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A review of the relationships between safety risk factors, practical solutions, and sustainable construction

Sadaf Noshin[1], Hafiz M. Shahzad Aslam[1], Atteq ur Rehman[1], Abrar Ahmad[2], Mazhar Yasin[1] and Ali Hamza[1]

[1] *University of Lahore Department of Technology, Lahore, Pakistan*

[2] *NTDC Department, Lahore, Pakistan*

Corresponding author:
Sadaf Noshin
sadaf.noshin@tech.uol.edu.pk

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Faculty of Civil Engineering and Architecture Osijek
Josip Juraj Strossmayer University of Osijek
Vladimira Preloga 3
31000 Osijek
CROATIA

Abstract:
Sustainability encompasses environmental, economic, and social dimensions, with safety standing as a crucial facet within the construction industry's social sustainability framework. This study addresses this vital concern by comprehensively analyzing published research on prominent safety risk factors and effective mitigation measures in construction projects, considering their influence on the industry's sustainability. A systematic literature review spanning 2008 to 2023 examined 32 pertinent articles from reputable journals. The review revealed 25 identified safety risk factors and 20 corresponding effective measures. These were categorised into labour, environmental, technical, and financial risks, forming the basis for a network diagram illustrating their interrelationships and associated mitigation strategies. Moreover, the study introduced a sustainability criterion, evaluating the various safety risk factor categories, and highlighting labour and environmental risks as the most significant concerns among the factors assessed. Finally, the research proposes future research directions aimed at elevating safety and sustainability within construction projects.

Keywords:
sustainability; safety risk factors; labor risk; mitigation measures; sustainability criterion

1 Introduction

The construction sector has seen significant improvements in recent years to counteract the exponential increase in the global population. The demand for more homes, infrastructure, workplaces, and facilities has caused the construction industry, which has grown to be a substantial component of every economy, to expand [1]. However, a substantial number of work-related fatalities and injuries have been linked to industry, making construction one of the most dangerous industries at present [2]. Construction-related accidents in the United States, China, Australia, and the Middle East have eclipsed those in other industries, including farming, shipbreaking, and fishing, which is a cause of concern [3]. The construction sector employs approximately 7 % of the global workforce; however, it bears responsibility for 30-40 % of all reported fatalities [4, 5]. We can attribute the significant rate of injuries in the construction sector to the peculiarities of the building trade, which heavily depends on the utilisation of heavy machinery and often requires employees to work under challenging and unfavourable conditions [6].

Because of the high risks involved in construction work and the inevitable relationship between employers and hazards, it is crucial to develop safety systems to prevent accidents and injuries. Technologically advanced countries have significantly invested in devising advanced safety standards to achieve zero-injury policies. However, construction safety is still in infancy in most developing nations [4]. The findings in Table 1 highlight the state of construction safety in various countries and suggest that this remains a persistent global issue. The construction industry is still far from achieving the 'zero accidents/wounds' goal. Clients who are unwilling to cooperate, have weak law enforcement, and have insufficient work processes are all blamed for nations' inadequate safety records. [7]. The concept of sustainability in the building sector has been discussed widely in recent years. Assessing sustainability in building construction is often measured by the level of accreditation, known as the "Leadership in Energy and Environmental Design (LEED)”. This certification program, established by the United States Green Building Council (USGBC), aims to encourage ecological objectives within built environments [8].

Three key factors drive the growth of green buildings. First, regulations and subsidies for environment-friendly buildings have played a significant role. Various federal, state, and municipal departments now require LEED certification for new publicly funded buildings, offering tax incentives to encourage LEED certification. Second, there was a rapid increase in demand in the private sector. Companies have realized the continuing benefits of green buildings, including reduced maintenance costs, a better standard of life for the people living there, and enhanced advertising opportunities [9]. However, there is a lack of research on how sustainable building practices affect the well-being of construction workers. Hinz et al. discovered that LEED grading methods focus less on societal sustainability, especially worker safety and health than on economic and environmental factors [9]. According to another study, LEED-licenced projects had a higher injury rate (48 %) than normal building projects. Safety issues associated with certain LEED building elements have not been adequately identified and reported.

Considering the expected increase in the implementation of LEED standards, it is crucial to acquire this knowledge to safeguard the wellbeing and health of construction workers [10] Nguyen et al. conducted a study to develop a detailed risk evaluation model incorporating various essential risk influences, including influence, likelihood, and controllability. Researchers evaluated the dangers of eco-friendly construction projects using mean scores and flexible evaluation techniques. By drawing on expert judgment, this approach can ascertain the relevance of risk variables, categories, and general risk degrees. Results showed that "lack of knowledge for environmentally conscious building designers" is the biggest threat, with "social resource risk in the development stage" being the most important threat category [11].

Table 1. Country-wise fatal injury rates

Countries	Description
United States	In 2012, the BLS found that 9,7 out of every 100,000 workers in the construction job were killed, which is higher than the average of 3,5 deaths per 100,000 workers for all industries [12].
United Kingdom	According to the HSE, the construction industry had a lower fatalities rate than the norm in 2020/21, with 0,41 deaths per million employees [13].
Australia	The agency said the construction industry's fatal accident rate in 2019 was 3,7 per one million employees, making it the safest in the private sector [14].
Pakistan	The ILO reported that the construction sector in Pakistan had a fatal injury rate of 15,5 deaths per one million employees, which is higher than the global average of 9,2 deaths per 100 thousand workers [15].
India	The NSSO reported in 2019 that the construction sector had a fatal injury rate of 36,9 deaths per 100,000 employees, which is higher than the global average of 9,2 deaths per 100,000 employees [16].

Numerous studies have been published on various subjects in construction safety. However, many previous reviews have focused on specific aspects of construction safety rather than providing an efficient and broad analysis. For instance, [17] examined what may cause workers to slip and fall at construction sites. Another study [2] emphasised time-honored occupational safety and health management practices. Safety in buildings has been studied in connection with using electronic design tools by [3, 18, 19] investigated the use of cutting-edge technologies to manage building sites safely.
Previous research has explored the risk factors and measures for sustainable construction. However, this industry faces safety risks that threaten its sustainability. Therefore, identifying and implementing effective measures to mitigate these risks is essential. This research seeks to address this knowledge gap by adopting a comprehensive approach to studying the relationships among safety risk factors, effective measures, and construction industry sustainability. By identifying the key factors contributing to industry safety risks and evaluating the effectiveness of measures to mitigate these risks, we propose integrated approaches that merge safety practices with sustainable construction methods to achieve optimal outcomes. This study provides a deeper understanding of how to improve the sustainability of the construction industry.

2 Research background

2.1 Environment-friendly construction sites

The goal of the construction business is to meet people's needs in terms of housing, infrastructure, and working conditions while also ensuring that subsequent generations can do the same. Sustainable construction plays a vital role in enhancing quality of life by adhering to sustainable standards to achieve environmental-friendly and sustainable buildings [20]. The sustainable construction strategy of the UK government and European policy focus on various aspects, including reducing CO_2 emissions, enhancing adaptation to Environmental Change, promoting biodiversity, efficient water management, sustainable supply usage, and efficient garbage disposal [21]. A sustainable building strategy requires precise design synonymous with conservation [22]. Moreover, sustainable construction is increasingly becoming a primary emphasis for construction professionals, aiming to enhance economic efficiency, restore and protect ecological systems, and improve overall human comfort [23].
The continuing process for sustainable growth in building construction and design attempts has been made to improve and protect environmental quality, human health and safety, and the well-being of current and future generations. This process used the effective methods and resources [24]. Sustainable buildings are a type of construction that aims to preserve and optimise functionality and usability. They are improved for aesthetic quality design and consider the entire lifecycle cost. Planning a building to minimise its environmental impact

while fulfilling its intended purpose contributes to achieving sustainability in building practices. Sustainable buildings provide healthy and pleasant environments for occupants while prioritising resource efficiency and ecological considerations. Balaban and Oliveira described sustainable buildings as integrating sustainability principles in design, construction, and management. In contrast, it gradually reduces the building industry's environmental footprint. They concluded that sustainable buildings offer a new approach to addressing health and environmental challenges and provide solutions for the future [7].
Green Buildings (GBs) have been acknowledged as a promising approach to reduce the negative environmental consequences of construction operations. The words "sustainable construction”, "green construction”, and "enriched productivity" have been used interchangeably across the literature. However, "sustainable construction" considers all the elements of building construction, including environmental, social, and economic factors [25].

2.2 Safety in eco-friendly construction

A key factor in achieving sustainable socioeconomic growth for employers in this sector is the health and safety of construction workers. A cutting-edge strategy for improving construction workers' health and safety performance is to use sustainable health and safety ideas that consider the economic and social welfare of construction employers. Exposure to lead, asbestos, silica, and other environmental and chemical risks causes recurrent physical problems that shorten the lives of many construction workers. The notion of sustainable health and safety helps maintain the health and safety of construction workers. Design elements and building techniques associated with using the LEED grading system provide various advantages to those involved in the construction industry, including lower operating costs and improved health and well-being of building occupants. [8]. However, several studies indicated that sustainable construction practices may have detrimental effects on employee health and safety [10]. Islam et al. discovered statistically suggestive evidence that more recordable incidents occurred in sustainable buildings than in conventional ones. According to further research that involves formal analysis of the safety risks related to implementing LEED requirements, integrating new materials, technologies, and innovative construction techniques tends to expose construction workers to new responsibilities and hazardous work environments [7]. Utilising new materials, technologies, and strategies in construction processes can introduce additional complexity because workers may be unfamiliar with the required methods and procedures. This process can lead to increased safety risks and hazards for field personnel during construction and maintenance operations, especially compared to traditional building design alternatives. Previous research indicated that the construction industry significantly affects the consumption of raw materials, accounting for 40 % of stone and sand, 25 % of natural wood, and 16 % of water worldwide. Another study highlighted that construction buildings contribute to 70 % of global timber consumption. Furthermore, construction buildings consume over 30 % of global energy, and traditional buildings contribute to environmental pollution by generating substantial waste throughout their life cycle [25].

3 Review methodology

Previous studies have highlighted the importance of literature reviews in synthesising existing knowledge and identifying gaps for future research. A systematic literature review (SLR) is a widely acknowledged method for conducting literature reviews because it reduces errors and bias. The SLR employs data extraction procedures and investigates various aspects of research articles to comprehensively understand the current state of knowledge in a specific field. An SLR can help identify paradigms and trends in research, thereby improving the quality of research conducted in the field [26].
Planning and computer search:

- This stage involved planning and conducting a systematic literature review (SLR) to identify safety risk factors and effective measures for sustainable buildings. Relevant articles were obtained by searching two academic databases, the Web of Science and

Scopus, using keywords related to green and sustainable buildings. Sixty papers published after 2008 were included in the analysis.

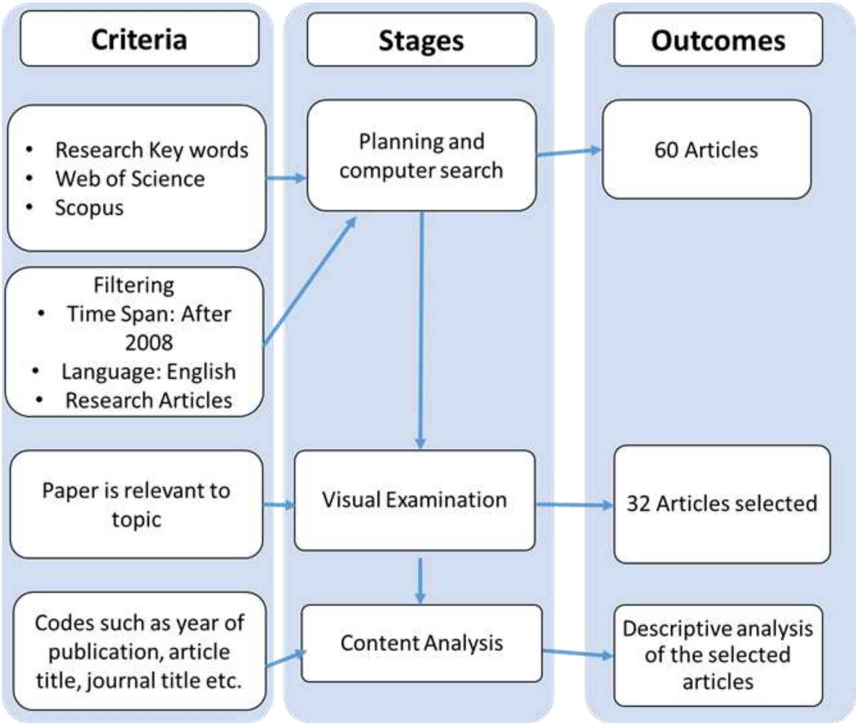

Figure 1. Summarize the SLR phases

Visual Examination:

- Irrelevant papers were excluded based on their titles, abstracts, and contents. Studies that did not consider safety risk factors or effective measures for sustainable construction were excluded. The remaining papers for relevance were examined and narrowed down to 32 for the content analysis (Figure 1).

Content Analysis:

- The content analysis technique was employed to analyse the collected papers and identify emerging patterns in the current literature. The process involved a descriptive analysis of the necessary information based on features such as the year of publication, article and journal titles, and research methodology.

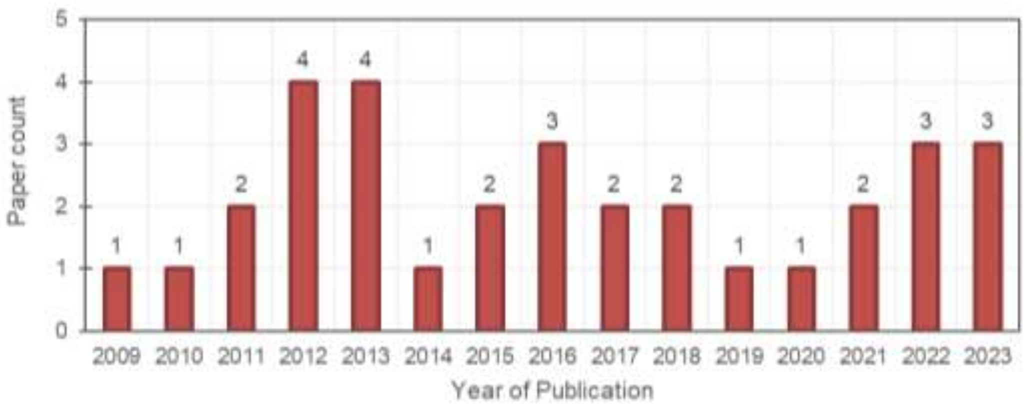

Figure 2. Distribution of safety risk factors and effective measures studies over the years (2009–2023)

The researchers conducted a descriptive examination of the 32 gathered papers, including journal title, journal ranking, year of publication, H-index, and Quartiles. The results show that most papers were from reputable journals with high H-indices and good quartiles. The Journal of Construction Engineering and Management had the most publications (10 articles), followed by Sustainability (six articles) and Safety Science (four papers). The number of published papers per year from 2009 to 2023 was relatively low, which is not surprising, given the specific focus of the SLR on safety risk factors and effective measures in sustainable construction projects, as shown in Figure 2.

4 Research methodology

A thorough analysis of peer-reviewed studies published on construction health and safety is the first step toward identifying the elements of safety practices. This research analysed 32 scholarly articles that meticulously examined the safety risk factors and effective mitigation measures prevalent in sustainable construction projects. The authors employed a rigorous selection process to identify and focus on the most frequently addressed categories of safety risk factors by conducting a descriptive visual examination and in-depth descriptive analysis of the most pertinent articles. Drawing inspiration from Islam et al., this research formulated its objectives and methodology, shaping the foundation of the study. Subsequently, this paper proposes a comprehensive understanding of the relationship between various safety risk factors and their corresponding mitigation measures, primarily derived from an extensive literature review. Researchers have developed sustainability criteria tied intricately to safety risk factors to advance this understanding. These criteria were meticulously structured, assigning weights to each factor contingent on the frequency and severity of occurrence within sustainable construction contexts.

Figure 3. Flow chart of research methodology

Moreover, this research introduced an evaluation framework termed the investigation level. In contrast, it is meticulously designed to assess and gauge the impact of safety risk factors against the backdrop of established sustainability criteria. This framework aims to quantify the extent to which these factors influence the sustainability performance of construction projects. A pivotal component of this research was the creation of a comprehensive flowchart, as illustrated in Figure 3, which portrays the intricate and systematic methodology employed throughout the study.

This visual representation elucidates the sequential process from the initial literature review and factor selection to developing sustainability criteria and the subsequent evaluation framework. This elaborate methodology provides a robust structure and ensures a comprehensive understanding of the interplay between safety risk factors and sustainability in construction projects.

The construction sector is often regarded as one of the riskiest in the economy, resulting in a significant number of deaths and injuries in recent years. While construction work carries inherently high risks worldwide, developing countries experience a three times higher fatality rate than developed nations. Numerous studies have been conducted to assess recent safety procedures and investigate the reasons for their poor safety performance. Extensive subcontracting, lack of safety training, low awareness, inadequate safety regulations and legislation, and uncooperative top management are consistently cited as the primary factors contributing to high fatality and injury rates, as highlighted in the existing literature. In particular, extensive subcontracting can lead to poor safety performance because of the subcontractors' limited safety commitments caused by resource constraints [7, 27].

Moreover, inadequate safety training for workers and top management has been identified as a significant factor contributing to poor safety climates in China, Pakistan, and Saudi Arabia. Other factors include a lack of awareness, insufficient provision of personal protective equipment, and a shortage of safety officers and first-aid resources. Inadequate policies and regulations are major reasons for subpar safety environments. In a separate study, India's poor safety records were attributed to improper enforcement of laws and regulations and corruption stemming from bureaucratic control.

Fatalities may go unreported, but if reported, they may be resolved through cash payments. Previous studies have investigated the discrepancy in accident rates between developing and developed countries, such as South Africa versus Singapore and China versus Australia. The findings from these studies indicate that the key factors contributing to these differences include a lack of management commitment, inadequate supervision, and variations in training and competence levels at construction sites.

Weak regulatory systems in developing countries have also been identified as factors that influence safety performance. Several studies from different angles have reported variables impacting construction safety practices based on an extensive evaluation of the related literature. However, identifying the precise causes of inadequate safety practices in sustainable buildings is crucial from a strategic perspective for all industries [7]. Various researchers have summarised the construction safety factors from previous studies listed in Table 2.

Multiple researchers have emphasised the significance of two key strategies for enhancing safety performance: subcontractor selection and the inclusion of safety requirements in contract documents [7]. Numerous studies have focused on identifying best practices to advance safety. For instance, Hinze et al. conducted a study that explored significant strategies, such as top management commitment, zero tolerance, safety training or workshops, subcontractor prequalification on safety, and regular safety performance meetings [9]. Various strategies have been recommended to achieve excellent construction safety performance, including informal site safety inspections, drug and alcohol testing, engaging experienced project managers, accounting for the additional costs associated with green materials and equipment, and implementing recognition programs.

Table 2. Aspects affecting building site safety measures

Code	Risk Factors	Category	Reference
R1	Absence of adequate safety training	Labour risk	[7, 28, 29]
R2	Excessive overtime work		[7, 28, 29]
R3	Labour disputes and strikes		[30]
R4	Lack of certified skilled labour		[7, 28, 29]
R5	Workers' physical fatigue		[7, 28, 29]
R6	Damages caused by human error		[30-32]
R7	Using inappropriate personal protective equipment		[26, 29-31, 33, 34]
R8	Lack of experiences of current contractors or subcontractors on assembly prefabricated components		[26, 33, 34]
R9	Poor precautions on working from height		[26, 33, 34]
R10	Absence of safety officers on site	Management risk	[7, 28, 29]
R11	Extensive subcontracting		[7, 28, 29]
R12	Lack of management practices and experiences		[7, 28-30]
R13	Lack of management commitment to safety programs		[7, 28-30]
R14	Lead time and schedule delay		[26, 33, 34]
R15	Lack of technical guidance	Technical risk	[7, 26, 31
R16	Lack of knowledge about modern disruptive technologies		[7, 30, 35]
R17	Improper quality control and defective work		[7, 28-30]
R18	Enormous difficulty in achieving return on high initial investment	Financial risk	[26, 29-31, 33, 34]
R19	Cost disadvantages due to higher performance materials cost		[7, 28, 29]
R20	Difficulties in project budgeting due to unfamiliarity in green projects		[26, 29-31, 33, 34]
R21	Green certification cost		[26, 31, 33, 34]
R22	Additional costs due to green material and equipment		[7, 28, 29]
R23	Poor Weather Condition	Environmental Risk	[7, 26, 28, 29, 33, 34]
R24	Waste minimization		[26, 33, 36]
R25	Comfort and health in built environment		[26, 33, 36]

In addition, Karakhan and Gambatese emphasised the importance of integrating safety concepts during the planning and design phases, involving top management in safety programs, and ensuring the presence of adequate safety signage at construction sites [37].
A comprehensive list of twenty (20) mitigation measures was developed by systematically exploring and analysing the literature by identifying and tabulating the most effective strategies. The findings of construction safety research conducted over the past few decades have played a crucial role in improving the safety performance of employers. Creating injury-free environments and promoting safety efforts within the construction industry require collaborative efforts from project teams [7, 26]. This research conclusion, summarised in Table 3, brings together the health and safety activities of all the primary participants in any project. The letter "M" stands for the efficient methods to ensure everyone's safety.

Table 3. Identified effective measures to reduce safety risk

Code	Effective Measures	Reference
M1	Assembling for detailed reports on safety measures on a frequent basis	[7,33]
M2	Obtaining the services of a skilled safety supervisor	[7, 28, 29]
M3	Providing labour safety insurance	[30,33]
M4	Ensuring that all employees adhere to safety requirements	[7, 29]
M5	Establishing proactive cost contingency plan	[7, 28, 33]
M6	Make sure the wearing of personal protection equipment	[30-32]
M7	Making sure suitable equipment is available	[26, 33, 34]
M8	Using past safety performance as a selection factor for subcontractors	[26, 33, 34]
M9	Adding a safety budget to the project expense	[26, 33, 34]
M10	Increasing senior management's understanding of safety	[7, 28, 29]
M11	Increasing self-defense and awareness among employees	[7, 28, 29]
M12	Participation of senior management in safety initiatives	[7, 28, 29]
M13	Constantly holding onsite safety meetings	[26, 34]
M14	Give contractors incentives to promote safety	[7, 26, 31]
M15	Delivering precise and comprehensive safety information	[7, 30, 35]
M16	Displaying warning and safety instructions and signs	[7, 28]
M17	Project managers or safety officers conduct routine safety inspections	[26, 29-31, 34]
M18	strict adherence to safety rules or code of conduct	[7, 28, 29]
M19	Including a safety clause in the contract with the subcontractor	[29, 30]
M20	Specific workshops or training for workers' safety	[7, 33, 36]

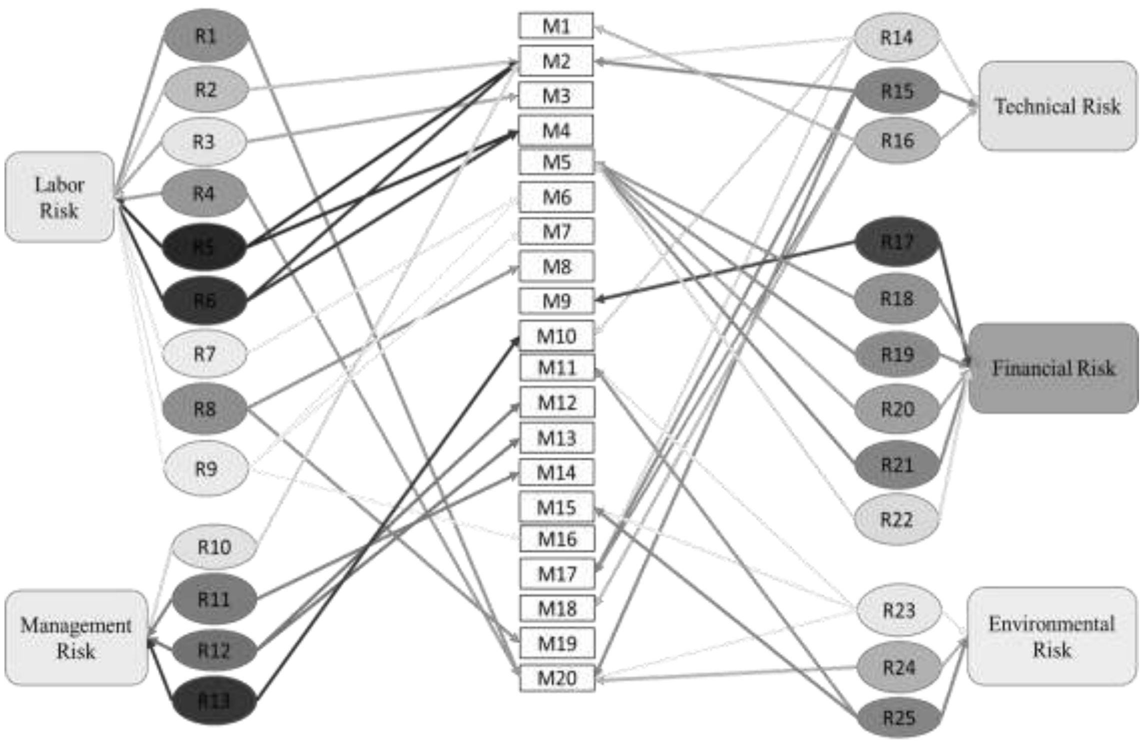

Figure 4. Relationship between risk factors and effective measures

Figure 4 illustrates the correlation between the different risk factors and their corresponding categories, along with the proposed measures to reduce risk. Each risk factor is assigned to a

category, such as labour, management, technical, financial, or environmental risks, and appropriate mitigation measures are suggested. For example, under labour risks, the risk of inadequate safety training (R1) is linked to specific workshops or training for worker safety (M20). Similarly, excessive overtime (R2) was associated with obtaining the services of a skilled safety supervisor (M2). Figure 4 presents a comprehensive relationship between the safety risk factors and their effective measures identified through a systematic literature review.
Establishing sustainability criteria is necessary to evaluate risk factors. The evaluation procedure was performed using the following steps:
Step 1: Develop sustainability criteria to be assessed and assign a weight to each criterion.
For example:

- Health and Safety: 30 %,
- Environmental Impact: 25 %,
- Cost and Budget: 20 %,
- Schedule and Timelines: 15 %,
- Quality of Work: 10 %.

Step 2: Identify the risk factors associated with each criterion
Step 3: Develop a matrix by cross-referencing the criteria and risk factors, and assign a score to each combination based on the level of impact or importance.
Step 4: Calculate the weighted score for each risk factor by multiplying the score with the assigned weight for the associated criterion.
For example:

$$\text{Absence of safety training} = (4 \cdot 0{,}30) + (1 \cdot 0{,}25) + (3 \cdot 0{,}20) + (3 \cdot 0{,}15) + (4 \cdot 0{,}10) = 3{,}10 \quad (1)$$

Table 4. Risk investigation level

Risk	Minimal	Low	Medium	High
Investigation Level	1	2	3	4

Table 4 delineates the investigation levels, denoting the varying intensities of risks observed at the construction sites. In the table, the colour-coded scheme signifies the magnitude of the risk levels: red represents the highest risk level, marked with a corresponding score of 4; yellow designates a medium risk level, paired with a score of 3; dark green indicates a low-risk level, attributed to a score of 2; and light green signifies a minimum risk level, denoted by a score of 1. This colour-based categorisation allows for a quick and visual understanding of the diverse risk intensities prevalent within construction sites, aiding the swift identification and prioritisation of potential hazards.
This assessment evaluates the safety risk factors associated with construction projects and uses various sustainability criteria to evaluate them, as shown in Table 5 and Figure 5. Safety risk factors are categorised into labour, management, financial, technical, and environmental. Each safety risk factor is assigned a score from 1 to 4, with a score of 4 indicating the highest risk level. The evaluation identifies several high- safety risk factors, including the absence of adequate safety training (R1), excessive overtime work (R2), labour disputes and strikes (R3), lack of certified skilled labour (R4), workers' physical fatigue (R5), damages caused by human error (R6), using inappropriate personal protective equipment (R7), poor precautions for working from heights (R9), absence of safety officers on site (R10), lack of management practices and experiences (R12), lack of management commitment to safety programs (R13), lead time and schedule delay (R14), lack of technical guidance (R15), poor weather conditions (R23), and comfort and health in the built environment (R25). These risk factors have scores ranging from 3 to 4, indicating medium to high risk.

Table 5. Evaluation of safety risk factors with sustainability criteria

Code	Risk Factors	Health and Safety	Environmental Impact	Cost and Budget	Schedule and Timelines	Quality of Work	Evaluation sustainability criteria
R1	Absence of adequate safety training	4	1	4	3	4	3,10
R2	Excessive overtime work	4	4	3	4	4	3,80
R3	Labor disputes and strikes	4	2	4	4	4	3,50
R4	Lack of certified skilled labour	4	1	4	4	4	3,25
R5	Workers' physical fatigue	4	4	4	4	4	4,00
R6	Damages caused by human error	4	4	4	4	4	4,00
R7	Using inappropriate PPE	4	3	2	3	4	3,20
R8	Lack of experiences of current contractors or subcontractors on assembly prefabricated components	4	2	3	2	2	2,80
R9	Poor precautions on working from height	4	4	4	4	4	4,00
R10	Absence of safety officers on site	4	2	3	3	4	3,15
R11	Extensive subcontracting	1	1	3	4	3	2,05
R12	Lack of management practices and experiences	4	2	3	4	3	3,20
R13	Lack of management commitment to safety programs	4	2	4	3	3	3,25
R14	Lead time and schedule delay	3	3	4	4	3	3,35
R15	Lack of technical guidance	3	3	4	4	3	3,35
R16	Lack of knowledge about modern disruptive technologies	2	2	3	3	2	2,35
R17	Improper quality control and defective work	3	2	3	3	4	2,85
R18	Enormous difficulty in achieving return on high initial investment	1	1	4	3	2	2,00
R19	Cost disadvantages due to higher performance materials cost	1	3	4	4	2	2,65
R20	Difficulties in project budgeting due to unfamiliarity in green projects	2	2	4	3	3	2,65
R21	Green certification cost	1	2	4	4	2	2,40
R22	Additional costs due to green material and equipment	2	2	4	4	3	2,80
R23	Poor Weather Condition	4	3	3	4	3	3,45
R24	Waste minimization	3	4	2	3	3	3,05
R25	Comfort and health in built environment	3	4	2	3	4	3,15

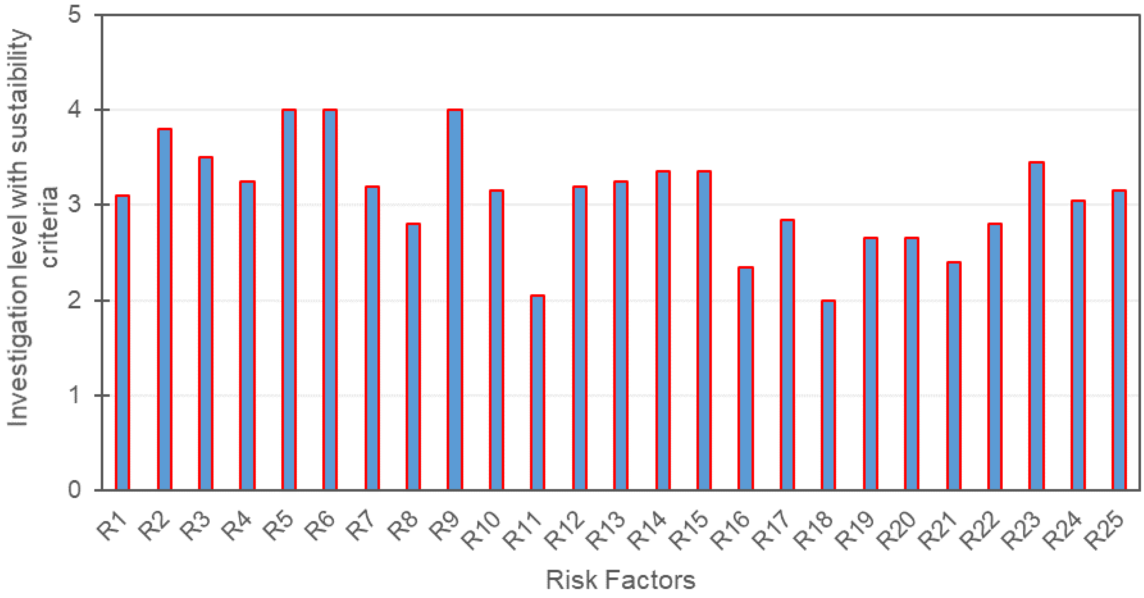

Figure 5. Investigation level of Safety risk factors with sustainability criteria

Other risk factors such as lack of experience of current contractors or subcontractors in the assembly of prefabricated components (R8), extensive subcontracting (R11), lack of knowledge about modern disruptive technologies (R16), improper quality control and defective work (R17), enormous difficulty in achieving a return on high initial investment (R18), cost disadvantages due to higher performance materials cost (R19), difficulties in project budgeting due to unfamiliarity with green projects (R20), green certification cost (R21), and additional costs due to green material and equipment (R22) have medium and low-risk scores ranging from 2 to 3.

Table 5 presents the overall evaluation of safety risk factors using the sustainability criteria. The analysis revealed that the labour risk factor had a medium to the highest level of risk at 88,9 %, followed by management risks at 75 %, technical risks at 33,3 %, and environmental risks at 100 %. These risk factors are crucial for ensuring the safety and sustainability of organisations. Therefore, measures must be taken to mitigate these risks and ensure the well-being of the workforce and the environment.

5 Conclusions

Based on the comprehensive assessment, this study successfully identified and evaluated various safety risk factors prevalent in construction projects. Using sustainability criteria and a scoring system ranging from 1 to 4, these factors were categorised into labour, management, technical, and environmental risks. The evaluation highlighted the critical safety risk factors rated with higher scores, signifying substantial concern within construction endeavours. Notably, issues such as inadequate safety training, excessive overtime, labour disputes, a lack of certified skilled labour, human errors, and deficiencies in safety equipment and precautions have emerged as high-risk factors.

Furthermore, this assessment sheds light on additional risk factors, including lack of experience with prefabricated components, extensive subcontracting, insufficient knowledge about modern disruptive technologies, and challenges related to green projects and materials, which present moderate to low levels of risk. Table 4, which encapsulates the overall evaluation using the sustainability criteria, emphasises the significance of these risk factors. The analysis indicates that labour and management risks pose substantial concerns, demanding immediate attention to safeguard workforce well-being and environmental sustainability. Labour risks, in particular, emerged as critically high at 88,9 %, closely followed by management risks at 75 %. Technical risks were noted at a moderate level of concern, measuring 33,3 %, whereas environmental risks demonstrated the highest level, registering 100 %.

In light of these findings, it is evident that addressing these identified risk factors is paramount to ensuring the safety, sustainability, and overall success of construction projects. Urgent measures and targeted interventions are required to mitigate these risks effectively, aiming to protect the workforce's well-being and preserve and promote a sustainable environment within the construction industry.

In conclusion, this assessment contributes significantly to recognizing and quantifying crucial safety risk factors in construction projects. This underscores the essential need for proactive measures and strategic interventions to mitigate these risks, fostering a safer and more sustainable future for the workforce and the environment.

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