Risk Analysis of Workers' Accidents at a Road Construction Project in Manado City

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Abstract: Road construction projects involve various occupational hazards that may compromise occupational safety. This study aims to identify potential hazards, assess occupational accident risks, and develop appropriate risk control strategies in road construction projects in Manado City. A descriptive evaluative method with a quantitative retrospective approach was employed. Data were collected from 37 respondents through questionnaires, supported by project documents and Job Safety Analysis (JSA). Risk assessment was conducted using Failure Mode and Effect Analysis (FMEA) based on severity, occurrence, and detection criteria, with risk priorities determined through the Risk Priority Number (RPN). The results indicate that excavation activities, asphalting, heavy equipment operations, and workplace conditions represent the highest risk activities. Landslide hazards during excavation were identified as the highest priority risk, with an RPN value of 25.15. Risk control measures include elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE). Effective implementation of these controls is expected to reduce accident risks and enhance occupational safety performance in road construction projects.

Keywords: *Analysis, Risk, Accident, Workers, Construction, Road.*

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I. INTRODUCTION

The construction industry in Indonesia has been growing rapidly in line with the government's increasing focus on infrastructure development. This sector has been identified as one of the sectors with high Occupational Safety and Health (OSH) risks.[1] During January–December 2024, the government reported 462,241 occupational accidents in Indonesia.[2] It shows how important OSH measures are, especially in the road construction sector, which is known for having high risks due to heavy equipment use, excavation work, material handling, and interactions with active traffic.

OSH is an effort to protect workers from the risk of accidents and work-related illnesses. The implementation of OSH in the construction sector is realized through the Construction Safety Management System (CSMS), which emphasizes the importance of hazard identification, risk assessment, and risk control. The effective implementation of the CSMS is expected to create a safe work place and improve project execution productivity.[3]

Occupational accidents on construction projects are generally caused by two main factors: unsafe acts and unsafe conditions. [4] Unsafe acts refer to unsafe actions caused by workers that have potential to cause accidents, while unsafe conditions refer to unsafe workplaces that have potential to cause accidents. Both factors must be systematically identified to ensure appropriate control measures are implemented.[5,6]

Job Safety Analysis (JSA) is one method used to identify potential hazards. JSA breaks down each work step, identifies potential hazards that may arise, and determines the necessary control measures.[7] After hazard identification is completed, the risk level is analyzed with the Failure Mode and Effect Analysis (FMEA) method. FMEA is used to prioritize risks based on severity, likelihood of occurrence, and detectability, which results in a Risk Priority Number (RPN).[8]

Many studies on the analysis of occupational accident risks in the construction sector have been performed with various approaches, particularly using the Job Safety Analysis (JSA), Hazard Identification, Risk Assessment, and Risk Control (HIRARC), Hazard Identification, Risk Assessment, and Determining Control (HIRADC), and Failure Mode and Effect Analysis (FMEA) methods. A summary from previous studies related to this research is presented in Table 1.

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Table 1. Previous Research

No	Researchers & Year	Research Title	Research Method	Research Relevance	Research GAP
1	Suryadana & Komaladewi (2024)	Analysis of Occupational Accident Risks with JSA on PT. Tunas Jaya Construction Projects.	Descriptive quantitative with JSA.	Both use JSA on construction projects.	Focuses on building projects, not road projects or CSMS.
2	Nababan, dkk (2023)	Risk Analysis Using JSA and HIRARC Approaches in the Phase II Construction of the Christian Center in Manado.	Descriptive quantitative with JSA and HIRARC.	Both analyze construction risks using JSA.	Focuses on buildings, not on road projects and FMEA.
3	Mardakngo (2021)	Job Safety Analysis (JSA), Part of the Construction Safety Plan (CSP) and Construction Safety Manajemen System (CSMS) in a Construction Contractor Selection Tender.	Qualitative descriptive through observation and interviews.	Both discuss OSH, JSA, and CSMS.	Hasn't measured accident risks quantitatively
4	Kumala & Dana (2023)	Hazard Analysis Using JSA Method in Stringing work by a PLN Subcontractor for the 150 kV Tanjung-Jati SUTT Reconductor Project.	Qualitative descriptive with JSA.	Both use JSA for risk analysis.	The research subject is not a road project.
5	Khoiri dkk. (2023)	Occupational Health and Safety (K3) Risk Analysis Using HIRADC and JSA Methods in Bridge Replacement Projects	Descriptive quantitative.	Both discuss the risks of occupational accidents in construction.	Hasn't examined unsafe acts and unsafe conditions in road projects.
6	Billah dkk. (2023)	Efforts to Control Work Accident Risks in Steel Construction Work Using the Job Safety Analysis (JSA) Method. (Case Study at Pt. Xyz)	Descriptive quantitative with JSA.	Both use JSA on construction projects.	Focuses on steel construction, not road projects
7	Aulia & Rahayu (2025)	Analysis of OSH Using HIRADC and JSA Methods (Case Study: Development of Mall 23 Paskal Extension)	Descriptive quantitative.	Both examined occupational safety and construction risks.	Didn't use unsafe acts and unsafe conditions as the basis for risk prioritization.
8	Diansyah (2024)	Application of Risk Management Using FMEA Method in the H.M. Ardan Road Drainage Channel Construction Project in East Kutai.	Descriptive quantitative with FMEA.	Both used FMEA in road projects.	Hasn't examined unsafe acts and unsafe conditions related to occupational accidents.
9	Rozi & Sari (2025)	Analysis of Occupational Accident Factors in the Pipe and Meter Service Process Using Fault Tree Analysis (FTA) and Failure Mode and Effect Analysis (FMEA) Methods.	Descriptive quantitative with FTA and FMEA.	Both use FMEA for occupational accident risk analysis.	Hasn't specifically examined unsafe acts and unsafe conditions.

Based on the results of previous studies, JSA methods have been widely used to identify potential hazards in various types of construction projects. Additionally, FMEA has been used to determine risk priorities based on Severity, Occurrence, Detection, and Risk Priority Number (RPN) values. However, most studies still focus on building, bridge, drainage, steel construction, and electrical transmission projects. Research examining occupational accident risks in road construction projects by integrating unsafe acts and unsafe conditions identification with risk assessment using the FMEA method remains relatively limited.

Considering these issues, this study aims to identify potential hazards in the primary activities of road construction work in Manado City, analyze the level of occupational accident risk caused by unsafe acts and unsafe conditions using JSA method and a modified FMEA, and to develop risk control strategies in alignment with the hierarchy of OSH controls and applicable regulations to minimize the risk of occupational accidents in road construction project.

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II. RESEARCH METHODS

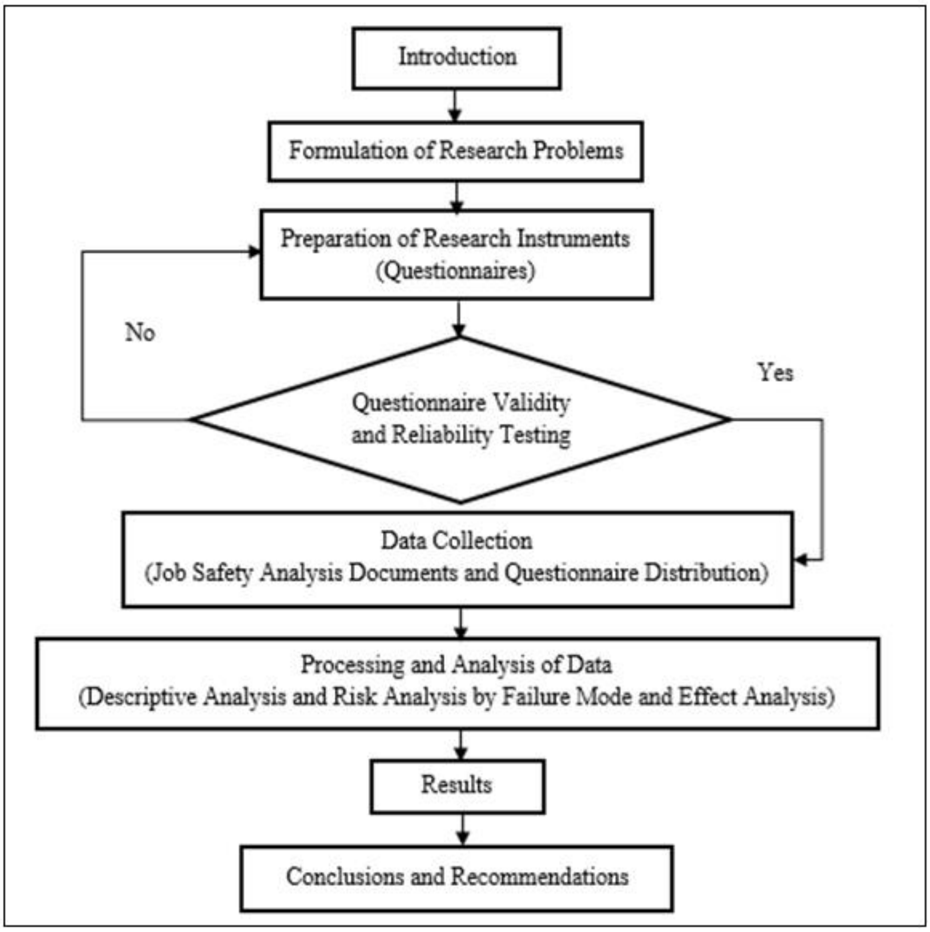

Fig 1. Flowchart

This study used a descriptive evaluative design with a quantitative retrospective approach. The study was based on a road construction project in Manado City that was completed during the 2023–2025 period. The study was designed to identify potential occupational hazards, assess the level of risk for occupational accidents, and develop risk control recommendations for road construction projects in the city of Manado.

Research data consists of primary and secondary data. Primary data was obtained through the distribution of questionnaires to respondents who were directly involved in the implementation of the road construction project. Secondary data was obtained from project documents, JSA documents, and other supporting documents related to occupational safety.

In this study, population refers to all workers participating in road construction projects in Manado City during 2023–2025 period. This study used non-probability sampling with a purposive sampling method, which selects respondents based on specific criteria and objectives aligned with the research needs. Respondents in this study were selected based on their direct participation in road construction project activities and their understanding of occupational risks in these projects. There were 37 respondents in this study.

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The questionnaire was tested for validity and reliability before being used in data collection to ensure that the instrument could measure the research variables accurately and consistently. The validity test, using Pearson's Product-Moment correlation at a 5% significance level, showed that all items had a calculated r value higher than the r table value (0.334), thus proving them valid. The reliability test, using Cronbach's Alpha, showed a value of 0.614, thus proving the instrument reliable. Therefore, all questionnaire items are acceptable for use in the study.

Data analysis was performed in three main steps: hazard identification, analysis of accident-causing factors, and risk assessment. Hazard identification was conducted using a JSA that had been compiled to identify potential hazards at each stage of road construction projects. Next, causes of accidents were analyzed based on unsafe acts and unsafe conditions identified through questionnaire results. The data was analyzed descriptively using the mean value to identify the most dominant factors.

Risk assessment was performed using FMEA based on the parameters Severity (S), Occurrence (O), and Detection (D). The mean value of each parameter was used to calculate the Risk Priority Number (RPN) using Equation (1).

$$RPN = S \times O \times D \quad (1)$$

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The RPN value is used to determine risk priorities, where risks with the highest RPN value become the top priority for control. Furthermore, risk control strategies are compiled based on the risk control hierarchy, which includes elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE).

III. RESULTS

A. *Characteristic of Respondents*

Characteristics of respondents showed that most respondents were in the productive age group, ranging from 41 to 50 years old. All respondents were male. In terms of education level, most respondents held a bachelor's degree (S1). Regarding work experience, most respondents had more than 10 years of work experience, and most of them held construction proficiency certificates. The characteristics showed that the respondents possessed sufficient experience and expertise to provide relevant assessments of the risk of occupational accidents in road construction projects.

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Table 2. Respondent Characteristics

Characteristics	Category	Frequency	Percentage
Age	20-30	3	8%
	31-40	11	30%
	41-50	12	32%
	>50	11	30%
Education Level	SHS/VHS	11	30%
	D3	5	14%
	S1	18	49%
	S2	3	8%
	S3	0	0%
Work Experience	<3 years	0	0%
	3-5 years	0	0%
	5-10 years	4	11%
	>10 years	33	89%
Certifications	Construction Professional Certificate	23	62%
	Bridge Engineering Certificate	1	3%
	Certificate of Competence in Engineering	4	11%
	No Certificate	9	24%

B. *Potential Hazard Identification Based on the JSA Document*

Identification results revealed several major potential hazards that frequently arise in road construction projects, especially in excavation, backfilling, road asphalting, asphalting, and structural work. According to the summary of dominant hazards from the JSA documents analyzed, the most frequently identified hazards are being struck by heavy equipment, landslides during excavations, dust exposure, and traffic disruptions. These risks typically arise during earthwork, compaction, material spreading, and road asphalting operations that require heavy equipment mobility and simultaneous work activities within a single work area.

Additionally, other potential hazards identified include high temperature exposure during asphalt asphalting, being struck by falling materials during structural and drainage work, and electrical shocks resulting from the use of work equipment and utilities on-site. These conditions indicate that road construction work carries a relatively high level of risk, necessitating consistent occupational safety controls throughout the project's implementation. Risk controls identified in the JSA document generally include the use of PPE, installation of temporary traffic signs, provision of work area safety barriers, project traffic management, use of experienced heavy equipment operators, and safety supervision throughout the duration of the work.

C. *Unsafe Acts and Unsafe Conditions Analysis*

Table 3. Results of the Unsafe Acts Analysis

No	Unsafe Acts Variable	Mean	Category
1	Workers don't use PPE as standard	2,92	Quite Often
2	Workers don't follow standard operating procedures	2,76	Quite Often
3	Workers ignore hazard identification from JSA	2,78	Quite Often
4	Workers do their jobs while fatigued or lacking concentration	2,16	Rarely
5	Workers take risky actions to speed up work	3,05	Quite Often

Table 4. Results of the Unsafe Conditions Analysis

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No	Unsafe Conditions Variable	Mean	Category
1	Workplace layout fails to meet occupational safety principles	2,38	Rarely
2	Materials and equipment are placed without considering potential hazards	2,41	Rarely
3	Works equipment is not consistently operational	2,43	Rarely
4	Safety systems at the work area are inadequate	2,81	Quite Often
5	Occupational safety supervision is not consistently enforced	3,16	Quite Often

Unsafe acts analysis is performed to identify unsafe work behaviors that could potentially lead to workplace accidents on road construction projects. Based on the analysis results, most unsafe act variables fall into category "quite often." The highest mean value was found in risky work actions to speed up work (3.05), followed by not use PPE as standard (2.92), ignore hazard identification results from JSA (2.78), and not follow standard operating procedures (2.76). Meanwhile, working while fatigued or lacking concentration had the lowest mean value (2.16) and fell into the "rarely" category. These results show that unsafe work behaviors are still present, particularly regarding compliance with PPE, work procedures, and established risk controls.

Unsafe conditions were analyzed to identify unsafe workplace conditions that could potentially increase the risk of workplace accidents in road construction projects. The results of the analysis showed that unsafe conditions are still present in road construction projects. The highest mean score was found in occupational safety supervision, which was not consistently implemented (3.16), followed by inadequate work area safety systems (2.81); both fell into the category of "quite often." Meanwhile, work area organization, placement of materials and equipment, and the condition of work equipment fell into the "rarely" category with mean values ranging from 2.38 to 2.43. Overall, these results indicate the need to improve safety supervision and work area safety systems to minimize the risk of workplace accidents.

D. Risk Analysis Using FMEA

Risks in this study were analyzed using FMEA approach. It was used to assess the level of occupational accident risk based on the severity of the impact, the likelihood of occurrence, and the ability to detect or control the risk. Risk assessment of potential hazards was based on the results of the JSA and the questionnaire responses from respondent. The assessment results were used to determine the priority level of the occupational accident risks requiring further control.

The assessment results in Table 5 show that the risk of being struck by heavy equipment has the highest severity level (S = 4.57), while high temperature exposure while asphalting has the highest likelihood of occurrence (O = 3.57). The highest detection value was found for the risk of landslides during excavation work (D = 3.08), showing that the risk is relatively more difficult to detect and control before it occurs.

Table 5. Results of Risk Priority Number (RPN) Calculations

Type of Potential Risk	Severity	Occurrence	Detection	RPN	Rank
Struck by heavy equipment	4,57	1,81	1,78	14,75	3
Landslides during excavations	3,43	2,38	3,08	25,15	1
High temperature exposure while asphalting	2,16	3,57	3,05	23,56	2
Accidents caused by general traffic	3,68	1,92	1,70	12,01	5
Slips or trips on the work site	1,46	3,27	2,70	12,90	4

Based on the RPN values, the risk of landslides during excavations is the top priority risk with a value of 25.15, followed by high temperature exposure while asphalting with a value of 23.56. The high values of these two risks are caused by a combination of relatively high occurrence rates and difficulty in detection. The risk of being struck by heavy equipment ranks third (14.75), while slipping or tripping (12.90) and accidents caused by general traffic (12.01) have lower priority. These results show that risk control needs to be focused on excavation and asphalting work because they have the highest risk levels regarding occupational safety.

E. Risk Control Strategies

Risk control strategies are implemented through several control measures, i.e., elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). These control strategies are adapted to the working conditions and potential hazards identified in road construction projects.

Based on the results of the risk analysis using FMEA, risk control strategies were designed with reference to the risk control hierarchy, which includes elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE). Controls for landslide risks while excavations are implemented through the installation of soil retention systems, soil condition inspections, worksite monitoring, and the use of helmets and safety boots. For asphalting, risks of high temperature exposure are managed through work schedule adjustments, providing adequate rest periods and drinking water, and the use of heat-resistant work clothing and gloves.

The risk of being struck by heavy equipment is controlled by regulating the movement routes of heavy equipment, installing work area barriers, improving work communication, and the use of safety vests and helmets. The risk of slipping or tripping can be minimized through the removal of leftover construction materials, proper organization of the work area, and the use of safety shoes. Meanwhile, the risk of accidents caused by general traffic is controlled through the installation of barriers and temporary traffic lanes, the deployment of traffic controllers, the placement of warning signs, and the use of reflective vests by workers. The implementation of these control strategies is expected to reduce the risk of occupational accidents and improve occupational safety in road construction projects.

Table 6. Results of Risk Priority Number (RPN) Calculations

Type of Potential Risk	Severity	Occurrence	Detection	RPN	Rank
Struck by heavy equipment	4,57	1,81	1,78	14,75	3
Landslides during excavations	3,43	2,38	3,08	25,15	1
High temperature exposure while asphalting	2,16	3,57	3,05	23,56	2
Accidents caused by general traffic	3,68	1,92	1,70	12,01	5
Slips or trips on the work site	1,46	3,27	2,70	12,90	4

IV. CONCLUSION

This study shows that potential hazards in road construction projects in Manado City are found in various stages of work, especially excavation, asphalting, heavy equipment operation, and workplace conditions. These potential hazards are caused by unsafe acts and unsafe conditions, where risky acts to speed up work are the most dominant unsafe acts, while inconsistent safety supervision is the most dominant unsafe condition.

Analysis results using JSA and FMEA showed that the risk of landslides during excavations had the highest risk level with a RPN of 25.15, followed by the risk of high temperature exposure during asphalting with a RPN of 23.56. Risk controls are recommended based on the hierarchy of controls through elimination, substitution, engineering controls, administrative controls, and the use of personal protective equipment (PPE) to improve occupational safety and support the implementation of the CSMS in road construction projects.

REFERENCES

[1]. Lestari, F., Sunindijo, RY., Loosemore, M., Kusminanti, Y., & Widanarko, B. (2020). A Safety Climate Framework for Improving Health and Safety in the Indonesian Construction Industry. *International Journal of Environmental Research and Public Health*, *17*(20). https://doi.org/10.3390/ijerph17207462

[2]. Kementerian Ketenagakerjaan Republik Indonesia. (2025). *Kasus Kecelakaan Kerja Tahun 2024*. Satudata Kemnaker. https://satudata.kemnaker.go.id/data/kumpulan-data/2447

[3]. Harefa, MB, Surbakti, AA, & Efendi, I. (2022). Kajian Penerapan K3 Pada Proyek Jalan Nasional Parapat—Ajibata. *Jurnal Multidisiplin Madani*, *2*(8), 3380–3383. https://doi.org/10.55927/mudima.v2i8.970

[4]. [4] Sholihah, Q. (2018). Implementasi Sistem Manajemen K3 Pada Konstruksi Jalan Sebagai Upaya Pencegahan Kecelakaan Kerja. *Buletin Profesi Insinyur*, *1*(1), 25–31. https://doi.org/10.20527/bpi.v1i1.6

[5]. Anddri, & Hutahaean, H. (2026). Identifikasi Tindakan Tidak Aman Pekerja Konstruksi pada Proyek Peningkatan Jalan. *Jurnal Praktik Keinsinyuran*, *3*(2). https://doi.org/10.25170/jpk.v3i02.7626

[6]. International Labour Organization. (2015). *Investigation of Occupational Accidents and Diseases: A Practical Guide For Labour Inspectors*. ILO.

[7]. Mardakngo, T. (2021). Analisis Keselamatan Pekerjaan (Job Safety Analysis), Bagian dari RKK Dan SMKK Dalam Suatu Tender Pemilihan Pelaksana Konstruksi. *Seminar Nasional Insinyur Profesional (SNIP)*, *1*(1). https://doi.org/10.23960/snip.v1i1.137

[8]. Sadewo, K., Oktaria, D., Arifianto, T., & Sunaryo, S. (2025). Penggunaan Metode Failure Mode and Effect Analysis (FMEA) untuk Meningkatkan Efektivitas Perawatan Platform Screen Door pada Stasiun Elevated MRT Jakarta. *Sains Data Jurnal Studi Matematika dan Teknologi*, *4*(1), 1–14. https://doi.org/10.52620/sainsdata.v4i1.285