International Journal of Sustainable Building, Infrastructure and Environment (IJOSBIE)
Vol. 7, No. 2, October 2026, pp. 18-26
ISSN: 2716-4829 DOI: https://doi.org/10.26877/ijosbie.v7i2.994

Adaptive Occupational Health and Safety Management in Coastal Revetment Construction: A Case Study of the Candidasa Beach Conservation Project, Bali

Dewi Handayani*, Baiq Najma Jauza, Ayu Made Nailashanti Priya Budarta, Arya Saputra, Akmal Iman Wibowo

Department of Civil Engineering, Universitas Sebelas Maret, Jl. Ir. Sutami No 36A, Surakarta, Central Java 57126, Indonesia

*dewi@ft.uns.ac.id

Abstract. Coastal revetment construction in tourism areas involves dynamic occupational health and safety risks due to direct exposure to tides, waves, currents, extreme weather, and public activities. This study examines adaptive Occupational Health and Safety (OHS) management in the Candidasa Beach Conservation Project, Bali. A qualitative descriptive case study was conducted using project documents, including the Construction Safety Plan, Job Safety Analysis–Construction Safety Analysis, daily OHS reports, RKL–RPL documents, and technical-environmental reports. The analysis focused on the relationship between oceanographic dynamics, safety risks, and adaptive control measures. The findings show that oceanographic conditions are key triggers of fluctuating safety risks affecting workers, equipment, and the public. Adaptive OHS management is reflected in safety planning, work-method adjustment, tidal-based scheduling, marine-specific personal protective equipment, and public access control. The study highlights the need for contextual and responsive OHS systems in coastal construction projects.

Keywords: adaptive OHS management, coastal revetment, coastal tourism, construction safety

1. Introduction

Construction safety studies indicate that the construction sector is highly exposed to accident risks due to the simultaneous involvement of workers, heavy machinery, materials, and multiple work activities. Almaskati et al. [1] emphasize that hazard identification, risk mitigation, the use of personal protective equipment, training, and supervision are essential elements of construction safety management. However, existing studies remain largely general in scope and have not specifically addressed the risk characteristics of coastal construction, where safety conditions are strongly influenced by oceanographic dynamics such as tides, waves, currents, and extreme weather.

In maritime construction, Rocha and Sattineni [2] indicate that activities such as dredging, beach nourishment, breakwater construction, and jetty construction involve specific safety challenges. These

© 2026 The Author(s). International Journal of Sustainable Building, Infrastructure and Environment (IJOSBIE) are published under the terms of the Creative Commons Attribution-ShareAlike (CC BY-SA 4.0). Authors retain the copyright to their work. Users may read, copy and distribute the work in any medium provided the authors and the journal are appropriately credited

include unpredictable working conditions, limited training, communication constraints, insufficient worker preparedness, and exposure to marine environmental factors. Although their study is relevant to coastal and maritime construction safety, it primarily addresses maritime construction safety in a broad context and does not specifically examine how safety management systems adapt operationally to tidal and wave fluctuations.

This study was conducted at Candidasa Beach, Karangasem Regency, Bali Province, as part of the Candidasa Beach Conservation Project (Figure 1). The site is an open coastal area directly exposed to oceanographic dynamics, including tides, waves, currents, and extreme weather. It also functions as an active tourism zone, where construction activities interact with public use of the beach. These characteristics make the site relevant for examining the adaptation of the Construction Safety Management System (SMK3) to dynamic oceanographic risks and public safety concerns.

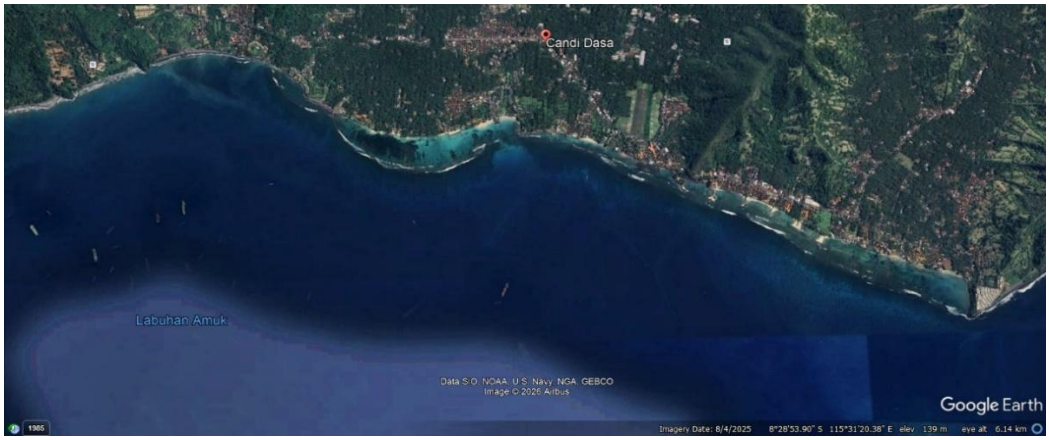


Figure 1. The study area is located at Candidasa Beach, Karangasem Regency, Bali (Source: Google Earth, accessed in August 2025)

In Indonesia, Tumatar and Marpaung [3] examined the implementation of the Construction Safety Management System (CSMS/SMKK) in coastal protection projects based on Ministry of Public Works and Housing Regulation No. 10 of 2021. However, their study primarily focused on regulatory compliance and did not specifically address how the CSMS adapts to changing marine conditions during on-site operations. In coastal construction, oceanographic dynamics, including tides, waves, currents, and extreme weather, can alter working conditions over time and directly influence daily safety decisions [4].

Recent developments in construction safety research have begun to shift towards more dynamic and responsive approaches to managing changing site conditions. Bao et al. [5] developed a dynamic safety checking method to improve construction safety, arguing that conventional safety management approaches tend to remain static. Nevertheless, this approach has not been specifically applied to coastal construction environments where safety risks are strongly influenced by oceanographic parameters. Therefore, studies examining the operational or real-time adaptation of CSMS/SMKK to tidal and wave fluctuations in revetment construction within active tourism zones remain very limited.

To address this gap, the present study offers a novel contribution by analysing the adaptation of the Construction Safety Management System (SMKK) in revetment construction within the Candidasa coastal tourism area, Bali. The analysis focuses on the integration of oceanographic risks into occupational health and safety planning, the adjustment of work methods, tide-based work scheduling, the use of personal protective equipment suitable for marine environments, and the control of public access around the project area. This study is expected to provide a reference for the development of adaptive occupational health and safety management in coastal construction, particularly in work environments influenced by oceanographic dynamics and tourism activities. The findings may contribute to improving worker safety, strengthening operational risk control, and enhancing public safety protection in coastal areas.

2. Methods

2.1. Research design and approach

This study employed a qualitative descriptive approach using a case study method. This approach was selected to enable an in-depth analysis of how the Occupational Health and Safety Management System (OHSMS) adapts to oceanographic dynamics in revetment construction within a coastal tourism area.

2.2. Research location and object

The study was conducted at the Candidasa Beach Conservation Project, located at Candidasa Beach, Karangasem Regency, Bali. The site is an open coastal area and an active tourism zone exposed to tides, waves, ocean currents, and extreme weather conditions. The object of the study was the implementation of the OHSMS in revetment construction activities.

2.3. Types and sources of data

This study used secondary data as the primary source of analysis. The data were obtained from official project documents containing information on occupational health and safety policies, work procedures, coastal environmental conditions, and risk control measures applied during project implementation. Table 1 summarises the types of secondary data reviewed and their functions in the analysis.

Table 1. Types of Secondary Data and Their Functions in the Analysis

Type of Document	Information Reviewed	Function in the Analysis
Construction Safety Plan	Project safety policies, plans, and procedures	To identify OHS planning and risk control measures
Job Safety Analysis–Construction Safety Analysis for revetment works	Work stages, potential hazards, and control measures	To analyse the adaptation of work methods to marine environmental risks
Daily HSE/OHS reports	Daily site conditions, supervision records, and operational responses	To assess operational adaptations to sea and weather conditions
RKL–RPL documents	Project environmental management and monitoring measures	To examine the relationship between environmental control and public safety
Project technical and environmental reports	Coastal site conditions, construction activities, and impact control measures	To support the synthesis of the relationship between oceanographic dynamics and OHS risks

2.4. Data collection method

Data were collected through document analysis. The project documents were systematically reviewed to identify oceanographic conditions, potential occupational health and safety risks, risk control procedures, and adaptive OHSMS measures implemented during revetment construction.

2.5. Data analysis method

The data were analysed using a qualitative descriptive approach. The analysis involved data reduction, classification of risk sources, mapping of risks affecting workers, equipment, and the public, and identification of adaptive OHSMS measures. The findings were then synthesised to explain the relationship between oceanographic dynamics and occupational health and safety controls in coastal construction. The overall research stages are illustrated in Figure 2.

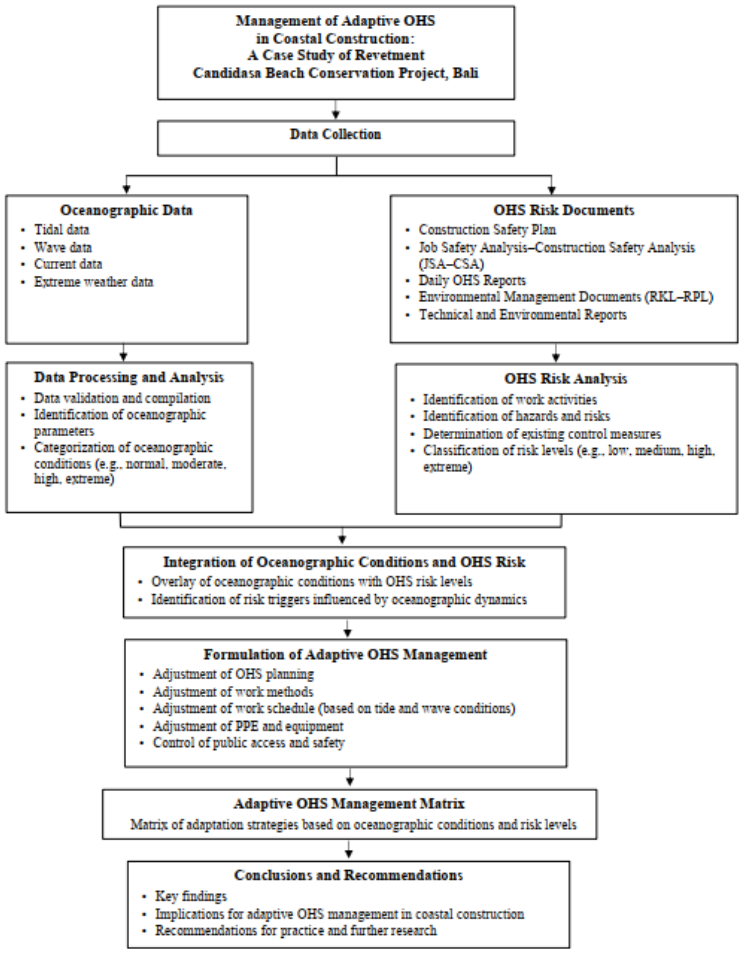


Figure 2. Research methodology

3. Results and Discussion

3.1. Revetment construction in coastal areas and beach tourism zones

Revetment construction in coastal areas is a coastal protection measure characterized by complex technical and environmental conditions. It is not only concerned with shoreline stabilization and erosion control, but also takes place in areas directly exposed to oceanographic dynamics, such as tides, waves, currents, and extreme weather. In beach tourism zones, these complexities are further intensified because construction activities often intersect with public spaces, tourist mobility, and local community activities. Therefore, the discussion of revetment construction should adopt an integrated perspective that considers technical requirements, occupational health and safety, and public safety.

A revetment is a coastal protection structure designed to reduce wave energy, mitigate coastal erosion, and maintain shoreline stability, particularly in coastal areas that are directly exposed to marine dynamics [4]. Unlike conventional onshore construction, revetment works are carried out within the land–sea transition zone, where working conditions are influenced by tides, waves, currents, and extreme weather. These environmental conditions create a dynamic and unstable work area, resulting in safety risks that vary over time [2]. In coastal tourism areas, such risks become more complex because construction activities occur close to tourists, local communities, and public facilities. Consequently, safety management should not be limited to workers and equipment but should also address public safety around the project site [6]. In this context, revetment construction in coastal tourism zones requires an

occupational health and safety management system that is adaptive, risk-based, and capable of responding simultaneously to changing oceanographic conditions and social activities [3].

3.2. Oceanographic dynamics as triggers of occupational safety risks

Tidal fluctuations affect the availability of work areas and effective working hours, particularly for activities conducted within the intertidal zone. As water levels rise, parts of the construction area may become inundated, slippery, and difficult to access, thereby increasing the likelihood of workers slipping, losing balance, or experiencing accidents caused by changes in working-surface elevation [4]. Waves also represent a dominant risk source on open beaches because they generate dynamic forces that may compromise the stability of workers, construction materials, and equipment. These conditions are consistent with a risk-based safety approach, which emphasizes the need to integrate external environmental hazards into hazard identification and occupational safety control processes [5]. Therefore, tides and waves should not only be regarded as environmental variables but also as direct triggers of changes in operational safety risk levels.

In addition to tides and waves, ocean currents and extreme weather further increase the complexity of occupational safety risks in coastal construction. Strong currents during tidal transition phases may increase the likelihood of workers, materials, or equipment being swept into deeper waters, while heavy rainfall and strong winds can reduce visibility, disrupt on-site communication, and limit the effectiveness of supervision [6], [7]. In tourism areas, these risks become more complex because public activities often occur in close proximity to construction zones. Therefore, the Occupational Health and Safety (OHS) management system for revetment construction should be adaptive by enabling adjustments to work methods, work schedules, personal protective equipment (PPE), and public access control in response to changing oceanographic conditions [8]. This analysis indicates that oceanographic dynamics should be recognised as key drivers of occupational safety risks and should inform the development of a responsive OHS management strategy for coastal construction projects.

3.3. Occupational health and safety management system in coastal construction

The Occupational Health and Safety (OHS) Management System in coastal construction serves as a risk control framework that integrates work activities, environmental conditions, and public safety. In revetment construction, risks arise not only from construction activities, heavy equipment, materials, and work methods, but also from oceanographic dynamics, including tides, waves, currents, and extreme weather. Therefore, a static OHS system is not fully adequate for coastal environments that change temporally. Modern OHS approaches emphasize hazard identification, risk assessment, control measures, training, the use of personal protective equipment (PPE), and the dynamic monitoring of working conditions, enabling safety decisions to be adjusted to actual site conditions [1], [5].

In coastal construction projects located in tourism areas, the scope of the OHS system should extend beyond worker protection to include public safety. The implementation of the Construction Safety Management System in coastal protection projects in Indonesia indicates that regulatory compliance provides an important foundation for safety management [3]. However, in active tourism zones such as Candidasa Beach, OHS implementation needs to be more adaptive through the adjustment of work methods, the scheduling of activities based on sea conditions, the use of PPE suitable for coastal environments, and the control of tourist access around the project area. This is consistent with studies on maritime construction safety, which emphasize that work in marine environments is affected by unpredictable conditions, field communication, worker preparedness, and exposure to weather and waves [2].

3.4. Adaptation of the OHS management system to oceanographic dynamics

The adaptation of the Occupational Health and Safety (OHS) management system in coastal construction represents a response to changing working conditions driven by oceanographic dynamics. In revetment construction, safety risks cannot be managed solely through static procedures, as tides, waves, currents, and extreme weather may alter the stability of the work area on a daily basis. Based on

the project documents, OHS adaptation is reflected in five key aspects: OHS planning, work methods, working hours, the use of personal protective equipment (PPE), and public safety.

The analysis indicates that OHS adaptation should begin at the planning stage by integrating wave- and current-related risks into hazard identification. This approach is consistent with construction risk management principles, which emphasise the identification of environmental hazards as the foundation for safety control [1], [5]. At the operational level, work methods should be adjusted or postponed when sea conditions are unsafe. Tidal-based work scheduling is also essential to reduce worker exposure during high-risk periods [4]. Furthermore, the use of marine-specific PPE serves as a technical control measure against risks such as slipping, being swept away by currents, and exposure to extreme weather. In active tourism zones, OHS adaptation should also include public access restrictions to ensure tourist safety [8]. Therefore, OHS management in coastal construction should be adaptive, context-specific, and responsive to oceanographic changes.

3.5. The role of public safety and the social dimension of OHS

In coastal tourism areas, public safety is a critical component of the Occupational Health and Safety (OHS) management system for revetment construction, as construction activities often occur in close proximity to public spaces. In the case of Candidasa Beach, the simultaneous presence of tourists, local communities, workers, equipment, and construction materials within the same area increases potential exposure to hazards. Therefore, OHS should not be viewed solely as a mechanism for worker protection, but also as a broader social risk control framework through access management, risk communication, and community protection around the project site.

The analysis indicates that the social dimension of OHS in coastal construction requires more comprehensive management than in conventional construction projects with limited public interaction. The overlap between construction activities and tourism use may increase accident risks for visitors if access to the work zone is not effectively controlled [9]. In practice, public safety can be managed through work-zone restrictions, warning signs, community outreach, site supervision, and coordination with local stakeholders. This approach is consistent with maritime construction safety studies, which emphasize communication, worker preparedness, and control of unpredictable working conditions [2]. In the Indonesian context, strengthening coastal OHS also requires community-based education, socialization, and training to minimize risks to workers and the public [8]. Thus, public safety broadens the function of the OHS management system from technical risk control to adaptive and participatory social governance [10].

3.6. Synthesis of findings and implications

The synthesis of findings indicates that OHS risks in revetment construction within coastal tourism areas do not occur in isolation. Rather, they are shaped by the interaction between oceanographic dynamics, construction work characteristics, and public activities. In the case of the Candidasa Beach Conservation Project, tides, waves, currents, and extreme weather act as external risk triggers, while the Occupational Health and Safety Management System (OHSMS) functions as an internal mechanism for adaptively controlling these risks.

Substantively, these findings confirm that coastal construction requires an OHS approach that differs from conventional land-based construction. Oceanographic dynamics cause worksite conditions to change temporally; therefore, hazard identification and risk control must be adjusted to actual field conditions [4]. OHSMS adaptation is implemented through the integration of marine environmental risks into OHS planning, adjustment of work methods, tidal-based work scheduling, use of personal protective equipment appropriate for coastal environments, and public access control. This approach is consistent with the concept of dynamic safety checking, which emphasises the need for safety systems that respond to changing working conditions [5]. Thus, OHSMS adaptation is not merely administrative, but also serves as an operational strategy to protect workers, equipment, and the surrounding community.

The implication of this study is the need to strengthen coastal construction OHSMS based on environmental and social risks. Practically, the findings can be used as a basis for developing an OHSMS adaptation matrix that links oceanographic parameters with daily safety decisions, such as postponing work, modifying work methods, or restricting tourist access. Academically, this study extends the literature on construction OHS by positioning oceanographic dynamics as an important variable in safety management systems [1]. In the Indonesian context, this study also reinforces the need for contextual OHSMS implementation in coastal protection projects, particularly in active tourism areas where risks to workers and the public occur simultaneously [3], [8]. Table 2 presents a summary of the analysis, discussion, synthesis of findings, and implications related to oceanographic dynamics in revetment construction.

Table 2. Summary of analysis, synthesis and implications oceanographic dynamics in revetment construction.

Oceanographic Dynamic	Main OHS Risk	Form of OHSMS Adaptation	Project Implication
Tides	Inundated and slippery work areas, with limited working time	Work scheduling based on tidal conditions	Reduces worker exposure during high-risk periods
Sea waves	Loss of worker balance, disruption to equipment, and material instability	Adjustment of work methods and temporary suspension of work under unsafe conditions	Improves operational safety in revetment construction
Ocean currents	Workers or materials may be swept into deeper waters	Use of marine-appropriate PPE and strengthened site supervision	Enhances risk control within coastal work zones
Extreme weather	Reduced visibility, disrupted communication, and increased accident risk	Daily condition monitoring and work feasibility assessment	Supports more responsive OHS decision-making
Tourism activities	Risks to tourists and local communities around the project area	Access restrictions, warning signs, public outreach, and coordination with local stakeholders	Expands OHSMS from worker safety to public safety

Another implication of these findings is the need to develop an OHSMS that is not only document-based, but also supported by dynamic monitoring of changing site conditions. Hong and Teizer [11] emphasise the importance of real-time trajectory analysis and proactive monitoring to control hazards on construction sites, while Niu and Leicht [12] demonstrate that project safety climate is dynamic and may vary according to project phases, working conditions, and workers' perceptions. Therefore, in revetment construction within coastal tourism areas, OHSMS adaptation should be directed towards an integrated system that links daily oceanographic conditions, operational decision-making, risk communication, and public safety control.

4. Conclusion

This study concludes that oceanographic dynamics are a major factor influencing occupational safety risks in revetment construction within the Candidasa Beach tourism area. Tides, waves, ocean currents, and extreme weather cause worksite conditions to change temporally, making risks to workers, equipment, materials, and the public difficult to manage through a static OHS approach. OHSMS adaptation is implemented by integrating oceanographic risks into OHS planning, adjusting work methods, scheduling activities based on tidal conditions, using personal protective equipment (PPE) appropriate for marine environments, and restricting public access around the construction area. These

findings emphasise that OHSMS in coastal construction must be adaptive, context-specific, and responsive to changes in the coastal environment and tourism activities.

Declaration of AI and AI assisted technologies in the writing process

During the preparation of this work the author(s) used Google Translate in order to Translate from Indonesian to English. After using this tool/service, the author(s) reviewed and edited the content as needed and take(s) full responsibility for the content of the publication.

Acknowledgements

The authors gratefully acknowledge the Candidasa Beach Conservation Project, Bali, for providing access to project documents and supporting data. Appreciation is also extended to the project team, safety officers, and relevant institutions for their support in OHS documentation. The interpretations and conclusions are solely those of the authors.

References

[1] D. Almaskati, S. Kermanshachi, A. Pamidimukkala, K. Loganathan, and Z. Yin, "A review on construction safety: Hazards, mitigation strategies, and impacted sectors," *Buildings*, vol. 14, no. 2, pp. 1–18, 2024, doi: 10.3390/buildings14020526.

[2] R. Rocha and A. Sattineni, "Safety in the maritime construction site: Capturing lessons learned," in *Proceedings of the 10th World Construction Symposium*, 2022, doi: 10.31705/WCS.2022.57.

[3] N. Tumatar and B. Marpaung, "Analysis of the implementation of SMKK (Construction Safety Management System) based on the Regulation of the Minister of PUPR No. 10/2021 on the construction project of coastal safety development," in *Proceedings of the International Conference*, pp. 437–444, 2024, doi: 10.5220/0012584400003821.

[4] R. R. Rahmawati, A. H. S. Putro, and J. L. Lee, "Analysis of long-term shoreline observations in the vicinity of coastal structures: A case study of south Bali beaches," *Water*, vol. 13, no. 24, 2021, doi: 10.3390/w13243527.

[5] Q. Bao, J. Zhou, Y. Zhao, X. Li, S. Tao, and P. Duan, "Developing a rule-based dynamic safety checking method for enhancing construction safety," *Sustainability*, vol. 14, no. 21, 2022, doi: 10.3390/su142114130.

[6] I. Pal, A. Kumar, and A. Mukhopadhyay, "Risks to coastal critical infrastructure from climate change," *Annual Review of Environment and Resources*, vol. 48, pp. 681–712, 2023, doi: 10.1146/annurev-environ-112320-101903.

[7] Y. Junjia, A. H. Alias, N. A. Haron, and N. Abu Bakar, "A bibliometric review on safety risk assessment of construction based on CiteSpace software and WoS database," *Sustainability*, vol. 15, no. 15, 2023, doi: 10.3390/su151511803.

[8] Z. Zakia, M. Sariani, I. Yuri Salena, M. A. Rafshanjani, D. Febrianty, and F. Hasdanita, "Strengthening coastal construction safety through community-based OHS socialization, education, and training in West Aceh," *Jurnal Karya Abdi Masyarakat*, vol. 8, no. 2, pp. 63–72, 2024, doi: 10.22437/jkam.v8i2.37428.

[9] N. D. U. Dewi, P. D. A. Mahendra, and M. H. Hanafiah, "Safety Tourism Policy in Bali: Infrastructure Challenges and Sustainable Public Management," *Jurnal Manajemen Pelayanan Publik*, vol. 9, no. 2, pp. 597–614, 2025.

[10] G. T. Navarro Claro, J. A. Bayona Soto, and J. G. Arévalo Ascanio, "Impact of the occupational health and safety management system (OHSMS) on human talent management and organizational performance in the construction sector," *Frontiers in Built Environment*, vol. 11, pp. 1–15, 2025, doi: 10.3389/fbuil.2025.1618356.

[11] K. Hong and J. Teizer, "Digital construction site layout planning and real-time trajectory analysis for proactive safety monitoring and control of struck-by hazards," *Automation in Construction*, vol. 177, p. 106353, 2025, doi: 10.1016/j.autcon.2025.106353.

[12] M. Niu and R. M. Leicht, “Evaluating the safety climate in construction projects: A longitudinal mixed-methods study,” *Buildings*, vol. 14, no. 12, p. 4070, 2024, doi: 10.3390/buildings14124070.