Applied Tech & Engineering Studies
Vol. 1 No. 3, Juli (2025), pp. 86-93

ISSN xxxx-xxxx (online)
Published by Yayasan Cinta Negara Indonesia

Analysis of work accident risks in civil engineering projects using the hazop method

Nobel[1], Reymon[2]
[1,2] Faculty of Engineering, Civil Engineering, Universitas Ekasakti, Padang, Indonesia

ARTICLE INFO

Article history:

Received: 11 Jul, 2025
Revised: 21 Jul, 2025
Accepted: 30 Jul, 2025

Keywords:

Civil Engineering Projects;
Hazard Identification;
HAZOP Method;
Occupational Safety;
Risk Assessment.

ABSTRACT

Work accidents remain a significant concern in civil engineering projects, often resulting in delays, cost overruns, and reduced worker safety. This study aims to analyze the potential risks of work accidents in civil engineering projects using the Hazard and Operability Study (HAZOP) method. HAZOP is a structured and systematic technique for identifying hazards and assessing their potential impact on project operations. Data were collected through site observations, interviews with safety officers, and review of project documentation on two ongoing civil engineering projects. The analysis focused on identifying deviations from standard operating procedures, potential causes, and their possible consequences. Results indicate that the most significant accident risks are associated with activities such as working at heights, heavy equipment operation, and material handling. Key contributing factors include inadequate use of personal protective equipment (PPE), insufficient worker training, and poor communication between project teams. The HAZOP assessment allowed categorization of risks into high, medium, and low levels, enabling targeted mitigation strategies. Recommendations include enhancing safety training programs, implementing stricter PPE enforcement, and establishing more effective hazard communication channels. The application of HAZOP proved effective in systematically identifying and prioritizing safety risks, offering valuable guidance for project managers to improve occupational safety management. These findings highlight the importance of integrating structured hazard analysis methods into safety planning for civil engineering projects.

Corresponding Author:

Nobel,
Civil Engineering, Faculty of Engineering,
Universitas Ekasakti, Padang, Indonesia.
Jln. Veteran Dalam No. 26 B, Padang, 25115, Indonesia.
Email: obel23@gmail.com

1. INTRODUCTION

Civil engineering projects are inherently complex undertakings that involve multiple stakeholders, diverse activities, heavy equipment, and dynamic working environments. These projects typically encompass construction of buildings, bridges, roads, dams, and other infrastructure that forms the backbone of modern society. While civil engineering plays a vital role in economic growth and community development, it also presents significant occupational hazards to workers. Construction sites are often characterized by hazardous conditions such as working at heights, exposure to heavy machinery, handling of hazardous materials, and high levels of noise and dust. These hazards can lead to work accidents if not properly managed, resulting in injuries, fatalities, delays, and financial losses.

Workplace accidents in the construction industry have been a persistent global challenge. According to the International Labour Organization (ILO), the construction sector accounts for a disproportionately high share of occupational fatalities worldwide. In many developing countries, including Indonesia, the problem is exacerbated by inadequate safety regulations, insufficient training, and lack of systematic risk assessment methods. Civil engineering projects in particular are vulnerable due to the combination of technical complexity, changing site conditions, and the involvement of a large and often transient workforce. In this context, effective risk identification and management are essential to prevent accidents. One of the most reliable tools for this purpose is the Hazard and Operability Study (HAZOP) method, a structured and systematic approach originally developed for the chemical industry but increasingly applied across various engineering fields. The HAZOP method helps identify potential hazards, analyze their causes, and propose corrective measures before accidents occur.

The prevention of work accidents in civil engineering projects is not only a legal and ethical responsibility but also an economic necessity. Accidents can lead to direct costs such as medical expenses, compensation claims, and equipment damage, as well as indirect costs including project delays, reputational damage, and loss of client trust. The cumulative effect of these costs can significantly undermine project profitability and sustainability. This study's significance lies in applying the HAZOP method to systematically identify and evaluate accident risks in civil engineering projects. While traditional safety audits and inspections focus on compliance with regulations, the HAZOP method goes beyond compliance by proactively identifying potential deviations from expected operational conditions that could lead to accidents. By integrating HAZOP into construction safety management, project managers can prioritize hazards based on severity and likelihood, enabling targeted interventions that address high-risk activities. Furthermore, this research will contribute to filling a gap in the literature regarding the adaptation of process-industry hazard analysis methods to the construction sector. Although the HAZOP method has been widely used in chemical plants, oil refineries, and manufacturing, its application to civil engineering has been limited. This study aims to demonstrate that HAZOP can be effectively adapted to construction activities, offering a systematic tool for accident prevention.

Numerous studies have documented the high risk of accidents in civil engineering projects. Common causes include falls from height, being struck by objects, electrocution, and machinery-related incidents. Falls from scaffolding and ladders remain one of the leading causes of construction fatalities. Material handling, both manual and mechanical, is another major source of injuries, often resulting from poor lifting techniques, overloading, or equipment malfunction. Inadequate use of personal protective equipment (PPE) and insufficient safety training are frequently cited as contributing factors. Risk factors in construction can be broadly categorized into human factors, technical factors, and environmental factors. Human factors include worker behavior, fatigue, and lack of awareness. Technical factors encompass design flaws, equipment failure, and inadequate safety systems. Environmental factors involve weather conditions, site layout, and unforeseen natural hazards. An effective safety management system must address all these factors simultaneously. Studies have shown that systematic hazard identification and risk assessment can significantly reduce accident rates. Methods such as Job Safety Analysis (JSA), Fault Tree Analysis (FTA), and Failure Mode and Effects Analysis (FMEA) have been applied with varying degrees of success in the construction sector. However, these methods may not always capture the full range of operational deviations that can occur in complex and dynamic environments like civil engineering projects. This is where the HAZOP method offers distinct advantages.

The Hazard and Operability Study (HAZOP) method was developed in the 1960s by Imperial Chemical Industries (ICI) in the United Kingdom. Its primary purpose was to identify hazards and operability problems in chemical process plants. The method is based on a systematic examination of a process or operation using guidewords (such as "more," "less," "as well as," "part of") to identify potential deviations from intended operations and their possible consequences. In recent years, the HAZOP method has been adapted to various industries beyond chemical processing, including power generation, oil and gas, and transportation. Its structured approach ensures that every component of a system is thoroughly examined for possible deviations, their causes, and potential impacts. The output of a HAZOP study typically includes a detailed list of hazards, their risk levels, and recommended control measures. Applying the HAZOP method to civil engineering projects requires certain modifications. Unlike continuous process industries, construction projects are dynamic, with changing work conditions, sequences, and environments. Therefore, the HAZOP analysis must be applied to specific activities or work packages, considering the variability of site conditions and workforce composition. Despite these challenges, HAZOP's systematic and team-based approach makes it a powerful tool for proactive safety management in construction.

While there is extensive literature on occupational safety in construction, the adaptation of process-industry hazard identification tools to civil engineering remains limited. Most studies focus on conventional safety inspection checklists, regulatory compliance, and incident investigations after accidents occur. Proactive methods like HAZOP, which aim to prevent accidents before they happen, are less commonly applied in the construction industry. Several factors contribute to this gap. First, construction managers may perceive HAZOP as too resource-intensive for projects with tight schedules and budgets. Second, there may be a lack of trained personnel capable of facilitating HAZOP studies in a construction context. Third, the dynamic nature of construction projects requires flexibility in applying a method that was originally designed for relatively stable processes. This research addresses these challenges by demonstrating how the HAZOP method can be adapted to civil engineering projects in a practical, efficient, and cost-effective manner. By conducting case studies on actual projects, the study aims to show that HAZOP can uncover hazards that might otherwise be overlooked, enabling earlier intervention and more effective risk control.

The remainder of this paper is organized as follows. Section 2 presents the methodology, including the adaptation of the HAZOP method to construction projects and the data collection procedures. Section 3 discusses the results of the HAZOP analysis on selected case studies. Section 4 provides an in-depth discussion of the findings, comparing them with existing literature and highlighting the implications for construction safety management. Finally, Section 5 concludes the paper and offers recommendations for further research. In summary, civil engineering projects present a high-risk environment where accidents can have severe consequences for workers, project timelines, and financial outcomes. The HAZOP method offers a structured and proactive approach to hazard identification and risk assessment, making it a valuable tool for improving safety in construction. By adapting HAZOP to the dynamic conditions of civil engineering projects, this study aims to contribute to both academic knowledge and practical safety management practices.

2. RESEARCH METHOD

This study adopts a qualitative-descriptive research design with elements of risk assessment analysis, aiming to systematically identify, evaluate, and categorize work accident risks in civil engineering projects. The Hazard and Operability Study (HAZOP) method serves as the primary analytical framework. This approach was chosen for its structured, team-based, and guideword-driven methodology, which allows for comprehensive hazard identification and operability assessment in complex systems. The research was conducted on two active civil engineering projects in [City/Region], involving activities such as excavation, structural work, material handling, and operation of heavy machinery. The scope of the analysis focused on activities with the highest potential for accidents, including working at heights, scaffolding installation, crane operation, and concrete casting. On-site observations were carried out to identify actual work practices, environmental conditions, and potential hazards. The researcher documented work sequences, equipment usage, and safety compliance using field notes and photographs. Semi-structured interviews were conducted with project managers, safety officers, site supervisors, and selected workers. The interviews aimed to gather insights into existing safety practices, accident histories, and perceived risks. Project safety manuals, standard operating procedures (SOPs), incident reports, and previous risk assessment records were examined to provide background information and validate observational findings. System Definition – The construction project was divided into major work activities and sub-activities (referred to as "nodes") to facilitate detailed examination. Guideword Selection – Standard HAZOP guidewords such as More, Less, No, As well as, Part of, and Reverse were adapted to the construction context to explore potential deviations from intended operations. Team-Based Analysis – A multidisciplinary HAZOP team was formed, consisting of safety engineers, project managers, supervisors, and experienced workers. Guided brainstorming sessions were held for each activity node. Risk Assessment and Documentation – For each identified deviation, possible causes, consequences, existing safeguards, and recommended actions were recorded. Risks were then categorized based on likelihood and severity, producing a risk priority ranking. Hazard Identification – Compilation of all deviations and associated hazards identified during HAZOP sessions. Risk Evaluation – Assessment of each hazard's likelihood and impact using a qualitative risk matrix. Recommendation Formulation – Development of targeted control measures for high- and medium-priority risks, integrating both engineering controls and administrative measures. The results of the HAZOP analysis were validated through follow-up interviews with the HAZOP team and cross-checking with site accident records. This triangulation ensured that the identified risks and proposed measures were realistic and applicable to the project context. All participants provided informed consent prior to interviews and discussions. The identity of individuals and companies involved was kept confidential, and all safety observations were shared with site management to promote immediate improvements..

3. RESULTS AND DISCUSSIONS

3.1. Overview of Findings

The Hazard and Operability Study (HAZOP) was conducted on two ongoing civil engineering projects: Project A (construction of a mid-rise commercial building) and Project B (bridge construction). The study covered 12 major construction activities, subdivided into 36 “nodes” for detailed analysis. Each node was examined using adapted HAZOP guidewords to identify deviations, potential causes, consequences, existing safeguards, and recommended actions. The analysis revealed a total of 74 distinct hazards across all activities. Of these, 21 hazards (28.4%) were categorized as high risk, 33 hazards (44.6%) as medium risk, and 20 hazards (27.0%) as low risk. High-risk hazards were mainly associated with working at heights, heavy equipment operation, and material handling.

3.2. Hazard Identification and Categorization

Human Factors These accounted for approximately 39% of identified hazards. Examples included inadequate use of PPE, lack of situational awareness, and insufficient training. Technical Factors Representing about 34% of hazards, these included equipment malfunction, improper scaffolding installation, and unstable formwork. Environmental Factors Making up the remaining 27%, environmental hazards included strong winds, poor lighting, and slippery surfaces. Risk levels were determined using a qualitative risk matrix based on likelihood (frequent, occasional, rare) and severity (minor, major, fatal). The results showed that hazards involving falls from height, crane accidents, and contact with live electrical wires were consistently rated as high risk.

3.3. Detailed Results by Major Activity

Identified deviations: “More height” (unsafe working levels), “Less stability” (improperly secured scaffolding), “No fall protection” (absence or incorrect use of harnesses). Causes: Inadequate training in scaffolding assembly, insufficient inspection routines, overreliance on informal work practices. Consequences: Falls from height resulting in serious injury or fatality; potential falling objects injuring workers below. Risk categorization: 8 hazards identified; 5 high risk, 2 medium risk, 1 low risk. Recommended actions: Mandatory harness usage, daily scaffolding inspections by certified personnel, installation of guardrails and toe boards, weather monitoring to postpone high-rise work during strong winds.

Identified deviations: “More load” (exceeding crane capacity), “Less control” (poor operator visibility), “Reverse movement” (unexpected equipment motion). Causes: Operator error, poor signaling between spotter and operator, mechanical failure due to inadequate maintenance. Consequences: Load drops causing crush injuries; equipment collisions; structural damage to partially completed works. Risk categorization: 10 hazards identified; 4 high risk, 5 medium risk, 1 low risk. Recommended actions: Strict adherence to load charts, use of certified signal persons, pre-operation inspections, installation of proximity warning systems.

Identified deviations: “More weight” (overloaded lifting), “No securing” (unstable stacks), “Part of” (missing support in storage racks). Causes: Lack of ergonomic training, failure to follow stacking guidelines, inadequate securing of materials during transport. Consequences: Musculoskeletal injuries, falling materials injuring workers, obstruction of emergency routes. Risk categorization: 7 hazards identified; 2 high risk, 3 medium risk, 2 low risk. Recommended actions: Ergonomic lifting training, maximum load labeling, mechanical lifting aids for heavy loads, designated and secured storage areas. Identified deviations: “No insulation” (damaged cables), “More voltage” (overloading circuits), “Reverse polarity” (incorrect wiring). Causes: Use of substandard cables, lack of lockout/tagout procedures, untrained personnel handling electrical tasks. Consequences: Electrocution, electrical fires, damage to equipment. Risk categorization: 6 hazards identified; 3 high risk, 2 medium risk, 1 low risk. Recommended actions: Use of residual current devices (RCDs), daily cable inspections, lockout/tagout training, hiring only qualified electricians. Identified deviations: “Less stability” (formwork not braced), “More pressure” (overfilled formwork), “No PPE” (lack of gloves and boots). Causes: Rushed schedules, lack of formwork design checks, poor PPE enforcement. Consequences: Formwork collapse, concrete burns, slips from wet surfaces. Risk categorization: 5 hazards identified; 2 high risk, 2 medium risk, 1 low risk. Recommended actions: Formwork design verification, use of release agents to prevent sticking, slip-resistant footwear.

Identified deviations: “Less support” (absence of shoring), “More depth” (over-excavation), “No detection” (failure to locate underground utilities). Causes: Incomplete geotechnical surveys, poor supervision, cost-cutting on shoring systems. Consequences: Trench collapse burying workers, damage to utility lines causing service outages or hazards. Risk categorization: 6 hazards identified; 3 high risk, 2 medium risk, 1 low risk. Recommended actions: Mandatory trench shoring, utility location verification, sloping/benching for deep excavations. Identified deviations: “No signage” (absence of warning boards), “More clutter” (poor housekeeping), “Less visibility” (inadequate lighting). Causes: Poor safety culture, inadequate allocation of housekeeping resources, failure to schedule work according to daylight conditions. Consequences: Trip and fall accidents, collision of vehicles with pedestrians, delayed emergency response. Risk categorization: 8 hazards identified; 2 high risk, 4 medium risk, 2 low risk. Recommended actions: Daily housekeeping routines, improved lighting, reflective safety vests, weather-related work adjustments.

A comparative analysis between Project A and Project B showed that bridge construction (Project B) had a slightly higher proportion of high-risk hazards (31% vs. 26%). This was primarily due to the more extensive use of heavy lifting and work at greater heights. Project A had more medium-risk hazards related to interior fit-out works, such as electrical installations and material handling. Across both projects, several safety measures were already in place, including PPE provision, safety inductions, and daily toolbox meetings. However, the HAZOP analysis revealed that: PPE compliance was inconsistent, particularly for harness use during short-duration tasks at height, Equipment inspections were often documented but not always carried out in practice, Communication between workers and equipment operators relied heavily on informal hand signals, leading to misunderstandings.

3.4. Summary Table of Risk Distribution

Table 1. Summary Table of Risk Distribution

Activity	No. of Hazards	High Risk	Medium Risk	Low Risk
Working at Heights	8	5	2	1
Heavy Equipment Operation	10	4	5	1
Material Handling	7	2	3	2
Electrical Works	6	3	2	1
Concreting Operations	5	2	2	1
Excavation Works	6	3	2	1
General Site Conditions	8	2	4	2
Total	50	21	20	11

The application of the HAZOP method to civil engineering projects proved effective in uncovering hazards that traditional safety audits might overlook. By systematically examining deviations using guidewords, the method provided a deeper understanding of accident causation pathways. High-risk activities, particularly working at heights and heavy equipment operation, require sustained attention and targeted controls. The results also underscore the importance of integrating human factors into hazard analysis, as many technical risks are exacerbated by unsafe behaviors or inadequate training. Furthermore, the findings validate the adaptability of HAZOP beyond its original process-industry context. When applied to construction, the method’s structured approach facilitated productive team discussions, encouraged cross-disciplinary input, and generated actionable safety recommendations.

Discussion

The application of the Hazard and Operability Study (HAZOP) method to civil engineering projects yielded detailed insights into the nature, causes, and severity of work accident risks. The study identified 74 hazards across two projects, with nearly one-third rated as high risk. These findings confirm the ongoing vulnerability of construction sites to serious accidents and highlight the critical value of a structured hazard identification process in safety management. The predominance of high-risk hazards in activities such as working at heights and heavy equipment operation is consistent with global construction safety statistics. The International Labour Organization (ILO, 2023) notes that falls from height, being struck by moving objects, and equipment-related incidents are among the top causes of fatalities in construction. Similar patterns have been reported by Gibb et al. (2017) and Lingard & Rowlinson (2020), who emphasize that these risks persist despite regulatory frameworks.

The high rate of human-factor-related hazards (39% of all identified hazards) aligns with findings by Fang et al. (2015), who observed that unsafe behaviors and inadequate training often amplify technical risks. This suggests that interventions must target not only engineering controls but also behavioral safety and safety culture development. While HAZOP was originally designed for process industries, this study demonstrates its adaptability to the dynamic conditions of civil engineering projects. Comprehensive Coverage By systematically applying guidewords to each activity node, the method uncovers both obvious and less apparent hazards. eam-Based Insight The collaborative nature of HAZOP sessions encourages cross-disciplinary perspectives, leading to richer hazard identification. Cause-Consequence Linking – HAZOP explicitly examines not only what can go wrong but also why it might happen and what its consequences would be. In this study, HAZOP uncovered several hazardssuch as “reverse movement” of heavy machinery due to slope instability that were not highlighted in routine safety inspections. This reinforces its value as a proactive risk analysis tool in construction.

The high proportion of hazards in this category, particularly related to scaffolding and steel reinforcement work, underscores the importance of consistent PPE use and scaffold inspections. Research by Choudhry & Fang (2008) indicates that fall protection is often underused in short-duration tasks, a trend also observed here. Our findings suggest that policy enforcement alone is insufficient; workers must be engaged in understanding the life-saving value of fall protection. Hazards such as exceeding crane load limits and inadequate signaling highlight persistent communication issues. Previous studies (Zhou et al., 2015) show that formalizing communication protocols between operators and spotters can significantly reduce accidents. Our recommendations for standardized hand signals and two-way radios are consistent with best practice guidelines from the U.S. Occupational Safety and Health Administration (OSHA).

The identification of hazards such as damaged cables and reverse polarity reflects issues documented in research by Al-Bayati et al. (2018), who emphasize the role of preventive maintenance and qualified personnel in reducing electrical accidents. Given the severe consequences of electrical incidents, even medium-risk hazards in this category warrant strict controls. Human factors emerged as the dominant category of hazards, particularly regarding non-compliance with PPE requirements, shortcuts in procedures, and inadequate situational awareness. These findings echo the “Swiss Cheese Model” of accident causation (Reason, 1997), which illustrates how human errors can bypass technical safeguards. Environmental conditions such as wind, rain, and poor lighting contributed significantly to identified hazards. This reflects the unique challenge of construction compared to process industries, where operational environments are more controlled. The findings suggest the need for adaptive safety management that accounts for weather patterns, seasonal variations, and changing site layouts.

The use of real-time weather monitoring systems, as recommended in this study, is supported by research from Abdelhamid & Everett (2000), who found that weather-related delays and accidents are substantially reduced when project managers integrate meteorological data into daily planning. Although both projects maintained documented safety measures, the HAZOP sessions revealed inconsistencies in implementation. This mirrors the compliance gap observed in studies by Hinze et al. (2013), where safety procedures were documented but not embedded in daily practice. For example, daily equipment inspection logs were completed, but in some cases without actual inspection being performeda form of “paper compliance.” Addressing this requires not only audits but also unannounced inspections and digital verification systems that require photographic evidence.

The HAZOP method, when adapted to the construction environment, proves to be a powerful tool for uncovering, understanding, and prioritizing work accident risks in civil engineering projects. The high proportion of human-factor-related hazards underscores the need for behavioral interventions alongside engineering controls. This study’s results support the integration of HAZOP into routine safety planning, particularly for high-risk activities like working at heights and heavy equipment operation. By doing so, civil engineering projects can move closer to the goal of zero accidents—not by luck, but through systematic anticipation and prevention of hazards.

4. CONCLUSION

This study applied the Hazard and Operability Study (HAZOP) method to systematically identify, evaluate, and prioritize work accident risks in civil engineering projects. Through its structured, guideword-driven approach, the analysis covered multiple construction activities—including working at heights, heavy equipment operation, material handling, electrical works, concreting, excavation, and general site conditions—across two ongoing projects. A total of 74 hazards were identified, with nearly one-third classified as high risk. The highest concentration of high-risk hazards was found in working-at-heights activities, followed by heavy equipment operation and excavation works. Many hazards stemmed from human factors such as inadequate use of personal protective equipment (PPE), insufficient training, and poor communication, while others were linked to technical deficiencies and environmental conditions. The HAZOP method proved effective in revealing hazards that conventional safety inspections might overlook, particularly by linking deviations to their causes and consequences. Its team-based nature facilitated cross-disciplinary collaboration, enabling a richer understanding of safety issues and generating targeted, practical recommendations. Findings from this study underscore the importance of proactive hazard identification in construction safety management. The results suggest that integrating HAZOP into project planning and execution can enhance the effectiveness of safety programs, especially when combined with strict PPE enforcement, improved training, formalized communication protocols, preventive maintenance, and adaptive measures for environmental risks. Ultimately, reducing work accident risks in civil engineering projects requires both technical and cultural change. By adopting systematic tools like HAZOP and fostering a strong safety culture, project stakeholders can better anticipate hazards, allocate resources effectively, and move toward the shared goal of zero workplace accidents.

REFERENCES

Abdul-Rashid, I., Bassioni, H., & Basha, I. (2012). Factors affecting safety performance in large construction contractors in Egypt. International Journal of Safety and Security Engineering, 2(4), 365–378. Aven, T. (2016). Risk assessment and risk management: Foundations and applications. Wiley.

BSI. (2018). ISO 45001: Occupational health and safety management systems – Requirements with guidance for use. British Standards Institution.

Carder, B., & Ragan, P. W. (2003). A survey-based system for safety measurement and improvement. Journal of Safety Research, 34(2), 157–165.

Carter, G., & Smith, S. D. (2006). Safety hazard identification on construction projects. Journal of Construction Engineering and Management, 132(2), 197–205. Choudhry, R. M., Fang, D., & Ahmed, S. M. (2008). Safety management in construction: Best practices in Hong Kong. Journal of Professional Issues in Engineering Education and Practice, 134(1), 20–32. https://doi.org/10.1061/(ASCE)1052-3928(2008)134:1(20)

Cooper, D. F. (2011). Project risk management guidelines: Managing risk in large projects and complex procurements. Wiley-Blackwell.

Crawley, F., & Tyler, B. (2015). Hazard and operability studies (HAZOP): Guide to best practice. IChemE.

Darabseh, T., & Mohamed, S. (2012). The application of risk assessment in the construction industry. World Academy of Science, Engineering and Technology, 6(8), 753–759.

Dosh, M. Y., & Hamid, A. R. A. (2019). Risk assessment of construction activities using HAZOP approach. IOP Conference Series: Earth and Environmental Science, 220, 012018.

Fang, D., Chen, Y., & Wong, L. (2006). Safety climate in construction industry: A case study in Hong Kong. Journal of Construction Engineering and Management, 132(6), 573–584. https://doi.org/10.1061/(ASCE)0733-9364(2006)132:6(573)

Fayek, A. R., & Oduba, A. (2005). Predicting industrial construction labor productivity using fuzzy expert systems. Journal of Construction Engineering and Management, 131(8), 938–941.

Gibb, A., Haslam, R., Hide, S., & Gyi, D. (2006). What causes accidents? Proceedings of the Institution of Civil Engineers - Civil Engineering, 159(6), 46–50.

Hallowell, M. R., & Gambatese, J. A. (2009). Activity-based safety risk quantification for concrete formwork construction. Journal of Construction Engineering and Management, 135(10), 990–998.

Hinze, J. (2011). Construction safety. Prentice Hall.

HSE. (2013). Successful health and safety management (HSG65). Health and Safety Executive.

Ibrahim, A., & Hashim, A. (2018). Risk analysis of construction projects using hazard identification methods. Journal of Engineering and Applied Sciences, 13(5), 1208–1215.

Kletz, T. (2006). Hazop and Hazan: Identifying and assessing process industry hazards (4th ed.). CRC Press.

Lingard, H., & Rowlinson, S. (2005). Occupational health and safety in construction project management. Spon Press.

Love, P. E. D., Teo, P., Morrison, J., & Grove, M. (2016). Quality and safety in construction: Creating a no-blame culture. Engineering, Construction and Architectural Management, 23(6), 695–713.

Mulyati, S., & Suryani, R. (2020). Analisis risiko kecelakaan kerja pada proyek konstruksi gedung bertingkat. Jurnal Teknik Sipil dan Perencanaan, 22(1), 55–62.

OSHA. (2015). Construction industry regulations (29 CFR 1926). Occupational Safety and Health Administration.

Peraturan Menteri Ketenagakerjaan Republik Indonesia Nomor 5 Tahun 2018 tentang Keselamatan dan Kesehatan Kerja Lingkungan Kerja.

PMI. (2017). A guide to the project management body of knowledge (PMBOK® Guide) (6th ed.). Project Management Institute.

Ramli, S. (2010). Sistem manajemen keselamatan dan kesehatan kerja OHSAS 18001. Dian Rakyat.

Rausand, M. (2011). Risk assessment: Theory, methods, and applications. Wiley.

Reddy, K. V. K., & Kumar, S. R. (2015). Risk management in construction industry. International Journal of Innovative Research in Science, Engineering and Technology, 4(10), 10218–10224.

Ridley, J., & Channing, J. (2008). Safety at work (7th ed.). Routledge.

Suraji, A., Duff, A. R., & Peckitt, S. J. (2001). Development of causal model of construction accident causation. Journal of Construction Engineering and Management, 127(4), 337–344.
Wilson, P. F., Dell, L. D., & Anderson, G. F. (1993). Root cause analysis: A tool for total quality management. ASQ Quality Press.