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Risk Assessment of Occupational Health Hazards in the Workforce During the Building Construction

Aliasghar Jahani[1], Moselem Mirzaie[1], Mohamad Vatani[2,*]

[1]Engineering Unit, Faraz Gostaran Constructions, Maragheh 5516743463, Iran, Iran
[2]Construction and Management Unit, Faraz Gostaran Constructions, Maragheh 5516743463, Iran, Iran
*Corresponding author: vatani@farazgostran.co

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***Abstract*:** Occupational health hazards in the construction industry are a significant concern, as workers are exposed to various physical, chemical, and environmental risks during the building construction process. A comprehensive risk assessment of these health hazards is essential to ensure worker safety and well-being. This assessment focuses on the identification, evaluation, and mitigation of health risks associated with construction tasks, such as exposure to hazardous materials (e.g., asbestos, silica dust), ergonomic challenges, noise and vibration, heat stress, and mental health issues. Workers in construction are often exposed to materials and working conditions that can lead to long-term health complications, including respiratory diseases, musculoskeletal disorders, hearing loss, and stress-related conditions. The risk assessment process involves evaluating the likelihood of these hazards occurring, their potential impact on workers, and implementing control measures such as proper personal protective equipment (PPE), ergonomic solutions, noise reduction strategies, and environmental controls. Additionally, regular monitoring and training programs are vital to ensure workers understand the risks and the necessary safety precautions. Effective risk management strategies are not only crucial for worker health but also contribute to improved productivity and reduced operational costs by preventing injuries and illnesses. By prioritizing occupational health in the construction process, companies can create safer work environments, enhance worker morale, and comply with regulatory standards. This risk assessment is an integral part of any building construction project, ensuring that health hazards are minimized, and the workforce remains protected throughout the project's lifecycle.

Keywords: Occupational health, Risk assessment, Construction workforce, Hazardous materials, Worker safety.

I. INTRODUCTION

The construction industry is recognized as one of the most hazardous sectors worldwide, with workers facing a variety of risks that can lead to both immediate and long-term health problems (Biswas et al., 2017). Despite advancements in safety regulations and protocols, occupational health hazards continue to pose significant challenges to construction workers (Jayakrishnan et al., 2013). As the demand for infrastructure and urban development increases, addressing health and safety concerns of the workforce becomes critical (Gupta, 2021). These health risks range from exposure to hazardous substances and physical injuries to psychological stresses, all of which can impair the health and productivity of workers if not properly managed (Mohamed, 2017).

Occupational health hazards in the construction sector are multifaceted and diverse (Boadu et al., 2023). From the very early stages of a building project, workers are exposed to various harmful conditions, including physical, chemical, and ergonomic risks (Tiwary & Gangopadhyay, 2011). Among these, exposure to hazardous materials such as asbestos, silica dust, and lead paint is particularly alarming due to their long-term health impacts, which include respiratory diseases and even cancer. In addition to chemical hazards, workers also face the threat of physical injuries, such as falls, musculoskeletal disorders, and hearing loss, often resulting from inadequate safety measures or improper equipment use (Lingard et al., 2012; Lingard, 2013). Ergonomic hazards are another critical area that affects workers in construction (Tak et al., 2011). Many tasks in construction require repetitive motion or the lifting of heavy objects, which can lead to long-term musculoskeletal issues, particularly in the back, shoulders, and joints (Jaffar et al., 2011). These types of injuries are often not immediately visible but can cause significant pain and suffering over time, impacting both the individual's health and the overall productivity of the workforce (Tiwary & Gangopadhyay, 2011). Addressing these ergonomic risks through proper training, tools, and practices is essential to preventing chronic health issues among construction workers (Ranasinghe et al., 2023).

Exposure to excessive noise and vibration is another prevalent issue in the construction industry, especially with the use of heavy machinery, drills, and other high-intensity equipment (Li et al., 2016). Prolonged exposure to these

elements can lead to hearing impairment, tinnitus, and other auditory conditions (Fernández et al., 2009), while vibration can cause hand-arm vibration syndrome (HAVS) and other circulatory disorders (Gerger et al., 2023). These conditions not only affect workers' physical health but also their ability to perform tasks efficiently, leading to lower productivity levels and increased healthcare costs (Edwards et al., 2020).

Heat stress is another occupational health risk that is often overlooked in construction settings (Shakerian et al., 2021). Workers, particularly those working outdoors in hot climates or during summer months, are at significant risk of dehydration, heat exhaustion, and even heatstroke. These conditions can lead to severe health consequences, and in some cases, fatalities, if not managed appropriately (Szer et al., 2022). Providing access to hydration, cooling systems, and regular breaks can help mitigate these risks and ensure that workers remain healthy throughout the construction process (Al-Bouwarthan et al., 2020). In addition to the physical risks, psychological health issues are increasingly being recognized as a critical concern in the construction industry (Abokhashabah et al., 2020). The demanding nature of the work, coupled with long hours, tight deadlines, and high-pressure environments, can lead to stress, anxiety, depression, and burnout (Jiang et al., 2020). These mental health issues can impair workers' focus and decision-making abilities, increasing the likelihood of accidents and reducing overall performance (Tiwary & Gangopadhyay, 2011). Establishing mental health support systems and fostering a culture of openness around psychological well-being is necessary for reducing the stigma and ensuring workers' mental health is prioritized (Frimpong et al., 2022).

The construction industry also faces challenges in ensuring the proper use of personal protective equipment (PPE). While PPE such as helmets, gloves, goggles, and hearing protection are essential for safeguarding workers from potential hazards, improper usage or lack of training on the correct application of PPE can reduce their effectiveness (Sehsah et al., 2020). Ensuring that workers are trained on how to properly use and maintain PPE is a fundamental component of any health and safety strategy in construction (Ammad et al., 2021). Furthermore, the implementation of effective safety training programs is critical for minimizing health risks on construction sites (Shazwan & Ee, 2018). Workers should be provided with thorough training on potential hazards, safe work practices, and emergency response procedures (Xu et al., 2022). This training should not be a one-time event but rather an ongoing process to ensure that workers remain aware of the risks and are equipped with the knowledge to protect themselves effectively (Zhang et al., 2023). In addressing occupational health risks in construction, it is essential to recognize the role of technology and innovation in enhancing safety (Bust et al., 2008). Advances in construction equipment, wearable devices, and monitoring systems can provide real-time data on workers' health and safety conditions (Enya, 2016). For example, wearable sensors can detect heat stress, fatigue, or hazardous exposure, allowing for timely intervention and the prevention of health issues before they become severe (Tiwary & Gangopadhyay, 2011).

The responsibility for managing health risks in construction does not lie solely with the workers but also with employers, contractors, and policymakers (Wang et al., 2012). Employers are required to ensure compliance with national and international safety standards, provide the necessary resources for protecting worker health, and create a work environment that prioritizes safety at all levels (Danielsen et al., 2017). Contractors must ensure that workers follow safety protocols and are provided with the necessary support to mitigate health risks (Tiwary & Gangopadhyay, 2011). Policymakers are also responsible for enforcing regulations that protect workers' health and well-being, ensuring that the construction industry remains a safe environment for all (Edwards et al., 2020).

The primary objective of this study is to assess and analyze the occupational health hazards faced by construction workers during the building process and to propose effective risk mitigation strategies. Given the diverse range of health risks, including exposure to hazardous materials, ergonomic challenges, noise and vibration hazards, heat stress, and mental health concerns—this study aims to provide a comprehensive evaluation of these risks and their potential impacts on worker well-being. By conducting a thorough risk assessment, the study seeks to identify the most critical hazards, examine their causes, and recommend preventive measures such as proper training, PPE usage, improved workplace ergonomics, and technological innovations. Additionally, the study emphasizes the importance of regulatory compliance and employer responsibilities in fostering a safe and healthy work environment. Ultimately, the findings aim to contribute to enhanced occupational health standards in the construction industry, ensuring both worker safety and overall project efficiency.

II. Workforce Occupational Risk Assessments

Occupational risk assessment is a critical component of workforce health and safety management, particularly in high-risk industries such as construction (Frimpong et al., 2022). It involves identifying potential hazards, evaluating the level of risk they pose, and implementing control measures to minimize or eliminate these risks (Danielsen et al., 2017). The construction industry, with its complex and dynamic nature, presents a wide range of occupational hazards that can significantly impact worker health (Boadu et al., 2023). These risks stem from various sources (Tiwary & Gangopadhyay, 2011). Conducting a thorough occupational risk assessment ensures that these hazards are systematically identified and mitigated before they lead to serious health consequences (Mohamed, 2017). One of the key aspects of workforce occupational risk assessments is hazard identification. This process involves recognizing all potential dangers that workers may encounter on a construction site (Fox et al., 2018). Common hazards include working at heights, operating heavy machinery, handling toxic substances, prolonged exposure to noise and vibration, and repetitive physical movements (Pinto et al., 2011). Identifying these hazards requires collaboration between safety experts, engineers, supervisors, and workers to gain a comprehensive understanding of all possible risks present in the workplace (Schulte et al., 2012).

Once hazards are identified, the next step is risk evaluation. This process involves assessing the severity and likelihood of each hazard causing harm (Becker & Smidt, 2015; De Felice et al., 2022). Figure 1 provides the main steps of risk evaluations.

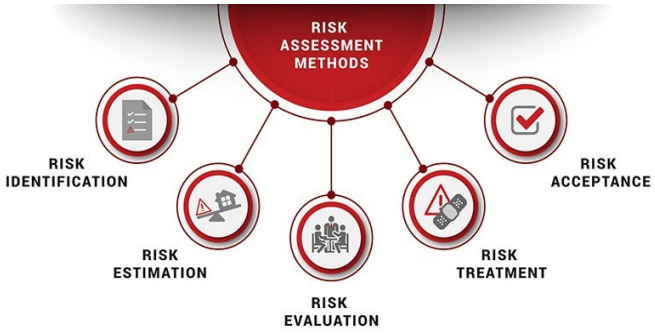

Fig. 1 Steps involved in workforce risk evaluation

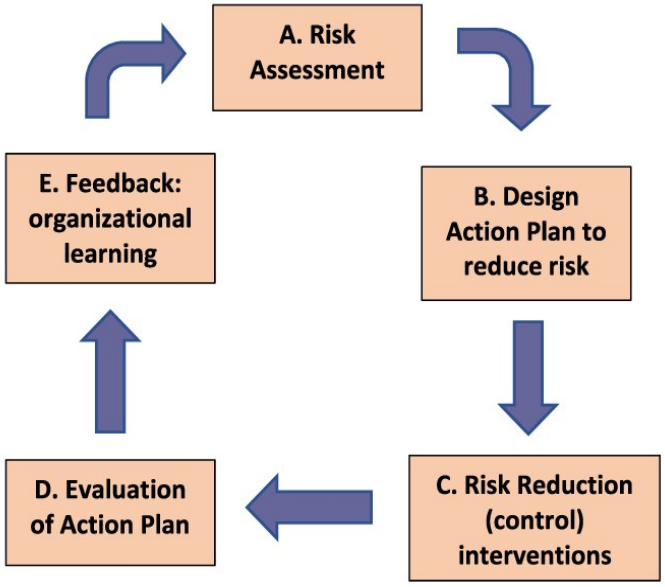

Fig. 2 Flowchart illustrating the risk assessment process (Oakman & Macdonald, 2019)

Fig. 3 Common occupational risks affecting the workforce

Risks are categorized based on their potential impact on workers' health, the frequency of exposure, and the existing control measures in place (see Figure 1). For instance, exposure to silica dust may have a high likelihood of occurrence in demolition activities, and its long-term health impact, such as lung diseases, can be severe (Becker & Smidt, 2015). By analyzing these factors, safety managers can prioritize which risks need immediate attention and intervention (Reinhold et al., 2015). A fundamental part of occupational risk assessments is the implementation of preventive and control measures (Falkiner, 2009). These measures are designed to either eliminate hazards or reduce the risk associated with them to an acceptable level were illustrated in Figure 2 (Oakman & Macdonald, 2019). The hierarchy of controls is commonly used to guide this process. It includes elimination (removing the hazard completely), substitution (replacing hazardous materials with safer alternatives), engineering controls (modifying equipment or processes to reduce exposure), administrative controls (establishing policies, training, and scheduling to minimize risk), and PPE as a last resort (Karakhan et al., 2020).

Another crucial factor in workforce occupational risk assessments is compliance with legal and regulatory standards (Fung et al., 2010). Governments and international safety organizations establish strict guidelines to protect workers from occupational hazards (Niu, 2010). Regulatory bodies such as the Occupational Safety and Health Administration (OSHA) and the International Labor Organization (ILO) provide frameworks that companies must follow to ensure workplace safety (Horie, 2010). Conducting risk assessments regularly helps organizations comply with these regulations and avoid legal penalties while fostering a safe work environment (Concha-Barrientos et al., 2004). Occupational risk assessments also emphasize monitoring and continuous improvement (Beck & Lenhardt, 2019). Risks in construction sites are dynamic, meaning they can change as the project progresses (Işık & Atasoylu, 2017). Regular inspections, safety audits, and worker feedback are essential in ensuring that previously identified risks are still being managed effectively and that new hazards are promptly addressed (Hulshof et al., 2019). Implementing a feedback loop allows organizations to refine their risk management strategies over time, ensuring the continuous protection of their workforce.

A successful occupational risk assessment must also consider worker participation and training (Wang et al., 2012). Employees are often the first to encounter hazards and can provide valuable insights into potential risks (Beck & Lenhardt, 2019). Involving them in the risk assessment process through regular safety meetings, hazard reporting systems, and participatory risk analysis ensures a more comprehensive evaluation (Karakhan et al., 2020). Moreover, workers must be trained on risk awareness, proper safety procedures, and the correct use of PPE to enhance their ability to protect themselves from hazards (Becker & Smidt, 2015). Also, risk assessments should include emergency preparedness and response planning (Sehsah et al., 2020). Despite preventive measures, accidents and hazardous situations can still occur (Mohamed, 2017). A well-structured emergency response plan ensures that workers are prepared to handle unexpected events, such as chemical spills, fires, or medical emergencies (Kumie et al., 2016; Teixeira et al., 2021; Boadu et al., 2023).

There are several methods for analyzing occupational risks in construction, each providing different levels of detail and precision (see Figure 4). These methods help safety professionals assess the likelihood and severity of potential hazards, allowing them to make informed decisions on mitigation strategies (Fornalchyk et al., 2021).

Qualitative risk analysis: Qualitative risk analysis is a straightforward approach that involves subjective assessments of risk levels based on expert judgment and experience. Risks are typically categorized into low, medium, or high levels based on predefined criteria. This method is useful for preliminary assessments and allows organizations to quickly identify critical hazards without requiring complex calculations.

Semi-quantitative risk analysis: This method combines qualitative judgment with numerical values to provide a more detailed risk assessment. Risks are ranked using a scoring system, considering factors such as likelihood, severity, and exposure duration. For example, a scale from 1 to 5 can be used to assign values to risk probability and impact, leading to a more structured prioritization of hazards.

Quantitative risk analysis: Quantitative risk analysis involves numerical and statistical techniques to calculate precise risk values. It considers real-world data, probabilities, and exposure rates to estimate the likelihood and consequences of risks. This method is particularly useful in complex construction projects where accurate risk assessments are necessary to ensure worker safety and regulatory compliance.

Job safety analysis (JSA): JSA is a method that involves breaking down a specific job into individual tasks and analyzing the risks associated with each step. By identifying hazards at each stage of a job, safety measures can be implemented to prevent accidents. This method is widely used in construction to enhance worksite safety by proactively addressing potential risks.

Hazard and operability study (HAZOP): HAZOP is a structured and systematic technique used to identify risks associated with complex systems and operations. It involves brainstorming sessions with multidisciplinary teams to evaluate deviations from normal operating conditions and their potential hazards. This method is particularly useful for large-scale construction projects with multiple risk factors.

Failure mode and effects analysis (FMEA): FMEA is a proactive risk assessment method that focuses on identifying potential failure points in construction processes and evaluating their impact. It helps prioritize risks based on severity, likelihood, and detectability, ensuring that the most critical hazards are addressed first.

Bowtie analysis: Bowtie analysis is a visual risk assessment technique that helps organizations understand the relationship between potential hazards, preventive measures, and consequences. It provides a clear representation of how risks can be managed effectively by linking causes, barriers, and consequences in a structured format.

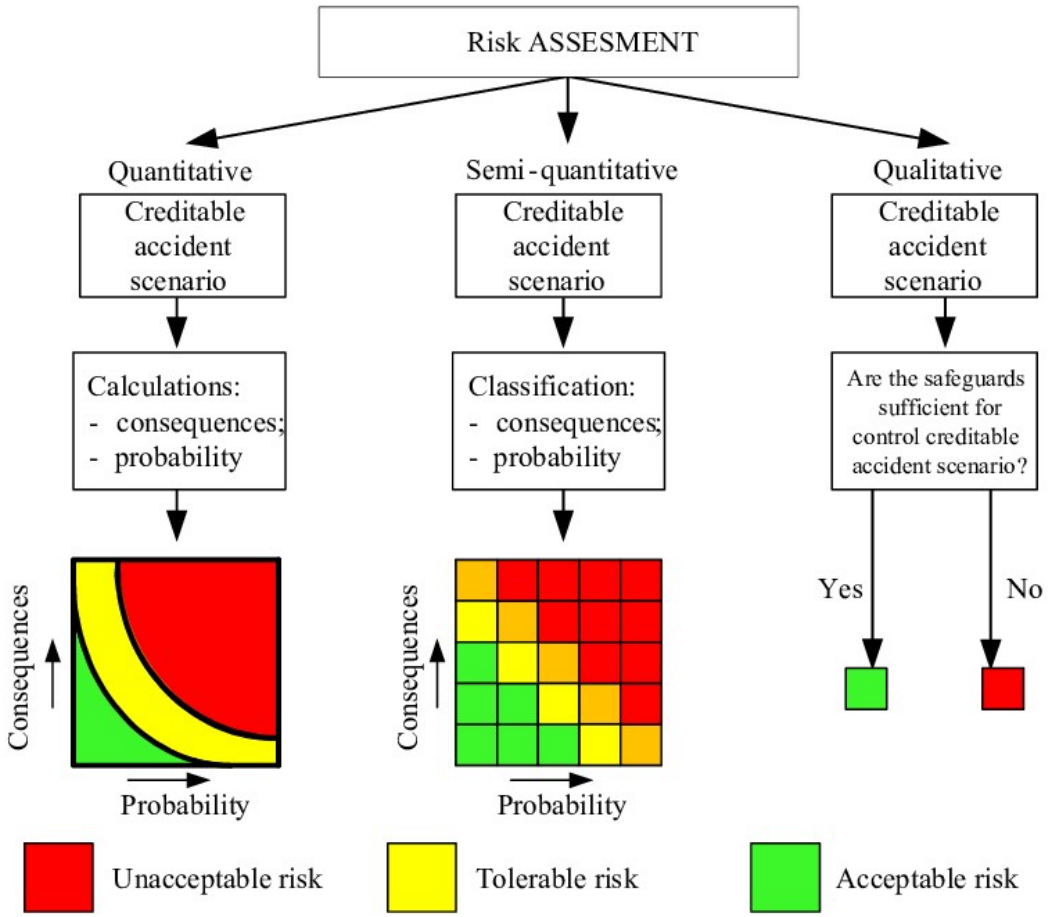

Fig. 4 Common methods of risk analysis (Fornalchyk et al., 2021)

A risk matrix is a widely used tool in risk assessment that helps categorize and prioritize hazards based on their likelihood and severity (Korshunov et al., 2020). Figure 5 is provided a common used risk matrix. It is typically a grid where one axis represents the probability of an event occurring (ranging from rare to very likely), while the other axis represents the severity of its consequences (ranging from minor to catastrophic). By plotting risks on the matrix, organizations can determine which hazards require immediate action and which ones is lower priority (Jensen et al., 2022). Risk matrices are usually divided into three main risk levels (Gul & Ak, 2018):

- Low Risk (Green Zone): These risks have minimal impact and are unlikely to cause significant harm. They may require basic safety measures but do not need urgent intervention.
- Medium Risk (Yellow Zone): These risks pose a moderate threat and should be managed proactively to prevent escalation. Control measures should be implemented to reduce their likelihood or severity.
- High Risk (Red Zone): These risks have severe consequences and require immediate action. If not addressed, they can lead to serious injuries, fatalities, or legal consequences.

By using a risk matrix, construction companies can effectively prioritize their safety efforts, ensuring that the most dangerous hazards are controlled first. The matrix serves as a simple yet powerful tool for decision-making in occupational health and safety management. It should be noted that the interpretation of risk assessment classifications, particularly in qualitative and semi-quantitative methods, heavily relies on the experience and judgment of safety professionals. Since these classifications are based on subjective evaluations of likelihood and severity, inconsistencies can arise due to variations in expertise, industry experience, and perception of hazards. For instance, what one expert considers a “medium” risk, another may classify as “high” depending on their past encounters with similar situations.

		Consequence				
		Negligible 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Likelihood	5 Almost certain	Moderate 5	High 10	Extreme 15	Extreme 20	Extreme 25
	4 Likely	Moderate 4	High 8	High 12	Extreme 16	Extreme 20
	3 Possible	Low 3	Moderate 6	High 9	High 12	Extreme 15
	2 Unlikely	Low 2	Moderate 4	Moderate 6	High 8	High 10
	1 Rare	Low 1	Low 2	Low 3	Moderate 4	Moderate 5

Fig. 5 A risk matrix used in occupational risk assessments (Kaya, 2018)

Therefore, it is crucial to ensure that risk assessments are conducted by trained professionals who can apply consistent criteria and rely on standardized guidelines. Regular calibration meetings and cross-checking risk evaluations among multiple experts can help mitigate discrepancies and improve accuracy in classification. Moreover, because human judgment plays a significant role in qualitative assessments, there is a risk of either underestimating or overestimating certain hazards. Underestimating risks may lead to insufficient safety measures, while overestimating risks could result in unnecessary costs and inefficiencies. To enhance reliability, risk classifications should be complemented with data-driven insights, historical incident reports, and feedback from workers directly exposed to the hazards. Organizations should also emphasize continuous learning and adaptation, allowing risk assessments to evolve based on new findings and technological advancements. By maintaining a balance between professional experience and objective data, companies can ensure more precise and effective risk management strategies.

III. Construction Workforce Safety in Iran

The construction industry in Iran is one of the most significant sectors contributing to the country's economic growth and infrastructure development (Ghafari et al., 2017). However, despite its crucial role, construction workforce safety remains a major challenge due to various factors, including outdated safety regulations, lack of enforcement, insufficient training programs, and economic constraints (Mohseni et al., 2015). Iranian construction workers often face hazardous conditions, leading to a high rate of workplace injuries and fatalities (Hatami et al., 2017). Addressing these safety concerns requires a comprehensive approach involving government regulations, employer responsibilities, worker awareness, and technological advancements (Ghoddousi et al., 2015). One of the primary concerns regarding construction workforce safety in Iran is the lack of strict enforcement of safety regulations (Amiri et al., 2014). While the country has occupational health and safety laws in place, their implementation is often weak, particularly in small and medium-sized construction projects (Mohammadi et al., 2018). Many contractors and project managers fail to comply with safety standards due to a lack of inspections and penalties. This results in unsafe working conditions where workers are exposed to risks such as falls from heights, exposure to hazardous materials, and unprotected machinery. Strengthening regulatory enforcement and increasing inspections are necessary to improve compliance and ensure safer workplaces (Mohammadi et al., 2018).

Another significant issue is the insufficient use of PPE among Iranian construction workers (Namian et al., 2022). Many workers do not wear helmets, gloves, goggles, or harnesses due to limited access, lack of awareness, or a disregard for safety protocols (Karimi & Taghaddos, 2020). In some cases, employers fail to provide adequate PPE, while in others, workers themselves neglect using safety gear due to discomfort or underestimation of risks (Ghoddousi et al., 2015). Raising awareness about the importance of PPE, along with strict enforcement measures, can help reduce injuries and fatalities on construction sites (Mohseni et al., 2015).

Fig. 5 A some of Iran's construction workforce challenges (source: Iranian news websites)

The high rate of falls from heights is a major cause of workplace accidents in Iran's construction industry (Heravi et al., 2022). Many workers perform tasks on scaffolding, ladders, and high-rise structures without proper fall protection systems (Ghafari et al., 2017). The absence of guardrails, safety nets, and harnesses increases the likelihood of severe injuries or fatalities (Mohammadi et al., 2018). Implementing fall protection measures, ensuring proper training on working at heights, and regular inspections of scaffolding structures can significantly enhance worker safety (Mohseni et al., 2015). Another challenge in Iran's construction industry is the lack of comprehensive safety training programs (Mohammadi et al., 2018). Many workers enter the industry with little or no formal safety education. Training on hazard identification, safe equipment operation, emergency response, and first aid is often minimal or completely absent (Amiri et al., 2014). Employers frequently prioritize project deadlines over worker education, leading to unsafe practices on job sites. Establishing mandatory safety training programs, either through government initiatives or employer-funded courses, can help workers develop the necessary skills to protect themselves and their colleagues (Golchin Rad & Kim, 2018).

Economic constraints and financial pressures also contribute to poor safety conditions in the construction industry. Many contractors and small construction companies operate on tight budgets, leading them to cut corners on safety measures (Zakeri et al., 1996). They may prioritize cost savings by investing in high-quality protective equipment, safety training, and proper worksite conditions (Mohammadi et al., 2018). Additionally, many construction workers in Iran are employed informally, meaning they lack job security, insurance, and access to medical care in case of accidents (Ghafari et al., 2017). Addressing these economic issues by introducing better labor protections, providing subsidies for safety investments, and ensuring workers have proper insurance coverage can improve overall safety conditions (Amiri et al., 2014).

Exposure to hazardous materials is another concern for Iranian construction workers. Many construction projects involve materials such as asbestos, silica dust, and toxic chemicals, which can lead to long-term health issues, including respiratory diseases and cancers. However, due to a lack of awareness and proper safety measures, many workers handle these materials without adequate protection (Mohammadfam et al., 2017). Implementing strict regulations on hazardous material use, improving ventilation systems, and ensuring workers receive training on handling toxic substances can reduce health risks (Abbasianjahromi & Talebian, 2021). The psychological well-being of construction workers is another often-overlooked aspect of workplace safety in Iran (Golchin Rad & Kim, 2018). Long working hours, job insecurity, financial stress, and high-risk work environments contribute to increased stress, anxiety, and mental health issues among workers (Mohammadi et al., 2018). Many laborers face intense pressure to meet deadlines, often without adequate rest periods (Heravi et al., 2022). Promoting mental health awareness, improving working conditions, and offering counseling services can help reduce the psychological burden on construction workers (Ghafari et al., 2017).

The role of technology and innovation in improving construction workforce safety in Iran cannot be ignored (Amiri et al., 2014). Advanced safety solutions, such as wearable devices that monitor workers' health, real-time hazard detection systems, and automation of dangerous tasks, can significantly reduce workplace accidents. However, the adoption of these technologies in Iran remains limited due to financial and infrastructural barriers (Mohammadi et al., 2018). Encouraging investment in modern construction safety technologies through government incentives and private sector collaboration can help bridge this gap. Finally, improving construction workforce safety in Iran requires strong collaboration between the government, employers, and workers (Ghafari et al., 2017). The government must strengthen safety regulations and enforcement, while employers need to take responsibility for providing safer work environments (Mohseni et al., 2015). Workers, on the other hand, should actively participate in safety programs and report hazards. By fostering a culture of safety, the construction industry in Iran can significantly reduce workplace injuries and fatalities, leading to a more productive and secure workforce.

IV. Conclusion

Ensuring workforce safety in Iran's construction industry is a pressing issue that requires immediate attention and comprehensive intervention. Despite the sector's significant contributions to economic growth and infrastructure development, construction workers continue to face numerous occupational hazards, including falls from heights, exposure to hazardous materials, lack of proper PPE, and psychological stress. The weak enforcement of safety regulations, insufficient worker training, and financial constraints further compound these risks, leading to high injury and fatality rates. To address these challenges, a multi-faceted approach is necessary. Strengthening regulatory enforcement, increasing workplace inspections, and holding employers accountable for safety violations can significantly improve compliance with occupational health and safety standards. Additionally, implementing mandatory safety training programs and raising worker awareness of protective measures can reduce workplace accidents. Financial incentives for contractors to invest in safety improvements, along with the adoption of modern construction technologies, can further enhance workplace safety. Moreover, addressing the mental health and well-being of construction workers is essential in fostering a healthier and more productive workforce. Collaboration between the government, construction companies, and workers is key to building a culture of safety in the industry. By prioritizing worker protection through risk assessment, preventive strategies, and technological advancements, Iran's construction sector can significantly reduce occupational injuries and fatalities. A safer working environment not only benefits individual workers but also improves overall productivity, project efficiency, and long-term sustainability in the industry.

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Authors' contributions

Aliasghar Jahani and Moselem Mirzaie conducted the main data analysis, contributed to the data collection, preprocessing, and interpretation, and were responsible for drafting the initial manuscript. Mohamad Vatani performed supervision, conceptual guidance and critical revision of the manuscript. Mohamad Vatani provided overall project administration and final approval of the version to be published. All authors read and approved the final manuscript.

Conflict of interest

The authors have not disclosed any competing interests.

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