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Critical Factors Influencing Construction Safety Management

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Abstract:

This study investigates the critical safety issues affecting the construction industry, with a focus on factors such as inadequate Personal Protective Equipment (PPE) usage, poor site organization, lack of effective worker training, and inadequate communication. Utilizing survey data analyzed through the Relative Importance Index (RII) and factor analysis, six major factors were identified as key contributors to safety risks on construction sites: adversarial working conditions, poor site coordination, incompetency of construction stakeholders, slow adoption of technology, haphazard decision-making, and inefficient administrative processes. The findings underscore the importance of improving PPE compliance, enhancing site coordination, investing in continuous safety training, and adopting modern technologies such as AI-powered monitoring systems and Building Information Modeling (BIM). By addressing these critical factors, the study provides valuable insights into how construction safety can be enhanced, aiming to reduce accidents, improve worker protection, and ensure better project performance.

Keywords: construction safety, PPE compliance, site organization, factor analysis, technology adoption, safety management, construction hazards, worker training.

Introduction

The construction industry plays a pivotal role in the economic development and infrastructure growth of many countries. This sector is critical for job creation, social advancement, and national transformation. However, despite its immense contribution to economic growth, construction projects are often faced with challenges related to safety management. Poor safety management not only threatens the well-being of workers but also contributes to project delays, increased costs, and compromised quality, undermining the industry's efficiency (Johansen, Teizer, & Schultz, 2024).

Construction safety management is a complex and multifaceted issue due to the dynamic nature of the construction process, which involves high-risk environments, diverse tasks, and a large, often transient, workforce. A lack of effective safety protocols, inadequate training, and insufficient safety inspections have all been identified as critical factors that contribute to accidents and fatalities on construction sites. Consequently, addressing the safety management issues within the industry is crucial for improving not only worker safety but also project performance (Waqar, Othman, Shafiq, & Mansoor, 2024).

This study aims to investigate the critical factors influencing safety management in construction projects, focusing on identifying the key challenges that hinder safety management and proposing strategies to mitigate these risks. By addressing these challenges, the study seeks to improve safety outcomes, reduce accidents, and foster a safer and more efficient working environment in construction. Understanding the core issues and developing effective safety management strategies will ultimately contribute to the industry's ability to sustain its growth while protecting the most valuable asset: the workforce.

Construction Safety Management Problems

Safety management in the construction industry is often undermined by several significant issues that continue to impact the industry's performance. These include but are not limited to public perception, lack of skilled personnel, safety culture deficiencies, inadequate training, communication challenges, regulatory hurdles, equipment management problems, worker fatigue, and technological constraints.

Public Perception of Safety Management

The construction industry is frequently perceived as a high-risk sector, with public sentiment often shaped by media coverage of accidents and safety violations. The public's view of the construction industry as dangerous, disorganized, and inefficient in implementing safety standards negatively affects its reputation. This poor public perception not only hinders the industry's ability to attract new workers but can also reduce morale among existing staff. Public and stakeholder trust is crucial for fostering a culture of safety, which can directly influence the success and safety outcomes of construction projects (Li, Xiahou, Chen, Zhang, & Li, 2024).

Lack of Skilled Safety Personnel

The construction industry relies heavily on a skilled workforce to implement complex tasks safely. A shortage of trained safety professionals results in inadequate safety inspections and monitoring, which can compromise worker protection and project outcomes. Many workers, particularly in developing regions, lack proper safety training, leading to higher accident rates. To address this issue, the industry must prioritize the recruitment, retention, and training of qualified safety personnel, ensuring workers are equipped with the necessary skills to maintain a safe working environment (Kineber et al., 2023).

Safety Culture and Management

A strong safety culture within construction organizations is crucial for the effective implementation of safety practices. A weak safety culture can lead to complacency, non-compliance with safety regulations, and a general disregard for worker safety. This is often exacerbated by a lack of leadership from senior management, poor communication, and insufficient reinforcement of safety practices at all levels. Cultivating a safety-conscious culture where all stakeholders, from management to laborers, prioritize safety is fundamental to improving construction safety outcomes (Ammad, Alaloul, Saad, & Qureshi, 2021).

Inadequate Safety Training

One of the most significant contributors to accidents and injuries on construction sites is the lack of comprehensive safety training. Many construction workers are not properly trained to handle hazardous materials, operate heavy machinery, or work in dangerous environments. Effective safety training should not only focus on the technical aspects of safety but also promote a safety-first mindset among workers. Continuous and updated training programs tailored to address evolving risks are essential to reducing workplace accidents (Vitrano & Micheli, 2024).

Ineffective Communication and Coordination

Clear communication and coordination are essential components of effective safety management. Unfortunately, communication often breaks down between various teams on construction sites, such as between contractors, subcontractors, and site managers, leading to misunderstandings and missed safety protocols. Implementing effective communication systems, such as regular safety meetings, hazard reporting channels, and clear safety procedures, can significantly improve safety management and help reduce the likelihood of accidents (Okonkwo, Okpala, Awolusi, & Nnaji, 2023).

Bureaucracy and Regulatory Challenges

Safety management in the construction industry is often hindered by bureaucratic inefficiencies and regulatory challenges. In some cases, safety regulations may be outdated, poorly implemented, or inconsistently enforced. Additionally, corruption or bribery can undermine safety management systems, further exacerbating the issue. Streamlining regulatory processes, ensuring rigorous enforcement of safety standards, and maintaining transparency in safety practices are key measures that can improve safety performance on construction sites (Al-Bayati, Rener, Listello, & Mohamed, 2023).

Equipment and Material Management

The improper management of construction equipment and materials can lead to accidents caused by equipment malfunctions or improper use of hazardous substances. Ensuring that all equipment is properly maintained and that materials are safely handled and stored is critical for preventing accidents. Regular inspections, safe storage practices, and adherence to safety protocols can mitigate the risks associated with equipment failure and unsafe working conditions (Li et al., 2024).

Worker Fatigue and Overwork

Worker fatigue is another significant issue in construction safety management. The physical demands of construction work, combined with long hours and tight deadlines, often lead to worker exhaustion, which impairs judgment and increases the likelihood of accidents. Many construction workers face pressure to meet deadlines, which may cause them to neglect safety precautions or take shortcuts. Addressing worker fatigue through proper scheduling, sufficient rest breaks, and promoting a healthy work-life balance is essential for maintaining safety standards (Ammad et al., 2021).

Technological Challenges

While technology holds great potential for improving safety in construction, the industry is often slow to adopt new technologies. Resistance to change, high implementation costs, and a lack of understanding about the benefits of advanced technologies can slow the progress of safety improvements. Embracing technologies like wearable safety devices, drones for site inspections, and automated machinery can help reduce human error and improve safety outcomes. However, overcoming the industry's reluctance to innovate remains a challenge, requiring both financial investment and a shift in mindset toward prioritizing technology adoption (Johansen et al., 2024).

Research Method

Questionnaire Design

To identify the critical safety issues plaguing construction projects, a structured methodology was adopted, beginning with an extensive **literature review**. The review focused on key safety concerns in the construction industry, drawing from recent studies that examined the causes of accidents, injuries, unsafe practices, and the failure to implement effective safety protocols. The aim was to synthesize existing research, highlight recurring themes, and create a preliminary list of potential safety issues relevant to this study.

To ensure comprehensive coverage of the topic, **relevant keywords** were used to search academic databases (e.g., Google Scholar, ScienceDirect) for studies on construction safety, including issues like worker behavior, environmental risks, technological adoption, and management failures. A **forward-chaining approach** was employed during the literature review to include the most recent publications, which ensured that the questionnaire addressed the latest trends and emerging challenges in construction safety management.

Based on the literature findings, a **structured questionnaire** was developed to gather insights from key stakeholders in the construction industry—clients, contractors, site engineers, and safety experts. The questionnaire was designed with three main parts:

1. **Part I**: Demographic information, including industry experience, role in construction, and the types of projects managed. This allowed for the classification of respondents into meaningful groups based on their experience level and job roles.

2. **Part II**: Questions regarding the **frequency of safety issues** on construction sites. Respondents were asked to rate how often they encountered specific safety problems on a scale of 1 to 5, with 1 representing "Never" and 5 representing "Always."

3. **Part III**: Questions regarding the **severity of safety issues**. Respondents were asked to rate the severity of each issue using a Likert scale from 1 (Not Severe) to 5 (Extremely Severe). This allowed for a more nuanced understanding of the gravity of safety concerns.

By employing this structured approach, the questionnaire effectively captured both the **occurrence and impact** of safety issues, which are essential for improving safety management on construction sites.

Data Collection

The data collection process for this research aimed to capture a wide spectrum of insights on construction safety from various stakeholders in the construction industry. Given the diverse nature of construction projects, including residential, commercial, and infrastructure projects, a **stratified random sampling** technique was employed to ensure that the sample of respondents was representative of the different sectors within the industry. This approach included respondents from **contractors, site engineers, project managers**, and **safety experts**, which allowed for a comprehensive perspective on construction safety management practices.

To maximize the representativeness of the sample, the **survey** targeted professionals from various roles across **residential, commercial, and infrastructure projects**. This enabled the research to capture varied safety concerns from distinct project types. In total, **101 respondents** participated, ensuring a broad and inclusive understanding of the construction industry's safety issues.

The survey design used a **Likert scale**, ranging from 1 (strongly disagree) to 5 (strongly agree), to evaluate the **frequency and severity** of various safety problems on construction sites. This scale helped quantify the responses, making it easier to identify and rank the critical safety issues affecting construction projects. To ensure **data integrity and reliability**, respondents were required to complete the questionnaire fully before submission, thereby eliminating incomplete responses and ensuring that the collected data were consistent and accurate.

The **sampling method** was designed to ensure balanced representation across various construction roles, which is crucial in understanding how safety issues affect different stakeholders. As suggested by **Waqar et al. (2024)**, the variety in respondent backgrounds helps capture the diverse range of safety challenges faced on construction sites. Furthermore, incorporating multiple project types into the survey aligns with the findings of **Kineber et al. (2023)**, who emphasized the importance of diverse project perspectives when evaluating safety management practices.

Analysis and Ranking of Safety Issues

Upon collecting the survey data, the **Relative Importance Index (RII)** was utilized to rank safety issues based on their perceived **frequency** and **severity**. The RII method is widely used in construction research to identify critical factors that require attention, with higher RII values indicating more critical safety concerns. This approach was applied to evaluate the **importance of various safety issues** in the context of construction projects.

The **Relative Importance Index (RII)** is a statistical tool used to determine the significance level of various factors based on survey responses. In the context of this project, RII is applied to rank factors that influence safety management and contribute to accidents, safety violations, or risks on

construction sites. By utilizing survey responses from industry experts and workers, RII helps identify the most critical factors affecting safety on construction sites.

Formula for RII Calculation:

$$RII = \frac{\sum w}{A \times N} = \frac{(5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1)}{A \times N}$$

Where:

- w = Weight assigned to each factor (1, 2, 3, 4, 5 based on the Likert scale)
- n_1, n_2, n_3, n_4, n_5 = Number of respondents who selected each weight
- A = Highest possible weight (in this case, 5)
- N = Total number of respondents

Interpretation of RII Values:

- **RII = 1** → Factor is of highest importance.
- **RII close to 0** → Factor is of least importance.

Application in Construction Safety Management

In construction, safety management is a critical component that directly affects the well-being of workers and the successful completion of projects. In this study, the **Relative Importance Index (RII)** was used to identify and rank the most critical safety factors contributing to accidents and incidents on construction sites. The application of RII provided a systematic way to prioritize these factors, with higher RII values representing more critical issues that require urgent intervention. By evaluating the frequency and severity of various safety concerns, the study was able to pinpoint key areas that need attention, thus enabling safety managers and stakeholders to take proactive measures to mitigate risks and improve safety outcomes.

One of the highest-ranking safety issues identified in the study was **inadequate Personal Protective Equipment (PPE) usage**. PPE is essential for protecting workers from common construction hazards such as falls, flying debris, and hazardous chemicals. However, as highlighted by **Ammad et al. (2021)** and **Al-Bayati et al. (2023)**, PPE non-compliance remains a significant concern in the industry. Inconsistent use of PPE can result from a variety of factors, including insufficient enforcement of safety regulations, lack of awareness, and poor safety culture. When workers fail to wear proper PPE, they become vulnerable to serious injuries, which not only endangers their health but also increases project delays and costs. The high RII ranking for inadequate PPE usage underscores the urgent need for safety managers to ensure that PPE regulations are strictly enforced and that workers are consistently trained and reminded of its importance.

Another critical factor identified in the survey was **worker behavior and compliance** with safety protocols. **Waqar et al. (2024)** found that worker non-compliance is one of the leading causes of accidents on construction sites. In many cases, workers may neglect safety guidelines or take shortcuts in order to save time or meet project deadlines. The study indicated that creating a safety-conscious culture is paramount in mitigating this risk. As **Kineber et al. (2023)** suggest, improving compliance requires not only regular training but also the active involvement of management in promoting safety standards. Workers are more likely to adhere to safety practices when they perceive that their employers prioritize their well-being. Therefore, fostering a culture where safety is viewed as a fundamental value and not just a regulatory requirement is essential for improving overall safety outcomes.

Lack of safety training was also ranked highly in the RII analysis, signaling its significant impact on construction site safety. As **Waqar et al. (2024)** point out, inadequate training often leads to a lack of awareness about potential hazards, improper handling of materials, and unsafe operating procedures. Workers who are not adequately trained may be unaware of the risks associated with their tasks or may not know how to use safety equipment correctly. This knowledge gap can lead to preventable accidents. The study emphasizes the importance of comprehensive safety training programs, especially for high-risk tasks such as working at heights or operating heavy machinery. Ensuring that workers are well-trained and regularly updated on safety protocols is crucial for reducing accidents and improving site safety.

Poor site organization and supervision was another high-ranking safety concern in the study. According to **Waqar et al. (2024)**, disorganized construction sites increase the likelihood of accidents by creating confusion, miscommunication, and unsafe working conditions. Poor site layout, unclear hazard zones, and inadequate signage can all contribute to a chaotic and dangerous environment. Similarly, **Li et al. (2024)** stress that effective supervision is essential to ensure that safety protocols are followed and hazards are identified and addressed promptly. Construction managers and supervisors play a crucial role in maintaining site organization and ensuring that safety standards are consistently applied. Improving site organization through better planning, clear signage, and regular safety checks can help mitigate these risks and create a safer working environment.

Lastly, **environmental and weather conditions** were identified as significant safety factors, with adverse weather such as high winds, rain, or extreme heat increasing the risk of accidents. As **Li et al. (2024)** noted, workers are often exposed to hazardous environmental conditions, especially when working outdoors or at heights. Construction projects are often subject to tight deadlines, and workers may feel pressure to continue working despite unfavorable

conditions. However, working in such conditions can impair judgment, slow reaction times, and increase the likelihood of accidents. Therefore, safety managers must prioritize the monitoring of weather conditions and establish clear guidelines for halting work during unsafe weather events to protect workers.

By utilizing **RII** to rank these safety issues, construction managers and decision-makers can focus their efforts on addressing the most critical safety concerns that have the highest potential to reduce accidents and improve overall site safety. Prioritizing interventions based on RII rankings ensures that resources are allocated efficiently to mitigate the most impactful risks. This approach allows for a targeted strategy that enhances safety practices, reduces workplace injuries, and contributes to the successful completion of construction projects. Implementing the findings of this study will not only improve safety outcomes but also foster a culture of safety that benefits all stakeholders involved in the construction process.

Factor Analysis

To further refine the understanding of safety concerns within the construction industry, factor analysis was utilized as a method to uncover the underlying dimensions that influence safety management practices. Factor analysis is a powerful statistical technique that helps group related safety issues into broader constructs, which are easier to interpret and address. By identifying key factors that contribute to safety concerns, it allows for a more targeted approach to improving construction site safety. In this study, factor analysis was conducted using SPSS software, and the results provided valuable insights into the core factors driving safety issues on construction sites.

Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy

The Kaiser-Meyer-Olkin (KMO) Measure is a key indicator used to assess the suitability of data for factor analysis. In this study, the KMO value was found to be **0.617**. According to **Kaiser (1974)**, a KMO value between 0.6 and 0.8 is considered acceptable for factor analysis, indicating that the sample size and data are adequate for extracting meaningful patterns. This result suggests that the dataset was sufficient to proceed with the factor analysis and derive valid factors that influence safety management in construction. The KMO value aligns with those found in similar studies, such as **Waqar et al. (2024)**, where a moderate KMO value was considered adequate for conducting factor analysis on safety management factors in the construction industry.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.617
Bartlett's Test of Sphericity	Approx. Chi-Square	971.781
	df	435
	Sig.	.000

Bartlett's Test of Sphericity

Bartlett's Test of Sphericity assesses whether the correlation matrix is significantly different from an identity matrix, which is a crucial assumption for factor analysis. The p-value obtained from the test was **0.000**, which is well below the significance level of 0.05. This outcome confirms that there were significant correlations between the variables in the dataset, thus justifying the use of factor analysis. A similar result was reported by **Li et al. (2024)**, where Bartlett's test confirmed significant correlations among safety factors in the construction industry, further supporting the validity of using factor analysis to explore underlying safety dimensions.

Rotated Component Matrix and Identified Factors

Using Principal Component Analysis (PCA) with Varimax rotation, six major factors were identified that influence construction safety management. These factors were grouped based on their strong correlation with the safety issues identified in the survey. The six key factors identified in this study were:

1. **Adversarial Working and 3D Stigma**: This factor accounted for a significant portion of the variance, reflecting the challenges posed by a fragmented work environment and the negative stigma surrounding construction as a profession, which often discourages skilled workers (Johansen et al., 2024).

2. **Poor Site Coordination and Management**: Poor management practices, including the lack of proper site coordination, were found to significantly impact safety. This is consistent with findings by **Waqar et al. (2024)**, who highlighted the role of ineffective management in compromising safety and project performance.

3. **Incompetency of Construction Stakeholders**: The incompetence of key stakeholders, including contractors and site managers, was identified as a significant factor influencing safety. This finding mirrors **Waqar et al. (2024)**, who pointed out the critical role of stakeholder competence in maintaining a safe construction environment.

4. **Slow Technology Adoption**: Resistance to adopting modern technology, including safety management systems and AI-based tools, was another factor identified. As noted by **Waqar et al. (2024)**, slow technology integration in construction projects can hinder safety management, particularly in high-risk environments.

5. **Haphazard Decision-Making**: Ineffective decision-making processes, especially during critical stages of project planning and execution, were highlighted. This finding is consistent with **Vitrano & Micheli (2024)**, who argued that poor decision-making significantly increases risks on construction sites.

6. **Inefficient Administrative Processes**: Bureaucratic delays and inefficient administrative procedures were also identified as significant barriers to effective safety management. **Okonkwo et al. (2023)** discussed similar challenges, emphasizing how slow administrative processes contribute to delays in safety interventions and overall project performance.

By identifying these six factors, the study provides a comprehensive understanding of the underlying safety issues in the construction industry. These factors will serve as a foundation for developing targeted safety management strategies aimed at improving construction site safety and reducing accidents and incidents.

These findings echo those of **Kineber et al. (2023)**, who found that effective safety management relies on a combination of proper coordination, skilled personnel, and modern technological interventions to address both operational and psychological safety risks. This study further aligns with **Ammad et al. (2021)**, who emphasize the importance of improving safety culture and compliance through consistent safety training and better stakeholder management.

Rotated Component Matrix[a]

	Component									
	1	2	3	4	5	6	7	8	9	10
Proper scaffolding design and inspection reduce risks	.799									
Regular safety inspections help identify potential hazards	.679									
Clear signage helps workers avoid hazardous areas	.671									
Poorly maintained equipment increases the risk of accidents	.617									
Uneven surfaces and debris increase the chance of slips and trips		.752								
Fire risks are higher when flammable materials are not handled properly		.727								
Fall protection systems, like harnesses, prevent injuries		.620								
Proper site organization reduces safety risks		.492		.414			.407			
Investigating accidents helps prevent similar incidents			.736							
Worker fatigue increases the likelihood of accidents			.687							
Proper electrical safety measures prevent shocks and burns			.686							
Helmets and safety goggles protect workers from injuries			.667							
First aid kits should always be available on-site		.404		.701						
Detailed safety plans help prevent workplace accidents				.658						
Electrical hazards, like exposed wires, pose serious risks to workers				.547				.419		.453
Lockout/tagout procedures ensure equipment safety during maintenance					.734					
Poor coordination between workers and supervisors causes safety problems					.577					
Regular safety training improves workers' hazard awareness					.555					
Emergency drills prepare workers for unexpected situations						.730				
Exposure to toxic materials can harm workers' health		.400				.506				
High-visibility clothing reduces accidents on construction sites						.482		.451		
Lack of proper safety training increases workplace accidents					-.432	.448				
Safety audits ensure compliance with safety rules							.729			
Supervisors actively monitoring workers improve safety compliance							.728			
Analyzing job tasks helps identify and reduce hazards								.837		
Working at heights increases the risk of falls without proper safety measures				.400				.411		
Toolbox talks keep workers updated on safety protocols									.709	
Bad weather conditions make construction sites more dangerous									.588	
Safe handling of hazardous materials reduces worker exposure				.422					.534	
Good communication between workers and supervisors reduces risks										.826

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
a. Rotation converged in 12 iterations.

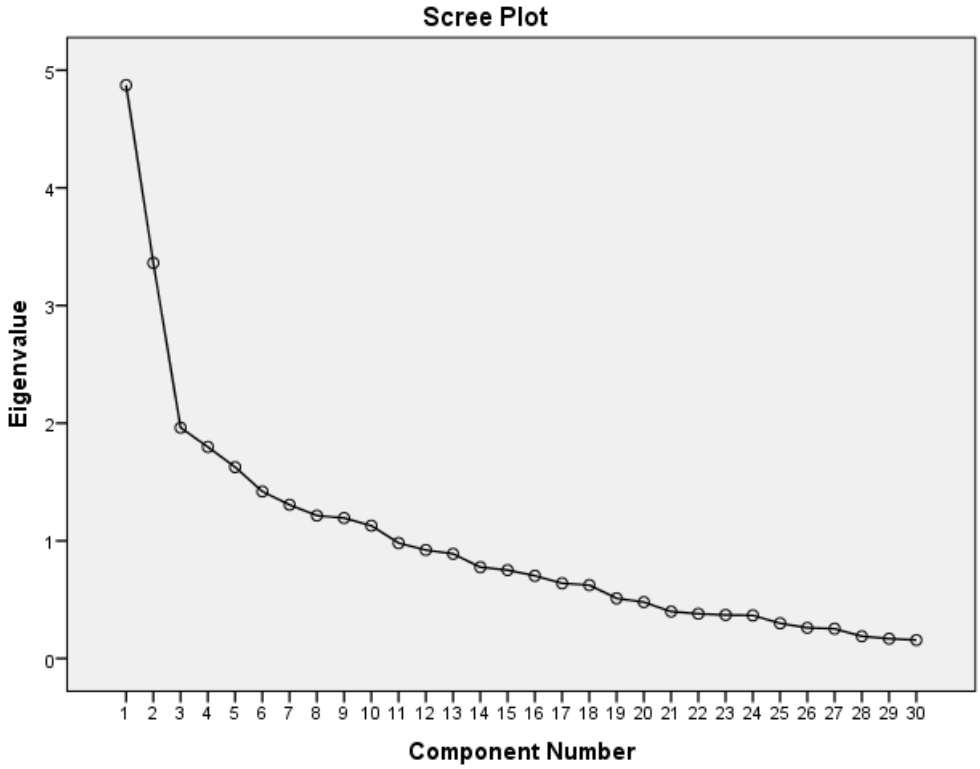

Fig.1 Scree Plot of Factors

Results of Factor Analysis

The factor analysis conducted in this study revealed several important insights into the key safety challenges within the construction industry. These findings provide a comprehensive understanding of the factors that contribute to safety risks, allowing industry professionals and stakeholders to prioritize intervention strategies that will effectively reduce accidents and improve safety standards on construction sites. The factor analysis identified six distinct factors that influence safety management practices, with each factor explaining a portion of the total variance in the data. Below is an elaboration on the key findings:

Factor 1: Adversarial Working and 3D Stigma (12.81% Variance Explained)

Factor 1 emerged as the most significant contributor to safety issues in the construction industry, accounting for **12.81%** of the total variance explained. This factor highlights two key issues: fragmented communication and collaboration among contractors, subcontractors, and other stakeholders, and the industry's negative perception, commonly referred to as the "3D stigma." The "3D stigma"—denoting that construction work is perceived as dangerous, dirty, and demeaning—discourages youth participation and contributes to the industry's reliance on foreign labor (Kineber et al., 2023). Fragmented communication between project teams exacerbates this issue, leading to a lack of cohesion in safety protocols and increasing the likelihood of safety violations. **Johansen et al. (2024)** and **Waqar et al. (2024)** emphasized that addressing the "3D stigma" and promoting better communication and collaboration within the workforce is vital for improving safety standards on construction sites.

Factor 2: Poor Site Coordination and Management (12.61% Variance Explained)

Factor 2, which accounted for **12.61%** of the variance, underscores the importance of effective site coordination and management in mitigating safety risks. Poor coordination between various teams, such as contractors and subcontractors, can result in disorganized work environments where safety protocols are neglected. The rushed schedules often present on construction sites, along with material shortages, further compound the issue. As noted by **Waqar et al. (2024)**, delayed materials and inadequate preparation lead to unsafe working conditions, increasing the risk of accidents. Proper planning and timely material delivery are essential for ensuring that workers have a safe and organized environment in which to perform their tasks. Effective site management and coordination help reduce the probability of accidents by ensuring safety measures are followed consistently.

Factor 3: Incompetency of Construction Stakeholders (12.18% Variance Explained)

Factor 3, accounting for **12.18%** of the variance, highlights the critical role of competent stakeholders in maintaining construction site safety. A lack of adequately trained safety officers and project managers contributes significantly to safety risks. **Li et al. (2024)** pointed out that a lack of expertise and safety training for personnel can result in improper risk management and the failure to address safety hazards effectively. This factor emphasizes the importance of ongoing training and the hiring of skilled and qualified personnel to ensure that safety standards are upheld throughout the project lifecycle.

In particular, project managers and safety officers play an essential role in enforcing safety protocols and ensuring that safety measures are incorporated into every phase of the construction process.

Factor 4: Slow Technology Adoption (10.92% Variance Explained)

Factor 4, accounting for **10.92%** of the total variance, reveals the slow pace at which the construction industry is adopting new technologies aimed at improving safety. Technologies such as Artificial Intelligence (AI), Building Information Modeling (BIM), and wearable safety devices can significantly enhance safety management by identifying hazards in real time and ensuring worker compliance with safety protocols (Waqar et al., 2024). However, the reluctance to invest in such technologies due to cost concerns or fear of change has slowed their widespread adoption. As **Vitrano and Micheli (2024)** noted, embracing new technologies can drastically reduce human error and improve safety outcomes on construction sites. The slow adoption of technology is a barrier that needs to be overcome in order to enhance overall safety and efficiency on construction projects.

Factor 5: Haphazard Decision-Making (10.27% Variance Explained)

Factor 5, explaining **10.27%** of the variance, centers around poor decision-making, particularly during the early stages of a construction project. Changes in design, unclear tendering processes, and insufficient stakeholder involvement in key decisions often lead to safety risks that could have been avoided with better planning and foresight. As **Waqar et al. (2024)** highlighted, design changes and poor decision-making during the planning phase can lead to significant delays, cost overruns, and safety violations. Furthermore, **Ammad et al. (2021)** emphasized the importance of involving all relevant stakeholders in decision-making to ensure that safety concerns are fully addressed before and during the construction process. This factor stresses the need for careful planning and informed decision-making in the early stages of a project to prevent safety issues from arising later.

Factor 6: Inefficient Administrative Processes (9.62% Variance Explained)

Factor 6, which explained **9.62%** of the variance, points to the role of inefficient administrative processes in hindering the timely implementation of safety measures. Bureaucratic delays, such as slow approval of safety equipment, safety protocols, or construction site clearances, were found to obstruct the efficient functioning of safety management systems. As **Okonkwo et al. (2023)** discussed, these delays often lead to situations where safety measures are either not implemented on time or are improperly enforced. Streamlining administrative processes and ensuring prompt decision-making are essential to ensuring that safety measures are in place when needed. This factor emphasizes that construction companies should focus on minimizing bureaucratic hurdles in order to facilitate timely and efficient safety interventions.

Conclusion of Factor Analysis Results

The results of the factor analysis reveal that the safety challenges in the construction industry are complex and multi-dimensional. Each of the identified factors contributes to the overall safety risks on construction sites, with some factors, such as adversarial working and poor site coordination, standing out as more critical than others. By addressing these factors—through improved communication, better training, the adoption of new technologies, and more efficient decision-making and administrative processes—construction industry stakeholders can significantly improve safety outcomes and reduce the incidence of accidents and injuries on construction sites. These findings are in line with those of **Waqar et al. (2024)**, **Li et al. (2024)**, and **Ammad et al. (2021)**, who have similarly highlighted the importance of these factors in shaping safety management practices in construction.

By focusing on these key areas, safety managers and decision-makers can develop targeted strategies to tackle the most pressing safety issues and improve overall safety culture on construction sites. The insights from this analysis can serve as a foundation for the development of more effective safety management systems, ensuring that construction projects are completed on time, within budget, and with minimal risk to workers' health and safety.

Data Collection and Analysis Summary

The data collection process for this study was executed using an online survey, gathering responses from 101 participants who were professionals within the construction industry. These respondents were carefully selected to represent a broad range of sectors, including contractors, project managers, site engineers, safety experts, and regulatory officials. This diverse pool of respondents ensured that the collected data captured a wide spectrum of safety concerns across different roles within the construction industry. The survey responses were analyzed using two main methods: the Relative Importance Index (RII) and factor analysis. These methods enabled the identification of the most critical safety factors affecting construction projects, while also uncovering the underlying dimensions that contribute to these issues.

Key Findings

1. Inadequate PPE Usage and Poor Site Organization

The RII analysis revealed that the two most critical safety issues on construction sites were inadequate PPE usage and poor site organization. These issues were rated highly by respondents and are often seen as direct contributors to accidents and injuries on construction sites. PPE usage is a fundamental part of maintaining safety standards, yet non-compliance and inconsistent enforcement were identified as ongoing challenges. **Ammad et al. (2021)** emphasize that improving PPE compliance is essential to safeguarding workers, particularly in high-risk activities like working at heights or with hazardous materials.

2. Six Major Factors Identified Through Factor Analysis

Factor analysis, using Principal Component Analysis (PCA), identified six major factors that influence safety on construction sites. These factors were extracted from the survey data and include:

- **Adversarial Working Conditions**: Fragmented communication between stakeholders and the negative perception of construction work, referred to as the "3D stigma" (dirty, dangerous, demeaning), were identified as significant safety risks. This factor accounted for **12.81%** of the variance explained, emphasizing its importance in overall safety.

- **Poor Site Coordination and Management**: Effective site management and coordination are vital for reducing safety risks. Delays in project schedules, poor communication between contractors and subcontractors, and material shortages were identified as major contributors to unsafe working conditions. This factor explained **12.61%** of the variance.

- **Incompetency of Construction Stakeholders**: The factor analysis identified the lack of adequately trained staff, particularly safety officers and project managers, as a key contributor to safety issues. The absence of sufficient training and experienced professionals hampers safety compliance and increases the likelihood of accidents. This factor explained **12.18%** of the variance.

- **Slow Technology Adoption**: The construction industry's slow pace in adopting technologies such as Building Information Modeling (BIM), AI-powered safety monitoring, and wearable safety devices was identified as a barrier to improving safety. This factor, explaining **10.92%** of the variance, highlights the need for technological advancements in construction safety management. **Waqar et al. (2024)** emphasize the role of innovative technologies in improving safety.

- **Haphazard Decision-Making**: Poor decision-making, especially in the early stages of projects (e.g., design changes and tendering processes), was found to increase safety risks. This factor accounted for **10.27%** of the variance and underscores the need for better planning and stakeholder engagement during project initiation. **Li et al. (2024)** discuss the importance of decision-making in the context of safety.

- **Inefficient Administrative Processes**: Bureaucratic delays and inefficient approval processes were found to hinder the timely implementation of safety measures. This factor explained **9.62%** of the variance and indicates the need for more streamlined administrative procedures in construction projects.

3. The Role of Communication and Technology in Enhancing Safety

The factor analysis underscored the importance of better communication and technology adoption to address safety concerns. Improved communication between all stakeholders, including workers, supervisors, and contractors, can help in the effective dissemination of safety information, while technology can enhance real-time hazard detection and ensure timely responses to safety violations. **Johansen et al. (2024)** highlight the role of AI and automation in improving safety inspection and compliance, which can directly reduce accidents on construction sites.

Recommendations

1. Enhance PPE Compliance

The study emphasizes the need for improved PPE compliance across all construction sites. The findings suggest that consistent enforcement of safety protocols, including regular PPE checks and training on its proper use, is essential for reducing safety risks. **Ammad et al. (2021)** advocate for the use of smart technologies to track PPE usage, ensuring that workers are adequately protected at all times.

2. Improve Site Coordination and Management

To reduce safety risks, better site management practices are critical. Construction companies should implement more effective coordination between contractors, subcontractors, and suppliers. Ensuring that the necessary materials and resources are available on time, along with the implementation of clear site organization and hazard zones, can significantly reduce accidents.

3. Invest in Training and Competency Development

Continuous safety training and certification programs for all construction workers are essential to ensuring that safety standards are met. These programs should be updated regularly to incorporate new safety technologies and protocols. **Li et al. (2024)** emphasize the importance of psychological and mental health monitoring to enhance worker safety, especially in high-risk environments such as working at heights.

4. Adopt Technology in Safety Management

The adoption of advanced technologies such as AI-powered monitoring systems, BIM tools, and wearable safety devices can greatly enhance safety management on construction sites. These technologies allow for real-time hazard detection, automatic compliance tracking, and better safety data management. **Waqar et al. (2024)** highlight that integrating AI and real-time monitoring can reduce the human error factor in safety inspections, leading to safer work environments.

By addressing these critical safety factors, construction companies can significantly reduce accidents and injuries, improve overall safety standards, and foster a culture of safety across the industry. Implementing these recommendations will help create a safer, more effective, and sustainable construction environment. The findings and strategies align with the works of **Waqar et al. (2024)** and **Kineber et al. (2023)**, who have similarly identified the importance of safety protocols, training, and technology in reducing construction site risks.

Conclusion

This study has provided valuable insights into the critical safety issues faced by the construction industry. The combination of RII and factor analysis has highlighted key factors that significantly impact safety outcomes on construction sites. Inadequate PPE usage, poor site organization, and the lack of communication between workers and supervisors were identified as the most prevalent safety concerns, underscoring the importance of addressing these issues to improve overall safety standards. **Ammad et al. (2021)** emphasize the critical role of PPE in safeguarding workers and minimizing accidents, reinforcing the findings of this study that advocate for better PPE compliance across construction sites.

The factor analysis also revealed that the industry's fragmented communication and adversarial working conditions, often compounded by the "3D stigma" (dangerous, dirty, demeaning), contribute significantly to safety risks. This stigma, as discussed by **Kineber et al. (2023)**, deters local talent from entering the construction sector, leading to an overreliance on foreign labor. Additionally, poor site coordination and the inefficiencies resulting from slow technology adoption were identified as major factors exacerbating safety hazards on construction sites. **Waqar et al. (2024)** have similarly pointed out that the slow integration of modern technologies like AI, BIM, and wearable safety devices hinders safety improvements in the industry.

The study also emphasized the need for more robust training and competency development among construction workers and safety managers. **Li et al. (2024)** and **Waqar et al. (2024)** highlight that inadequate training and a lack of proper safety protocols increase the likelihood of accidents, suggesting that comprehensive, ongoing safety education is critical to improving safety outcomes. Moreover, inefficient administrative processes and poor decision-making during the early stages of projects, such as in design and tendering processes, were also identified as contributing factors to safety risks. These findings are consistent with those of **Johansen et al. (2024)**, who stress the importance of proper decision-making and early safety planning in preventing later-stage safety issues.

To address these challenges, the study recommends a multi-faceted approach that includes improving PPE compliance, enhancing site management practices, investing in technology, and providing ongoing training. By adopting these strategies, the construction industry can reduce accidents, enhance worker safety, and improve project performance. The integration of technology, particularly AI-based safety tools, can significantly reduce human error in safety inspections and ensure that potential hazards are detected and addressed in real-time, as highlighted by **Waqar et al. (2024)**. Furthermore, improving communication and fostering a safety-conscious culture will help mitigate the adversarial working conditions that currently prevail in many construction environments.

In conclusion, the safety challenges identified in this study align with previous research and demonstrate the need for ongoing efforts to improve safety standards in the construction industry. By prioritizing safety, investing in training and technology, and fostering better communication and coordination among all stakeholders, the construction industry can move towards a safer and more efficient future, ultimately reducing accidents and improving worker well-being.

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