Unsafe rooftop lifting operation, where workers stand close to suspended loads without proper safety distance.

FMEA results provide an overall picture of building hazards, showing how severity, occurrence, and detectability interact. Data indicate that hazard severity is generally high, with a mean of approximately 8.6, suggesting that most identified hazards can cause serious injuries if uncontrolled, emphasizing the need for preventive measures. Occurrence values averaged 6.6, indicating that workers frequently encounter these hazards. This shows that some risks are not rare but occur repeatedly and accumulate over time, increasing their likelihood without adequate preventive measures. Therefore, regular safety inspections, hazard identification, and continuous monitoring are necessary. Detectability averaged 6.25, indicating that while some hazards can be identified and addressed before incidents occur, many risks may still be overlooked due to insufficient supervision, underreporting of near-misses, and lack of training. This combination of high severity, relatively high occurrence, and limited detectability highlights critical points requiring intervention, helping construction managers prioritize safety improvements.

Figure 5 summarizes the risk parameters in a chart, emphasizing the interplay between hazard severity, occurrence, and detectability. The figure shows that severe hazards, even with moderate occurrence and low detectability, require special attention from management and field teams. Systematic handling of these factors enables projects to establish a balanced and effective safety management mechanism and reduce the likelihood of occupational accidents. These results form the basis for developing effective risk mitigation strategies, including technical controls, behavioral interventions, and improved monitoring systems, to create a safer working environment for all personnel.

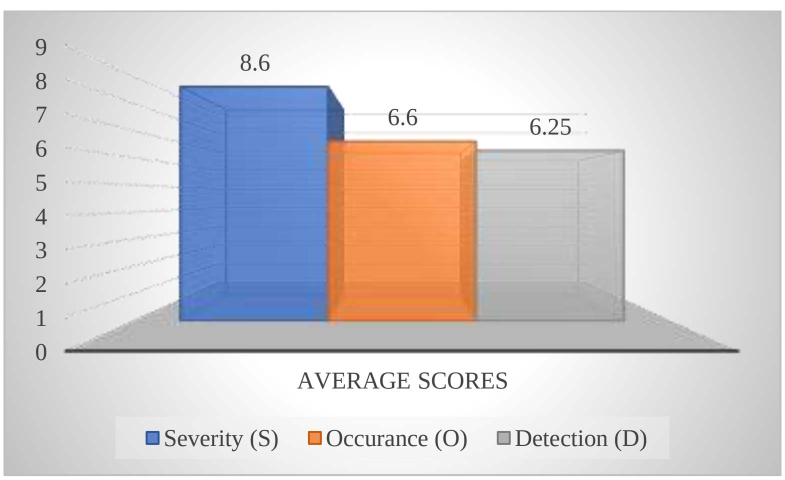

Figure 5: Overall risk profile showing severity as the main contributor to RPN values.

FMEA analysis demonstrated that building hazards were well-classified and could be categorized according to their underlying causes, including technical factors, human behavior, and a combination of both. This classification allows safety experts to better understand hazard severity and the contributing factors. Among the identified factors, technical issues had the greatest impact, with an RPN of 966, indicating that deficiencies in equipment, machinery, and construction processes are the primary hazards in the construction industry. These results highlight the need for effective engineering controls, regular machinery maintenance, and strict adherence to technical procedures.

Behavioral factors, such as worker adherence to safety protocols and compliance with operational methods, obtained an RPN of 780, indicating that human behavior is crucial in construction safety. Even technically well-designed systems can present risks if workers do not prioritize safety or follow regulations. Combined technical and behavioral deficiencies received an RPN of 560, illustrating that when human errors coincide with technical shortcomings, they create significant additional risks that cannot be ignored. Additionally, some unspecified hazards were identified with an RPN of 576; these hazards are not easily detectable and usually arise from insufficient information or complex interactions among different factors. Overall, technical factors were the most prevalent, followed by behavioral and combined causes. Figure 6 visually depicts this risk distribution, highlighting the dominance of technical factors, followed by behavioral and combined causes.

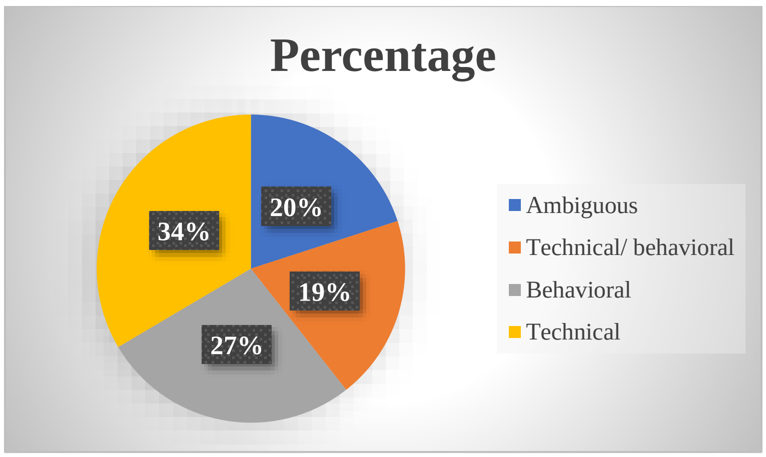

Figure 6: Risk distribution shows technical factors dominant, followed by behavioral and combined causes.

These findings indicate that risk reduction requires attention to all aspects: technology and equipment, worker behavior, and clear procedures. If construction managers address these three areas simultaneously, they can make more informed decisions on where interventions are necessary to minimize hazards. This approach not only improves workplace safety but also reduces the likelihood of incidents throughout the project.

FMEA results analysis shows that hazard occurrence (O) on construction sites is strongly influenced by organizational and behavioral factors. One significant factor is pressure from tight project deadlines, which forces workers to accelerate their tasks to meet schedules. This urgency increases the likelihood of errors and indicates that time pressure is a key contributor to hazards.

Another critical factor increasing site hazards is discomfort from PPE. If protective equipment such as helmets, gloves, or workwear is unsuitable, heavy, or uncomfortable, workers may be reluctant to wear them consistently, reducing protection and increasing the probability of accidents. Overconfidence among some experienced workers was also noted, leading them to underestimate risks and disregard safety instructions, potentially resulting in unintended incidents. These factors demonstrate that hazards are not solely technical issues but are also influenced by human behavior, organizational culture, and work environment conditions. Therefore, effective managerial practices are required for risk reduction.

Regarding hazard detectability (D), several barriers prevent effective identification and control before incidents occur. A major challenge is underreporting; due to cultural norms or fear of negative consequences, workers often do not report near-misses or unsafe behaviors. This fear of blame reduces transparency and limits the sharing of lessons learned among team members. In addition, insufficient supervision exacerbates these challenges, allowing hazards to remain unaddressed.

Figure 7 illustrates how most hazards arise from tight deadlines, work habits, and worker behavior, whereas detectability is limited due to weak reporting culture, fear of blame, and inadequate managerial oversight. These findings emphasize the importance of strengthening safety culture, empowering workers to report hazards, and improving supervision. By simultaneously addressing organizational and behavioral factors that affect hazard occurrence and detectability, managers can better identify risks and implement corrective actions in a timely manner, thereby reducing both the probability and severity of workplace incidents.

Figure 7: Occurrence driven by deadlines and habits; detection hindered by weak reporting culture

5. Discussion

The FMEA analysis conducted in this study provides an important understanding of the multidimensional aspects of construction site safety. While the Results section focused on quantifying risks and identifying their sources, the Discussion contextualizes these findings with existing research, examines their practical significance, and suggests areas for improvement. This section interprets high-risk areas such as working at heights, managerial negligence, and crane operations, situating them within the global discourse on construction safety.

Working at heights received the highest Risk Priority Number (RPN = 560). This finding aligns with global statistics that identify falls from heights as one of the leading causes of fatalities in the construction industry (U.S. Bureau of Labor Statistics, 2024; International Labour Organization [ILO], 2021). According to Hinze and Gambatese (2003), such incidents occur not only due to inadequate safety measures but also due to workers' reluctance to properly use personal protective equipment (PPE). The present study confirms this perspective, showing that discomfort from harness use and a cultural disregard for PPE contribute as significantly as technical deficiencies to the occurrence of these incidents.

Managerial negligence and oversight were identified as the second highest risk (RPN = 420). This indicates that poor leadership can exacerbate other hazards. This finding is consistent with Zohar's foundational research on the "safety climate" (Zohar, 1980), which shows that when supervisors prioritize safety, workers are more likely to adhere to safety practices. The results indicate that safety is not merely about accident prevention but also requires the presence of supportive mechanisms and effective management (Christian, Bradley, Wallace, & Burke, 2009; Neal & Griffin, 2006).

The third critical risk pertains to crane operations and lifting activities, with an RPN of 378. This highlights the need for careful attention to operator skill and equipment reliability. Previous studies have shown that crane-related incidents often result from human error, inadequate signaling, and insufficient training (Abudayyeh, Fredericks, Butt, & Shaar, 2006; Beavers, Moore, Rinehart, & Schriver, 2006). In this study, it is recommended to implement Permit-to-Work (PTW) systems, assign trained supervisors, and address psychological tendencies such as overconfidence among operators to mitigate these vulnerabilities (Occupational Safety and Health Administration [OSHA], 2010; California FACE [NIOSH], 2000).

A key finding of the FMEA analysis is the distribution of RPN scores among technical, behavioral, and combined factors, which were 966, 780, and 560, respectively. This raises the recurring question of whether accident prevention should focus more on engineering solutions or on behavioral and cultural practices? (CPWR – The Center for Construction Research and Training, 2013; Muñoz-La Rivera, Mora-Serrano, & Oñate, 2021). Figure 8 visually illustrates how technical, behavioral, and managerial factors interact to reduce RPN scores. In other words, both technical and behavioral aspects are critical in construction safety and must be addressed simultaneously.

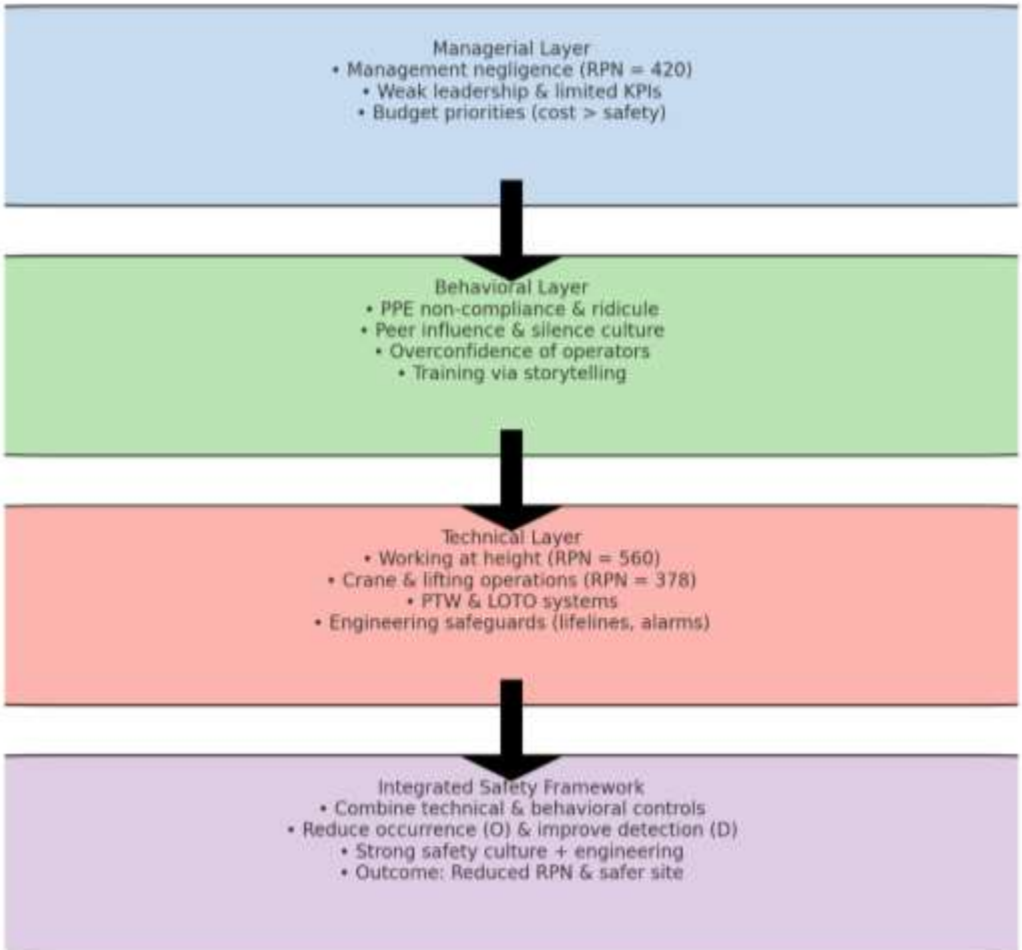

Figure 8: . Layered schematic of managerial, behavioral, and technical safety factors leading to an integrated framework for reducing RPN.

According to Reason's "Swiss Cheese" model (Reason, 1997), accidents typically result from latent system weaknesses (e.g., faulty equipment or budget constraints) and active errors (e.g., unsafe behaviors and negligence). The current findings strongly support this notion. Even when technical hazards are mitigated, factors such as haste, disregard for PPE, and a culture of silence continue to contribute to increased RPN (de Mattos, Rocha, & de Castro Moura Duarte, 2024).

These results indicate that focusing solely on technology is insufficient. Ignoring human factors can lead organizations to a "safety paradox," wherein advanced technology creates a false sense of security, prompting riskier behaviors (Hale & Borys, 2013; Wilde, 2001). High severity ($S \approx 8.6$) is expected in construction due to the inherently hazardous nature of the work, but focusing only on severity is insufficient. Instead, risk reduction requires addressing both the probability of occurrence ($O \approx 6.6$) and hazard detectability ($D \approx 6.25$).

- **Occurrence (O):** In construction, hazard occurrence is strongly influenced by time pressure and organizational culture. Fang and Wu (2011) demonstrated that high time pressure increases the likelihood of unsafe actions, a finding consistent with other studies identifying haste as a major accident factor (Zhang, Wu, & Feng, 2015; Mohandes, Marzouk, & El-Said, 2022).
- **Detectability (D):** Detectability remains low because incidents are often underreported due to fear of blame. This reflects a lack of "psychological safety," where workers do not feel secure in reporting issues without negative consequences (Edmondson, 1999, 2018). The use of anonymous reporting channels and a "no-blame" policy can address this gap (Dong, Wang, & Liu, 2013).

Therefore, safety improvement strategies should focus on both reducing the likelihood of incidents (O) and enhancing hazard detection (D). This includes mitigating environmental pressures that lead to unsafe behaviors and establishing systems capable of identifying hazards before accidents occur.

The high RPN associated with managerial negligence underscores the critical importance of management commitment, which has been shown to significantly impact safety performance (Beavers et al., 2006; Toole, 2002). When financial savings are prioritized over worker safety, the entire safety system is compromised. Conversely, proactive leadership with appropriate resource allocation, effective communication, and personal engagement can strengthen safety culture and improve risk perception (Choudhry, Fang, & Mohamed, 2007; Hale & Borys, 2013).

Implementing Key Performance Indicators (KPIs) for supervisors is crucial. Choudhry, Fang, and Mohamed (2007) demonstrated that measurable indicators of managerial responsibility can enhance compliance with safety procedures and support continuous improvement. Thus, management involvement should be considered a primary measure, equal to engineering controls, rather than merely a supportive action (Hale & Borys, 2013).

Behavioral findings from FMEA indicate that disregarding PPE is linked to organizational safety culture. Hofstede (2001) suggests that in collectivist societies, peer influence may be stronger than direct managerial instructions. Therefore, the role of safety engineers and peer-level programs may be more impactful than top-down directives (Lingard, Cooke, & Blismas, 2018).

Additionally, narrative-based training and sharing real incident stories are recommended, supported by psychological evidence that storytelling is more effective in behavior modification than purely rule-based training (Mattingly, 2017). Overconfidence among crane operators can be hazardous, as high familiarity may reduce risk perception and encourage unsafe practices (Mohamed, 2002).

Recommended measures align with global best practices:

- Implementation of PTW systems, widely used in high-risk industries such as oil and gas, which effectively reduce construction accidents (HSE, 2015; IChemE, 2009).
- Enforcement of Lockout-Tagout (LOTO) procedures to prevent electrical hazards (OSHA, 2021; NIOSH, 1998).
- Deployment of non-punitive reporting systems, proven in aviation, to enhance hazard detectability (Reason & Hobbs, 2003; ICAO, 2016; European Union, 2014; OSHA, 2010).

The FMEA provides lessons extending beyond specific projects, emphasizing the integration of technical and behavioral considerations for broader application:

- Companies should implement both technical solutions (e.g., lifelines, RCDs) and motivational strategies (e.g., incentives, safety ambassadors) (HSE, 2020; Fang & Wu, 2011).
- Safety KPIs should be incorporated into performance evaluations to prioritize safety (HSE, 2015; Hale & Borys, 2013).
- Training should go beyond checklists, focusing on behavior and cultural aspects (OSHA, 2021; Hale & Borys, 2013).

Despite the valuable insights from FMEA, limitations exist. First, scoring for occurrence and detectability is subjective. Second, some causal factors were categorized as “ambiguous” due to difficulty in distinguishing technical versus behavioral origins. Future research could employ advanced methods, such as Bayesian risk modeling or machine-learning-based accident analysis, to refine these classifications (Li, Lu, & Zhang, 2014; Zhang, Fang, & Wu, 2021; Wang, Li, & Zhang, 2022).

Moreover, cross-cultural comparisons could improve understanding of how cultural norms influence safety compliance. For example, strategies effective in collectivist cultures may not work in individualist cultures. Therefore, future studies should explore adapting safety interventions for a diverse workforce (IChemE, 2009; Meng, Liu, Li, & Hu, 2021).

6. Conclusion

This study investigated construction site safety in Kabul using the Failure Mode and Effects Analysis (FMEA) method, focusing on both technical and behavioral aspects. The results indicate that construction in developing countries such as Afghanistan involves significant hazards. These risks arise from weak supervision, inadequate protective equipment, and a poor safety culture. Using field data from ten government, residential, and commercial projects, the study identified, measured, and prioritized key hazards.

The highest risks included working at heights (RPN = 560), managerial negligence (RPN = 420), and crane operations (RPN = 378). These hazards reflect deficiencies in equipment and behavioral issues such as time pressure, improper use of personal protective equipment (PPE), and inadequate supervision. The high severity of these hazards (approximately 8.6) indicates serious potential consequences, while shortcomings in occurrence (O) and detectability (D) relate to workplace culture and underreporting.

These findings are consistent with global studies, indicating that construction safety issues in Afghanistan follow international patterns. However, cultural and managerial factors exacerbate these problems. Improving safety requires both engineering measures—such as scaffold inspections, Lockout-Tagout (LOTO) systems, and crane operation training—and addressing cultural and psychological barriers, including peer pressure and the lack of safe reporting systems.

In summary, FMEA results show that technical solutions alone are insufficient for construction safety. Sustainable improvement requires integrating physical safeguards, managerial accountability, and behavioral initiatives. This approach can reduce risks, strengthen safety culture, and ultimately save lives. Nevertheless, the current study has limitations, such as the subjective scoring in FMEA and the focus on only ten projects in Kabul. Future research should employ more advanced methods to enhance the reliability and generalizability of these findings.

Funding:This research did not receive any financial support from other organizations or institutions. All expenses and required resources were provided by the author. No entity was involved in any stage of the research, and it is confirmed that there was no support that could influence the results. This reflects the author's independence.
Conflict of Interest: The author declares that there are no conflicts of interest in this study. There are no financial or personal relationships that could affect the research. All opinions and conclusions are based on scientific evidence, and this statement contributes to the transparency and ethics of the research.
Acknowledgment: I would like to express my deepest gratitude to Prof. Dr. Mohammad Arif Kosheyar at KPU for his continuous guidance, valuable suggestions, and constructive feedback throughout the research process. His insightful comments and encouragement significantly enhanced the quality and clarity of this paper. I am also grateful for his support in reviewing the methodology, data analysis, and interpretation of results, which greatly contributed to the robustness and reliability of the findings. Additionally, I appreciate his patience and dedication in providing timely advice and sharing his expertise in the field. Without his mentorship and continuous involvement, the successful completion of this research would not have been possible. This acknowledgment reflects my sincere appreciation for his indispensable role in this stud.
Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.

References

[1] Abdelhamid, T., & Everett, J. (2000). Identifying root causes of construction accidents. *Journal of Construction Engineering and Management, 126*(1), 52–60. https://doi.org/10.1061/(ASCE)0733-9364(2000)126:1(52)

[2] Abreu, F. E. (2019). Risk management through FMEA in construction projects. *Journal of Civil Engineering and Architecture, 15*(1), 45–52.

[3] Abudayyeh, O., Fredericks, T. K., Butt, S. E., & Shaar, A. (2006). An investigation of crane accidents in the construction industry. *Journal of Construction Engineering and Management, 132*(7), 701–710. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:7(701)

[4] Afghanistan National Development Strategy. (2020). *Infrastructure and construction development report*. Kabul, Afghanistan.

[5] Ahmed, K., & Azhar, R. (2017). Application of risk assessment techniques in Middle East construction projects. In *Proceedings of the 6th International Conference on Construction Engineering and Management*.

[6] Albasyouni, W., Abotaleb, I., & Nassar, K. (2023). Proposing the use of failure mode and effect analysis (FMEA) as risk assessment tool in construction. *International Journal of Innovative Technology and Exploring Engineering, 12*(12).

[7] Alkilani, A., Jupp, J., & Sawhney, R. (2013). Issues of construction health and safety in developing countries: A case of Jordan. *Australasian Journal of Construction Economics and Building, 13*(3), 141–156. https://doi.org/10.5130/AJCEB.v13i3.3439

[8] Beavers, J. E., Moore, J. R., Rinehart, R., & Schriver, W. R. (2006). Crane-related fatalities in the construction industry. *Journal of Construction Engineering and Management, 132*(9), 901–910. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:9(901)

[9] Behm, M. (2005). Linking construction fatalities to the design for construction safety concept. *Safety Science, 43*(8), 589–611. https://doi.org/10.1016/j.ssci.2005.04.002

[10] California FACE (NIOSH). (2000). *Construction worker is crushed by steel beams when overloaded nylon slings fail* (Fatality Assessment and Control Evaluation Program, Report 00CA001).

[11] Choudhry, J. (2009). Developing a model of construction safety culture. *Safety Science, 47*(6), 891–901. https://doi.org/10.1016/j.ssci.2008.01.004

[12] Choudhry, R. M., Fang, D., & Mohamed, S. (2007). The nature of safety culture: A survey of the state-of-the-art. *Safety Science, 45*(10), 993–1012. https://doi.org/10.1016/j.ssci.2006.09.003

[13] Choudhry, S., & Fang, D. (2008). Why operatives engage in unsafe work behavior: Investigating factors on construction sites. *Safety Science, 46*(4), 566–584. https://doi.org/10.1016/j.ssci.2007.06.027

[14] Christian, M. S., Bradley, J. C., Wallace, J. C., & Burke, M. J. (2009). Workplace safety: A meta-analysis of the roles of person and situation factors. *Journal of Applied Psychology, 94*(5), 1103–1127. https://doi.org/10.1037/a0016172

[15] Clarke, A. (2006). The relationship between safety climate and safety performance: A meta-analytic review. *Journal of Occupational Health Psychology, 11*(4), 315–327. https://doi.org/10.1037/1076-8998.11.4.315

[16] Cooper, H. (2001). *Improving safety culture: A practical guide*. Chichester, UK: Wiley.

[17] CPWR – The Center for Construction Research and Training. (2013). *Safety culture and climate in construction: Bridging the gap between research and practice*. Silver Spring, MD: CPWR.

[18] de Mattos, L. A., Rocha, R., & de Castro Moura Duarte, F. J. (2024). Human error and violation of rules in industrial safety: A systematic literature review. *Work, 79*(3), 1237–1253. https://doi.org/10.3233/WOR-230186

[19] Dhillon, B. S. (2004). *Reliability, quality, and safety for engineers*. Boca Raton, FL: CRC Press.

[20] Dong, A., Wang, X., & Liu, H. (2013). Construction workers' reasons for not reporting work-related injuries. *International Journal of Occupational Safety and Ergonomics, 19*(1), 3–12. https://doi.org/10.1080/10803548.2013.11076962

[21] Edmondson, A. C. (1999). Psychological safety and learning behavior in work teams. *Administrative Science Quarterly, 44*(2), 350–383. https://doi.org/10.2307/2666999

[22] Edmondson, A. C. (2018). *The fearless organization: Creating psychological safety in the workplace for learning, innovation, and growth*. Hoboken, NJ: Wiley.

[23] European Union. (2014). *Occurrence reporting in civil aviation*. Regulation (EU) No. 376/2014, April 2014.

[24] Fang, D., & Wu, C. (2011). Development of a safety culture interaction (SCI) model for construction projects. *Safety Science, 49*(4), 806–818. https://doi.org/10.1016/j.ssci.2011.01.009

[25] Flin, R., Mearns, K., O'Connor, P., & Bryden, R. (2000). Measuring safety climate: Identifying the common features. *Safety Science, 34*(1–3), 177–192. https://doi.org/10.1016/S0925-7535(00)00012-6

[26] Ghosh, A., & Jintanapakanont, S. (2004). Identifying and assessing the critical risk factors in an underground rail project in Thailand: A factor analysis approach. *International Journal of Project Management, 22*(8), 633–643. https://doi.org/10.1016/j.ijproman.2004.01.002

[27] Gibb, A. P. (2003). Behavioral aspects of safety in construction projects. *Proceedings of the Institution of Civil Engineers, 156*(2), 1–7. https://doi.org/10.1680/muen.2003.156.2.1

[28] Glendon, A., & Stanton, N. (2000). Perspectives on safety culture. *Safety Science, 34*(1–3), 193–214. https://doi.org/10.1016/S0925-7535(00)00013-8

[29] Hale, A. R., & Borys, D. (2013). Working to rule, or working safely? Part 2: The management of safety rules and procedures. *Safety Science, 55*, 222–231. https://doi.org/10.1016/j.ssci.2012.05.013

[30] Hale, P., Borys, A., & Else, D. (2012). Management of safety in construction projects: A review. *Safety Science, 50*(4), 443–456. https://doi.org/10.1016/j.ssci.2011.10.017

[31] Hallowell, A., & Gambatese, M. (2010). Qualitative research: Application of the Delphi method to CEM research. *Journal of Construction Engineering and Management, 136*(1), 99–107. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000137

[32] Hallowell, M. R. (2010). Safety risk perception in construction companies in the Pacific Northwest of the USA. *Construction Management and Economics, 28*(4), 403–413. https://doi.org/10.1080/01446190903490079

[33] Hallowell, M. R., & Gambatese, J. A. (2009). Activity-based safety risk quantification for concrete formwork construction. *Journal of Construction Engineering and Management, 135*(10), 990–998. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:10(990)

[34] Health and Safety Executive (HSE). (2015). *Permit-to-work (PTW) systems: Guidance on effective implementation*. London, UK: HSE. Retrieved August 26, 2025, from https://www.hse.gov.uk/comah/sragtech/permit-to-work.htm

[35] Health and Safety Executive (HSE). (2020). *Electrical safety and residual current devices (RCDs)*. London, UK: HSE. Retrieved August 26, 2025, from https://www.hse.gov.uk/electricity/rcd.htm

[36] Hinze, J. (1997). *Construction safety* (2nd ed.). Upper Saddle River, NJ: Prentice Hall.

[37] Hinze, Y., & Gambatese, M. (2003). Factors that influence safety performance of specialty contractors. *Journal of Construction Engineering and Management, 129*(2), 159–164. https://doi.org/10.1061/(ASCE)0733-9364(2003)129:2(159)

[38] Hofstede, G. (2001). *Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations* (2nd ed.). Thousand Oaks, CA: Sage.

[39] Huang, X., & Hinze, J. (2006). Owner's role in construction safety. *Journal of Construction Engineering and Management, 132*(2), 164–173. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:2(164)

[40] Institution of Chemical Engineers (IChemE). (2009). Effective permit-to-work systems. *Loss Prevention Bulletin, 209*, 1–5.

[41] International Civil Aviation Organization (ICAO). (2016). *Annex 19 — Safety management* (2nd ed.). Montreal, Canada: ICAO.

[42] International Labour Organization. (2021). *Safety and health in construction: An ILO code of practice*. Geneva, Switzerland: International Labour Office.

[43] International Labour Organization. (2022). *Global estimates on occupational accidents and work-related illnesses*. Geneva, Switzerland: International Labour Office.

[44] Kartam, A. R., & Bouz, I. A. (1998). Fatalities and injuries in the Kuwaiti construction industry. *Accident Analysis and Prevention, 30*(6), 805–814. https://doi.org/10.1016/S0001-4575(98)00052-4

[45] Kheni, S., Gibb, A., & Dainty, A. (2008). Health and safety management within small- and medium-sized enterprises in developing countries: A study of Ghana. *Construction Management and Economics, 26*(4), 361–372. https://doi.org/10.1080/01446190801918751

[46] Li, Y., Lu, H., & Zhang, J. (2014). Bayesian networks for construction safety risk analysis. *Safety Science, 62*, 166–174. https://doi.org/10.1016/j.ssci.2013.08.011

[47] Liao, H.-L., & Perng, C.-W. (2014). Data mining for occupational injury prevention in the construction industry. *Safety Science, 62*, 142–153. https://doi.org/10.1016/j.ssci.2013.08.005

[48] Lingard, H., & Rowlinson, S. (2005). *Occupational health and safety in construction project management*. London, UK: Spon Press.

[49] Lingard, H., Cooke, M., & Blismas, N. (2018). The impact of coworkers' safety violations on an individual worker. *Safety Science, 108*, 273–282. https://doi.org/10.1016/j.ssci.2017.08.024

[50] Mattingly, K. (2017). Storytelling as a means of enhancing construction safety training. *Journal of Safety Research, 62*, 81–88. https://doi.org/10.1016/j.jsr.2017.06.005

[51] Mearns, R. A., Whitaker, S. M., & Flin, R. (2003). Safety climate, safety management practice and safety performance in offshore environments. *Safety Science, 41*(8), 641–680. https://doi.org/10.1016/S0925-7535(02)00011-5

[52] Meng, Q., Liu, W., Li, Z., & Hu, X. (2021). Influencing factors, mechanism and prevention of construction workers' unsafe behaviors: A systematic literature review. *International Journal of Environmental Research and Public Health, 18*(5), 2644. https://doi.org/10.3390/ijerph18052644

[53] Mitropoulos, K., & Cupido, G. (2009). Safety as an emergent property: Investigation into the work practices of high-reliability framing crews. *Journal of Construction Engineering and Management, 135*(5), 407–415. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:5(407)

[54] Mohamed, S. (2002). Safety climate in construction site environments. *Journal of Construction Engineering and Management, 128*(5), 375–384. https://doi.org/10.1061/(ASCE)0733-9364(2002)128:5(375)

[55] Mohandes, A., Marzouk, H., & El-Said, M. (2022). Impacts of stress on workers' risk-taking behaviors. *Journal of Construction Engineering and Management, 148*(3). https://doi.org/10.1061/(ASCE)CO.1943-7862.0002209

[56] Molenaar, C., Park, R., & Washington, S. (2009). Framework for measuring corporate safety culture and its impact on construction safety performance. *Journal of Construction Engineering and Management, 135*(6), 488–496. https://doi.org/10.1061/(ASCE)0733-9364(2009)135:6(488)

[57] Muñoz-La Rivera, F., Mora-Serrano, J., & Oñate, E. (2021). Factors influencing safety on construction projects (fSCPs): Types and categories. *International Journal of Environmental Research and Public Health, 18*(20), 10884. https://doi.org/10.3390/ijerph182010884

[58] National Institute for Occupational Safety and Health (NIOSH). (1998). *Preventing worker deaths from electrocution* (DHHS [NIOSH] Publication No. 98–131). Cincinnati, OH: U.S. Department of Health and Human Services.

[59] Neal, A., & Griffin, M. A. (2006). A study of the lagged relationships among safety climate, safety motivation, safety behavior, and accidents at the individual and group levels. *Journal of Applied Psychology, 91*(4), 946–953. https://doi.org/10.1037/0021-9010.91.4.946

[60] Occupational Safety and Health Administration (OSHA). (2021). *Control of hazardous energy (lockout/tagout), 29 CFR 1910.147*. U.S. Department of Labor. Retrieved August 26, 2025, from https://www.osha.gov/etools/lockout-tagout

[61] Occupational Safety and Health Administration (OSHA). (n.d.). *Fall protection, 29 CFR 1926 Subpart M*. U.S. Department of Labor. Retrieved August 26, 2025, from https://www.osha.gov/fall-protection

[62] Occupational Safety and Health Administration. (2010). *Cranes and derricks in construction, 29 CFR 1926 Subpart CC*. U.S. Department of Labor. Retrieved August 26, 2025, from https://www.osha.gov/cranes-derricks

[63] Rajput, B. R., & Jha, S. A. (2018). Application of FMEA in construction risk management. *International Journal of Civil Engineering and Technology, 9*(7), 1207–1214.

[64] Reader, J., & O'Connor, J. (2013). Leadership and safety performance in high-risk industries. *Journal of Safety Research, 47*, 189–197. https://doi.org/10.1016/j.jsr.2013.07.001

[65] Reason, J. (1997). *Managing the risks of organizational accidents*. Aldershot, UK: Ashgate.

[66] Reason, J., & Hobbs, A. (2003). *Managing maintenance error: A practical guide*. Aldershot, UK: Ashgate.

[67] Seo, B., Lee, J., Kim, K., & Jee, Y. (2002). An analysis of safety behaviors of construction workers using structural equation modeling. *Accident Analysis and Prevention, 34*(3), 401–411. https://doi.org/10.1016/S0001-4575(01)00036-6

[68] Song, S. Y., & Kim, Y. (2007). Construction safety management using FMEA: Application to structural steel erection. In *Proceedings of ARCOM Conference* (pp. 55–63).

[69] Stamatis, D. H. (2003). *Failure mode and effect analysis: FMEA from theory to execution*. Milwaukee, WI: ASQ Quality Press.

[70] Sunindijo, G., & Zou, J. (2013). The influence of safety leadership on safety performance in construction. *International Journal of Project Management, 31*(7), 1027–1039. https://doi.org/10.1016/j.ijproman.2012.12.018

[71] Toole, N. M. (2002). Construction site safety roles. *Journal of Construction Engineering and Management, 128*(3), 203–210. https://doi.org/10.1061/(ASCE)0733-9364(2002)128:3(203)

[72] U.S. Bureau of Labor Statistics. (2024). *National census of fatal occupational injuries in 2023 – Summary*. U.S. Department of Labor. Retrieved August 26, 2025, from https://www.bls.gov/news.release/cfoi.nr0.htm

[73] Wang, Y., Li, J., & Zhang, H. (2022). Study on influencing factors of construction workers' unsafe behavior based on text mining of 500 accident reports. *Frontiers in Psychology, 13*, 886390. https://doi.org/10.3389/fpsyg.2022.886390

[74] Wilde, G. J. S. (2001). *Target risk 3*. Toronto, Canada: PDE Publications.

[75] Wu, W., et al. (2022). Analysis of behavioral strategies of construction safety subjects using evolutionary game model. *Buildings, 12*(3), Article 313. https://doi.org/10.3390/buildings12030313

[76] Zhang, X., Wu, Y., & Feng, Y. (2015). Schedule compression impact on construction project safety. *Frontiers of Engineering Management, 2*(4), 371–379. https://doi.org/10.15302/J-FEM-2015037

[77] Zhang, Z., Fang, X., & Wu, B. (2021). Machine learning-based analysis of construction accident causes. *Automation in Construction, 123*, 103529. https://doi.org/10.1016/j.autcon.2020.103529

[78] Zohar, D. (1980). Safety climate in industrial organizations: Theoretical and applied implications. *Journal of Applied Psychology, 65*(1), 96–102. https://doi.org/10.1037/0021-9010.65.1.96

[79] Zohar, D. (2010). Thirty years of safety climate research: Reflections and future directions. *Accident Analysis and Prevention, 42*(5), 1517–1522. https://doi.org/10.1016/j.aap.2009.12.019

[80] Zou, J., & Sunindijo, G. (2014). Construction management and safety culture in China and India. *International Journal of Project Management, 32*(2), 286–298. https://doi.org/10.1016/j.ijproman.2013.05.011