ISSN 1392-3730/eISSN 1822-3605

VILNIUS TECH
Vilnius Gediminas Technical University

JOURNAL of CIVIL ENGINEERING and MANAGEMENT

2025
Volume 31
Issue 8
Pages 893–908
https://doi.org/10.3846/jcem.2025.24790

A SYSTEMATIC REVIEW ON SAFETY PRACTICES IN HIGH-RISE BUILDING CONSTRUCTION: BENEFITS, BARRIERS, AND STRATEGIC IMPROVEMENTS

Wei Rui LEI[1], Muhamad Azry KHOIRY[1,2]✉, Azrul A MUTALIB[1,2]

[1]*Department of Civil Engineering, Faculty Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43650, Bangi, Malaysia*
[2]*Smart and Sustainable Township Research Center, Faculty Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43650, Bangi, Malaysia*

Article History:
- received 11 October 2024
- accepted 12 June 2025

Abstract. High-rise building construction has long been considered one of the most dangerous jobs globally. However, there is currently a lack of comprehensive systematic reviews that approach the implementation of safety practices in high-rise construction. This study aims to fill the following research gaps: first, to understand the significance and identify the barriers faced to implementing safety practices in high-rise construction; second, to propose a framework to improve safety performance. A total of 109 articles from databases were thoroughly reviewed in this study.
The research identified six categories of benefits, five types of safety barriers, and 15 strategies proposed to overcome these barriers. In terms of the number of sources, "reduced accident rates" and "improved organizational reputation" were identified as the top benefits in terms of the significance of safety practices. "Lack of health and safety training" was deemed the largest barrier. To address these challenges, this paper explores the strategies and risk mitigation measures from the perspectives of six stakeholders: regulatory agencies, government, owners, contractors, consultants, and workers. The findings suggest that establishing strict market entry mechanisms are fundamental while strengthening worker safety training and conducting regular safety inspections and real-time site monitoring are the most effective methods.

Keywords: high-rise building, benefits, barriers, construction safety practice, stakeholders, strategies.

✉Corresponding author. E-mail: *azrykhoiry@ukm.edu.my*

1. Introduction

The building construction sector, as a crucial driver of global economic growth, makes a significant contribution to GDP. However, one of the major challenges in the development of the construction industry is ensuring safety during construction. Studies conducted by various researchers have consistently shown that the fatal outcome rate in the construction sector is alarmingly high (Arifin et al., 2023; Gill & Clark, 2024). The National Safety Council (2013) reported that 10,000 people have died on construction sites in the US over the past fifteen years. This figure represents the highest number of fatalities among all industries during this period (Mahmoudi et al., 2014).

According to data from the Ministry of Housing and Urban-Rural Development of the People's Republic of China (2023), the general trend of construction accidents and deaths has been declining over the past 5 years, the absolute value remains high, as Figure 1 shows. Safety has

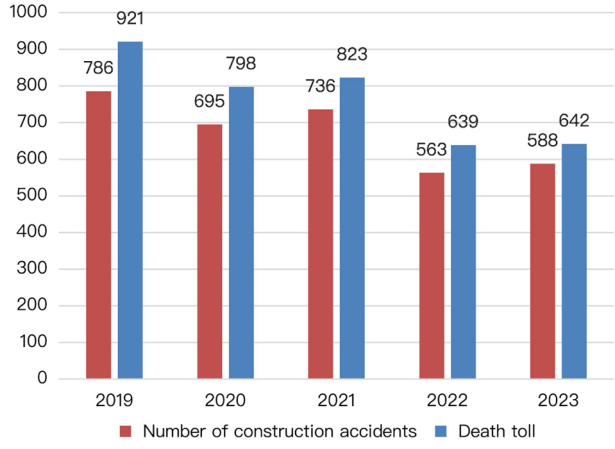

Figure 1. Statistics on the number of construction accidents and deaths in China from 2019 to 2023 (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2023)

become a critical factor hindering the sustainable development of the construction industry.

Table 1 displays the accident types of building construction in China. There were a total of 1682 incidents of high-altitude falling accidents, accounting for 53%, 447 incidents of object strikes, accounting for 14.1%, representing 9.5% of the total, and 257 incidents involving crane injuries, making up 8.1%; 148 cases of mechanical injuries, making up 4.7% of the total, and 90 cases of electric shock accidents, representing 2.8%, as well as 247 incidents of fire, suffocation, traffic accidents and other accidents, accounting for 7.8% (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2021). The higher proportion of accidents, such as falls from heights, object strikes, foundation pit collapses, and crane-related injuries, are unique to high-rise construction. These types of incidents account for up to 84.7% of the total accidents, indicating that high-rise construction is the primary source of safety incidents in China's construction industry.

The primary causes of accidents are linked to the distinctive characteristics of the construction industry. Aminbakhsh et al. (2013) revealed that factors such as constantly changing work environments, heavy equipment, high-altitude operations, the extensive use of advanced machinery, and simultaneous multi-trade operations make construction sites particularly hazardous. The nature of the high-rise construction sector determines the dangerous essence of the construction site; however, neglecting safety management is the direct cause of injury and even fatality.

The primary factors contributing to poor safety performance, as highlighted in much of the literature reviewed, include extensive subcontract, low safety awareness, inadequate safety training, Imperfect safety regulations, and lack of support from top management. Construction accidents and injuries result in both explicit and implicit costs. Wang et al. (2006) identified explicit costs as including medical expenses and workers' compensation insurance, while Mahmoudi et al. (2014) noted that implicit costs encompass delays in construction progress, decreased worker motivation, and damage to the reputation of construction companies. Therefore, safety is an issue that cannot be overlooked, especially during the construction of high-rise buildings.

Despite efforts to address safety issues, the results have been unsatisfactory, with construction accidents continuing to be widespread. National programs led by government authorities and initiatives from private companies have not sufficiently reduced the rate of construction accidents, which remains alarmingly high. This demonstrates that these measures are insufficient for effectively managing unsafe practices at construction sites. This phenomenon has attracted the attention of many researchers who have conducted studies on construction safety issues. However, there has been limited focus on identifying the key barriers to safety practices and exploring strategies to successfully implement safety practices in high-rise building construction. Therefore, this study concentrates on identifying and classifying critical barriers that hinder implementing safety practices in high-rise building construction. Additionally, it will explore strategies to overcome these barriers to enhance safety performance, ultimately aiming to improve overall safety outcomes.

Existing studies have systematically reviewed construction safety, but few concentrated on the uniqueness of high-rise building construction safety. For instance, Siraj and Fayek (2019) primarily focus on general construction, with limited research on the specific risks of high-rise buildings (such as working at heights, deep foundation pit collapse, etc.). In addition, most existing reviews emphasize theoretical analysis but lack practical recommendations for actual construction safety management. Moreover, a more integrated approach is needed, focusing on cross-stakeholder collaboration and technological advancements in safety management within high-rise projects.

Therefore, the research objectives of this study are: first, to explore why safety practices are necessary in high-rise building construction; second, to identify the barriers or challenges currently faced by safety practices; and finally, to examine the countermeasures found in existing research to address these obstacles. By reviewing the literature on the benefits, barriers, and countermeasures of implementing safety practices in the construction sector, this study systematically identifies the obstacles currently hindering the advancement of construction safety practices and summarizes existing solutions. This paper is the first step, which focuses on the theoretical part. Building on this foundation, in the next phase of our research, we

Table 1. Statistics of construction safety accident types in China from 2016 to 2020 (Ministry of Housing and Urban-Rural Development of the People's Republic of China, 2022)

Safety accidents types	2016	2017	2018	2019	2020	Proportion
Fall from height	235	332	329	379	407	53.0%
Object strike	66	96	81	121	83	14.1%
Collapse	59	66	80	54	42	9.5%
Crane injury	32	55	71	54	45	8.1%
Mechanic injury	24	23	32	43	26	4.7%
Electric shock	7	21	21	19	22	2.8%
Other type	17	33	68	65	64	7.8%

will adopt a practical approach by collecting survey data from Jiangsu Province, China, to validate these safety barriers and assess the feasibility of existing countermeasures. Through quantitative data analysis, the study aims to explore an integrated pathway that synthesizes theory and practice for promoting safety practices. Ultimately, it seeks to develop a Jiangsu model for construction safety management. This study contributes by offering a comprehensive review specifically targeting high-rise buildings and by proposing innovative strategies to address gaps in safety management.

The research framework of this paper is as follows: The introduction explains the significance of this study and the overall research objectives. Section 2 presents the research methods and process. Section 3.1 discusses the benefits of implementing safety practices. Section 3.2 reveals the barriers to implementing safety practices. Section 4 explores strategies and methods to overcome these barriers. Section 5 discusses the research findings, and Section 6 presents the research conclusions.

2. Research methodology

The literature search was carried out in two steps. Initially, a manual search was conducted in web engines and databases including Web of Science, Google Scholar, as well as Scopus database. To ensure the reliability of the research, we only included studies published in reputable, peer-reviewed journals, industry reports from recognized organizations, or proceedings from established conferences. To figure out relevant sources, the specific research keywords were chosen to be "Safety practice", "Safety barriers/challenges", "Safety benefits", and "Construction industry". Subsequently, the titles and abstracts of the sources were screened, and those deemed relevant to this study were selected for full retrieval. The inclusion criteria of sources: (a) addressed safety barriers in high-rise construction, (b) published between 2000 and 2024, (c) available online, and (d) written in English. After correlation and article quality screening, 109 sources in total were investigated to discover safety benefits and barriers to implementing safety practices in high-rise building construction.

Additionally, content analysis was conducted to identify safety benefits, safety barriers, and methods to enhance safety performance. We assessed the quality of the selected papers based on their methodological rigor, relevance to high-rise construction safety, and the credibility of the research sources. We prioritized studies that provided insights into unique safety challenges and practices within the context of high-rise construction, such as high-altitude work, crane operations, and structural integrity risks. This analysis was carried out in three rounds. The first round identified 34 benefits from 41 sources after extensive analysis. The second round identified 27 barriers from 109 sources. The third round uncovered 15 strategies to overcome these barriers, derived from 19 sources. All selected papers meet high-quality standards, ensuring the reliability and relevance of our findings. Figure 2 highlights the research methodology of this paper.

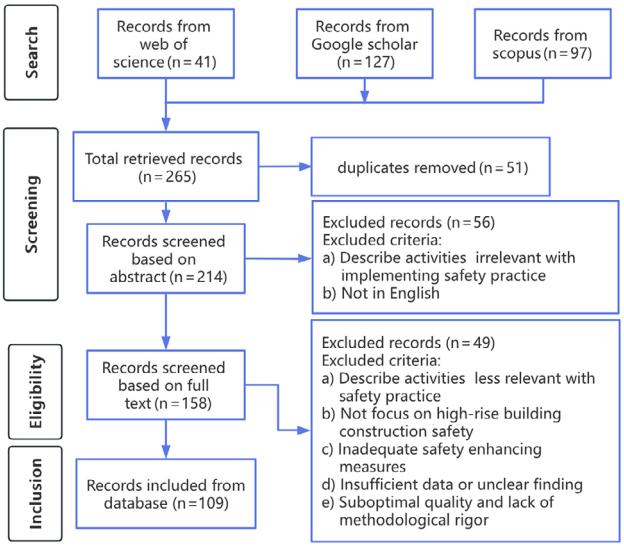

Figure 2. Research methods flowchart

Geographical biases can occur if studies are predominantly selected from certain regions or countries, which might limit the generalizability of the findings. To mitigate this, we made a conscious effort to include research from diverse geographic locations. We performed searches in multiple international databases to ensure that studies from various regions, including both developed and developing countries, were represented. While we aimed to minimize biases, we recognize that there are limitations in the literature selection process. For example, the exclusion of non-English language studies and the reliance on certain databases may have inadvertently excluded relevant research. Additionally, some studies may have been missed due to search term limitations or inaccessible sources.

3. Results and discussion

3.1. Benefits of implementing safety in high-rise building construction

Hallowell et al. (2013) believed that a strong safety culture can be cultivated through the successful implementation of the safety program, as it necessitates collaboration between managers and workers in executing the program. This section provides a comprehensive review of safety benefits and their sources. As indicated in Table 2, these benefits are organized into 6 categories.

Within the category of reduction of accidents and elimination of hazards, the reduction in work-related accident rates is the primary benefit of implementing safety practices, followed closely by improved working conditions within high-rise buildings. This is due to the complex environment of high-rise construction, which involves heavy machinery, high-altitude operations, scaffolding instability, etc. Adopting safety practices, such as installing pro-

Table 2. Benefits of implementing safety practices in high-rise building construction

Benefits of safety practices	Specific Benefits	Authors
Reduction of accidents and elimination of hazards	Reduced accident rates in high-rise	Robson et al. (2007), Yiu et al. (2018, 2019), Fernández-Muñiz et al. (2009), Buniya et al. (2021)
	Decrease in near-misses and recorded accidents	Yiu et al. (2016, 2018, 2019), Choudhry and Fang (2008)
	Improved safety of working conditions in high-rise buildings	Yiu et al. (2018, 2019), Choudhry and Fang (2008), Kamoli et al. (2021)
	Decreased harm to workers at height	Fernández-Muñiz et al. (2009), Yiu et al. (2018, 2019)
	Better accident investigation and analysis processes	Yiu et al. (2018, 2019), Goh and Chua (2013)
	Enhanced worker protection at height	Lakhiar (2021), Kineber et al. (2023)
	Reduction in falls from heights	Salvador and Van Thinh (2016), Lakhiar (2021), Kineber et al. (2023)
Strengthened safety perception and awareness	Improved safety awareness and enhanced safety commitments related to high-rise	Yiu et al. (2018), Choudhry and Fang (2008), Chan et al. (2010)
	Increased support for OSH training and information	Yiu et al. (2018, 2019), Kineber et al. (2023)
	Employees reject violations and reckless operations in high rise	Yiu et al. (2016), Choudhry and Fang (2008)
Better project management (operation efficiency)	Incorporation of safety management into project management	Buniya et al. (2021) Yiu et al. (2018, 2019)
	Better management of complex environments in high-rise projects	Lakhiar (2021), Kineber et al. (2023)
	No interruptions in work progress and improved project continuity in high-rise projects	Yiu et al. (2018), Lakhiar (2021), Kineber et al. (2023)
	Better safety culture	Buniya et al. (2021)
	Improved project management	Yiu et al. (2018, 2019)
	Efficient top-down communication	Yiu et al. (2018, 2019)
	A substantial influence on safety performance	Manzoor et al. (2022)
Cost reduction and profit maximization	Reduced accidents and expenses in high-rise projects	Buniya et al. (2021), Robson et al. (2007), Yiu et al. (2018, 2019)
	Improved cost efficiency	Salvador and Van Thinh (2016)
	Reduced material damage	Fernández-Muñiz et al. (2009), Moorkamp et al. (2014)
	Enhanced financial performance	Fernández-Muñiz et al. (2009), Salvador and Van Thinh (2016)
Heightened organizations' reputation (standard compliance)	Improved organization framework for high-rise projects	Yiu et al. (2018, 2019), Aminbakhsh et al. (2013), Garnica and Barriga (2018)
	Establish a brand reputation and public perception	Yiu et al. (2018, 2019), Salvador and Van Thinh (2016), Smallman and John (2001), Ju and Rowlinson (2014)
	Compliance with safety regulations specific to high-rise construction and high safety audit scores	Yiu et al. (2018, 2019), Lakhiar (2021)
	Demonstrate social responsibility	Salvador and Van Thinh (2016)
	Improved competitiveness and productivity	Fernández-Muñiz et al. (2007, 2009), Salvador et al. (2016), Ju and Rowlinson (2014)
	Improved profitability	Fernández-Muñiz et al. (2009), Hatema et al. (2022)
	Retains skilled workers	Salvador and Van Thinh (2016)
	Increases sustainable development	Salvador and Van Thinh (2016)
Workers' wellbeing	Improvement on employees' remuneration	Yiu et al. (2018, 2019)
	Decreased risk for workers in high-rise projects	Yiu et al. (2018, 2019)
	Overcoming deficiency	Salvador and Van Thinh (2016)
	Job satisfaction	Salvador and Van Thinh (2016)
	Enthusiasm and vigorous work atmosphere	Salvador and Van Thinh (2016)

tective nets, utilizing Personal Fall Arrest Systems (PFAS), and using scaffolding that has passed the bearing capacity verification, can significantly improve working conditions in high-rise settings, thereby reducing harm to workers.

Turner Construction, by adopting a comprehensive Safety Management System (SMS), achieved significant safety improvements across multiple projects. For example, in a large high-rise building project in New York, Turner saw a 40% reduction in accident rates after implementing the SMS. By reducing accidents and improving work efficiency, Turner successfully minimized the additional costs associated with downtime and accident management, thereby enhancing the overall economic efficiency of the project (Turner Construction, 2020).

Within the category of strengthened safety perception and awareness, the heightened safety awareness and commitments enhance workers' support for occupational safety and health (OSH) training. Through attending well-structured and engaging safety training, workers gain a clear understanding of the hazards present in high-rise construction. Furthermore, the commitment to safety demonstrated by project managers serves as a role model for workers. As a result, workers are more likely to reject safety violations and reckless behavior (Choudhry & Fang, 2008; Yiu et al., 2018; Labor Department, 2024).

Within the category of improved project management, the incorporation of safety management into project management practices has fostered better safety performance, resulting in an enhanced safety culture (Yiu et al., 2018). Top management allocates adequate funds for safety practices and establishes clear, well-defined procedures, thus improving project managers' abilities to manage emergencies and accidents (Goh & Chua, 2013; Labor Department, 2024). Consequently, this leads to fewer interruptions in work progress, improving project continuity in high-rise projects, increasing operational efficiency, and a better safety climate through effective safety management. For instance, Lendlease, a globally renowned construction and infrastructure company, implemented a Safety Management System (SMS) in a high-rise building project in Australia. In this project, Lendlease successfully reduced the accident rate by 35% through enhanced on-site management, the introduction of intelligent monitoring systems, and real-time data analysis. Additionally, the project timeline was shortened, and work efficiency improved by 20% (Lendlease, 2017).

Within the category of cost reduction and profit maximization, the implementation of the Safety Management System (SMS) could yield favorable outcomes in terms of cost savings. Savings, either in the sense of compensating workers or the losses caused by project delays or even suspension, can be realized. Consequently, the overall financial performance of the project can be enhanced (Moorkamp et al., 2014; Yiu et al., 2018). As a typical case, by implementing the Safety Management System (SMS), Skanska has successfully reduced accident rates across multiple construction projects. Specifically, Skanska's 2018 report highlighted that the implementation of SMS led to a reduction in accident incidence by approximately 30% across several projects. This not only enhanced site safety but also decreased downtime and medical costs associated with accidents, thereby improving overall project efficiency and profitability (Skanska, 2018).

Within the category of heightened organization's reputation, by complying with safety standards specific to high-rise construction, organizations can achieve accident prevention and high safety audit scores. When workers are more likely to follow safety regulations, it results in significant financial savings by reducing unplanned expenses associated with insurance, healthcare, compensation, and fines. Moreover, organizations with high safety audit scores enjoy improved reputations and stronger brand identities, along with greater returns on their investments in occupational safety and increased profitability.

Within the category of workers' well-being, the benefit mainly refers to that safety practices provide significant benefits for workers. The construction industry can create job opportunities and absorb labor on a national level (Khoiry et al., 2017; Nurhendi et al., 2022). However, accidents, work-related injuries, and illnesses directly impact the economy and place a considerable burden on families and society. By implementing safety practices, the risks for workers in high-rise construction are reduced, leading to fewer accidents and fatalities. Consequently, the company embraces lower accident-related costs, allowing for more funds to be allocated to workers' salaries (Yiu et al., 2018, 2019). Figure 3 represents the 6 categories of benefits of implementing safety practices and their sources visually.

3.2. Barriers to implementing safety practices in high-rise building construction

According to the sources of barriers, the obstacles to safety implementation can be divided into 5 categories based on the source of risks: regulatory, resource & financial, organizational, operational, and worker-related barriers. The relevant literature to date on barriers to safety implementation is outlined in Table 3.

3.2.1. Regulatory barriers

Establishing a comprehensive, clear, and enforceable set of construction occupational safety regulations is the foundation for implementing safety practices. Awwad et al. (2016) indicated that construction safety regulations are too general and lack of specific safety regulations related to high-rises in many developing countries. As a result, many companies are unable to develop their own safety regulations based on national laws and instead have to rely on their own experience or piece together various international safety standards.

The lack of strict enforcement of OHS regulations is another hardship to overcome (Tam et al., 2004), especially for high-rise safety regulations. In developing countries like Pakistan and India, there is frequently insufficient regulatory enforcement of safety standards in construction. This results in contractors and workers not complying with safety protocols.

3.2.2. Resource and financial barriers

In the construction industry, the high cost of safety equipment, training, inspections, and protective measures, along with limited resource allocation, is a common issue. Subcontractors often lack the funds to purchase safety equipment such as proper scaffolding, anchor points, and personal protective equipment. The absence of these resources creates additional challenges in maintaining a safe working environment. What's more, Awwad et al. (2016) surveyed owners and found that none of the owners provided any rewards for implementing safety practices.

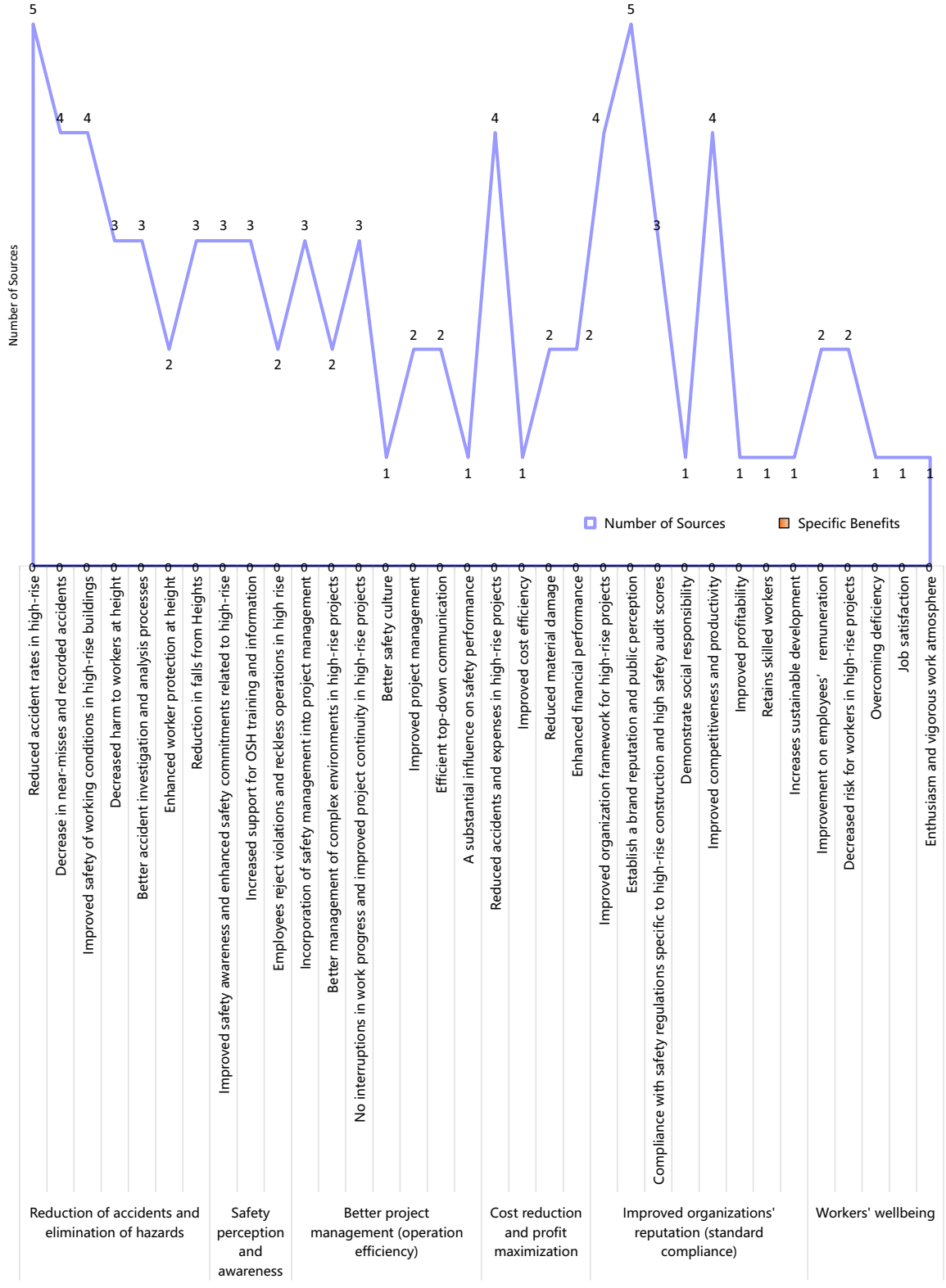

Figure 3. Benefits of safety practices and their sources

Table 3. Barriers of implementing safety practices in high-rise building construction

Barriers in General	Barriers in Details	Sources
Regulatory Barriers	Inadequate H&S standards specific to high-rise safety	Awwad et al. (2016), Alnunu and Maliha (2015), Hamid et al. (2008), Revathi et al. (2017), Zahoor et al. (2016), Priyadarshani et al. (2013), Kadiri et al. (2014), Ali and Omran (2016), Cooney (2016), Agbede et al. (2016), Buniya et al. (2021)
	Insufficient legislation and a dearth of height-related specific safety decree	Awwad et al. (2016), Alnunu and Maliha (2015), Zahoor et al. (2016), Cooney (2016), Agbede et al. (2016), Chiocha et al. (2011), Buniya et al. (2021)
	A dearth of penalties for non-compliance with safety standards	Tam et al. (2004), Alnunu and Maliha (2015)
	Lack of strong regulatory enforcement for safety standards in high-rise construction	Awwad et al. (2016), Belayutham and Ibrahim (2019), Tam et al. (2004), Alnunu and Maliha (2015), Keng and Razak (2014)
Resource and Financial Barriers	Shortage of finance for high-rise safety practice	Ghahramani (2017), Murugasamy et al. (2020), Mashwama et al. (2019)
	High cost and limited allocation of resources for safety equipment, training, inspection and protective measures	Yiu et al. (2016), Goh and Chua (2013), Kineber et al. (2023), Belayutham and Ibrahim (2019)
Organizational Barriers	Fail to assign dedicated administrator responsible for inspecting the worksite in high-rise construction	Awwad et al. (2016), Tam et al. (2004), Alnunu and Maliha (2015)
	Lack of rewards and penalties towards safety	Yiu et al. (2018, 2019), Goh and Chua (2013), Awwad et al. (2016), Murugasamy et al. (2020), Ju and Rowlinson (2014)
	Lack of health and safety (H&S) training for high-rise construction	Yiu et al. (2018, 2019), Salvador and Van Thinh (2016), Awwad et al. (2016), Belayutham and Ibrahim (2019), Tam et al. (2004), Alnunu and Maliha (2015), Hamid et al. (2008), Ghahramani (2017), Keng and Razak (2014), Choudhry and Fang (2008), Priyadarshani et al. (2013), Kadiri et al. (2014), Ali and Omran (2016), Mouleeswaran (2014), Cheah (2007), Durdyev et al. (2017), Mashwama et al. (2019), Oke et al. (2017), Saeed (2017), Enshassi et al. (2007)
	Failing to consider contractors' prior safety performance during the contract award process	Awwad et al. (2016), Charehzehi and Ahankoob (2012), Fernández-Muñiz et al. (2009), López-Arquillos et al. (2015), Ali and Omran (2016)
Operational Barriers	Extensive subcontractors	Yiu et al. (2018)
	Lack of safety awareness towards high-rise construction among project managers	Goh and Chua (2013), Kineber et al. (2023), Garnica and Barriga (2018), Buniya et al. (2021), Tam et al. (2004), Alnunu and Maliha (2015), Hamid et al. (2008), Ghahramani (2017), Ali and Omran (2016), Mahfuth et al. (2019, 2020)
	Regardless of safety in selecting subcontractors or when contracting with them	Awwad et al. (2016)
	Insufficient risk assessment specific to high-rise building construction	Lakhiar (2021)
	Insufficient accident record keeping, lack of accident analysis and failure to update safety programs	Awwad et al. (2016), Mahfuth et al. (2018), Revathi et al. (2017), Agbede et al. (2016), Buniya et al. (2021), Nawi et al. (2017), Okoye et al. (2016), Cheah (2007), Durdyev et al. (2017)
	Lack of well-planned and regular safety meetings	Tam et al. (2004), Alnunu and Maliha (2015), Keng and Razak (2014), Maliha et al. (2021), Spillane and Oyedele (2013), Mouleeswaran (2014), Ali and Omran (2016)
	Lack of safety inspection for high-rise construction	Buniya et al. (2021), Hamid et al. (2008), Charehzehi and Ahankoob (2012), Cheah (2007), Durdyev et al. (2017), Mashwama et al. (2019), Oke et al. (2017), Mohamed et al. (2009)
	Low prioritization of safety	Yiu et al. (2018), Fernández-Muñiz et al. (2007), Goh and Chua (2013), Kineber et al. (2023)

End of Table 3

Barriers in General	Barriers in Details	Sources
Worker-related Barriers	Low education level, uncertified worker and lack of experience	Tam et al. (2004), Alnunu and Maliha (2015), Hamid et al. (2008), Ghahramani (2017), Priyadarshani et al. (2013), Kadiri et al. (2014), Nawi et al. (2017), Durdyev et al. (2017), Mashwama et al. (2019), Saeed (2017)
	High rate of worker turnover in high-rise construction	Yiu et al. (2018)
	Tight project schedule of high-rise construction and high work pressure	Yiu et al. (2016), Kineber et al. (2023), Moorkamp et al. (2014), Ali and Omran (2016), Alnunu and Maliha (2015), Hamid et al. (2008), Revathi et al. (2017), Mnjula et al. (2014), Choudhry and Fang (2008), Nawi et al. (2017), Cheah (2007), Guo et al. (2016), Durdyev et al. (2017), Zerguine et al. (2016), Meliá and Becerril (2009), Mullen (2004), Kadiri et al. (2014)
	Inadequate communication among project teams	Zulkifle and Hanafi (2017), Garnica and Barriga (2018), Lakhiar (2021), Kineber et al. (2023)
	Taking for granted that safety is solely the responsibility of safety supervisor.	Fernández-Muñiz et al. (2007), Kineber et al. (2023)
	Limited dedication to Occupational Health and Safety (OHS)	Yiu et al. (2016, 2018), Kineber et al. (2023), Awwad et al. (2016), Hamid et al. (2008), Charehzehi and Ahankoob (2012), Zulkifle and Hanafi (2017), Chiocha et al. (2011), Nawi et al. (2017), Durdyev et al. (2017), Mashwama et al. (2019), Mohamed et al. (2009), Saad (2016), Diugwu et al. (2012), Toole (2002), Walters (2010)
	Insufficient safety awareness among workers, especially regarding working at heights	Tam et al. (2004), Alnunu and Maliha (2015), Keng and Razak (2014), Maano and Lindiwe (2010)
	Low level of awareness on using PPE when working at heights	Ghahramani (2017), Keng and Razak (2014), Andi (2008), Revathi et al. (2017), Vitharana et al. (2015), Mahfuth et al. (2018), Diugwu et al. (2012)
	Disobliging industry standards and safety protocols especially related to high-rise building construction	Buniya et al. (2021)

3.2.3. Organizational barriers

In organizational barriers, the lack of H&S training for high-rise construction is the most significant. Keng and Razak (2014) stated that training seeks to minimize human errors that could lead to incidents and enable employees to accomplish tasks competently and repetitively. Although many workers recognize the importance of training, they often prioritize completing tasks quickly to earn their wages, rather than attending training sessions (Choudhry & Fang, 2008).

Lack of rewards and penalties towards safety is the second largest organizational barrier. Consultants play a crucial role in overseeing safety measures on construction sites. Awwad et al. (2016) revealed that in the Lebanese construction sector, the majority of the consultants focused solely on fulfilling the essential safety requirements outlined in the contract. What's more, there are no incentives provided by consultants for contractors to implement safety measures, and only a few implemented penalizing actions in the event of safety violations.

3.2.4. Operational barriers

Insufficient safety awareness of high-rise construction among project managers was widely mentioned in the reviewed literature (Goh & Chua, 2013). High-rise buildings have more complex designs, which increases the difficulty of coordinating safety measures across multiple floors, and different stages of construction. However, the project managers focus solely on the tight schedule, with safety neglected. What's more, Awwad et al. (2016) found that project managers often fail to strictly enforce safety by penalizing unsafe behavior.

Insufficient accident record keeping in high-rise construction is the second largest operational barrier (Mahfuth et al., 2018; Revathi et al., 2017). Without accident records, it is impossible to conduct accident cause analysis, identify gaps in current safety practices, or even determine ways to improve them. This also hinders the updating of existing safety programs and the establishment of occupational injuries databases.

Subcontract is an important section of the construction sector, especially for high-rise building construction. Awwad et al. (2016) mentioned that safety procedures were conveyed to subcontractors in safety meetings, and their appropriate execution was tracked by contractors. However, extensive subcontracting complicates site management for the main contractor, which in turn adversely affects safety (Yung, 2009).

Implementing Safety Management Systems (SMS) in both small and medium-sized enterprises (SMEs) and large enterprises in construction can present distinct challenges. for small and medium-sized enterprises, due to limited financial resources, fewer staff, and lack of specialized safety management teams, these companies may struggle with providing in-depth safety training, conducting detailed

risk assessments, and maintaining compliance with safety regulations. For instance, R&D Construction (UK), a small to medium-sized construction company, implemented an SMS by focusing on high-risk tasks and simplifying documentation. They integrated mobile apps to monitor safety checks and reports, reducing the administrative burden while enhancing site-specific safety awareness (Construction Safety Council of the UK, n.d.).

Large enterprises face a different series of challenges when implementing SMS. These companies typically work on larger-scale projects with multiple subcontractors, making communication and consistent safety monitoring across various teams more difficult. Skanska (Sweden/USA) has adopted a comprehensive SMS for all its projects. They utilize real-time safety monitoring technologies, including wearable devices that track worker movements and alert them to potential hazards. Skanska has integrated a global safety standard across its operations, providing extensive training to both employees and subcontractors. As a result, they reduced incident rates significantly across large-scale construction sites (Skanska, 2021).

3.2.5. Worker-related barriers

The tight schedule of high-rise construction and high work pressure are the most notable worker-related barriers. As a result, the turnover rate of workers is very high. Lack of certified skilled labor is a common issue faced by the construction industry worldwide. In China, while most residential buildings in medium and large cities are high-rise, owners frequently request short project durations, resulting in tight schedules imposed on contractors. This leads to excessive overtime for laborers. What's more, workers often endure immense pressure to complete a large amount of work within a shortened timeframe.

Correct use of personal protective equipment (PPE) in high-rise buildings is a proactive measure to ensure the safety of workers, but there are still workers who choose not to use PPE due to ignorance, neglect, apathy, overconfidence, and religious beliefs (Keng & Razak, 2014; Maliha et al., 2020).

The primary issue is the attitude of the workers. Followed by an inadequate commitment to OHS. The knowledge, abilities, and skills of workers, especially concerning risks and hazards in their tasks, can help decrease incidents. Safe Start (2017) reported that we cannot hope for individuals to adhere to safety procedures if they do not know them or are not skilled enough to implement them effectively. According to Garnica and Barriga (2018), the primary challenges for safety management arise from failure to communicate. Consequently, insufficient communication between managers and employees can result in deficient craftsmanship, incidents, and time overruns.

Alcohol intake habits can significantly impact employees' behaviors. Getting drunk when working at heights may be fatal. It is estimated that alcohol abuse causes 20–25% of workplace accidents. Mnjula et al. (2014) revealed that overconsumption of alcohol results in declined output and reduced effectiveness.

Additionally, an employee is impacted by the actions of their peers in the workplace. Provided that co-workers follow safety, protocols and work safely during construction, it may psychologically encourage the worker to do the same to avoid standing out negatively. Figure 4 displays the barriers of implementing safety practices in high-rise building construction and their source.

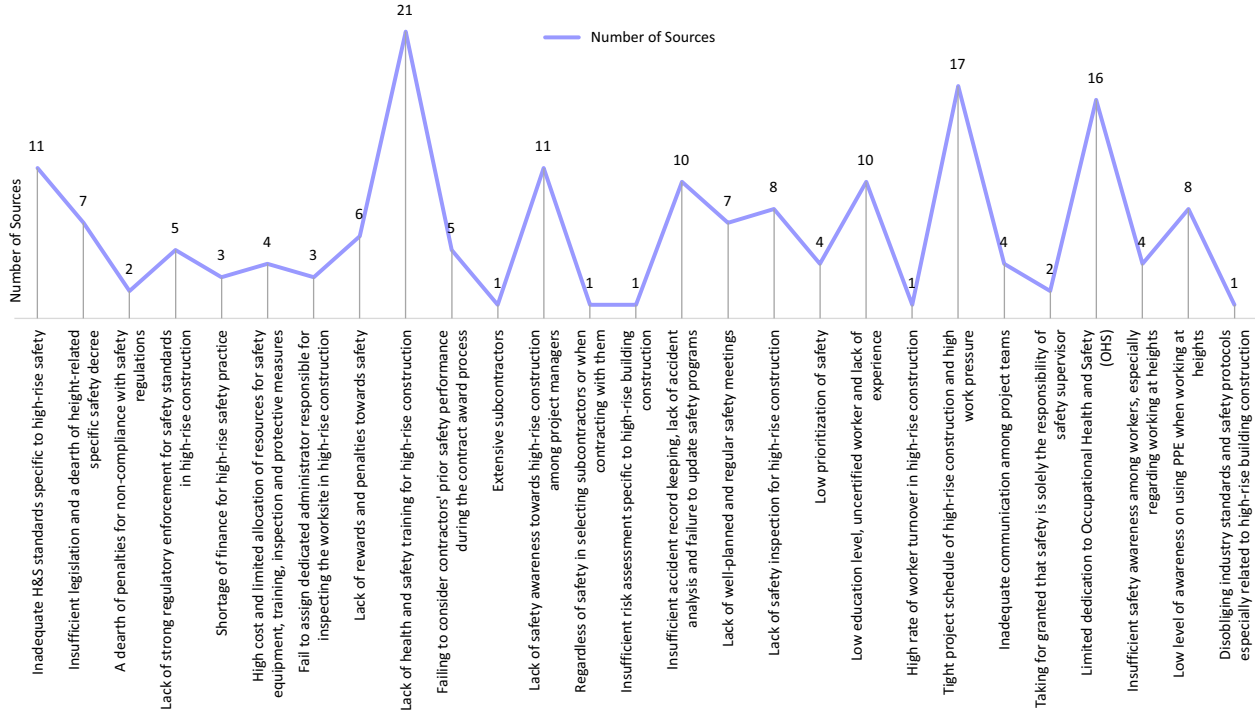

Figure 4. Barriers of safety practices in high-rise building construction and their sources

4. Strategies for effectively implementing safety practices in high-rse building construction

To enhance safety in high-rise building construction, this section further identified methods to overcome these above five categories of barriers, including the following strategies, which are categorized into five main types, i.e., institutional strategies, financial strategies, management intervention strategies, engineering control strategies, and technological innovation strategies, corresponding to the barriers they aim to overcome in high-rise building construction safety.

4.1. Regulatory barriers – Institutional strategies

4.1.1. Establishing national safety educational standards specific to high-rise

Safety training is a fundamental component of safety education. However, construction safety regulations are too general and lack of specific safety regulations related to safety education. Therefore, the need for national safety standards specific to high-rise safety education is urgent.

4.1.2. Resource & Financial Barriers- Financial strategies: Allocate budget for safety equipment in high-rise projects

For financial barriers, in the bidding phase, the owners should take into consideration allocating safety budget to purchase safety equipment, such as PPE, stable scaffold, and so on. If provided safety budget, all recommended strategies can be implemented. Additionally, the government should schedule periodic site visits to guarantee that safety practices are being implemented (Alnunu & Maliha, 2015).

4.2. Organizational barriers – Management intervention strategies

4.2.1. Safety training schemes

For organizational barriers, a dearth of safety training is the major barrier. Charehzehi and Ahankoob (2012) revealed that proper training is crucial in enhancing work effectiveness as well as safety performance, Safety training may cover communication about project-specific or task-specific hazards, safe work practices, company policies, and safety objectives. Training generally begins with a general orientation and is followed by more specific instruction tailored to the particular tasks that workers will be undertaking (Maliha et al., 2021). Safety training offers an opportunity to instill safe practices, facilitate hands-on experience, and encourage workers to carry out their tasks safely (Mubashar et al., 2013).

4.2.2. Establish a strict system of rewards and penalties

As for alcohol and drug abuse during worktime (Yiu et al., 2018; Tayeh et al., 2019) suggested establishing a strict penalty system to deter unsafe behavior. First, the government should impose an insurance fee on contractors, which will be returned if the contractor meets safety standards once upon completion of the project. Incentives encourage workers to be vigilant about their safety behaviors and to refrain from engaging in unsafe practices (Maliha et al., 2021). On the other hand, disciplinary action serves as a punishment for workers who violate on-site safety regulations. Tayeh et al. (2019) agreed that combining rewards and punishments is an approach to cultivating a culture of safety among site employees.

4.2.3. Grant unconditional right of consultant to stop work in case of safety violation

The key function of consultants in a safety program is to make sure that the safety practices outlined in the contract are effectively implemented on-site. These responsibilities include carrying out frequent inspections and engaging in accident inquiries. Therefore, consultants should be granted by owners the unconditional authority to halt work in the event of a safety violation (Awwad et al., 2016).

4.2.4. Define the responsibilities of the safety supervisor

Besides enforcing its internal safety criteria on sites through the project consultants, the government should further assign a safety supervisor to carry out additional safety inspections of high-rise sites. The most effective approach is to appoint a dedicated safety supervisor, who is primarily responsible for executing and guiding the implementation of the H&S program elements (López-Arquillos et al., 2015), such as inspecting and monitoring PPE, as well as ensuring compliance with site safety regulations and standards. H&S inspections serve as a tool for managers to assess safety conditions onsite.

4.2.5. Choose contractors with high-safety performance

Owners play a crucial role in strengthening contractors' commitment to safety by carefully selecting contractors, evaluating their past safety performance, and including incentives in the contract to promote the adoption of safety practices. During the bidding process, safety consultants on behalf of owners should prioritize selecting contractors with a strong safety performance record.

4.3. Operational barriers – Engineering control strategies

4.3.1. Hold routine safety meetings to raise awareness of particular risks among employees in high-rise

For operational barriers, routine H&S meetings are crucial for sharing H&S information with all stakeholders (Maliha et al., 2021). A well-structured safety meeting can boost morale (Alnunu & Maliha, 2015). To enhance the effectiveness of safety meetings, more relevant and up-to-date content should be provided by a variety of qualified speakers.

4.3.2. Keep accident records of high-rise construction

As an important way to improve safety performance, recordkeeping activities involve documenting all incidents, capturing details such as position, time, work environment, and reasons. Furthermore, this entails analyzing incident records to identify trends and deficiencies within the organization's safety programs or shortcomings in their implementation. Subsequently, the manager focuses on finding solutions to address these issues (Maliha et al., 2021; López-Arquillos et al., 2015). Conducting high-rise site analysis and updating safety protocols to address job-specific hazards are effective strategies for continuously enhancing a contracting firm's safety performance.

4.3.3. Emergency preparedness for high-rise construction hazards

A high-rise emergency plan must be implemented to handle emergencies, designating either the owner or the insurance company as responsible for managing the situation and allocating the necessary resources (Maliha et al., 2021). For instance, safety plans should address accidents such as falls from heights, electric shocks, or being struck by falling objects. These plans should prioritize securing healthcare and additional support services in the vicinity and ensuring that first aid supplies are sufficiently stocked to handle possible emergencies (Alnunu & Maliha, 2015).

4.3.4. Enhance subcontract management on high-rise construction site

Subcontract is critical component of high-rise construction, where a significant portion of work is typically subcontracted. Hallowell et al. (2013) advised to select subcontractor and personnel based on their H&S performance. Only those with a proven track record of safe work practices should be qualified to participate in the bidding process. Furthermore, it is essential to conduct comprehensive evaluations of subcontractors to ensure they comply with safety standards.

4.4. Worker-related barriers – Technological innovation strategies

4.4.1. Design for Manufacturing and Assembly (DfMA)

Among worker-related barriers, the tight schedule and high pressure are the biggest. One way to avoid tight schedule is to import of advanced construction technology. As a nontraditional method, DfMA is introduced in the high-rise construction to improve construction performance through prefabrication and industrialized building systems (IBS). As a component of the IBS, prefabrication construction involves the production of building elements in a designed setting either off-site or on-site, which are then assembled at the construction site (Saad et al., 2022). Abd Razak et al. (2022, 2023) emphasized that DfMA, when integrated with technologies like Building Information Modelling (BIM), can optimize the design, manufacturing, and assembly processes, leading to better quality, safety, and efficiency. The key ways for DfMA to enhance high-rise construction safety involve the following:

- Reduced On-Site Work: By prefabricating components in controlled environments, fewer construction activities take place on-site, minimizing exposure to hazards with heavy machinery.
- Use of BIM: DfMA often integrates with BIM, which can simulate construction processes and identify potential safety risks before actual construction starts.
- Standardized Processes: Prefabrication and modular methods ensure that safety protocols are standardized and enforced consistently, leading to safer working conditions.

4.4.2. Formulate reasonable work schedule

Another way to deal with tight schedule is to formulate reasonable work schedule. During the traditional construction, due to the complex processes, strict sequences, and long concrete curing times, it is hard to avoid tight schedule. Whereas, project managers must create an appropriate work schedule by parallel construction organization, increasing personnel and material investment, carrying out multiple unit projects simultaneously to maximize project time savings while ensuring adequate rest for workers. Thus, reducing workers fatigue and stress.

4.4.3. Job Hazard Analysis (JHA) for high-rise construction

Job hazard analysis is a management tool used in safety training and risk mitigation; it offers staffs with guidance on safely executing each step of their tasks. The process typically starts with a review of high-rise construction-related activities to identify potential serious hazards. Other resources may include OSHA records, reports of violations, accident investigation reports, interviews with workers, or even intuitive assessments to pinpoint risks and accidents (López-Arquillos et al., 2015).

4.4.4. Workers monitoring and tracking system

To tackle the problem of not using PPE, the monitoring and tracking techniques, such as a combined RFID and GPS proposed by Cai et al. (2014) to locate and track workers. Composed of tagging systems, tags, and readers, RFID technology has gained widespread popularity due to its high speed (Rafique et al., 2022). A sensor system based on Bluetooth Low Energy (BLE) beacons was introduced by Gómez-de-Gabriel et al. (2019) to supervise the correct application of harnesses. Additionally, the Personal Fall Arrest System (PFAS) serves as a crucial safety measure for workers at risk of falling during their tasks, which acts as the ultimate safeguard, halting a person's fall when they are in danger while working at heights.

Figure 5 outlines a safety management framework to overcome safety barriers to implementing safety practices, which are categorized into five groups: Regulatory, Resource & Financial, Organizational, Operational, and Work-

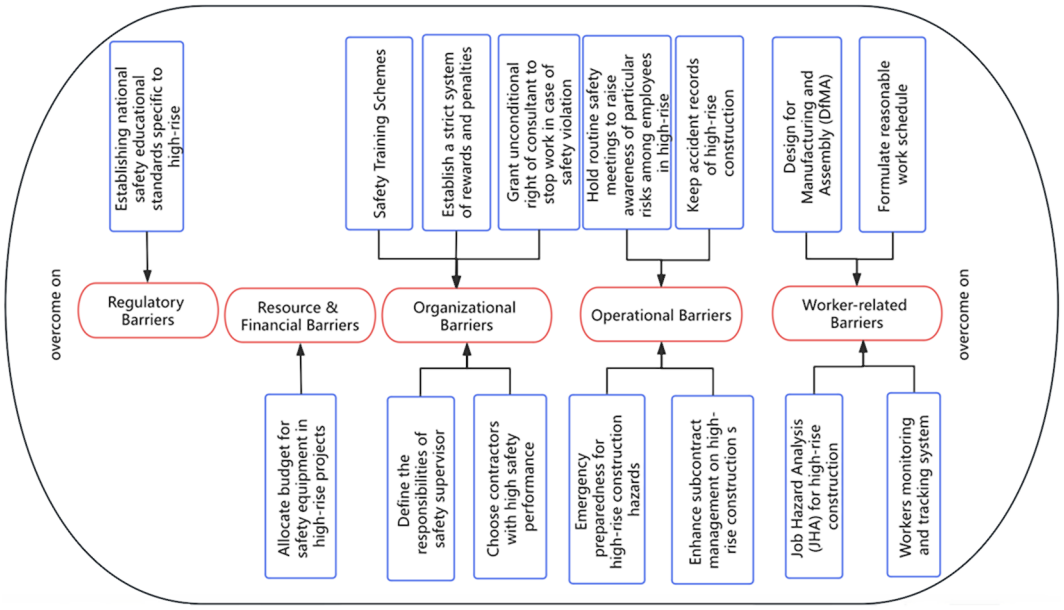

Figure 5. Safety management framework for overcoming barriers in implementing safety practices

er-related. Each group is associated with specific strategies to address the barriers. For example, under Regulatory Barriers, establishing national safety education standards specific to high-rise construction is suggested, while Resource & Financial Barriers can be tackled by allocating budgets for safety equipment. Organizational Barriers are addressed by defining safety supervisor responsibilities and selecting contractors with strong safety performance. Operational Barriers are handled by enhancing subcontractor management and formulating a reasonable work schedule. Lastly, Worker-related Barriers focus on job hazard analysis and workers' monitoring systems to ensure safety on-site.

5. Discussion

Awwad et al. (2016) conducted a study in Lebanon, the study compares companies with and without Safety and Health Management Systems (SHMS), revealing that larger companies were more likely to implement safety systems. This offers valuable insights into how company size impacts safety management practices. The research also provided actionable recommendations for improving safety practices in Lebanon, emphasizing the need for stronger regulation enforcement, improved safety education, and better collaboration between stakeholders. In addition, a comparison of Lebanese safety regulations with OSHA standards revealed significant gaps in enforcement and specificity, indicating the need for stronger regulations and clearer safety guidelines in Lebanon. The author also highlighted that it is important to promote Cross-Stakeholder Collaboration. Government, contractors, consultants, and insurance companies should collaborate more effectively to improve safety management systems.

While the study focuses on Lebanon's construction industry, its findings may not be applicable to other countries or regions, especially those with more robust safety regulations. However, the recommendations may still be valuable for other developing countries with similar safety challenges.

The strategies outlined for overcoming barriers in high-rise construction safety have evolved significantly over time, reflecting advances in technology, management practices, and a deeper understanding of safety challenges. Initially, the focus was on basic safety practices, such as allocating budgets for safety equipment and implementing safety training programs. As construction safety research and practices advanced, more comprehensive strategies were developed to address not only resource and organizational barriers but also emerging operational and worker-related issues. For example, safety training programs have transitioned from general orientations to more specialized instruction tailored to specific tasks, as suggested by Charehzehi and Ahankoob (2012) and Maliha et al. (2021), emphasizing the importance of task-specific hazards and safe practices to improve safety performance.

More recently, technology has played a pivotal role in evolving these strategies. The integration of Design for Manufacturing and Assembly (DfMA) and Building Information Modeling (BIM) is a notable advancement. As highlighted by Saad et al. (2022) and Abd Razak et al. (2022, 2023), these technologies help optimize construction processes, improving safety by reducing on-site work and identifying potential safety risks during the design phase. This marks a shift from traditional methods to more automated and controlled environments, significantly minimizing exposure to hazards and improving overall safety performance.

Additionally, the use of monitoring systems like RFID and GPS for worker tracking and Personal Fall Arrest Systems (PFAS) represents a cutting-edge approach to addressing worker-related barriers (Cai et al., 2014; Gómez-de-Gabriel et al., 2019). These systems ensure real-time monitoring of workers' safety behaviors and the correct

use of safety equipment, enhancing the ability to enforce safety regulations on-site. Such innovations reflect the increasing reliance on digital solutions to proactively prevent accidents and ensure compliance with safety standards. Over time, these technologies will likely become even more integrated, further streamlining safety practices and reducing risks in high-rise construction projects.

In conclusion, the evolution of strategies for overcoming safety barriers in high-rise construction has moved from fundamental measures like training and equipment allocation to more sophisticated, technology-driven approaches. This progression highlights the increasing importance of integrating modern tools and systems into safety management practices, offering both immediate improvements and long-term benefits for worker protection and safety performance.

6. Conclusions

This study comprehensively explores the benefits, barriers, and strategies for implementing safety practices in high-rise construction. Regulatory, resource, organizational, operational, and worker-related obstacles were identified, with key challenges including insufficient H&S standards, high costs, and lack of safety awareness among project managers. Despite these challenges, the research provides a detailed overview of existing issues and highlights the need for stakeholder collaboration to overcome these barriers. In construction, safety management is never the responsibility of just one person or role. This paper proposes a new safety management framework from the perspective of cross-stakeholder collaboration, addressing the lack of coordination among stakeholders identified in existing research. For example, the risk of falls from heights is not solely caused by unsafe worker behavior, it is closely related to the construction site environment and safety measures. This paper delves deeper into the causes of high-rise construction accidents and the benefits, barriers, and solutions to implementing safety practices. It also attempts to evaluate existing mitigation measures based on the effectiveness of safety practices and concludes the following: To enhance safety management in high-rise construction, policymakers should strengthen regulations specific to high-rise projects, encourage the use of advanced safety technologies, and promote cross-stakeholder collaboration. They should also mandate ongoing training and certification for workers and safety officers while promoting a proactive safety culture through leadership initiatives. Industry practitioners, on the other hand, should implement cost-effective safety management tools, ensure transparent communication across all stakeholders, and empower workers to actively participate in safety initiatives.

Specifically, this paper focuses on the adoption of advanced safety technologies, such as AI-driven risk prediction and real-time monitoring systems, to enhance risk management. Additionally, we recommend the development of comprehensive training programs for workers and safety officers tailored to the unique risks of high-rise construction, such as working at heights and deep foundation pits. Finally, we emphasize the need for stricter safety regulations and policies at both the local and national levels to ensure consistent and effective safety practices across the industry, aiming to bridge the gap between research and practical implementation, ensuring safer high-rise construction practices.

The findings of this study hold significant managerial implications and practical application value for both policymakers and industry practitioners. Policymakers can use the recommendations to strengthen safety regulations in high-rise construction, promote the adoption of advanced technologies, and encourage cross-stakeholder collaboration to improve safety management efficiency. For industry practitioners, the study offers practical solutions, such as implementing advanced safety technologies, enhancing worker training, and improving communication mechanisms, which can help increase safety on construction sites, reduce accidents, and ultimately enhance the overall efficiency and sustainability of projects. However, based on the author's abilities and insights, this article has some shortcomings, such as the lack of longitudinal studies or comprehensive data on the effectiveness of safety management interventions.

7. Future research directions

Future research can further explore: The application of technological innovations in construction safety, such as the role of artificial intelligence and big data analysis in safety risk prediction and the dynamic changes in safety risks in different construction environments, with studies focusing on the adaptability of safety practices in different regions and building types, or further investigate ways to better define the roles of various stakeholders in safety practices or explore how safety management efficiency can be enhanced through technical approaches, such as data mining.

Acknowledgements

The researchers of this study would like to thank the Malaysian Ministry of Higher Education and the National University of Malaysia for the opportunity and financial support through the Fundamental Research Grant Scheme FRGS/1/2024/SSI12/UKM/02/3 in conducting this study.

References

Abd Razak, M. I., Khoiry, M. A., Wan Badaruzzaman, W. H., & Hussain, A. H. (2022). DfMA for a better-industrialized building system. *Buildings*, *12*(6), Article 794. https://doi.org/10.3390/buildings12060794

Abd Razak, M. I., Khoiry, M. A., Badaruzzaman, W. H. W., Hussain, A. H., & Zain, M. Z. M. (2023). Pembangunan kerangka pelaksanaan prinsip rekabentuk untuk pembuatan dan pemasangan ke arah pembinaan secara digital dan mampan di Malaysia. *Jurnal Kejuruteraan*, *35*(2), 351–360. https://doi.org/10.17576/jkukm-2023-35(2)-06

Agbede, J. O., Manu, P., Agbede, O. A., & Mahamadu, A. M. (2016). Health and safety management practices in the Nigerian construction industry: A survey of construction firms in South Western Nigeria. In *CIB World Building Congress 2016* (Vol. 2, pp. 293–304), Tampere, Finland.

Ali, H., & Omran, A. (2016). Strategies for improving the safety performance of construction contractors. *Annals of Faculty Engineering Hunedoara – International Journal of Engineering*, *14*, 109–113.

Alnunu, M. Z., & Maliha, M. R. (2015). Evaluation of factors affecting on safety performance at high workplace in Gaza Strip 2014. *Journal of Civil and Environmental Engineering*, *5*(1), Article e167. https://doi.org/10.4172/2165-784X.1000167

Aminbakhsh, S., Gunduz, M., & Sonmez, R. (2013). Safety risk assessment using analytic hierarchy process (AHP) during planning and budgeting of construction projects. *Journal of Safety Research*, *46*, 99–105. https://doi.org/10.1016/j.jsr.2013.05.003

Andi, A. (2008). Construction workers' perceptions toward safety culture. *Civil Engineering Dimension*, *10*(1), 1–6.

Arifin, K., Ahmad, M. A., Abas, A., & Mansor Ali, M. X. (2023). Systematic literature review: Characteristics of confined space hazards in the construction sector. *Results in Engineering*, *18*, Article 101188. https://doi.org/10.1016/j.rineng.2023.101188

Awwad, R., El Souki, O., & Jabbour, M. (2016). Construction safety practices and challenges in a Middle Eastern developing country. *Safety Science*, *83*, 1–11. https://doi.org/10.1016/j.ssci.2015.10.016

Belayutham, S., & Ibrahim, C. K. I. C. (2019). Barriers and strategies for better safety practices: The case of construction SMEs in Malaysia. *Construction Economics and Building*, *19*(1), Article 6331. https://doi.org/10.5130/AJCEB.v19i1.6331

Buniya, M. K., Othman, I., Sunindijo, R. Y., Kineber, A. F., Mussi, E., & Ahmad, H. (2021). Barriers to safety program implementation in the construction industry. *Ain Shams Engineering Journal*, *12*, 65–72. https://doi.org/10.1016/j.asej.2020.08.002

Cai, H., Andoh, A. R., Su, X., & Li, S. (2014). A boundary condition-based algorithm for locating construction site objects using RFID and GPS. *Advanced Engineering Informatics*, *28*, 455–468. https://doi.org/10.1016/j.aei.2014.07.002

Chan, D. W., Chan, A. P., & Choi, T. N. (2010). An empirical survey of the benefits of implementing pay for safety scheme (PFSS) in the Hong Kong construction industry. *Journal of Safety Research*, *41*, 433–443. https://doi.org/10.1016/j.jsr.2010.07.001

Charehzehi, A., & Ahankoob, A. (2012). Enhancement of safety performance at construction site. *International Journal of Advanced Engineering Technology*, *5*(1), 303–313.

Cheah, C. Y. (2007). Construction safety and health factors at the industry level: The case of Singapore. *Journal of Construction in Developing Countries*, *12*, 81–99.

Chiocha, C., Smallwood, J., & Emuze, F. (2011). Health and safety in the Malawian construction industry. *Acta Structilia*, *18*, 68–80. https://doi.org/10.38140/as.v18i1.112

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

Construction Safety Council of the UK. (n.d.). *SME safety management report*.

Cooney, J. P. (2016). *Health and safety in the construction industry*: *A review of procurement*, *monitoring*, *cost effectiveness and strategy* [Doctoral dissertation]. University of Salford, UK.

Diugwu, I. A., Dorothy, B., & Egila, A. E. (2012). Effective regulation and level of awareness: An exposé of Nigeria's construction industry. *Open Journal of Safety Science and Technology*, *2*, 140–146. https://doi.org/10.4236/ojsst.2012.24018

Durdyev, S., Mohamed, S., Lay, M. L., & Ismail, S. (2017). Key factors affecting construction safety performance in developing countries: Evidence from Cambodia. *Australasian Journal of Construction Economics and Building*, *17*(4), 48–65. https://doi.org/10.5130/AJCEB.v17i4.5596

Enshassi, A., Mayer, P. E., Mohamed, S., & El-Masri, F. (2007). Perception of construction managers towards safety in Palestine. *International Journal of Construction Management*, *7*(2), 41–51. https://doi.org/10.1080/15623599.2007.10773101

Fernández-Muñiz, B., Montes-Peón, J. M., & Vázquez-Ordás, C. J. (2007). Safety management system: Development and validation of a multidimensional scale. *Journal of Loss Prevention in the Process Industries*, *20*, 52–68. https://doi.org/10.1016/j.jlp.2006.10.002

Fernández-Muñiz, B., Montes-Peón, J. M., & Vázquez-Ordás, C. J. (2009). Relation between occupational safety management and firm performance. *Safety Science*, *47*, 980–991. https://doi.org/10.1016/j.ssci.2008.10.022

Garnica, G. B., & Barriga, G. D. C. (2018). Barriers to occupational health and safety management in small Brazilian enterprises. *Production*, *28*, Article e20170046. https://doi.org/10.1590/0103-6513.20170046

Ghahramani, A. (2017). Diagnosis of poor safety culture as a major shortcoming in occupational health and safety AS 18001-certified companies. *Industrial Health*, *55*, 138–148. https://doi.org/10.2486/indhealth.2015-0205

Gill, J. R., & Clark, C. E. (2024). Falls from height; physical findings – Adult. In *Encyclopedia of forensic and legal medicine* (3rd ed.) (pp. 499–506). Elsevier. https://doi.org/10.1016/B978-0-443-21441-7.00080-7

Goh, Y. M., & Chua, D. (2013). Neural network analysis of construction safety management systems: A case study in Singapore. *Construction Management and Economics*, *31*, 460–470. https://doi.org/10.1080/01446193.2013.797095

Gómez-de-Gabriel, J. M., Fernández-Madrigal, J. A., López-Arquillos, A., & Rubio-Romero, J. C. (2019). Monitoring harness use in construction with BLE beacons. *Measurement*, *131*, 329–340. https://doi.org/10.1016/j.measurement.2018.08.032

Guo, B. H., Yiu, T. W., & González, V. A. (2016). Predicting safety behavior in the construction industry: Development and test of an integrative model. *Safety Science*, *84*, 1–11. https://doi.org/10.1016/j.ssci.2015.11.020

Hallowell, M. R., Hinze, J. W., Baud, K. C., & Wehle, A. (2013). Proactive construction safety control: Measuring, monitoring, and responding to safety leading indicators. *Journal of Construction Engineering and Management*, *139*(10), Article 04013010. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000730

Hamid, A. R. A., Majid, M. Z. A., & Singh, B. (2008). Causes of accidents at construction sites. *Malaysian Journal of Civil Engineering*, *20*, 242–259.

Hatema, Z. M., Kassemc, M. A., Alic, K. N., & Khoiryd, M. A. (2022). A new perspective on the relationship between the construction industry performance and the economy outcome – A literature review. *Jurnal Kejuruteraan*, *34*(2), 191–200. https://doi.org/10.17576/jkukm-2022-34(2)-02

Ju, C., & Rowlinson, S. (2014). Institutional determinants of construction safety management strategies of contractors in Hong Kong. *Construction Management and Economics*, *32*(7–8), 725–736. https://doi.org/10.1080/01446193.2014.909048

Kadiri, Z. O., Nden, T., Avre, G. K., Oladipo, T. O., Edom, A., Samuel, P. O., & Ananso, G. N. (2014). Causes and effects of accidents on construction sites: A case study of some selected construction firms in Abuja, FCT Nigeria. *IOSR Journal of Mechanical and Civil Engineering*, *11*, 66–72. https://doi.org/10.9790/1684-11516672

Kamoli, A., Hamid, R. A., & Mahmud, S. H. B. (2021, September 25). Benefits of the application of occupational health and safety management system. In *Proceedings of the 2nd International Professional Doctorate and Postgraduate Symposium*, Universiti Teknologi Malaysia, Kuala Lumpur, Malaysia.

Keng, T. C., & Razak, N. A. (2014). Case studies on the safety management at construction site. *Journal of Sustainable Science and Management*, *9*, 90–108.

Khoiry, M. A., Razak, M. I. A., Kamaruzzaman, S. N., & Abdullah, A. (2017). Kebolehpercayaan & kesahan soal selidik kelewatan dalam projek pembinaan menggunakan model pengukuran Rasch. *Jurnal Kejuruteraan*, *29*(1), 13–21. https://doi.org/10.17576/jkukm-2017-29(1)-03

Kineber, A. F., Antwi-Afari, M. F., Elghaish, F., et al. (2023). Benefits of implementing occupational health and safety management systems for the sustainable construction industry: A systematic literature review. *Sustainability*, *15*(17), Article 12697. https://doi.org/10.3390/su151712697

Labor Department. (2024). *Code of practice on safety management*. http://www.labour.gov.hk/eng/public/os/manage.pdf

Lakhiar, M. T. (2021). Occupational health and safety performance in high-rise building projects in Pakistan: A systematic literature review. *Operational Research in Engineering Sciences*: *Theory and Applications*, *4*(1), 99–114. https://doi.org/10.31181/oresta2040199l

Lendlease. (2017). *Safety performance and efficiency in construction*.

López-Arquillos, A., Rubio-Romero, J. C., Carrillo-Castrillo, J., & Suarez-Cebador, M. (2015). Effectiveness of construction safety programme elements. In P. Cortés, E. Maeso-González, & A. Escudero-Santana, A. (Eds.), *Lecture notes in management and industrial engineering*. *Enhancing synergies in a collaborative environment* (pp. 285–289). Springer, Cham. https://doi.org/10.1007/978-3-319-14078-0_32

Maano, N. E., & Lindiwe, Z. (2017). Occupational health and safety provision awareness among construction workers on the construction industry of Windhoek, Namibia. *International Journal of Health*, *5*, 60–63. https://doi.org/10.14419/ijh.v5i1.7294

Mahfuth, K., Loulizi, A., Tayeh, B. A., & Alhallaq, K. (2018). Unacceptable forms of work for safety in the construction sector – Palestinian National Authority. *International Journal of Civil Engineering*, *9*(13), 328–341.

Mahfuth, K., Loulizi, A., Al Hallaq, K., & Tayeh, B. A. (2019). Implementation phase safety system for minimizing construction project waste. *Buildings*, *9*, Article 25. https://doi.org/10.3390/buildings9020025

Mahfuth, K., Loulizi, A., Tayeh, B. A., Al Hallaq, K., & Aisheh, Y. I. A. (2020). Using safety system during the design phase to minimize waste in construction projects. *Journal of King Saud University – Engineering Sciences*, *34*(3), 170–179. https://doi.org/10.1016/j.jksues.2020.09.006

Mahmoudi, S., Ghasemi, F., Mohammadfam, I., & Soleimani, E. (2014). Framework for continuous assessment and improvement of occupational health and safety issues in construction companies. *Safety and Health at Work*, *5*(3), 125–130. https://doi.org/10.1016/j.shaw.2014.05.002

Maliha, M. N., Tayeh, B. A., & Abu Aisheh, Y. I. (2020). Building Information Modeling (BIM) in enhancing the applying of knowledge areas in the Architecture, Engineering and Construction (AEC) industry. *Open Civil Engineering Journal*, *14*, 388–401. https://doi.org/10.2174/1874149502014010388

Maliha, M. N., Abu Aisheh, Y. I., Tayeh, B. A., et al. (2021). Safety barriers identification, classification, and ways to improve safety performance in the Architecture, Engineering, and Construction (AEC) industry: Review study. *Sustainability*, *13*(6), Article 3316. https://doi.org/10.3390/su13063316

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

Mashwama, N., Aigbavboa, C., & Thwala, W. (2019). Occupational health and safety challenges among small and medium-sized enterprise contractors in South Africa. In R. Goossens (Ed.), *Advances in intelligent systems and computing*. *Vol. 792*: *Advances in social and occupational ergonomics*. *AHFE 2018* (pp. 68–76). Springer, Cham. https://doi.org/10.1007/978-3-319-94000-7_7

Meliá, J. L., & Becerril, M. (2009). Health behaviour and safety in the AEC industry. *Psicothema*, *21*, 427–432.

Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2021). *Construction safety management platform*. https://zlaq.mohurd.gov.cn/fwmh/bjxcjgl/fwmh/pages/default/index.html

Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2022). *Notice from the General Office of the Ministry of Housing and Urban-Rural Development on the Production Safety Accidents in Housing and Municipal Engineering in 2020*. https://www.mohurd.gov.cn/gongkai/zc/wjk/art/2022/art_17339_768565.html

Ministry of Housing and Urban-Rural Development of the People's Republic of China. (2023). *Statistics on the number of construction accidents and deaths in China*.

Mnjula, N. H. C., & De Silva, N. (2014). Factors influencing safety behaviours of construction workers. In *Proceedings of the 3rd World Construction Symposium 2014*: *Sustainability and Development in Built Environment* (pp. 256–264), Colombo, Sri Lanka.

Mohamed, S., Ali, T. H., & Tam, W. Y. V. (2009). National culture and safe work behaviour of construction workers in Pakistan. *Safety Science*, *47*, 29–35. https://doi.org/10.1016/j.ssci.2008.01.003

Moorkamp, M., Kramer, E. H., Gulijk, C. V., & Ale, B. (2014). Safety management theory and the expeditionary organization: A critical theoretical reflection. *Safety Science*, *69*, 71–81. https://doi.org/10.1016/j.ssci.2014.03.013

Mouleeswaran, K. (2014). Evaluation of safety performance level of construction firms in and around Erode zone. *International Journal of Innovative Research in Science*, *Engineering and Technology*, *3*(3), 1586–1594.

Mubashar, M. J., Mufti, N. A., & Amjad, M. (2013). The effects of safety training on safety culture in construction industry. *International Journal of Engineering Research* & *Technology*, *2*(10), 641–647.

Mullen, J. (2004). Investigating factors that influence individual safety behavior at work. *Journal of Safety Research*, *35*, 275–285. https://doi.org/10.1016/j.jsr.2004.03.011

Murugasamy, M., Sakthivel, M., & Shanmugam, V. (2020). Study on barriers in the implementation of safety management system in construction projects. *AIP Conference Proceedings*, *2240*(1), Article 040002. https://doi.org/10.1063/5.0011085

National Safety Council. (2013). *Injury facts*.

Nawi, M. N. M., Ibrahim, S. H., Affandi, R., Rosli, N. A., & Basri, F. M. (2017). Factor affecting safety performance construction industry. *International Review of Management and Marketing*, *6*, 280–285.

Nurhendi, R. N., Khoiry, M. A., & Hamzah, N. (2022). Conceptual framework factors affecting construction labour productivity. *Jurnal Kejuruteraan*, *34*(1), 89–99. https://doi.org/10.17576/jkukm-2022-34(1)-08

Oke, A., Aigbavboa, C., & Seemola, M. (2017). Importance of safety guidelines on South African construction sites. In P. Arezes

(Ed.), *Advances in intelligent systems and computing*. *Vol. 604*: *Advances in safety management and human factors*. *AHFE 2017* (pp. 152–160). Springer, Cham. https://doi.org/10.1007/978-3-319-60525-8_16

Okoye, P. U., Ezeokonkwo, J. U., & Ezeokoli, F. O. (2016). Building construction workers' health and safety knowledge and compliance onsite. *Journal of Safety Engineering*, *5*(1), 17–26.

Priyadarshani, K., Karunasena, G., & Jayasuriya, S. (2013). Construction safety assessment framework for developing countries: A case study of Sri Lanka. *Journal of Construction in Developing Countries*, *18*, 33–51.

Rafique, M. Z., Haider, M., Raheem, A., Ab Rahman, M. N., & Amjad, M. S. (2022). Essential elements for Radio Frequency Identification (RFID) adoption for Industry 4.0 smart manufacturing in context of Technology-Organization-Environment (TOE) framework – A review. *Jurnal Kejuruteraan*, *34*(1), 1–10. https://doi.org/10.17576/jkukm-2021-34(1)-01

Revathi, K., Ezhilmathi, P., Manoj, K. R., Sivaranjani, M., & Devaki, R. (2017). Safety issues, problems and recommendations to Indian construction industry. *International Journal of Innovative Research in Science*, *Engineering and Technology*, *6*(3), 2319–8753.

Robson, S. L., Clarke, A. J., Cullen, K., Bielecky, A., Severin, C., Bigelow, L. P., Irvin, E., Culyer, E., & Mahood, Q. (2007). The effectiveness of occupational health and safety management system interventions: A systematic review. *Safety Science*, *45*, 329–353. https://doi.org/10.1016/j.ssci.2006.07.003

Saad, N. M. (2016). *The influence of safety culture on safety performance in Saudi Arabian construction industry* [PhD thesis]. University of Salford, UK. http://usir.salford.ac.uk/id/eprint/41398/

Saad, S., Alaloul, W. S., Ammad, S., Altaf, M., & Qureshi, A. H. (2022). Identification of critical success factors for the adoption of Industrialized Building System (IBS) in Malaysian construction industry. *Ain Shams Engineering Journal*, *13*, Article 101547. https://doi.org/10.1016/j.asej.2021.10.021

Saeed, Y. S. (2017). Safety management in construction projects. *Journal of Duhok University*, *20*, 546–560. https://doi.org/10.26682/sjuod.2017.20.1.48

Safe Start. (2017). *4 causes of safety culture problems*. https://safestart.com/news/4-causes-safety-culture-problems/

Salvador, L. R., & Van Thinh, D. (2016, May). Occupational safety and health: An overview. In *2016 IEEE 11th International Symposium on Applied Computational Intelligence and Informatics* (*SACI*) (pp. 355–360). IEEE. https://doi.org/10.1109/SACI.2016.7507413

Siraj, N. B., & Fayek, A. R. (2019). Risk identification and common risks in construction: Literature review and content analysis. *Journal of Construction Engineering and Management*, *145*(9), Article 03119004. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001685

Skanska. (2021). *Sustainability and safety report 2021*. https://group.skanska.com

Skanska. (2018). *Sustainability report 2018*. https://group.skanska.com/4a194c/siteassets/investors/reports-publications/annual-reports/2018/annual-and-sustainability-report-2018.pdf#page=22.12

Smallman, C., & John, G. (2001). British directors' perspectives on the impact of health and safety on corporate performance. *Safety Science*, *38*(3), 227–239. https://doi.org/10.1016/S0925-7535(01)00003-0

Spillane, J., & Oyedele, L. O. (2013). Strategies for effective management of health and safety in confined site construction. *Construction Economics and Building*, *13*(3), 50–64. https://doi.org/10.5130/AJCEB.v13i4.3619

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

Tayeh, B. A., Alaloul, W. S., & Muhaisen, W. B. (2019). Challenges facing small-sized construction firms in the Gaza Strip. *Open Civil Engineering Journal*, *13*, 331–340. https://doi.org/10.2174/1874149501913010051

Toole, T. 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)

Turner Construction. (2020). *Safety management and risk reduction report*. https://www.turnerconstruction.com

Vitharana, V. H. P., De Silva, G. H. M. J., & De Silva, S. (2015). Health hazards, risk and safety practices in construction sites – A review study. *Engineer*: *Journal of the Institution of Engineers*, *Sri Lanka*, *48*(3), 35–44. https://doi.org/10.4038/engineer.v48i3.6840

Walters, D. (2010). *The role of worker representation and consultation in managing health and safety in the construction industry*. International Labour Organization.

Wang, W. C., Liu, J. J., & Chou, S. C. (2006). Simulation-based safety evaluation model integrated with network schedule. *Automation in Construction*, *15*(3), 341–354. https://doi.org/10.1016/j.autcon.2005.06.007

Yiu, N. S. N., & Chan, D. W. M. (2016). A taxonomic review of the application of safety management systems in construction. *Journal of International Scientific Publications*: *Ecology* & *Safety*, *10*, 394–408.

Yiu, N. S. N., Sze, N., & Chan, D. W. (2018). Implementation of safety management systems in Hong Kong construction industry – A safety practitioner's perspective. *Journal of Safety Research*, *64*, 1–9. https://doi.org/10.1016/j.jsr.2017.12.011

Yiu, N. S. N., Chan, D. W. M., Shan, M., & Wong, F. K. W. (2019). Implementation of safety management system in managing construction projects: Benefits and obstacles. *Safety Science*, *117*, 23–32. https://doi.org/10.1016/j.ssci.2019.03.027

Yung, P. (2009). Institutional arrangements and construction safety in China: An empirical examination. *Construction Management and Economics*, *27*(5), 439–450. https://doi.org/10.1080/01446190902855633

Zahoor, H., Chan, A. P. C., Masood, R., Choudhry, R. M., Javed, A. A., & Utama, W. P. (2016). Occupational safety and health performance in the Pakistani construction industry: Stakeholders' perspective. *International Journal of Construction Management*, *16*(3), 209–219. https://doi.org/10.1080/15623599.2015.1138027

Zerguine, H., Jalaludin, J., & Tamrin, S. B. M. (2016). Behaviour based safety approach and factors affecting unsafe behaviour in AEC industry: A review. *Asia Pacific Environmental and Occupational Health Journal*, *2*(1), 1–12.

Zulkifle, Z., & Hanafi, W. N. W. (2017). Impact of safety management practices enforcement toward employee safety in construction industry. In *8th International Economics and Business Management Conference*. https://doi.org/10.15405/epsbs.2018.07.02.58