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EVALUATING SAFETY ENGAGEMENTS AND NEAR-MISS INCIDENTS IN CONSTRUCTION: AN ETHNOGRAPHIC CASE STUDY

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ABSTRACT: The global construction industry faces significant challenges in achieving high safety standards, with near-miss incidents often highlighting gaps in adherence to safety protocols. This study investigates the relationships between near-miss incident frequency and key safety engagements—knowledge level, adherence to safety protocols, and toolbox meeting participation. Using an ethnographic case study approach, 99 structured observations were conducted on three construction projects in Oregon to evaluate real-time safety practices and performance. Quantitative analysis using Spearman correlation revealed a moderate, significant negative correlation between toolbox meeting participation and near-miss incidents, emphasizing the importance of regular, interactive safety discussions in fostering a proactive safety culture. Adherence to safety protocols demonstrated a strong, significant negative correlation with near-miss incidents, highlighting the necessity for consistent compliance in reducing risks. A moderate negative correlation was observed between knowledge level and near-miss incidents, suggesting that situational application and hands-on training may be more impactful than general safety knowledge. While the findings highlight key safety engagement factors, the study's scope is limited to ethnographic observations and structured correlations, necessitating further exploration using controlled experimental designs. This study provides practical and academic contributions. From a practical standpoint, this study offers recommendations for improving toolbox meeting quality and integrating experiential training to reduce incidents. Academically, the study advances understanding of the interplay between proactive and reactive safety behaviors, contributing empirical evidence to the discourse on safety engagement in construction.

1. INTRODUCTION

Construction sites are inherently high-risk environments where effective safety practices are crucial for preventing incidents and ensuring worker well-being (Hallowell and Gambatese 2009). Despite advancements in safety protocols, the construction industry continues to experience a high rate of safety incidents, including near-miss events that often precede more severe incidents (Sunindijo and Zou 2013). This persistent challenge underscores the importance of investigating the underlying factors that influence safety outcomes, particularly the roles of worker behavior, engagement in safety practices, and adherence to protocols. While fostering a proactive safety culture has been widely recognized as essential, gaps remain in understanding the specific interplay of safety engagements, such as knowledge level, adherence to safety protocols, toolbox meeting participation, and their correlation with safety outcomes on construction sites (Pereira et al. 2018). Addressing these gaps is critical for developing targeted interventions that reduce incidents and foster a safer work environment (Zhou et al. 2015).

Near-miss incidents in construction, described as incident precursors, are unplanned events that had the potential to cause injury, illness, or property damage but did not result in harm due to a combination of

external conditions (e.g., a falling object landing on a scaffold instead of striking a worker), unintentional safety redundancies (e.g., a worker unknowingly violating Occupational Safety and Health Administration (OSHA) fall protection regulations but avoiding injury due to a temporary barrier), or human intervention (e.g., a supervisor stopping a worker from working in an unsafe excavation before or during a trench collapse, preventing injury) (Hashmi et al. 2024). These incidents serve as critical leading indicators of workplace hazards, providing opportunities for intervention before more severe incidents occur. Unlike minor safety violations or unsafe behaviors, near-misses involve a deviation from standard safety procedures that, under slightly different circumstances, could have resulted in harm (Gnoni et al. 2022; Cambraia et al. 2010). However, challenges such as underreporting and inconsistent documentation hinder their effectiveness as a safety improvement tool. This study aims to evaluate how key safety engagements—knowledge level, adherence to safety protocols, and toolbox meeting participation— correlate with near-miss incidents, providing a data-driven approach to strengthening safety interventions on construction sites. By analyzing these relationships, the research seeks to contribute to the development of proactive safety management strategies that mitigate risks and enhance overall construction site safety.

2. LITERATURE REVIEW

2.1 Safety Engagement and Incident Reduction in Construction

Safety in the construction industry remains a primary concern worldwide, with incidents and injuries occurring at disproportionately higher rates compared to other industry sectors. Recent studies emphasize that construction sites are inherently high-risk environments due to factors such as the use of heavy machinery, dynamic site conditions, and the involvement of diverse personnel with varying safety expertise (Hashmi et al. 2024; Woźniak and Hoła 2024). The importance of fostering a proactive safety culture has gained prominence as an effective approach to mitigating these risks. Research highlights the need to shift from reactive to proactive safety practices, focusing on preventative strategies that address the root causes of safety lapses (Meng et al. 2024; Jung et al. 2023). Recent studies have demonstrated that near-miss incidents serve as predictive indicators of workplace hazards, revealing gaps in existing safety measures, such as inadequate training, inconsistent adherence to protocols, and insufficient hazard identification (Xiang et al. 2024; Pereira et al. 2018). Incorporating behavioral safety models and predictive analytics into near-miss analysis has proven effective in reducing incident severity and frequency (Sunindijo and Zou 2013; Rozenfeld et al. 2010). The present study builds upon these approaches by assessing how engagements influence near-miss occurrences, providing empirical insights for targeted safety interventions.

2.2 Safety Engagement and Measurement

Safety engagement refers to workers' active involvement, awareness, and participation in safety-related activities, behaviors, and protocols aimed at minimizing risks and improving workplace safety culture (Lingard and Pink 2020; Rozenfeld et al. 2010). It encompasses various proactive and reactive safety behaviors, such as knowledge level, safety protocol adherence, toolbox meeting participation, and hazard reporting. Engagement metrics are measurable indicators used to assess the extent to which workers participate in safety-related activities and comply with safety standards. In construction, key engagement metrics include the extent of participation in toolbox meetings and the extent of adherence to safety protocols, both of which provide quantifiable insights into proactive and reactive safety behaviors (He et al. 2019). The extent of participation in toolbox meetings has been shown to significantly improve workers' safety attitudes, communication, and risk awareness (Winge et al. 2019; Zhou et al. 2015; Mitropoulos et al. 2005). Studies by Goh and Binte Sa'adon (2015) highlight the importance of tailoring these meetings to address site-specific risks, thereby fostering proactive participation and enhancing their effectiveness. Another critical engagement metric is the extent of adherence to safety protocols, which includes the consistent use of personal protective equipment (PPE), compliance with site safety rules, and proper housekeeping. Recent research indicates that strict adherence to safety protocols is strongly associated with reduced incident rates. However, adherence often becomes more stringent after an incident has occurred, reflecting a reactive rather than proactive approach to safety (He et al. 2019). Proactively

embedding adherence into the workplace culture is essential for sustained improvements in safety performance (Lingard and Pink 2020; Rozenfeld et al. 2010).

2.3   Gaps in the Literature and Research Focus

Despite extensive research on safety culture, training, near-miss detection metrics, and engagement metrics, gaps remain in understanding the direct relationships between specific engagements with respect to safety and incident reduction outcomes. Although Wachter and Yorio (2014) provided a robust empirical model linking safety management practices and worker engagement with reduced accidental rates, their study relied primarily on self-reported data and did not integrate real-time observational metrics or explore near-miss incidents specifically. For instance, no study has quantified the impact of toolbox meetings, protocol adherence, and knowledge levels on near-miss incidents using robust statistical methods such as Spearman correlation. Recent efforts by Li et al. (2024) and Pereira et al. (2018) demonstrate the potential of advanced analytical techniques to provide actionable insights into safety performance metrics. Given the non-linear and complex nature of safety metrics, Spearman correlation provides a robust analytical approach for capturing these relationships, while ethnographic observations offer contextual depth in understanding worker behaviors. The study described herein addresses these gaps by examining the relationships between knowledge level, adherence to safety protocols, toolbox meeting participation, and near-miss incident frequency. Employing an ethnographic case study approach, the research provides empirical evidence on the effectiveness of engagements with respect to safety in reducing near-miss incidents. Doing so contributes to developing targeted interventions that enhance safety culture and performance in the construction industry. This study employs an ethnographic case study approach combined with quantitative analysis to investigate these relationships systematically.

3. RESEARCH METHODOLOGY

This study employs an ethnographic case study methodology to evaluate the correlation between safety engagements—specifically, knowledge level, adherence to safety protocols, and toolbox meeting participation—and safety outcomes, particularly near-miss incidents. Ethnographic research is well-suited for understanding complex, site-specific interactions and cultural factors, providing an in-depth examination of how safety engagements are implemented and maintained in real-world construction environments (Leicht et al. 2010; Phelps and Horman 2010). This research was conducted across three distinct construction projects, selected to provide diverse insights into safety engagement behaviors at different construction stages and project types. The study was conducted on three construction sites to ensure a comprehensive analysis across different project scopes and safety environments. Project A was a heavy engineering construction / industrial project (wastewater treatment plant project), valued at $75 million and 75% complete at observation time. Project B was a heavy engineering construction / industrial project (water treatment plant project) valued at $35 million and 65% complete at the time of data collection. Project C was a building construction project (university building) valued at $200 million and 50% complete when the observations were conducted. These projects provided diverse construction environments, allowing for an analysis of safety engagements in both industrial and commercial settings while considering different levels of project completion.

3.1   Study Design

This study adopted a structured four-stage ethnographic research design to evaluate the relationship between safety engagement metrics and near-miss incidents, as illustrated in **Figure 1**. In the first stage, the research team defined the study objectives by identifying gaps in construction safety engagement and reviewing relevant literature on behavioral safety, ethnographic methods, and correlation analysis (Woźniak and Hoła 2024). This foundation informed the development of an ethnographic framework, including a structured observation plan across multiple project sites. The second stage focused on data collection through 99 structured observations across three construction projects. Observers recorded worker behavior related to three key engagement metrics—knowledge level, toolbox meeting participation, and adherence to safety protocols—alongside near-miss incidents as the primary safety outcome. In the third stage, the collected data were analyzed using both qualitative insights and quantitative analysis through Spearman

correlation to examine the relationships between engagement metrics and near-miss incident frequency. This approach allowed for the identification of meaningful, non-linear associations while maintaining contextual depth through ethnographic insights. The final stage involved interpreting the findings, identifying patterns, and developing practical recommendations for improving safety engagement and reducing near-miss incidents. These findings were shared with industry stakeholders through reports and presentations to support broader safety culture improvements.
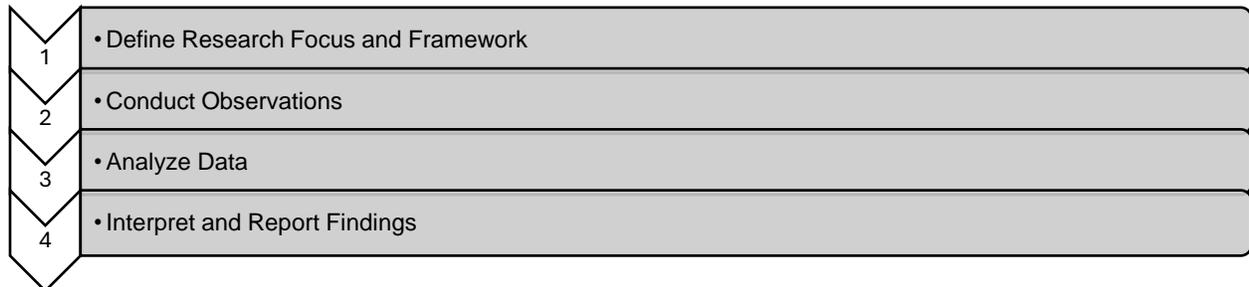

Figure 1. Ethnographic research methodology for evaluating construction safety practices

3.2 Data Collection

Data collection consisted of 99 structured observations conducted across three distinct construction projects, evaluating three key safety engagements: knowledge level, adherence to safety protocols, and toolbox meeting participation. Observations were distributed across projects as follows: 39 observations in Project A (wastewater treatment plant), 39 observations in Project B (water treatment plant), and 21 observations in Project C (university building). These projects provided diverse construction environments, allowing for a broad assessment of safety performance across both industrial and commercial settings. Knowledge level was assessed on a 1–5 scale, reflecting workers' understanding of safety protocols associated with work during construction execution, ranging from no or minimal understanding (1) to comprehensive understanding (5). Adherence to safety protocols was recorded as a percentage, calculated by scoring each protocol (e.g., proper PPE usage, adherence to housekeeping standards, compliance with JHA requirements, safe operation of equipment, presence and effectiveness of signage, organization of tools and materials, effective team coordination and communication, and implementation of engineering controls) on a scale from 0% (non-adherence) to 100% (full adherence), then averaging the scores. Toolbox meeting participation was similarly rated on a 1–5 scale, measuring engagement from minimal interaction (1) to proactive involvement (5).

The researcher strictly followed structured observation protocols to ensure consistency and minimize observer bias, and multiple trained observers were deployed to standardize data collection. Observers assessed safety engagements using predefined rating scales to maintain objectivity in the documentation. Near-miss incidents were recorded as binary data (0 = no incidents, 1 = observed actual near-miss). A near-miss incident was confirmed only after project key personnel conducted an investigation using root cause analysis, verifying that the event resulted from a hazardous deviation from the construction execution plan, OSHA standards, or other regulatory requirements. Such deviations had the potential to cause injury, illness, or property damage under slightly different circumstances. This classification process ensures that all documented near-misses are validated based on established safety regulations and investigative findings, eliminating subjective judgment and reinforcing the study's methodological rigor.

A team of ten trained observers conducted structured safety observations across the three construction sites to ensure data reliability and comprehensive assessment. The project manager observed field operations once or twice a day for 30–60 minutes per field safety observation. Four superintendents each conducted a minimum of three observations per day, totaling three hours, with at least one hour per safety observation. The quality manager integrated safety observations into quality inspections, reinforcing that all personnel hold responsibility for site safety. The safety manager performed a minimum of three safety observations daily, each lasting at least one hour, and conducted four site visits per day, dedicating one hour per active construction activity. The researcher conducted three site visits per day, with a minimum of

30 minutes per observation. Lastly, two front-line supervisors conducted continuous, uninterrupted safety observations throughout field operations, ensuring at least 7.5 hours of direct observation per shift. Each observer followed a structured schedule to capture engagement behaviors in real time, providing an extensive and systematic evaluation of safety practices on active construction sites. Observations were conducted during active construction hours, such as the daily morning safety meetings and field operations, over a 24-week period to capture real-time engagement in safety practices. Each observation followed a structured protocol using predefined rating scales to assess workers' knowledge levels, safety protocol adherence, and toolbox meeting participation. Observers were strategically positioned at various locations within the construction sites, including work zones, staging areas, break zones, and job site trailers, to gain a holistic understanding of safety behavior across different site activities. Safety observations were non-intrusive, ensuring that worker behavior remained natural and uninfluenced by the presence of observers. When required, follow-up discussions were conducted with site personnel to clarify observations while maintaining participant confidentiality. This approach ensured that the study accurately reflected real-world construction site conditions while adhering to ethical standards in ethnographic research.

To ensure sufficient statistical power to detect meaningful relationships between the engagement metrics and the safety metric, a power analysis was conducted to determine the minimum required sample size. Given the unknown population of construction projects and workers, a standard power analysis equation for correlation studies was employed. The analysis determined that a minimum sample size of N = 52 observations was necessary to achieve statistically significant results (Cohen, 1992). The actual sample size of 99 observations exceeded this threshold, enhancing the robustness and reliability of the findings. These structured metrics and the sampling approach align with prior methodologies emphasized by Pereira et al. (2018), providing a robust framework for evaluating safety practices in construction environments.

3.3   Data Analysis

Data analysis employed a mixed-methods approach, combining qualitative insights with quantitative correlation analysis. Spearman correlation was utilized to examine relationships between safety engagements (knowledge level, adherence to safety protocols, and toolbox meeting participation) and the safety metric (near-miss incident frequency). This method accounts for non-parametric data and outliers, ensuring robust findings. The analysis framework builds on the principles of mixed-method research advocated by Abowitz and Toole (2010) and integrates observational data to validate trends and patterns in safety engagements. Findings revealed moderate correlations between safety engagements and near-miss incident frequency, underscoring the critical role of proactive safety engagement and adherence to protocols in reducing workplace hazards.

3.4   Rationale for Ethnographic Approach

The ethnographic methodology was selected for its ability to provide in-depth, contextual insights into construction safety practices. Meng et al. (2024) highlight that ethnographic approaches enable the identification of implicit cultural and behavioral factors influencing safety outcomes. This method allows real-time observation of safety practices, bridging the gap between theoretical constructions and practical applications. Phelps and Horman (2010) emphasize the value of long-term, detailed ethnographic studies in uncovering patterns and cultural dynamics that drive safety performance, making this approach particularly suited to the complexities of construction environments. By leveraging insights from these foundational studies and integrating structured observational methods, this study provides a comprehensive framework for understanding and improving construction safety practices, contributing practical and theoretical advancements to the field.

4. RESULTS AND DISCUSSION

The structured observations in this study focused on four primary construction disciplines: structures, civil, electrical, and mechanical work, covering a total of 49 observations for structures, 21 for civil, 15 for electrical, and 14 for mechanical work, as shown in Table 1. These disciplines encompassed a variety of construction activities, providing a comprehensive assessment of safety performance across different work

environments. The structures discipline involved activities such as installing scaffolding for the mechanical building in Project A, removing scaffolding after roof work completion, and placing a concrete foundation for Project C. Given the high-risk nature of these tasks, strict adherence to safety protocols, particularly in fall protection and lifting operations, was essential. The civil discipline included activities such as grading, paving, and trenching, with trenching presenting heightened risks due to soil stability concerns and worker safety, requiring strict compliance with excavation safety standards. A total of 21 observations were recorded for civil activities across all three projects. The electrical discipline comprised wiring, conduit installation, transformer placement, and electrical panel installations in projects A and B. These tasks demanded a high level of precision and adherence to electrical safety regulations to prevent hazardous exposures and ensure safe operations, with 15 observations recorded. The mechanical discipline included HVAC system installation, pump placements, and setting up temporary supports in Projects A and B, requiring coordination across multiple trades and compliance with safety procedures for heavy equipment operation, resulting in 14 recorded observations. Each discipline's knowledge level, adherence to safety protocols, and toolbox meeting participation were quantified using mean values derived from the observations recorded within that discipline. Similarly, near-miss incidents were measured as binary data, with values indicating the proportion of observations in which a near-miss occurred. For instance, a mean value of 0.12 equates to 12% of observations involving a near-miss, while 0.14 equates to 14%, highlighting discipline-specific variations in safety performance. By integrating these quantitative metrics, the study provides a descriptive overview of safety engagement variations across disciplines. However, statistical correlation analysis was conducted across all 99 observations to examine the overall relationships between safety engagements and near-miss incidents rather than isolating specific disciplines, as shown in Table 2.

4.1 Discipline-Specific Observations

The results indicate notable differences in mean safety engagement levels across construction disciplines, as shown in Table 1. The structures and mechanical disciplines exhibited relatively high average knowledge levels (3.94 and 3.93, respectively) and adherence to safety protocols (80.37% and 81.79%). Despite this, both recorded moderate near-miss incident rates of 12% and 14%, respectively, likely to reflect the complex and high-risk nature of tasks such as scaffolding, crane operations, and heavy equipment handling. The civil discipline showed strong adherence to safety protocols (81.95%) and the highest average toolbox meeting participation score (3.90 out of 5), yet it recorded the highest near-miss incident rate (14%). This suggests that while civil workers actively engage in safety practices, the inherent hazards of excavation and trenching demand heightened vigilance and reinforcement of trench safety protocols. In contrast, the electrical discipline had the highest protocol adherence (82.67%) and the lowest near-miss incident rate (0.00), which reflects the highly regulated nature of electrical tasks where strict compliance is vital to mitigate exposure risks. These findings underscore the need to tailor safety interventions by discipline, ensuring that training and engagement strategies are responsive to discipline-specific risks.

Table 1. Mean engagement metrics across construction disciplines based on observed activities

Discipline	Activity Description	Knowledge Level Mean (1-5)	Adherence to Safety Protocols Mean (%)	Toolbox Meeting Participation Mean (1-5)	Actual Near-miss Incident Mean (0-1)
Structures (n=49)	Concrete formwork, shoring, scaffolding, and crane operation	3.94	80.37	3.65	0.12 (12%)
Civil (n=21)	Grading, paving, trenching	3.86	81.95	3.90	0.14, (14%)
Electrical (n=15)	Wiring, conduit, duct bank, and transformer installation	3.60	82.67	3.93	0.00 (0%)
Mechanical (n=14)	HVAC, pumps, and temporary supports installation	3.93	81.79	3.64	0.14 (14%)

4.2 Statistical Analysis and Key Relationships Alignment with Existing Literature

The Spearman correlation test was used to evaluate the relationships between safety engagements (knowledge level, adherence to safety protocols, and toolbox meeting participation) and the safety metric (near-miss incident frequency), as summarized in Table 2. The statistical analyses revealed that adherence to safety protocols demonstrated the strongest negative correlation with near-miss incidents (ρ = -0.54, 95% CI: -0.66 to -0.39, p < 0.0000001), underscoring the critical role of consistent compliance with safety measures such as PPE usage, housekeeping, and engineering controls. This finding aligns with the findings by Pereira et al. (2018), who emphasized that adherence to safety protocols is a cornerstone of effective safety management, reducing the likelihood of unsafe behaviors and reinforcing a culture of proactive risk mitigation. Toolbox meeting participation exhibited a moderate negative correlation (ρ = -0.45, 95% CI: -0.57 to -0.31, p < 0.00001), reinforcing the value of regular, interactive safety discussions in fostering proactive safety behaviors. This result supports the conclusions of Zhou et al. (2015), who advocated for participatory safety discussions tailored to site-specific risks to enhance communication and risk awareness. The observed correlation highlights the importance of participation in toolbox meetings as structured platforms for reinforcing safety expectations, addressing concerns, and ensuring alignment between workers and safety management practices.

Table 2. Spearman correlation analysis between safety engagements and safety metrics

Safety Engagements	Spearman Correlation Coefficient (ρ)	p-value	95% Confidence Interval	Interpretation
Knowledge Level vs. Near-Miss Incidents (n=99)	-0.31	0.0015	(-0.47, -0.14)	Moderate, significant negative correlation
Adherence to Safety Protocols vs. Near-Miss Incidents (n=99)	-0.54	<0.0000001	(-0.66, -0.39)	Strong, significant negative correlation
Toolbox Meeting Participation vs. Near-Miss Incidents (n=99)	-0.45	<0.00001	(-0.57, -0.31)	Moderate, significant negative correlation

Similarly, knowledge level showed a moderate negative correlation with near-miss incidents (ρ = -0.31, 95% CI: -0.47 to -0.14, p = 0.0015), suggesting that while safety knowledge is essential, its impact is amplified when coupled with experiential training and situational application. This finding extends the discourse established by Sunindijo and Zou (2013), who emphasized that theoretical knowledge alone is insufficient; instead, knowledge must be translated into practice through hazard recognition drills, on-site simulations, and hands-on training initiatives. The relationship between knowledge level and incident reduction highlights the importance of bridging the gap between theoretical understanding and real-world safety implementation. Overall, these findings provide empirical evidence supporting the role of safety engagements in reducing the frequency of near-miss incidents. The strong correlation observed for adherence to safety protocols suggests that maintaining habitual compliance with site safety requirements is paramount. The correlation between toolbox meeting participation and near-miss incidents highlights the effectiveness of structured safety discussions in reinforcing a proactive safety culture, while the findings related to knowledge level emphasize the need for continuous training programs that integrate both theoretical and practical learning approaches. These insights contribute to the broader discourse on proactive safety strategies and reinforce the necessity of a multifaceted approach that combines behavioral safety models with compliance-driven safety measures to achieve a safer construction environment.

4.3 Practical Implications

The findings of this study highlight the importance of bridging the gap between safety engagements and practical implementation. While knowledge level is a key predictor of incident reduction, its effectiveness depends on hands-on applications such as hazard recognition drills, on-site simulations, and real-time safety coaching. This relationship reinforces the need for continuous training programs that integrate theoretical knowledge with experiential learning, ensuring workers can apply safety concepts in dynamic

environments (Sunindijo and Zou, 2013). Moreover, the strong correlation between adherence to safety protocols and near-miss incidents underscores the necessity of embedding compliance mechanisms into daily operations rather than relying solely on reactive enforcement measures. Site supervisors and safety managers should focus on proactive interventions, including habitual reinforcement of safety protocols, real-time safety feedback, and regular verification of compliance practices. The findings align with behavioral safety models by demonstrating that proactive engagement and reinforcement of safe practices can significantly reduce near-miss incidents, further supporting the importance of integrating these approaches into routine site practices.

Similarly, the role of toolbox meeting participation in enhancing communication and reinforcing safety culture suggests that structured, interactive safety discussions should go beyond compliance checklists. To maximize effectiveness, toolbox meetings should incorporate real-world case studies, peer-led safety dialogues, and problem-solving exercises that encourage worker engagement and ownership of safety responsibilities (Zhou et al. 2015). By integrating behavioral safety models with compliance-driven safety measures, construction firms can sustain a proactive safety culture that reduces incidents and strengthens workforce accountability. These insights provide actionable recommendations for improving site-level safety engagements, enhancing worker participation in safety practices, and reinforcing the long-term effectiveness of safety interventions.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Key Findings

This research study explored the relationships between safety engagements—knowledge level, adherence to safety protocols, and toolbox meeting participation—and near-miss incident frequency to evaluate their effectiveness on construction sites. Using an ethnographic methodology, the findings emphasized the importance of proactive safety engagement strategies in reducing near-miss incidents. The reliability of the dataset, as confirmed by the power analysis, strengthens confidence in the study's findings. However, since observations were conducted across three specific projects, two heavy engineering (wastewater and water treatment plants) and one building (university building), the applicability of results should be considered within similar project environments rather than generalized across the entire construction industry. Toolbox meetings were identified as critical for enhancing worker engagement, communication, and risk awareness. Additionally, the practical application of safety knowledge, supported by hands-on training and experiential learning, was shown to bridge the gap between theoretical understanding and real-world practices, contributing to improved safety outcomes.

5.2 Limitations and Recommendations

A potential limitation of this study is that the classification of near-miss incidents is inherently linked to deviations from safety protocols, which may introduce a confounding relationship between adherence to safety protocols and near-miss incident frequency. Since near-misses were identified based on non-compliance with safety procedures, this structural dependency could have contributed to the strong negative correlation observed in Table 2. However, this relationship reflects real-world safety dynamics, where failure to adhere to safety protocols is a well-documented precursor to hazardous events. Rather than viewing this dependency as a limitation, it reinforces the critical role of compliance in preventing near-misses. Future research could explore alternative near-miss classification approaches, such as third-party incident reports or independent audits, to validate these findings while assessing additional contextual factors influencing near-miss occurrences. Additionally, experimental or longitudinal studies may help isolate the direct effects of safety protocol adherence from other contributing variables, further strengthening the understanding of safety engagement and incident prevention in construction environments.

Beyond this methodological consideration, this study acknowledges that the safety engagement metrics used, while significant, do not fully capture the complexity of safety dynamics across different construction disciplines. A deeper analysis of site-specific risks, worker behaviors, and cultural dynamics is necessary

to complement these quantitative insights and ensure a more comprehensive understanding of safety performance. While structured observation protocols were implemented to minimize observer bias, the ethnographic nature of the study inherently involves researcher presence on-site, which may have influenced worker behavior. To mitigate this effect, project managers agreed not to disclose the ethnographic nature of the study to workers, allowing for more natural interactions and reducing potential behavioral bias. Future research could further address this limitation by incorporating blind data collection techniques, such as unannounced audits or automated safety monitoring systems, to eliminate observer influence entirely. The findings of this study offer three actionable recommendations to enhance construction safety outcomes: (1) enhance toolbox meeting quality by tailoring discussions to address site-specific risks and promote proactive safety behaviors, thereby fostering greater worker engagement and communication; (2) reinforce compliance with safety protocols through structured reinforcement programs, including weekly audits and real-time feedback mechanisms, to ensure consistent adherence to PPE usage, housekeeping standards, and site-specific safety plans; and (3) integrate experiential training—such as hazard recognition drills, on-site simulations, and scenario-based exercises—to bridge the gap between theoretical knowledge and practical application. By implementing these strategies, construction managers and site supervisors can cultivate a proactive safety culture that minimizes near-miss incidents and promotes sustainable improvements in safety performance.

5.3   Future Research Directions

Future research should build upon these findings by exploring additional safety engagements and metrics, such as supervisory communication, safety climate, and team dynamics, to provide a more comprehensive understanding of factors influencing safety outcomes. Expanding the study scope to include diverse project types and sizes—such as high-rise buildings, infrastructure projects, and smaller-scale building developments—along with variations in geographical regions and organizational contexts, will enhance the applicability of results to a broader range of construction environments. Longitudinal studies could evaluate the sustained impact of safety interventions over time, offering deeper insights into their long-term effectiveness. Moreover, advanced technologies such as real-time wearable safety monitoring devices present promising opportunities to track worker adherence to safety protocols in uncontrolled environments. These devices could capture objective, continuous data on safety compliance, such as PPE usage and movement patterns, while eliminating observational bias inherent in human-led ethnographic studies. However, implementing wearable devices may present challenges, such as addressing worker privacy concerns and overcoming the high initial costs of device acquisition and deployment. Organizations should balance these challenges with the potential benefits of real-time data collection and improved safety outcomes. Integrating predictive analytics with wearable data could further enable proactive identification of high-risk behaviors or conditions, supporting immediate corrective actions and contributing to safer work environments. Finally, future research should further explore safety engagements, including cultural and behavioral factors that influence safety outcomes. Specifically, studies should examine how organizational practices and individual worker attitudes interact to shape safety performance, emphasizing controlled experimental designs to establish causal relationships. These insights will support the development of targeted strategies to reduce incidents and foster proactive safety cultures across diverse construction environments.

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