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Identification and control of Occupational Health and Safety (OHS) risks in the slope and drainage reinforcement project on the Paksebali – Selat Provincial Road Section

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ABSTRACT

The slope and drainage reinforcement project on the Paksebali–Selat Provincial Road section involves a relatively high potential for Occupational Health and Safety (OHS) risks due to excavation works, concrete casting, the use of heavy equipment, and hazardous working environment conditions. This study aims to identify extreme and high risks that may lead to work accidents and to determine appropriate OHS risk control measures for the project. The research method employed is a quantitative descriptive approach, with data collected through field observations, interviews, questionnaires, and documentation studies. Risk assessment was conducted based on the AS/NZS 4360 standard by multiplying the probability and severity levels, whereas risk control was analyzed using the Plan–Do–Check–Act (PDCA) cycle approach. The results indicated that the risks identified in this project fell into the extreme and high-risk categories, particularly in excavation works, road shoulder concrete casting, and heavy equipment mobilization. Potential hazards included landslides, being struck by equipment, and accidents caused by improper work methods. Risk control measures were implemented through improvements in work methods, enforcement of Personal Protective Equipment (PPE) usage, enhanced supervision, installation of safety signs, and the regular implementation of training and safety meetings. The application of appropriate risk control measures is expected to minimize workplace accidents and improve overall project safety performance.

Keywords: Occupational Health and Safety (OHS); risk management; road construction project.

1. INTRODUCTION

Road infrastructure development in Indonesia has intensified significantly in recent years, particularly at the provincial level, as part of broader efforts to improve regional connectivity, accessibility, and economic growth. Alongside this expansion, slope and drainage reinforcement projects have become increasingly common, especially in areas with complex topography and high rainfall intensity. However, such projects are consistently associated with elevated Occupational Health and Safety (OHS) risks due to the combination of excavation activities, unstable ground conditions, heavy equipment operation, and construction works conducted adjacent to active traffic. Empirical evidence from construction safety studies indicates that accidents related to slope instability, equipment malfunction, and traffic exposure remain among the most frequent and severe incidents in road construction projects, posing serious risks not only to construction workers but also to road users (Guo et al., 2022; Li et al., 2023).

These challenges are clearly observable in slope and drainage reinforcement projects along the Paksebali–Selat Provincial Road section in Bali. This corridor is characterized by steep terrain, high annual rainfall, and continuous traffic flow, creating a working environment with heightened accident potential. Construction activities, such as deep excavation, concrete casting, and heavy equipment mobilization, are carried out within limited spatial boundaries while the road remains operational. Consequently, construction workers face hazards, including landslides, excavation collapse, and equipment-related accidents, whereas road users are exposed to risks arising from reduced road capacity, construction debris, and inadequate traffic control. These risks have become increasingly critical in the context of accelerated infrastructure delivery, tight project deadlines, and growing regulatory demands for compliance with the Occupational Health and Safety Management System (SMK3) and public safety standards.

The construction of slope and drainage reinforcement projects involves significant potential hazards. These hazards pose threats to the safety of workers and other individuals in the workplace, arising from work processes, project installations or equipment, working environment conditions, or human factors. The road construction industry uses equipment that continues to evolve in both form and technological sophistication. The use of work equipment is a major contributor to occupational accident risks, particularly those caused by improper operating methods and inadequate worker competence in operating such equipment.

During the implementation of slope and drainage reinforcement work, various potential occupational accident risks may arise at each stage of construction. These include both low- and high-risk work activities (He et al., 2022). Occupational accidents may occur owing to hazardous conditions related to machinery, the work environment, production processes, the nature of the work, and work methods. Worker characteristics and behavior play a crucial role in determining accident rates; a lack of awareness and insufficient knowledge or skills to perform job tasks can endanger both equipment and workers.

Occupational accidents are defined as accidents related to company activities, including accidents that occur as a result of work, during the execution of work, and while traveling to and from the workplace. Common occupational accidents in construction projects include falling objects or being struck by objects, often due to inadequate safety signage at project sites. Data from BPJS Ketenagakerjaan (2017) indicate that 123,041 occupational accident cases were reported in Indonesia. In 2018, the number of occupational accidents increased to 173,105 cases. The high incidence of occupational accidents in the construction sector indicates insufficient understanding and implementation of OHS practices in the field (Bourahla et al., 2024). One of the risks frequently encountered in construction projects is OHS risk, as highlighted in previous studies.

A considerable number of occupational accidents also occur on roadways during maintenance activities; therefore, risk analysis is essential during maintenance work as well. Based on the Republic of Indonesia Law No. 25 of 1991 concerning Manpower, it is stipulated that every worker has the right to receive protection in terms of Occupational Health and Safety.

Despite the growing body of research on OHS in construction projects, several critical gaps remain. First, from a contextual perspective, existing studies have predominantly focused on general building construction or large-scale infrastructure projects, with limited empirical attention given to slope and drainage reinforcement works conducted on active provincial roads, particularly in regions with complex topography and high rainfall such as Bali. Second, from a methodological standpoint, most prior studies tend to apply risk assessment techniques in isolation, with minimal integration between structured risk assessment standards such as AS/NZS 4360 and continuous improvement frameworks like the Plan–Do–Check–Act (PDCA) cycle. As a result, risk analysis often remains static and insufficiently responsive to dynamic site conditions. Third, from a practical perspective, many studies primarily emphasize risk identification and risk ranking without extending the analysis to risk evaluation, acceptance criteria, and systematic monitoring, limiting the applicability of their findings for real-world safety management. Addressing these gaps, this study contributes by examining OHS risks in a slope and drainage reinforcement project on an active provincial road in Bali, employing an integrated AS/NZS 4360–PDCA approach that not only prioritizes risks but also evaluates risk acceptance and proposes implementable control measures to support safer and more sustainable road construction practices.

2. LITERATURE REVIEW

OHS is a critical aspect of construction projects due to the high level of hazards associated with heavy equipment operation, excavation works, material handling, and environmental conditions (Badri et al., 2012). Several studies have emphasized that road construction projects are among the sectors with the highest accident rates, primarily caused by unsafe work methods, inadequate equipment inspection, unfavorable environmental conditions, and low safety awareness among workers.

Previous studies indicate that OHS risks in road construction projects generally originate from work methods, construction equipment, materials, working environment, and human factors. Susanti (2022) identified that excavation works, heavy equipment mobilization, and asphalt paving are dominant sources of high-risk accidents in road projects. Similarly, highlighted that heavy equipment operation poses the highest risk, particularly when operators lack sufficient skills and certification.

Risk management standards such as AS/NZS 4360 emphasize the importance of systematic risk identification, risk assessment, and risk control. Risk assessment is conducted by evaluating the likelihood and severity of hazards, allowing risks to be categorized into low, medium, high, or extreme levels. Furthermore, effective risk control should follow a structured management approach, such as the Plan–Do–Check–Act (PDCA) cycle, to ensure continuous improvement in safety performance. It can be concluded that comprehensive risk identification combined with systematic risk control strategies is essential to minimize occupational accidents in slope and drainage reinforcement projects (Yiu et al., 2019).

3. METHODOLOGY

This study employed a quantitative descriptive research method to analyze Occupational Health and Safety (OHS) risks in the slope and drainage reinforcement project on the Paksebali–Selat Provincial Road section (Soltanzadeh, et. al., 2023). The research was conducted directly at the project site for one month. Data collection techniques included: (1) Field observation to identify potential hazards during construction activities; (2) Interviews with project management and safety officers; (3) Questionnaires distributed to 40 respondents consisting of project owners, consultants, supervisors, foremen, skilled workers, and laborers; (4) Documentation studies, including project drawings and standard operating procedures (SOPs).

Risk assessment was performed using the AS/NZS 4360 standard, where risk level is determined by multiplying probability and severity values. The probability and severity were measured using a Likert scale. The reliability and validity of questionnaire data were tested using SPSS software. Risk control strategies were analyzed using the PDCA (Plan–Do–Check–Act) approach.

4. RESULT AND DISCUSSION

4.1. Risk Identification

Risk identification was conducted through direct field observations, questionnaire analysis, and interviews with project stakeholders. The identified risks were grouped into five main factors: work methods, equipment, materials, working environment, and human resources (Wang, et. al., 2020). Each factor represents a major source of OHS hazards commonly encountered in road construction projects as can be seen in Table 1.

Table 1. Risk Identification

Item	Risk Factor	Hazard Identification
X1	Work Method Factors	Improper excavation methods may lead to occupational accidents such as trench collapse or workers being buried.
		Inappropriate work methods during asphalt paving can increase the likelihood of work accidents.
		Lack of understanding of proper work methods in shoulder concrete casting may cause occupational accidents.
X2	Equipment Factors	The risk of accidents increases if excavation equipment is not inspected regularly.
		Failure of hydraulic or mechanical systems in asphalt paving equipment can cause fatal accidents.
		Damage to concrete mixer equipment may result in workers being exposed to spilled concrete mixtures during shoulder casting.
X3	Material Factors	Hot asphalt materials may cause work accidents if not handled carefully during paving operations.
		The use of reinforcing steel that does not comply with national standards (SNI) may cause accidents during concrete reinforcement work.
		Untidy shoulder concrete casting and scattered concrete materials on the road may cause accidents to workers or passing road users.
X4	Working Environment Factors	Excavation work carried out under extreme weather conditions (heavy rain or strong winds) may lead to serious accidents.
		Asphalt paving conducted during peak traffic hours may endanger workers and passing road users.
		Shoulder concrete casting performed in busy areas may expose workers to accidents due to continuous traffic movement.
X5	Human Resource Factors	Workers who do not wear complete Personal Protective Equipment (PPE) during excavation are more likely to suffer work-related injuries.
		Insufficient skills of heavy equipment operators during asphalt paving operations may lead to occupational accidents.
		Lack of coordination among workers during construction activities may endanger workers on site.

Source: Data Analysis (2025)

The results indicate that improper work methods, such as incorrect excavation techniques, unstandardized asphalt paving procedures, and inadequate concrete casting practices, pose significant risks to workers. These conditions may lead to incidents such as trench collapse, workers being struck by materials, and slips or falls during construction activities.

Equipment-related risks were mainly associated with insufficient inspection and maintenance of heavy machinery, including excavators, asphalt paving equipment, and concrete mixers. Failures in hydraulic or mechanical systems significantly increase the likelihood of severe accidents, particularly during asphalt paving operations.

Material-related risks involved the handling of hot asphalt, the use of non-standard reinforcing steel, and poor housekeeping during concrete casting, which could endanger both workers and road users. Meanwhile, environmental risks were strongly influenced by external conditions such as extreme weather, traffic density, and limited working space. Human resource risks were largely related to inadequate PPE usage, insufficient skills of equipment operators, and weak coordination among workers (Wong et al., 2020). Overall, the identification process revealed that most hazards originated from a combination of unsafe conditions and unsafe actions, highlighting the need for integrated risk control strategies.

4.2. Risk Assessment

Risk assessment was carried out using the AS/NZS 4360 standard, by multiplying the probability and severity values obtained from questionnaire responses. The probability reflects how often a risk is likely to occur, while severity represents the potential impact of the incident on workers, equipment, and project performance.

Table 2. Risk Assessment Results

No.	Risk Factor	Hazard Description	Probability	Severity	Risk Level
1	Work Method	Improper excavation methods may lead to occupational accidents	2	3	6
2	Work Method	Inappropriate work methods during asphalt paving increase accident risk	2	3	6
3	Work Method	Lack of understanding of proper methods in shoulder concrete casting may cause accidents	2	3	6
4	Equipment	Accident risk increases if excavation equipment is not inspected regularly	2	2	4
5	Equipment	Hydraulic or mechanical failure of asphalt paving equipment may cause fatal accidents	4	4	16
6	Equipment	Damage to concrete mixer equipment may expose workers to spilled concrete mixture	3	2	6
7	Material	Hot asphalt materials may cause accidents if not handled carefully during paving	4	2	8
8	Material	Use of non-standard reinforcing steel may cause accidents during concrete works	3	2	6
9	Material	Poor housekeeping during shoulder concrete casting may cause accidents to workers or road users	2	3	6
10	Working Environment	Excavation work under extreme weather conditions (rain or strong wind) may lead to serious accidents	4	5	20
11	Working Environment	Asphalt paving during peak traffic hours may endanger workers and road users	2	3	6

No.	Risk Factor	Hazard Description	Probability	Severity	Risk Level
12	Working Environment	Shoulder concrete casting in busy areas may expose workers to traffic-related accidents	3	2	6
13	Human Resources	Workers not wearing complete PPE during excavation are more likely to be injured	2	2	4
14	Human Resources	Lack of operator skills in asphalt paving operations may lead to accidents	3	4	12
15	Human Resources	Poor coordination among workers may endanger on-site personnel	2	3	6

Source: Data Analysis (2025)

Based on the assessment results as can be seen in Table 2, two risks were identified as the most critical: (1) Excavation works under extreme weather conditions, which reached an extreme risk level (risk value = 20); (2) Hydraulic or mechanical failure of asphalt paving equipment, categorized as a high risk (risk value = 16).

Most risks related to work methods, materials, and human resources were classified as medium (risk value = 6–8), while several equipment and human resource risks were categorized as low to medium risks. The dominance of environmental and equipment-related risks indicates that external conditions and mechanical reliability play a crucial role in determining accident severity in road construction projects.

These findings confirm that risk magnitude is not solely determined by frequency but also by the severity of potential consequences, especially when heavy equipment and unstable ground conditions are involved

4.3. Risk Control

Risk control measures were formulated based on the PDCA (Plan–Do–Check–Act) cycle, ensuring systematic and continuous improvement in OHS management.

First, Plan: Risk control planning involved preparing standard operating procedures (SOPs), conducting safety meetings, arranging traffic management plans, and ensuring the availability of PPE and safety equipment. Second, Do: Implementation included enforcing SOP compliance, conducting routine equipment inspections, installing safety signs, assigning flagmen, and ensuring workers use PPE correctly. Third, Check: Monitoring activities were carried out through regular safety inspections, supervision by safety officers, and evaluation of worker behavior and equipment condition. Fourth, Act: Corrective actions included revising work methods, providing additional training, replacing damaged equipment, and improving coordination among workers.

The application of the PDCA cycle proved effective in addressing both technical and behavioral safety issues, particularly in reducing risks associated with heavy equipment operation and hazardous environmental conditions (Low et al., 2019).

4.4. Risk Acceptance

The level of risk acceptance is determined by the product of probability and severity. Risks are then classified into four categories: Unacceptable, Undesirable, Acceptable, and Negligible. Based on Table 4.6, the risk acceptance scale is presented in Table 3.

Table 3. The Risk Acceptance Scale

Risk Assessment Value (x)	Risk Acceptance Category	Description
$x \geq 15$	Unacceptable	Risks at this level are not acceptable and require immediate corrective actions to eliminate or significantly reduce the risk.
$5 \leq x < 15$	Undesirable	Risks are not desirable and must be controlled and monitored to prevent escalation into higher risk levels.
$3 \leq x < 5$	Acceptable	Risks are acceptable provided that routine control measures and standard safety procedures are maintained.
$x < 3$	Negligible	Risks are considered insignificant and can be ignored without specific control measures.

Source: Godfrey (1996)

The results showed that: (1) Two risks were classified as Unacceptable, requiring immediate corrective actions; (2) Most risks fell under the Undesirable category, indicating that they must be controlled and monitored continuously; (3) A small number of risks were categorized as Acceptable, provided that routine safety procedures are maintained.

Unacceptable risks were primarily associated with environmental and equipment factors, emphasizing that such risks cannot be tolerated without substantial control measures. Undesirable risks, although not immediately dangerous, could escalate if left unmanaged, particularly during prolonged construction periods.

4.5. Risk Evaluation and Monitoring

Risk evaluation focused on determining appropriate strategies for managing dominant risks, including risk avoidance, risk reduction, risk mitigation, and risk transfer. Continuous monitoring was emphasized to ensure that implemented control measures remained effective under changing site conditions.

For environmental risks, especially excavation during extreme weather, risk evaluation led to the implementation of stop-work policies until safe conditions were restored. Equipment-related risks were managed through daily inspections, preventive maintenance, and operator competency evaluations. Human resource risks were mitigated through enhanced supervision, training programs, and improved communication systems. Regular monitoring allowed early detection of new hazards and ensured timely corrective actions, contributing to improved safety performance throughout the project duration.

4.6. Risk Factors in the Paksebali–Selat Slope and Drainage Reinforcement Project

Based on the overall analysis, the dominant risk factors affecting the project can be summarized as follows: (1) Work Method Factors: Improper excavation, paving, and casting procedures contributed to medium-level risks; (2) Equipment Factors: Mechanical failures and insufficient inspections posed high risks, particularly during asphalt paving; (3) Material Factors: Hot asphalt handling and non-standard materials resulted in medium risks; (4) Environmental Factors: Extreme weather conditions and traffic exposure generated the highest risk levels; (5) Human Resource Factors: Inadequate PPE usage, limited skills, and poor coordination contributed to low to medium risks.

Among these factors, environmental and equipment risks were the most dominant, requiring priority attention in risk control planning (Costella, et. al., 2020). This finding highlights the importance of adaptive safety management that considers both technical and environmental dynamics in road construction projects.

5. CONCLUSION

This study demonstrates that slope and drainage reinforcement works on active provincial roads involve substantial OHS risks, with environmental and equipment-related hazards emerging as the most critical contributors to potential accidents. Extreme risks were identified in excavation activities conducted under adverse weather conditions, while high risks were associated with mechanical failures of asphalt paving equipment. The integrated application of the AS/NZS 4360 risk assessment framework and the Plan–Do–Check–Act (PDCA) cycle proved effective in systematically identifying, prioritizing, evaluating, and controlling OHS risks within a dynamic construction environment. To translate these findings into actionable safety improvements, the following recommendations are proposed based on key project stakeholders: (1) Contractors should prioritize preventive risk control during the planning and execution stages by developing task-specific standard operating procedures (SOPs) for excavation, heavy equipment operation, and traffic management. This should be supported by mandatory daily equipment inspections, enforcement of Personal Protective Equipment (PPE) usage, and allocation of sufficient resources for safety supervision; (2) Site managers are responsible for operational risk management during the implementation stage. They should conduct routine safety briefings, monitor compliance with SOPs, and enforce stop-work policies when environmental conditions such as heavy rainfall or unstable slopes pose unacceptable risks. The use of real-time supervision and safety checklists can strengthen on-site risk control mechanisms; (3) Local governments play a critical role at the regulatory and oversight level. They should strengthen safety governance by integrating OHS performance indicators into project approval and monitoring processes, particularly for road projects conducted under live traffic conditions. Periodic safety audits and enforcement of SMK3 compliance can help ensure consistent safety standards across provincial infrastructure projects; (4) Supervising consultants should function as independent safety monitors throughout the construction lifecycle. Their role includes verifying the adequacy of risk assessments, evaluating the effectiveness of implemented control measures, and providing timely corrective recommendations when deviations from safety standards are identified.

These targeted, role-specific actions provide a practical pathway for reducing accident risks while maintaining project efficiency and public safety.

Ethical Approval

Ethical approval was not required as the study did not involve human subjects or the collection of personal or sensitive data, and all research activities complied with standard ethical research practices.

Informed Consent Statement

Informed consent was not applicable because no individual-level data were collected, and all information used in the study was obtained anonymously for academic purposes.

Authors' Contributions

Conceptualization and methodology, I.G.A.S. and I.N.I.K.; validation and supervision, I.K.A.A. and I.G.F.S.T.; data collection and analysis, I.G.A.S.; writing original draft preparation, I.G.A.S.; writing review and editing, I.G.A.S. and I.N.I.K. All authors have read and approved the final manuscript.

Disclosure statement

The authors declare no conflict of interest related to this study.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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