JURNAL LOCUS: Penelitian & Pengabdian
Volume 5 No. 5 May 2026
E-ISSN 2829-7334| P-ISSN 2829-5439
Homepage: https://locus.rivierapublishing.id/index.php/jl

Analysis of Occupational Safety and Health (OSH) Risk Management in West Nusa Tenggara Province Using the HIRARC (Hazard Identification, Risk Assessment and Risk Control) and FMEA (Failure Mode and Effects Analysis) Methods

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Keywords
hirarc, fmea, construction safety, risk assessment

ABSTRACT
Due to the intensive use of labor, heavy equipment, and construction materials, construction projects pose high occupational safety and health (OSH) risks, raising the potential for workplace accidents and occupational diseases; therefore, this study aims to identify potential hazards and determine risk levels based on likelihood and severity using the HIRARC (Hazard Identification, Risk Assessment, and Risk Control) and FMEA (Failure Mode and Effects Analysis) methods. Data were collected through field observations, questionnaires, and interviews on two construction projects in Mataram. Risk assessment was conducted using a 5×5 risk matrix by evaluating Likelihood (L) and Severity (S), while FMEA was applied to prioritize risks using the Risk Priority Number (RPN). The results indicate that out of 50 work activities analyzed, 28 activities (56%) were categorized as medium risk, 13 activities (26%) as high risk, 7 activities (14%) as extreme risk, and 2 activities (4%) as low risk. High and extreme risks were predominantly associated with structural work, heavy equipment operations, and work at heights, which have inherently higher hazard exposure. These findings demonstrate that construction projects have significant OSH risk levels that require systematic and continuous risk management. The application of HIRARC and FMEA methods provides a structured and comprehensive approach for hazard identification, risk evaluation, and prioritization. Furthermore, applying risk controls based on the hierarchy elimination, substitution, engineering, administration, and PPE is essential to reduce risks to acceptable levels. Continuous improvement through better supervision, regular training, and consistent PPE use is necessary for a safer, healthier, and more productive workplace.

INTRODUCTION

Construction projects, both large and small-scale, inherently carry a high risk of work accidents due to the intensive use of labor, heavy equipment, and materials (Chan et al., 2022; Hwang et al., 2023; Kim et al., 2022; Topal & Atasoylu, 2022). Therefore, preventive measures are needed to anticipate potential accidents and occupational diseases. According to data from the International Labour Organization (ILO), the construction sector accounts for around 30% of the total fatal work accidents in the world, with a significantly higher fatality rate than other sectors (ILO, 2021). In Indonesia, work accidents in the construction sector also show an alarming trend, with many reports of cases of falling from heights, being hit by materials, and accidents involving heavy equipment (BPJS Ketenagakerjaan, 2023).

Several previous studies have examined Occupational Safety and Health (K3) risk management in various construction projects. Abryandoko (2018) used the HIRARC and

Safety Policy methods to assess K3 risks in construction projects and found that a systematic approach is able to identify potential hazards more comprehensively. Hakim et al. (2024) applied the HIRARC method in analyzing the potential for work accidents at PT. Arkelindo Bara Sejahtera and concluded that this method is effective for determining risk control priorities. Pakartiningsih et al. (2025) combined FMEA and FTA methods in mitigating construction safety risks in the Situ Rempoa project, which showed that an FMEA-based preventive approach is able to identify potential failure modes before an accident occurs. Rahman & Fahma (2021) used the FMECA method in the identification of critical points in the packaging industry, which is relevant to the FMEA principle for risk prioritization based on RPN. Rifani et al. (2022) applied construction K3 with the HIRARC method to driveway access works, which showed that this method can be adapted to different types of construction work with different risk characteristics.

However, there are still some research gaps that need to be filled (Baako et al., 2022; Bans-Akutey, 2021; Chavarro et al., 2017; McIntyre, 2005). First, most of the previous research has focused on construction projects in Java, while studies on K3 risk management on construction projects in the Eastern Region of Indonesia, especially West Nusa Tenggara Province, are still very limited. Second, there are still few studies that integrate the HIRARC and FMEA methods simultaneously within a single analytical framework to obtain more comprehensive results, where HIRARC excels in the identification and assessment of risks based on likelihood and severity, while FMEA offers an advantage in risk prioritization through RPN. Third, there have not been many studies that have presented empirical data on the distribution of risk levels in multi-storey building construction projects in the Mataram area, so a study is needed that can be the basis for policy makers in formulating targeted risk control strategies.

In both large-scale and small-scale construction work, projects inherently carry a high risk of occupational accidents due to the extensive use of labor, heavy equipment, and materials (Sousa et al., 2014; Alomari et al., 2024). Therefore, preventive measures are required to anticipate potential accidents and work-related illnesses (Abubakar et al., 2025; Mastrantonio et al., 2024). In response to this issue, research is needed to identify and analyze occupational safety and health (OSH) risks in construction work (Raziq & Ahmed, 2025). This analysis was conducted using a survey method through questionnaires and interviews, and the data were processed in the form of frequency distribution tables (Mastrantonio et al., 2024).

This research aims to identify potential hazards that can threaten occupational safety and health in building construction projects in Mataram, as well as determine the risk level of each hazard identified based on the level of likelihood of occurrence and severity of impact using the HIRARC and FMEA methods. This research is expected to provide theoretical benefits in the form of enriching the literature on K3 risk management in the construction sector, especially by integrating two complementary risk analysis methods, as well as becoming a reference for future researchers in developing risk management models that are more adaptive to project characteristics in the Eastern Indonesia region. Practically, the results of this study can be a reference for contractors and supervisory consultants in developing more effective occupational safety procedures, assisting project management in determining risk control priorities based on the level of hazards identified, and providing recommendations for project owners in supervising the implementation of K3 in the field in a more structured and sustainable manner.

RESEARCH METHOD

HIRARC (Hazard Identification, Risk Assessment, and Risk Control) was a systematic method used to identify hazards, assess risk levels, and determine control measures to ensure Occupational Safety and Health. This method is commonly applied in construction projects, manufacturing industries, mining, and other sectors with potential workplace hazards.

Hazard Identification

Hazard Identification is a systematic process of recognizing and documenting all potential hazards that may cause workplace accidents, occupational diseases, property damage, or disruption of work processes. This process considers four main aspects:

- **Work Activities**: All stages of work, from preparation to execution and completion.
- **Equipment and Machinery**: Physical condition, usage methods, and maintenance of tools and machines.
- **Materials**: Physical, chemical, and toxicological properties of materials that may endanger workers.
- **Work Environment**: Physical conditions, layout, temperature, humidity, noise, lighting, and other environmental factors.

The results of hazard identification form the basis for risk assessment and risk control strategies to ensure effective OSH implementation.

Risk Assessment

Risk Assessment is the process of evaluating the level of risk from previously identified hazards. Its purpose is to determine severity, likelihood, and exposure level so that risks can be prioritized.

Main steps include:

- Determining **Severity**: Measuring the potential impact on safety, health, and material losses.
- Assessing **Likelihood**: Estimating the probability of occurrence based on past experience, accident data, and existing conditions.
- Assessing **Exposure**: Evaluating how frequently workers are exposed to hazards.
  Risk levels are categorized as low, medium, high, or extreme.

Table 1. Risk Level Categories

Risk Value	Category	Action
1–5	Low	Acceptable risk, routine control
6–10	Medium	Additional control required
11–15	High	Immediate control required
16–25	Extreme	Work must be stopped until safe

Source: (Nagara, 2020)

Table 2. Risk Matrix K3

Severity\ Likelihood	1 (Very Rare)	2 (Rare)	3 (Occasional)	4 (Frequent)	5 (Very Frequent)
1 Very Minor	1 (Low)	2 (Low)	3 (Low)	4 (Low)	5 (Medium)
2 Minor	2 (Low)	4 (Low)	6 (Medium)	8 (Medium)	10 (High)
3 Moderate	3 (Low)	6 (Medium)	9 (Medium)	12 (High)	15 (High)
4 Major	4 (Low)	8 (Medium)	12 (High)	16 (High)	20 (Extreme)
5 Fatal	5 (Medium)	10 (High)	15 (High)	20 (Extreme)	25 (Extreme)

Source: (Nagara, 2020)

Risk Control.

Risk Control is the process of determining and implementing measures to eliminate or minimize risks that have been assessed in the Risk Assessment stage. The primary objective of risk control is to prevent workplace accidents, occupational diseases, and material losses through the application of effective control strategies. Risk control measures generally follow the hierarchy of control as outlined below:

a. **Elimination** (completely removing the source of the hazard).
b. **Substitution** (replacing materials, equipment, or work processes with safer alternatives).
c. **Engineering Controls** (designing or modifying equipment, systems, or the work environment to reduce exposure to hazards).
d. **Administrative Controls** (establishing work procedures, schedules, training, and supervision to reduce risk).
e. **Personal Protective Equipment (PPE)** (providing and mandating the use of appropriate PPE as the last line of defence when risks cannot be fully eliminated).

FMEA (Failure Mode and Effects Analysis)

FMEA (Failure Mode and Effects Analysis) is a systematic method used to identify potential failure modes in products, processes, or systems, analyze the causes and effects of those failures, and determine improvement priorities based on risk levels.

Identifying Potential Failures (Failure Modes)

Identifying potential failure modes is the initial stage in the FMEA method. It aims to determine all possible ways in which a system, component, process, or product may fail before the failure actually occurs.

Analysis Process

Analysis is the process of breaking down data, problems, or conditions into smaller components so they can be more easily understood, compared, and concluded. In FMEA, this involves evaluating each identified failure mode to understand its effects, causes, and level of risk.

a. **Risk Assessment Using Three FMEA Parameters**

- **Severity (S):** The impact of the failure
- **Occurrence (O):** The frequency of occurrence
- **Detection (D):** The likelihood that the failure will be detected before it occurs

b. **Calculating the Risk Priority Number (RPN)**

$$RPN = S \times O \times D$$

Where:

- **S (Severity):** Level of impact caused by the failure (1 = insignificant, 10 = very severe)
- **O (Occurrence):** Likelihood of the failure occurring (1 = very rare, 10 = very frequent)
- **D (Detection):** Likelihood that the failure is not detected before it occurs (1 = very easily detected, 10 = very difficult to detect)

c. Risk Prioritization

Risks are prioritized based on the highest RPN values.

RESULT AND DISCUSSION

The object of this study consists of two building construction projects, namely the Mataram Mayor's Office Building Project and the Administrative High Court (PTTUN) Building Project in Mataram. These two projects were selected because they share similar characteristics, including multi-story building construction, structural work complexity, the use of heavy equipment, and significant Occupational Safety and Health (OSH) risks.

The Mataram Mayor's Office Building Project is a regional government office development funded through the Regional Revenue and Expenditure Budget (APBD), with a contract value of IDR 56,861,830,000 (fifty-six billion eight hundred sixty-one million eight hundred thirty thousand rupiah). The project is located in Mataram City and has an implementation period of 239 calendar days. The parties involved include the Public Works and Spatial Planning Office (PU PR) of Mataram City as the project owner, PT Momen Estentika Konsultan as the design consultant, PT Arestas Wkaksana Konsultan as the supervision/construction management consultant, and PT Damai Indah Utama as the contractor. Project photo documentation was used to represent field conditions during the study.

Based on field observations and the identification of work activities in the construction project, a hazard identification process was carried out to determine sources of potential risks that may lead to workplace accidents. This identification aims to recognize all unsafe conditions originating from equipment, materials, work methods, and the work environment. Each work activity was analyzed to determine the main hazard sources and the types of hazards generated, including mechanical, physical, chemical, electrical, and ergonomic hazards.

Table 3. Likelihood (L) Scale Based on Number of Accidents

Number of Accidents	Likelihood (L)
0	1 (Very Rare)
1	2 (Rare)
2	3 (Occasional)
3	4 (Frequent)
≥ 4	5 (Very Frequent)

Table 4. Severity (S) Scale Based on General Construction Impact Level

Hazard Type	Severity (S)
Mechanical	4
Physical	4
Chemical	3
Electrical	5
Ergonomic	3

The risk value is calculated using the following formula:$R = L \times S$

Where:

- **R** = Risk Value
- **L** = Likelihood
- **S** = Severity

Table 5. Risk Category

Risk Value (R)	Category
1 – 4	Low
5 – 9	Medium
10 – 16	High
17 – 25	Extreme

Risk Assessment

Risk assessment is a stage used to determine the level of risk for each hazard identified in work activities. This process is carried out by evaluating two main components, namely Likelihood (L) and Severity (S). Likelihood (L) describes the probability of a hazard occurring under certain working conditions, while Severity (S) indicates the level of impact or consequences that may arise if the event actually occurs.

Table 6. Parameters for Risk Value Calculation

Component	Description
Likelihood (L)	How often the hazard may occur
Severity (S)	How severe the impact is
Risk Value (R)	The result of L × S

Source: ISO 45001:2018 Standard

The risk value is calculated using the following formula:

$$R = L \times S$$

Where:

- **R** = Risk Value
- **L** = Likelihood (Probability of Occurrence)
- **S** = Severity (Level of Impact)

Table 7. Risk Assessment

No	Likelihood (L)	Likelihood Description	Severity (S)	Impact Description	Risk Value (R = L × S)	Risk Category
1	1	Very Rare	1	Very Minor	1–4	Low
2	2	Rare	2	Minor	5–9	Medium
3	3	Occasional	3	Moderate	10–14	High
4	5	Very Frequent	5	Fatal	15–25	Extreme

Source: ISO 45001:2018

The recapitulation of risk levels was conducted to obtain an overview of the distribution of assessment results across 50 work activities using a 5×5 risk matrix. This recapitulation aims to quantitatively identify the proportion of each risk category, which can serve as a basis for determining risk control priorities in construction projects.

Table 8. Risk Level Recapitulation

No	Risk Category	Number of Activities	Percentage (%)
1	Low	2	4%
2	Medium	28	56%
3	High	13	26%
4	Extreme	7	14%
Total			50

Source: Project Data, 2026

Based on Table 8, most activities fall into the medium category (56%), while the remaining 40% are categorized as high and extreme, requiring further priority control. These findings indicate that construction projects have a significant level of risk exposure, thus requiring systematic implementation of risk control in accordance with OSH risk management principles.

Table 9. Construction Project OSH Risk Matrix

L/S	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Source: ISO 45001:2018

Table 10. Ringkasan Zona Resiko

Risk Zone		Total	Percentage	Interpretation
	Low	2	4%	Acceptable risk
	Medium	28	56%	Requires routine control
	High	13	26%	Priority control required
	Extreme	7	14%	Immediate control required

Based on the risk matrix analysis, the majority of work activities fall into the medium category (56%), indicating that most risks can still be controlled through supervision and consistent implementation of procedures. However, 26% of activities fall into the high category and 14% into the extreme category, indicating significant probability and/or impact that require immediate priority control.

High and extreme risks are generally associated with structural work, heavy equipment operations, and work at heights, which inherently carry greater hazards. Therefore, systematic and layered risk control measures are required in accordance with the Hierarchy of Risk Control principles to reduce risk levels to an acceptable threshold.

Risk Control

In construction projects, risk control must be carried out proactively, systematically, and in a layered manner, rather than merely reactively. One of the primary approaches used is the Hierarchy of Control, which is designed to reduce risk levels to an acceptable level.

The following table presents systematic risk control efforts across 50 construction work activities based on the Hierarchy of Control principles. Risk control is implemented through five layers: elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). Each activity is evaluated based on Likelihood (L), Severity (S), and Risk (R) to determine the risk category.

This table aims to provide a comprehensive overview of hazard mitigation efforts and the priority of control measures that need to be implemented in the field.

CONCLUSION

Based on the results of the research on Occupational Safety and Health (OSH) risk management analysis in construction work activities using the HIRARC and FMEA methods, the following conclusions can be drawn: The construction projects studied have various potential hazards that may threaten occupational safety and health. These hazards originate from work activities, construction equipment and materials, and dynamic environmental conditions. Therefore, systematic and continuous hazard identification is essential to minimize workplace accidents and occupational diseases. The analysis shows that each hazard has varying levels of risk, ranging from low to high. These levels are determined based on the combination of likelihood and severity. High-risk hazards must be prioritized as they have significant potential impacts on worker safety, project continuity, and potential losses. The implementation of HIRARC and FMEA methods has proven to provide a systematic, structured, and comprehensive approach to identifying, analyzing, and evaluating OSH risks. Although risk levels have decreased after control implementation, some aspects still require improvement for optimal effectiveness. Several recommendations were identified to improve the OSH risk management system, including enhancing supervision of OSH procedures, improving standard operating procedures, providing regular training and awareness programs, and optimizing the use of PPE. Consistent implementation of these measures is expected to significantly reduce risks and create a safer, healthier, and more productive work environment.

REFERENCE

Abryandoko, W. (2018). Penilaian risiko keselamatan dan kesehatan kerja dengan menggunakan metode HIRARC dan safety policy. *Rekayasa Sipil, 12*(1).

Abubakar, A. S., Folorunso, C. O., & Windapo, A. O. (2025). Global research activities, trend and future research of OSH technologies in the construction industry. *Safety Science, 183*, 106760. https://doi.org/10.1016/j.ssci.2025.106760

Alomari, K. A., Tayeh, B. A., & Alaloul, W. S. (2024). Managing occupational health and safety risks in construction projects to achieve social sustainability – A review of literature. *Procedia Computer Science, 243*, 1–10. https://doi.org/10.1016/j.procs.2024.09.157

Baako, I., Alhassan, H., & Gidisu, P. (2022). Understanding and spotting research gaps through a systematic literature review. *International Journal of Research and Innovation in Social Science, 6*(3), 549–554.

Bans-Akutey, A. (2021). Identifying research gaps in scholarly work – A review. *Academia Letters.*

Chan, A. P. C., Yang, Y., Choi, T. N. Y., & Nwaogu, J. M. (2022). Characteristics and causes of construction accidents in a large-scale development project. *Sustainability, 14*(8), 4449.

Chavarro, D., Tang, P., & Ràfols, I. (2017). Why researchers publish in non-mainstream journals: Training, knowledge bridging, and gap filling. *Research Policy, 46*(9), 1666–1680.

Hakim, P. T., Ningrat, K. N., & Aristriyana, E. (2024). Penerapan metode Hazard Identification Risk Assessment and Risk Control (HIRARC) dalam menganalisis potensi kecelakaan kerja pada PT. Arkelindo Bara Sejahtera. *Jurnal Mahasiswa Teknik Industri, 1*(2).

Hwang, J.-M., Won, J.-H., Jeong, H.-J., & Shin, S.-H. (2023). Identifying critical factors and trends leading to fatal accidents in small-scale construction sites in Korea. *Buildings, 13*(10), 2472.

Kim, Y.-S., Lee, J. Y., Yoon, Y.-G., & Oh, T.-K. (2022). Effectiveness analysis for smart construction safety technology (SCST) by test bed operation on small-and medium-sized construction sites. *International Journal of Environmental Research and Public Health, 19*(9), 5203.

Mastrantonio, R., Cofini, V., Mastrangeli, G., Pettinaro, M., Mastrodomenico, M., & Fabiani, L. (2024). Occupational risk perception of construction workers: A cross sectional study. *Frontiers in Public Health, 12*, 1338604. https://doi.org/10.3389/fpubh.2024.1338604

McIntyre, D. (2005). Bridging the gap between research and practice. *Cambridge Journal of Education, 35*(3), 357–382.

Nagara, Y. (2020). *Analisis pengendalian bahaya kerja pada produksi kelom geulis Sheny dengan menggunakan metode HIRADC.* Universitas Brawijaya.

Pakartiningsih, A. S., Dwi Dinariana, D. D., & Fitri Suryani, F. S. (2025). Applying FMEA and FTA in construction safety risk mitigation: A preventive approach of the Situ Rempoa Project. *Journal of Architecture and Civil Engineering, 10*(7), 140–151. https://doi.org/10.35629/8193-1007140151

Rahman, A., & Fahma, F. (2021). Penggunaan metode FMECA (Failure Modes Effects Criticality Analysis) dalam identifikasi titik kritis di industri kemasan. *Jurnal Teknologi Industri Pertanian, 31*, 110–119. https://doi.org/10.24961/j.tek.ind.pert.2021.31.1.110

Raziq, M. M., & Ahmed, Z. (2025). Occupational safety and health risk assessment during maintenance stage of construction projects: A multi-pronged fuzzy-based approach. *Expert Systems with Applications, 275*, 126879. https://doi.org/10.1016/j.eswa.2025.126879

Rifani, Y., Mulyani, E., & Pratiwi, R. (2022). Penerapan K3 konstruksi dengan menggunakan metode HIRARC pada pekerjaan akses jalan masuk (Studi kasus: Jl. Prof. Dr. H. Hadari Nawawi). *Jurnal Teknik Kelautan dan Tambang, 5*.

Sousa, V., Almeida, N. M., & Dias, L. A. (2014). Risk-based management of occupational safety and health in the construction industry – Part 1: Background knowledge. *Safety Science, 66*, 75–86. https://doi.org/10.1016/j.ssci.2014.02.008

Topal, S., & Atasoylu, E. (2022). A fuzzy risk assessment model for small scale construction work. *Sustainability, 14*(8), 4442.