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Operational Risk Mitigation Strategies for Labor and Construction Equipment Based on ISO 31000:2018 (Case Study of Central Sulawesi Provincial Road Projects)

Muh. Munqiz Muchlis[1]; Andi Asnudin[2]; Adnan Fadjar[3]

[1] Postgraduate Student of Civil Engineering Department, Tadulako University
[2] Civil Engineering Study Program, Faculty of Engineering, Tadulako University
[3] Civil Engineering Study Program, Faculty of Engineering, Tadulako University

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Abstract: Operational risks in road construction projects remain a major challenge affecting project performance, especially in developing regions with complex geographical conditions. This study aims to analyze operational risks related to labor and equipment, as well as formulate mitigation strategies based on ISO 31000:2018 for provincial road construction projects in Central Sulawesi, Indonesia. A mixed-method approach was used by combining qualitative and quantitative techniques. Primary data were collected through questionnaires, field observations, and semi-structured interviews with 40 respondents, including project managers, supervisors, safety officers, heavy equipment operators, and field workers. Secondary data were obtained from project reports, incident records, maintenance logs, and contract documents. Risk analysis was conducted using a risk matrix based on likelihood and consequence criteria from ISO 31000:2018. Research results indicate that labor-related risks—such as workplace accidents, physical fatigue, and non-compliance with personal protective equipment (PPE) use—remain significant operational issues affecting safety performance. Equipment-related risks, including equipment damage, downtime, non-compliance with preventive maintenance, and specification mismatches, also contribute to delays and reduced productivity. Validity and reliability tests confirmed that all research instruments are statistically acceptable, with Cronbach's Alpha values ranging from 0.785 to 0.876. The study further shows that preventive maintenance systems, competency-based safety training, stricter monitoring of PPE usage, and the integration of risk management into daily operational planning are effective mitigation strategies to reduce operational risks. This research contributes to the practical implementation of ISO 31000:2018 in road construction management and provides recommendations to improve work safety, operational efficiency, as well as the overall sustainability of project performance.

Keywords: *ISO 31000:2018, Operational Risk, Construction Equipment, Occupational Safety, Road Project.*

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I. INTRODUCTION

The road construction project in Central Sulawesi Province plays a crucial role as supporting infrastructure for economic growth and the enhancement of interregional connectivity. The construction of quality roads can facilitate the distribution of goods and services, as well as accelerate community mobility. However, the implementation of these projects is often faced with various complex operational challenges (Ridho, 2022).

Operational risks that arise during project implementation can have a significant impact on the performance of labor and construction equipment. Some common problems include work accidents due to lack of occupational health and safety awareness, damage to heavy equipment due to suboptimal use, and project delays caused by both technical and non-technical factors. In addition, discrepancies between technical specifications and on-site execution also often become a serious obstacle (Gusti, et al., 2021).

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To address these various issues, a systematic and structured risk management approach is required. ISO 31000:2018 exists as an international standard that provides a comprehensive framework for managing risk. This standard not only helps in the identification and evaluation of risks but also provides guidance for developing effective mitigation steps (Nurdiani, 2022).

This research focuses on two provincial road reconstruction projects in Central Sulawesi Province, namely the Sp. Buatan–Bilo Road Project in Tolitoli Regency and the Tulo–Simoro Road Project in Sigi Regency. This study aims to (1) identify operational risks related to labor and construction equipment, (2) analyze the level of risk using the ISO 31000:2018 framework, (3) formulate effective operational risk mitigation strategies, and (4) evaluate the effectiveness of the applied mitigation measures.

The findings of this study are expected to contribute to the development of construction risk management practices and improve work safety as well as project performance in road construction projects in Indonesia.

II. LITERATURE REVIEW

➤ *Operational Risks in Construction Projects*

Operational risk refers to the possibility of loss arising from inadequate or failed internal processes, human error, equipment failure, or external events. In construction projects, operational risk is very dynamic due to the involvement of many stakeholders, the operation of heavy equipment, and hazardous work environments (Anita, et al., 2023).

Operational risks related to labor generally include work accidents, fatigue, lack of safety awareness, and non-compliance with the use of personal protective equipment (PPE). Equipment-related risks include the frequency of breakdowns, downtime duration, maintenance failures, and discrepancies between equipment specifications and project requirements (Bramistra, 2024).

➤ *ISO 31000:2018 Framework*

The ISO 31000 framework helps organizations build the foundation and structure to integrate risk management into policies, culture, and work practices. The components of this framework include leadership and commitment, integration into organizational processes, planning, implementation, performance evaluation, and continuous improvement. In construction projects, this framework is important to ensure that every work unit, including field implementers and supervisory teams, consistently applies risk management (Lestari, et al., 2025).

ISO 31000:2018 establishes principles and guidelines for risk management applicable to all organization sectors, including construction. This framework includes stages consisting of (1) Risk Identification, (2) Risk Analysis, (3) Risk Evaluation, and (4) Risk Treatment or mitigation. This standard emphasizes continuous improvement, inclusiveness, and the integration of risk management into organizational processes (Guritno, et al., 2024).

➤ *Risk Matrix*

A risk matrix is an important tool in risk management used to identify, analyze, and visualize risk levels based on two main components, namely probability (likelihood) and impact. Risks are mapped in the form of a matrix with a certain scale, then classified into categories such as low, medium, high, to extreme to facilitate the determination of mitigation priorities. The use of a risk matrix helps decision-makers better understand the level of risk, formulate handling strategies, and allocate resources effectively. In addition, a risk matrix also improves communication among stakeholders and supports a more structured decision-making process. Nevertheless, the implementation of a risk matrix still requires accurate data, expert judgment, and regular evaluation to ensure that risk assessment results remain relevant and objective (Asnudin et al., 2024, 2026). An example of a risk matrix structure can be seen in Table 2..

Table 2. Risk Matrix

Impact / Likelihood	Very Low	Low	Medium	High	Very High
Almost Certain	5	10	15	20	25
Likely	4	8	12	16	20
Possible	3	6	9	12	15
Unlikely	2	4	6	8	10
Rare	1	2	3	4	5

Source: Asnudin et al. (2024, 2026)

➤ *Risk Mitigation Strategies*

In the context of construction projects, especially infrastructure projects such as road construction, the application of ISO 31000:2018 is highly relevant because construction projects have a high level of uncertainty and are prone to various types of risks. Risks such as work accidents, delays of heavy equipment, technical failures, and non-compliance with work quality can have major consequences on costs, time, and work safety (Lisananda, 2021).

Risk mitigation strategies in construction projects generally involve preventive actions aimed at minimizing the likelihood and consequences of operational risks.

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Common mitigation actions consist of (1) Competency-based occupational safety training, (2) Preventive maintenance programs, (3) Continuous monitoring and supervision, (4) Integration of risk management into project planning, (5) Implementation of occupational health and safety systems. Effective mitigation strategies can reduce the frequency of accidents, improve equipment productivity, and increase stakeholder satisfaction (Sholeh, 2023).

III. RESEARCH METHODOLOGY

➢ *Research Design*

This study uses a mixed-methods approach that combines qualitative and quantitative methods. The qualitative approach is used to explore operational risks and their causes through interviews and field observations, while the quantitative approach is applied to measure the likelihood and consequences of risks using structured questionnaires (Judijanto, et al., 2024).

Qualitatively, this study aims to describe in depth the types of operational risks faced by labor and equipment in the implementation of provincial road projects, as well as to reveal the causal factors of risks based on interviews with key informants, such as field supervisors, project managers, and heavy equipment operators. The analysis technique was conducted using a thematic approach to identify patterns of risk and management practices occurring in the field (Duli, 2020).

Meanwhile, quantitatively, this study aims to measure the level of likelihood and consequence of each risk using a rating scale based on ISO 31000:2018, so that risk evaluation can be carried out through a risk matrix. Quantitative data is obtained through the distribution of questionnaires to respondents involved in the project, then analyzed to determine risk priorities and the most relevant mitigation strategies (Mukhlis, et al., 2024).

➢ *Research Location*

The research was conducted on two provincial road reconstruction projects in Central Sulawesi Province, namely the Sp. Buatan–Bilo road reconstruction project in Tolitoli Regency and the Tulo–Simoro road reconstruction project in Sigi Regency. Both projects were selected due to their operational complexity, challenging terrain, and high exposure to risks related to work and equipment.

➢ *Data Collection Techniques*

Data collection consists of primary data, namely structured questionnaires, semi-structured interviews, and field observations, as well as secondary data, namely incident reports, equipment maintenance logs, daily project reports, contract documents, and specifications.

➢ *Population and Sample*

The population includes project managers, supervisors, equipment operators, mechanics, HSE officers, and field workers involved in the selected project. Purposive sampling technique was used to select respondents with relevant operational experience. A total of 40 respondents participated in this study.

➢ *Research Variables*

The research variables consisted of (1) labor operational risks, (2) equipment operational risks, (3) risk mitigation strategies, and (4) mitigation effectiveness.

➢ *Validity and Reliability Testing*

Instrument validity was tested using Pearson Product-Moment correlation, while reliability was assessed using Cronbach's Alpha. All variables showed acceptable reliability values above 0.70.

➢ *Data Analysis*

Risk analysis was conducted using a risk matrix based on ISO 31000:2018 by evaluating the likelihood and consequences of identified risks.

➢ *Research Variables*

The research variables consist of (1) labor operational risk, (2) equipment operational risk, (3) risk mitigation strategy, and (4) mitigation effectiveness.

➢ *Validity and Reliability Test*

The validity of the instrument was tested using the Pearson Product Moment correlation, while reliability was assessed using Cronbach's Alpha. All variables showed acceptable reliability values above 0.70.

➢ *Data Analysis*

Risk analysis is carried out using a risk matrix based on ISO 31000:2018 by evaluating the likelihood and consequences of the identified risks.

IV. RESULTS

➢ *General Project Overview*

The Sp. Buatan–Bilo project had a contract value of IDR 17.49 billion with a project duration of 300 calendar days. The Tulo–Simoro project had a contract value of IDR 4.72 billion after contract adjustment and a project duration of 137 calendar days. Both projects involved extensive road reconstruction activities, including earthworks, drainage systems, asphalt pavement construction, structural work, and road safety facilities.

➢ *Respondent Characteristics*

A total of 40 respondents participated in this study. The majority of respondents were aged between 31 and 40 years and held a bachelor's degree. Most respondents worked as field supervisors, HSE officers, and technical personnel. The diversity of respondent backgrounds contributed to comprehensive risk perceptions and operational insights. These data are presented in Table 4.1 below.

➢ *Project Overview*

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Table 3 Respondent Characteristics

Characteristic	Category	Frequency
Age	20-30 years	13
	31-40 years	18
	41-50 years	4
	>50 years	5
Gender	Male	35
	Female	5
Education	High school equivalent	4
	Diploma (D1–D4)	5
	Bachelor's (S1)	30
	Postgraduate (S2/S3)	1
Position	Field supervisor	9
	Supervisor/Foreman	5
	Safety Officer	9
	Heavy equipment operator	3
	Field worker	3
	Project manager	1
	Other	10
Work duration	<3 months	5
	3–6 months	14
	6–12 months	7
	>12 months	14

➢ *Validity and Reliability Test*

The results of the validity test showed that all questionnaire items had a correlation coefficient greater than the critical r value of 0.312, confirming the validity of all indicators. The validity test results for each statement item are presented in Table 4..

Table 4. Results of the Validity Test of the Research Instrument (n = 40)

No.	Variable / Indicator	r-calculated	r-table (α=0.05, df=38)	Remark
1	Labor Risk			
	Frequency of work accidents	0.612	0.312	Valid
	Level of physical & mental fatigue	0.745	0.312	Valid
	Level of PPE usage compliance	0.689	0.312	Valid
2	Equipment Risk			
	Frequency of equipment breakdowns	0.721	0.312	Valid
	Duration of equipment downtime	0.703	0.312	Valid
	Equipment specification mismatch	0.658	0.312	Valid
3	Mitigation Strategy			
	Frequency of HSE training implementation	0.734	0.312	Valid
	Compliance with preventive maintenance schedule	0.697	0.312	Valid
	Integration of risk management into contract docs	0.715	0.312	Valid
4	Mitigation Effectiveness			
	Effectiveness in reducing accident rates	0.768	0.312	Valid
	Improvement in equipment productivity	0.682	0.312	Valid
	Stakeholder satisfaction	0.704	0.312	Valid

Reliability testing showed that the Cronbach's Alpha values ranged from 0.785 to 0.834 for each variable, while the overall instrument achieved a reliability coefficient of 0.876, indicating very high reliability. The results of the reliability test for each variable are presented in Table 5.

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Table 5 Results of the Research Instrument Reliability Test (n = 40)

No.	Variable	Number of Items	Cronbach's Alpha	Remark
1	Labor Risk	3	0.812	Reliable (High)
2	Equipment Risk	3	0.785	Reliable (High)
3	Mitigation Strategy	3	0.834	Reliable (High)
4	Mitigation Effectiveness	3	0.796	Reliable (High)
	Entire Instrument	12	0.876	Reliable (Very High)

- *Analysis of Labor Operational Risks*

This study identifies several dominant operational risks related to the workforce consisting of (1) work accidents, (2) physical and mental fatigue, and (3) non-compliance with the use of PPE. Younger workers tend to underestimate risks due to limited experience, while older workers show stronger risk awareness but experience greater physical fatigue. Safety officers and supervisors generally have a more critical perception of job risks compared to field workers.

- *Analysis of Equipment Operational Risks*

Risks related to equipment consist of (1) frequent equipment breakdowns, (2) long downtime duration, and (3) non-compliance with equipment specifications. Heavy equipment such as excavators, rollers, graders, and dump trucks are very important for the continuity of the project. Lack of maintenance significantly affects productivity and project schedules.

- *Risk Analysis Based on Probability and Impact Matrix*

Risk analysis based on the probability-impact matrix in this study refers to SNI ISO 31000:2018 using two main criteria, namely the probability of the risk occurring and the level of impact it causes. Probability is determined based on the average (mean) value of respondents' perceptions on a scale of 1–5 and is classified into five levels, ranging from very unlikely to certain. Meanwhile, risk impact is categorized based on the level of consequences on work safety, project operations, financial losses, and project reputation, ranging from very low to very high. The combination of these two criteria results in a 5×5 risk matrix that is used to visually map the significance level of each risk. Based on research data, the risk mapping in the 5x5 probability-impact matrix is presented in Table 6 as follows:

Table 6 Probability-Impact Risk Matrix

Likelihood / Impact	Very Low	Low	Medium	High	Very High
Almost Certain (4,21–5,00)	-	-	Productivity improvement (3,74)	-	-
Likely (3,41–4,20)	-	Stakeholder satisfaction (3,77)	PPE compliance (3.31); maintenance compliance (3,26)	-	-
Possible (2,61–3,40)	-	-	Occupational Health and Safety (OHS) training frequency (2.80); RKS risk integration (3,09)	Effectiveness of accident reduction (3,23)	-
Unlikely (1,81–2,60)	-	-	Fatigue level (2.49); Failure frequency (2.09); Downtime duration (2.31); Specification non-conformance (2,06)	-	-
Rare (1,00–1,80)	-	-	-	Occupational accident frequency (1,49)	-

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The mapping results show that compliance with the use of PPE and adherence to the preventive maintenance schedule are in the orange zone (high risk) because they have a high probability despite having a moderate impact, thus requiring special mitigation and strict supervision. Several other variables, such as the effectiveness of accident rate reduction, frequency of occupational safety and health training, integration of risk management in project work plans, worker fatigue levels, and frequency of equipment damage are in the yellow zone (medium risk), which requires regular control and monitoring. Meanwhile, equipment productivity improvement and stakeholder satisfaction are in the green zone (low risk), indicating positive conditions that need to be maintained. Although work accident frequency is in the low probability range, it still remains a concern due to its high impact on worker safety. Based on these results, project management needs to prioritize control over risks with high probability through field supervision, enforcement of rules, and increasing worker awareness. In addition, evaluation of the effectiveness of mitigation programs and continuous monitoring needs to be carried out so that risks remain controlled and do not escalate. This risk mapping provides a systematic basis for decision-making, resource allocation, and the development of risk mitigation strategies effectively in accordance with the principles of SNI ISO 31000:2018.

➢ *Risk Mitigation Strategies*

The most effective mitigation strategies identified in this study consist of (1) competency-based occupational safety training, (2) preventive equipment maintenance, (3) integration of risk management into daily work planning, (4) continuous monitoring and supervision, and (5) stakeholder engagement and communication. The implementation of a preventive maintenance schedule successfully reduced equipment downtime and improved operational efficiency.

V. DISCUSSION

Research results indicate that the implementation of risk management in provincial road projects in Central Sulawesi is influenced by both the external and internal context of the project. From the external aspect, the project must adapt to occupational safety regulations, challenging geographical conditions, high rainfall, and limited access to the project site. Meanwhile, from the internal aspect, it was found that human resources and equipment have varying levels of readiness. The education level of the workforce is relatively good, but the implementation of a safety culture is still inconsistent, especially in compliance with the use of personal protective equipment and the execution of preventive equipment maintenance. These conditions indicate that the success of the project is not only influenced by technical planning but also by the organization's readiness to manage operational risks sustainably.

Risk identification produces several key risks that are divided into three categories, namely labor risks, equipment risks, and management system risks. In the labor aspect, the dominant risks are the level of physical and mental fatigue of workers and low compliance with the use of personal protective equipment (PPE). In the equipment aspect, the identified risks include equipment damage, downtime, and the mismatch of equipment specifications with project requirements. Meanwhile, in the management system, the main risks include a low frequency of occupational health and safety (OHS) training, weak implementation of risk management in RKS documents, and low compliance with preventive maintenance schedules. Interview and observation findings indicate that OHS supervision in the field is still considered formalistic and has not been fully implemented effectively.

Risk analysis using the probability-impact matrix shows that most risks fall into the moderate category, while some risks are categorized as high and require prioritized handling. The highest priority risks include lack of OHS competency, unfit operational equipment, and risk management documents that have not been implemented in the field. These risks have a high probability and significant impact on worker safety, operational continuity, and project target achievement. The research results also indicate a relationship between low OHS training and compliance with PPE usage, as well as a relationship between preventive maintenance and a reduction in equipment failure frequency and downtime. These findings affirm that the implementation of systematic risk management can improve the effectiveness of project safety and operations. A complete recap of probability assessments, impacts, scores, and risk levels for all variables is presented in Table 7.

Table 7 Results of Risk Probability and Impact Analysis

Risk Code	Risk	Probability	Impact	Score (P×I)	Risk Level
Labor Risk					
TK-01	Frequency of work accidents	Rare (1)	High (4)	4	Low
TK-02	Level of physical & mental fatigue	Unlikely (2)	Medium (3)	6	Low
TK-03	Level of PPE usage compliance	Likely (4)	High (4)	16	High
Equipment Risk					
AL-01	Frequency of equipment breakdowns	Unlikely (2)	Medium (3)	6	Low
AL-02	Duration of equipment downtime	Unlikely (2)	Medium (3)	6	Low
AL-03	Equipment specification mismatch	Unlikely (2)	Low (2)	4	Low
Mitigation Strategy Risk					
SM-01	Frequency of HSE training implementation	Possible (3)	Medium (3)	9	Medium
SM-02	Compliance with preventive maintenance schedule	Possible (3)	Medium (3)	9	Medium
SM-03	Integration of risk management into contract docs	Possible (3)	Low (2)	6	Low

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Mitigation Effectiveness Risk					
EM-01	Effectiveness in reducing accident rates	Possible (3)	High (4)	12	Medium
EM-02	Improvement in equipment productivity	Likely (4)	Medium (3)	12	Medium
EM-03	Stakeholder satisfaction	Likely (4)	Low (2)	8	Medium

Based on the risk evaluation results, the risk treatment strategy is focused on efforts to reduce probability and impact through preventive approaches and continuous monitoring. Recommended efforts include enhancing field-based occupational health and safety training, daily toolbox meetings, routine inspections of heavy equipment, implementation of pre-operation checklists, audits of RKS implementation, and strengthening supervision of PPE usage. In addition, a monitoring and review system is conducted daily, weekly, monthly, and annually using measurable performance indicators to ensure the effectiveness of risk management implementation.

Table 8 Risk Matrix Analysis Results

Indicator	Probability	Impact	Score (P×I)	Risk Level
Frequency of work accidents	1	4	4	Low
Level of physical & mental fatigue	2	3	6	Medium
Level of PPE compliance	4	4	16	Very High
Frequency of equipment damage	2	3	6	Medium
Equipment downtime duration	2	3	6	Medium
Equipment specification non-conformity	2	2	4	Low
Frequency of HSE training implementation	3	3	9	Medium
npliance with preventive maintenance schec	3	3	9	Medium
Integration of risk management in RKS	3	2	6	Medium
Effectiveness in reducing accident rates	3	4	12	High
Increase in equipment productivity	4	3	12	High
Stakeholder satisfaction	4	2	8	Medium

Table 9 Risk Matrix

Likelihood / Impact	1	2	3	4	5
1	1	2	3	4	5
2	2	4	6	8	10
3	3	6	9	12	15
4	4	8	12	16	20
5	5	10	15	20	25

Overall, this study produced an integrated risk management model based on ISO 31000:2018, which covers the stages of context establishment, risk identification, risk analysis, risk evaluation, risk treatment, as well as monitoring and review. This model emphasizes the importance of integration between technical aspects, human resources, and management systems in controlling road construction project risks. The success of risk management implementation depends not only on the completeness of the documents but also on the consistency of field implementation, the commitment of all stakeholders, and a strong and sustainable work safety culture.

VI. CONCLUSION

This study concludes that operational risks related to labor and construction equipment remain the main challenges in provincial road construction projects in Central Sulawesi. Labor risks include work accidents, fatigue, and low compliance with PPE, while equipment risks include frequency of breakdowns, downtime, and equipment nonconformity.

The implementation of ISO 31000:2018 has proven effective in supporting the systematic identification, analysis, evaluation, and mitigation of risks. Competency-based safety training, preventive maintenance programs, and integrated risk management planning significantly enhance operational safety and productivity. Further research confirms that valid and reliable risk assessment instruments

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are crucial to supporting evidence-based decision-making in construction risk management.

RECOMMENDATIONS

Based on the research results, several recommendations that can be given to improve the effectiveness of risk management in provincial road projects in Central Sulawesi are to strengthen the occupational safety training program for all project personnel through regular and field-based practical training, enhance the preventive maintenance system for heavy equipment through regular inspections and supervision of maintenance schedules, and tighten supervision and enforcement of compliance with the use of personal protective equipment (PPE) to minimize the potential for work accidents. In addition, risk management needs to be integrated into daily operational planning so that each project activity has clear and measurable risk control procedures, accompanied by regular monitoring and evaluation of the effectiveness of the mitigation strategies that have been implemented. Further research is recommended to involve a larger number of project samples and to develop analytical methods using a more complex quantitative approach so that the research results can provide a more comprehensive, accurate, and widely applicable picture of risks in other construction projects.

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