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AN ASSESSMENT OF FACTORS CONTRIBUTING TO CONSTRUCTION SITE ACCIDENTS IN BUILDING CONSTRUCTION PROJECTS

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A B S T R A C T

The construction industry is widely recognized as one of the most hazardous sectors, with a higher accident rate compared to other industries. Construction site accidents pose significant risks to workers and result in substantial economic losses. This study aims to analyze the factors contributing to construction site accidents in building construction projects, with a focus on the Kaski district of Nepal. Through a comprehensive literature review and expert consultations, a mixed-methods research approach was employed to identify and categorize key factors, including material-related factors, personal protective equipment (PPE)-related factors, equipment-related factors, scaffolding and ladder-related factors, and health and welfare-related factors. To achieve the objective data was collected from the 400 respondents and analyzed using the measures of central tendency, and the Relative Importance Index (RII). The study findings revealed variations in perception among contractors, engineers/consultants, and laborers, emphasizing the importance of effective communication and collaboration to improve construction site safety. The identified factors provide valuable insights for concerned authorities and safety managers to develop targeted interventions and create a safer working environment in the construction industry.

1. INTRODUCTION

The construction industry contributes significantly to global economic development but is also one of the most dangerous, with numerous accidents and fatalities occurring each year (Luo et al., 2022; Gunduz et al., 2017; Shen et al., 2024). The persistently high accident rate in the construction industry is primarily due to inherent hazards, the dynamic nature of the construction site environment, and a shortage of appropriately trained construction workers (Liu et al., 2023; Chen et al., 2020; Ajith et al., 2019). The International Labour Organization (ILO) reports that occupational accidents result in over 2.78 million deaths annually. Approximately one out of every six fatal accidents occur in the construction sector. These accidents not only have severe health implications but also lead to significant financial losses (Zhang et al., 2019).

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Accurate and comprehensive accident analysis is critical for improving construction safety. Effective preventive measures can be implemented to reduce the occurrence of similar incidents by identifying the contributing factors that lead to accidents (Goncalves et al., 2021). Therefore, it is crucial to analyze past incidents to prevent the recurrence of similar accidents and improve workplace safety. By examining the causes of accidents, safety professionals can take appropriate measures to eliminate or minimize these identified causes. Project managers should prioritize risk identification and analysis when developing a safety master plan to reduce construction site accidents. Proactive risk management is a critical best practice in engineering management (Htet et al., 2023). Employee safety behavior is critical in construction safety management, and employee safety awareness and skills are important factors influencing accident prevention (Gao et al., 2023).

According to the U.S. Bureau of Labour Statistics (BLS) (2022), the construction sector experienced the highest number and rate of fatal work injuries compared to other private industry sectors such as transportation and warehousing, agriculture, and manufacturing. In 2022, the fatality rate in construction was 13.0 deaths per 100,000 full-time workers, up from 12.3 in 2021. However, this rate was still lower than those in farming, fishing, and forestry (23.5) and transportation and material moving (14.6). These statistics underscore the critical need for enhanced safety measures and proactive risk management in the construction industry (figure 1).

Because of this recognition of the industry's inherent risks, focused studies have been conducted in areas such as construction safety performance measurement, safety programs, and human factors. Researchers hope to improve safety outcomes and reduce risks associated with construction activities by addressing these critical areas, ultimately working to improve the industry's overall safety reputation and create a safer working environment (Jin et al., 2019).

Research on construction safety has been extensively conducted in developed countries, but the persistently high accident rates in developing countries have shifted the research focus toward these regions. While previous studies have explored factors causing construction site accidents globally, there is a lack of research specifically addressing the factors relevant to building construction activities in developing countries, such as Nepal. This study aims to fill this gap by analyzing accident cases and relevant literature to identify safety factors and understand the characteristics of building construction projects in developing countries. The study emphasizes the significant safety factors associated with each activity in the construction process, providing valuable insights for concerned authorities and safety managers to make informed decisions promptly.

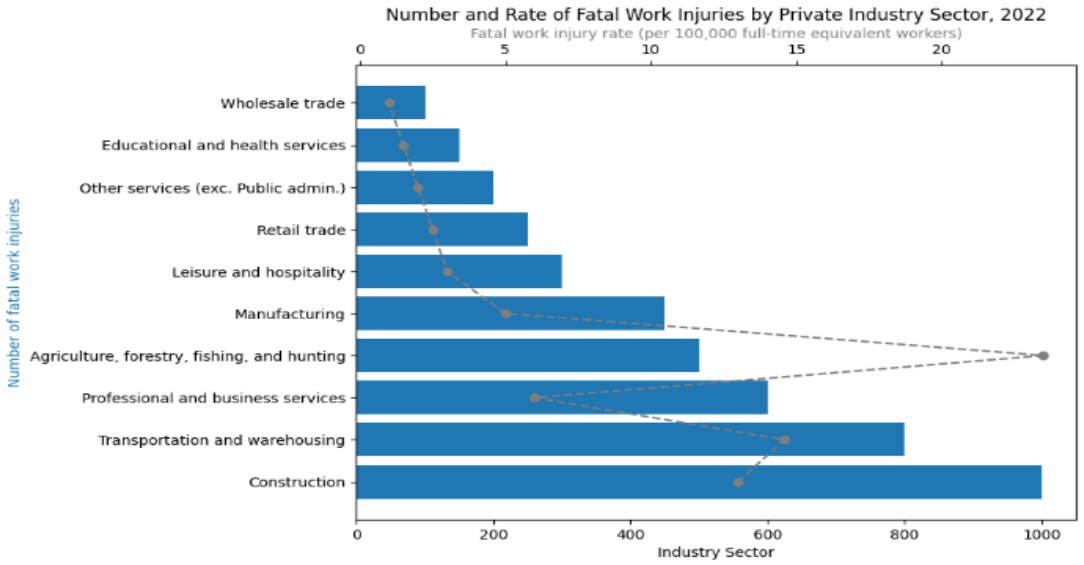

Figure 1: Number and rate of fatal work injuries by private industry sector in 2022. (Source: U.S. Bureau of Labor Statistics)

2. LITERATURE REVIEW

Occupational hazards are workplace conditions or situations that pose risks to employees' health and safety, potentially causing injury, illness, or other harm (Dhakal & Giri, 2024). Both academia and industry face challenges when it comes to construction safety. Numerous construction accidents are caused by the various activities that occur on construction sites daily. These accidents result in significant compensation for construction companies. As a result, improving construction safety has become a major research focus in academia (Luo et al., 2022). To effectively control construction site accidents, it is critical to prioritize education, training, and safety management (Yang et al., 2023).

A study performed a thorough literature review by searching multiple databases and using keyword co-occurrence analysis. They identified four key categories: safety education, safety management, accident prevention, and PPE quality, which were used to develop a conceptual framework for critical success factors (Figure 2). The study emphasizes the tendency to overlook PPE misuse due to a focus on visible outcomes such as injuries, which makes it difficult to identify hazardous behaviors on time (Ammad et al., 2021). Construction site accidents are more common when there is a lack of comprehensive company policies, unsafe practices, unfavorable attitudes among construction personnel, insufficient management commitment, and insufficient knowledge and training on worker safety (Teo et al., 2005).

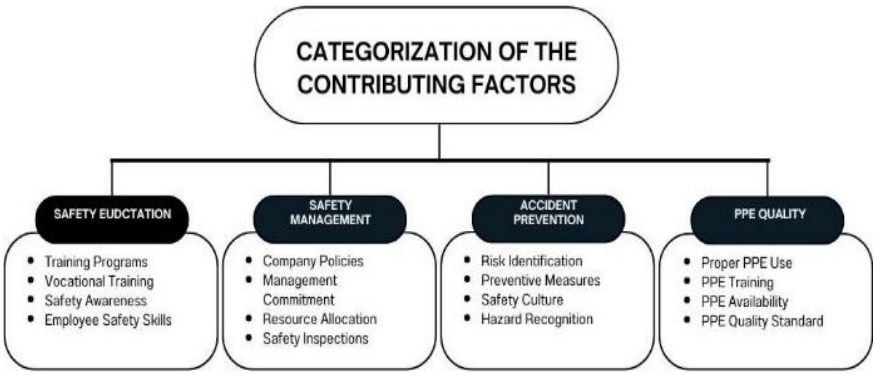

Figure 2: Categorization of Contributing Factors

The key elements influencing safety performance encompass the inadequate safety consciousness of top management, insufficient training, deficient safety awareness among project managers, reluctance to allocate resources for safety, and reckless operational practices (Tam et al., 2004). The primary factors that impact safety performance include the lack of strong safety culture among top management, inadequate training programs, insufficient safety awareness among project managers, reluctance to prioritize safety resource allocation, and engaging in unsafe operational practices (Sawacha et al., 1999). Not using PPE, lack of vocational training, and working extended hours were found to significantly increase the likelihood of work-related injuries among construction workers (Lette et al., 2018). Similarly, personnel issues pose significant barriers to health and safety (H&S) performance (Kolo, 2015). The factor contributing to accidents among workers, particularly those resulting in minor injuries, was the absence of adequate safety training (Lette et al., 2018). However, various challenges were observed in safety practices, including workers' unfamiliarity with work procedures, inadequate financial resources allocated for safety management, workers' lack of awareness, and communication barriers between supervisors and workers (Adhikari & Giri, 2024).

Several recommended strategies to address these issues include implementing comprehensive safety training, allocating a sufficient budget for safety management, securing a full commitment from top management, and providing safety booklets as resources (Keng & Razak, 2014). Formulating policies, establishing safety standards, issuing and revoking safety compliance certificates at various levels, providing safety training, organizing seminars and workshops, and raising public awareness through enlightenment campaigns are all part of the actions involved in ensuring safety (Okoye et al., 2016). To enhance safety performance, contractors should employ interventions that combine physical safeguards with the promotion of a favorable safety culture (Feng, 2013). Clients are advised to prioritize the safety responsibilities, which include actively engaging in on-site safety programs, assessing and evaluating safety data, designating a safety team, choosing contractors with a strong safety record, outlining safety requirements in tender documents, and conducting regular inspections of plant and equipment (Votano & Sunindijo, 2014), incorporating clear responsibilities for clients, contractors, and subcontractors within H&S legislation. These responsibilities can be achieved through goal-based legislation that includes primarily absolute duties, as well as through prescriptive legislation or guidance (Umeokafor et al., 2022).

Furthermore, the lack of a comprehensive safety policy and plan, insufficient and infrequent safety inspections, improper use of PPE, the absence of safety training programs, and insufficient budget allocation for safety management are the main safety concerns at construction sites for public buildings (Giri et al., 2023)**.** Prioritizing the promotion of active safety management and the implementation of awareness programs specifically created for construction workers will improve safety measures. Additionally, before beginning their duties, contractors should provide additional training to workers on how to use equipment properly, which would help reduce accidents on construction sites. The safety of construction sites will therefore be greatly improved by raising awareness of potential risk factors and providing employees and contractors with the knowledge to reduce these risks (Giri, 2020).

Construction site accidents are caused by elements like insufficient safety training, poor management, and unfavorable attitudes among construction workers (Alateeq & Ali, 2023). Numerous studies have pinpointed important elements in various construction projects, including high-rise and residential structures. Despite the existing literature on factors contributing to construction site accidents in building construction projects, there is a need for further research to explore the interplay and relative importance of these factors. Further study is also needed to comprehend the contextual variables and underlying mechanisms that affect the likelihood of accidents in building construction projects.

3. METHODOLOGY

The study takes a systematic approach to developing the contributing factor classification framework. It entails a thorough review of existing literature, analysis of accident factors, and expert consultations to ensure that all relevant factors are included. To assess the factors contributing to construction site accidents in building construction projects, a mixed-methods research approach was employed. This approach involved both quantitative and qualitative data collection and analysis methods to gather comprehensive and in-depth insights into the identified factors. According to our research objective, the total building population was determined to be 123. We selected two laborers from each of the under-construction buildings within this population. Out of the 400 respondents approached for the survey, a total of 246 laborers participated, consisting of 109 skilled laborers 137 unskilled laborers, 60 contractors, and 94 engineers/supervisors. After gathering the data, it was organized, revised, and systematically coded. Quantitative analysis of the data was conducted utilizing Microsoft Excel and SPSS. The findings were then interpreted, and the results were presented.

4. RESULT AND DISCUSSION

Table 1 presents the perceptions of contractors, engineers/consultants, and laborers regarding various factors responsible for construction site safety. The different identified factors are:

Material Handling and Housekeeping: All three groups (contractors, engineers/consultants, and laborers) perceive material handling and housekeeping as important factors for construction site safety. The average values for material handling and housekeeping are relatively high across all groups, indicating a consensus on their significance. Contractors and engineers/consultants tend to have slightly higher perceptions than laborers for these factors, but the differences are not substantial.

Precaution against the Fall of Material & Persons: Contractors rate this factor higher compared to engineers /consultants and laborers. Engineers /consultants and laborers have similar perceptions, but engineers /consultants rate it slightly lower. Overall, all groups recognize the importance of precautions against the fall of material and persons, but contractors show a higher level of concern.

Prevention for Unauthorized Entry at Construction Sites: Contractors rate this factor higher compared to engineers/consultants and laborers. Engineers/consultants and laborers have similar perceptions, but engineers/consultants rate it slightly higher. All groups acknowledge the importance of preventing unauthorized entry, but contractors emphasize it more.

First Aid Kits & Paramedical Equipment: Contractors rate the availability of first aid kits and paramedical equipment higher compared to engineers/consultants and laborers. Engineers/consultants and laborers have relatively lower perceptions of this factor. Contractors appear to place greater emphasis on the provision of first aid kits and paramedical equipment.

Warning Signs & Symbols at the Construction Site: Contractors rate the presence of warning signs and symbols lower compared to engineers/consultants and laborers. Engineers/consultants and laborers have similar perceptions, with engineers/consultants rating it slightly higher. There is a need for contractors to recognize the importance of clear warning signs and symbols at construction sites.

Personal Protective Equipment (PPE): Contractors consistently have higher perceptions of the importance of PPE compared to engineers/consultants and laborers. Engineers/consultants and laborers have similar perceptions, but engineers/consultants rate it slightly higher. All groups acknowledge the significance of PPE, but contractors show a stronger emphasis on its importance.

Construction Equipment: Contractors and engineers/consultants tend to have higher perceptions of construction equipment factors compared to laborers. The differences in perceptions among the groups are not substantial. All groups recognize the importance of proper construction equipment for safety.

Temporary Construction (Scaffolds, Ladders) Related Factors: Contractors rate temporary construction factors slightly higher compared to engineers/consultants and laborers. Engineers/consultants and laborers have similar perceptions, but engineers/consultants rate it slightly higher. There is a consensus among all groups on the importance of proper scaffolding and ladder use

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Health and Welfare Facilities: Contractors and engineers/consultants rate health and welfare facilities higher compared to laborers. Contractors have the

highest perception, followed by engineers/consultants, while laborers' rate is relatively lower. The provision of adequate health and welfare facilities should be a priority, especially for laborers.

Training and Behaviour-Related Factors: The factors related to training and behavior can contribute to safety issues in construction and engineering projects. Addressing these factors through adequate training, reinforcing safety precautions, improving hazard recognition, promoting PPE compliance, ensuring equipment maintenance, and managing workloads can significantly enhance safety performance and reduce the likelihood of accidents or incidents on construction sites.

Major Causes of Accidents: All three groups (contractors, engineers/consultants, and laborers) have similar perceptions regarding the major causes of accidents. Careless behavior, lack of training, and failure to follow safety precautions are considered the most significant causes of accidents. Overall, the table highlights the varying perceptions among contractors, engineers/consultants, and laborers regarding construction site safety factors. While there is a consensus on the importance of many factors, some variations exist. These findings emphasize the need for effective communication, collaboration, and training among all stakeholders to enhance construction site safety and create a safer working environment for everyone involved.

Table 1. Factors responsible for construction site accidents

Factors	Contractors	Engineer/ Consultants	Labors
Material Handling Related Factors			
Housekeeping	0.543	0.577	0.547
Precaution against the fall of material & persons.	0.513	0.445	0.480
Prevention for unauthorized entry at construction sites.	0.463	0.485	0.415
First aid kits & paramedical equipment	0.483	0.385	0.377
Warning signs & symbols at the construction site.	0.420	0.381	0.360
Personal Protective Equipment-Related Factors			
Safety Boots	0.637	0.553	0.545
Helmets	0.657	0.528	0.543
Safety Glass	0.510	0.449	0.473
Gloves	0.687	0.577	0.576
Safety Belts	0.437	0.449	0.419
Mask or face shield	0.373	0.436	0.404
Safety Jackets	0.387	0.381	0.405
Raincoats	0.447	0.417	0.383
Construction Equipment-Related Factors			
Excavator	0.620	0.628	0.594
Vibrator	0.553	0.604	0.525
Rammer	0.540	0.549	0.486
Mixer	0.643	0.640	0.636
Trippers and trucks for proper material supply	0.660	0.687	0.656
Mason’s tools like a trowel, hammer, chisel, brushes, leveling tools	0.600	0.691	0.641
Temporary Construction (Scaffolds, ladders, and their uses) Related Factors			
Materials used	0.637	0.536	0.571
Fixing scaffolds and ladders	0.647	0.583	0.569
Inspection and maintenance of scaffolds	0.600	0.485	0.549
Use of scaffolds and orientation of placing	0.623	0.560	0.519
Health and Welfare-Related Factors			
Shelter	0.563	0.585	0.597
Facilities for drinking water	0.707	0.617	0.648
Sanitary facilities	0.583	0.545	0.598
Awareness and protection against hazardous substances	0.480	0.428	0.420
Appropriate construction methods while working in a dangerous environment	0.460	0.421	0.431
Training and Behaviour Related Factors			
Careless Behaviour	0.853	0.868	0.867
Lack of training	0.873	0.864	0.887
Slips and falls	0.797	0.809	0.789
Failure to follow safety precautions	0.850	0.872	0.879
Failure to identify the unsafe condition	0.810	0.826	0.842
Failure to wear proper safety protection	0.847	0.834	0.809
Machinery Malfunction	0.747	0.838	0.814
Overpressure of work	0.810	0.879	0.886

Table 2 includes suggestions for improvement, which highlight potential areas for enhancing safety measures on construction sites. These suggestions range from providing safety booklets and including safety in planning to offering first aid training, conducting regular toolbox talks, and providing motivation and safety rewards. Overall, the table highlights the varying perceptions among contractors, engineers/consultants, and laborers regarding construction site safety factors. While there is a consensus on the importance of many factors, some variations exist. These findings emphasize the need for effective communication, collaboration, and training among all stakeholders to enhance construction site safety and create a safer working environment for everyone involved.

Table 2. Suggestions for improvement

Suggestions for the Improvement			
Provision of safety in the condition of the contract	0.833	0.855	0.826
Provision of safety booklets on-site	0.843	0.853	0.859
Include the safety part in planning	0.870	0.849	0.801
Provision of safety budget and insurance for workers	0.867	0.881	0.867
First aid training for workers and availability of first aid kits on construction sites	0.863	0.826	0.846
Regular toolbox talks on the construction site	0.900	0.881	0.882
Involvement of construction site workers in safety training and awareness classes	0.820	0.879	0.810
Provision of motivation and safety rewards	0.810	0.868	0.846
No work in difficult health conditions and unfavorable weather conditions	0.797	0.853	0.796
Facilities of PPE for all workers at construction sites	0.903	0.915	0.895

As shown in Table 3 the average RII, means and p-values were analyzed to determine the significance of these factors among contractors, engineers/consultants, and laborers. In terms of material-related factors, the study found that contractors rated these factors as the most significant, followed by engineers/supervisors and laborers. The mean values indicated that contractors perceived material-related factors as more critical compared to engineers/supervisors and laborers, and the differences were statistically significant. Similarly, PPE-related factors were considered important by all three groups, with contractors assigning the highest RII mean values. The differences in mean values between contractors and engineers/supervisors, as well as between contractors and laborers, were statistically significant, suggesting variations in perception among the groups. Equipment-related factors also showed a significant influence on construction site safety, with engineers/supervisors rating them slightly higher than contractors and laborers. However, the differences in mean values were not statistically significant, indicating a similar perception among the groups. Scaffolding and ladder-related factors were perceived as significant by all three groups, with engineers/supervisors assigning the highest RII mean values. The differences in mean values between engineers/supervisors and contractors, as well as between engineers/supervisors and laborers, were statistically significant. Health and welfare-related factors were also considered important, although the differences in RII mean values between the groups were relatively small. However, the p-values indicated statistically significant differences in perception.

Table 3. Average RII, Mean-value, and P-value

Factors	Average RII			Mean-value			P-value		
	Labor	Contractor	Engineer and supervisor	Labor	Contractor	Engineer and supervisor	Labor	Contractor	Engineer and supervisor
Material-Related	0.43	0.48	0.45	2.18	2.42	2.27	<0.05	<0.05	<0.05
PPE-Related	0.46	0.51	0.47	2.33	2.58	2.36	<0.05	<0.05	<0.05
Equipment-Related	0.58	0.60	0.63	2.9	3.01	3.16	0.24	0.27	0.26
Scaffolding &Ladde-Related	0.55	0.62	0.54	2.75	3.13	2.70	0.18	0.29	0.29
Health &Welfare	0.53	0.55	0.51	2.69	2.79	2.59	<0.05	<0.05	<0.05

One study by Manzoor et al. (2022) investigated the factors contributing to construction site accidents in building projects through a comprehensive literature review. The authors identified several key factors, including human error, inadequate safety training, poor supervision, and lack of communication. The study emphasized the need for a proactive approach to safety management and recommended the implementation of safety training programs and effective supervision strategies. In a similar vein, Li et al. (2021) investigated the factors that contribute to construction site accidents in high-rise building projects. The authors revealed that inadequate safety training, a poor safety culture, and insufficient hazard identification and control measures were the most significant factors in a survey of construction professionals. The importance of promoting a positive safety culture and improving safety training programs in high-rise construction projects was

emphasized in the study (Nadhim et al., 2016). In addition, Williams et al. (2019) investigated the factors that contribute to construction site accidents in residential building projects. The authors identified factors such as inadequate safety training, poor safety management, and subcontractor-related issues as key contributors to accidents. To reduce construction site accidents, the study emphasized the importance of effective safety management systems and collaboration among project stakeholders (Giri, 2023). To improve the identification of safety risks on construction sites, workers' ability to recognize and assess risks must be improved, as well as effective communication between construction managers and workers (Park & Kim, 2013).

Overall, our findings suggest that different stakeholders in building construction projects have varying perceptions of factors contributing to construction site accidents. Contractors, engineers/consultants, and laborers prioritize different aspects, emphasizing the need for effective communication and collaboration among these groups to improve construction site safety. The results of this assessment can guide the development and implementation of targeted safety measures and interventions to mitigate the identified factors and promote a safer working environment in the construction industry.

5. CONCLUSION

The construction sector is widely acknowledged as one of the most dangerous industries, exhibiting a greater frequency of accidents when compared to other sectors. Extensive research efforts have been directed toward identifying critical safety factors that effectively prevent construction accidents. However, limited attention has been given to exploring the effective management of construction site accidents. This study aimed to assess the factors contributing to construction site accidents in building construction projects. By conducting a comprehensive analysis, this research examined the perceptions of contractors, engineers/consultants, and laborers regarding the significance of various factors. The findings revealed notable variations in perception among these stakeholders. Contractors assigned high importance to material-related factors, PPE-related factors, and scaffolding and ladder-related factors. Engineers/supervisors emphasized equipment-related factors and scaffolding and ladder-related factors. On the other hand, laborers considered health and welfare-related factors to be particularly crucial. These disparities underscore the importance of effective communication and collaboration among stakeholders to comprehensively address safety concerns. Prioritizing the identified factors and developing effective safety measures and interventions can effectively mitigate risks and enhance construction site safety.

Moreover, the study's outcomes are expected to enhance accident analysis practices in the construction industry. The developed contributing factor classification framework offers a standardized and systematic approach to accident analysis, enabling practitioners and researchers to gain deeper insights into accident causation. The outcomes of this study offer valuable insights to construction managers, particularly in enhancing the safety of workers, thereby fostering a positive safety culture within the building construction industry.

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