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Construction Worker Safety Risk Management Based on As/Nzs Iso 31000:2018: A Case Study of Infrastructure Projects in Disaster-Prone Areas

Jesica Margaretha Sane[1]; Andi Asnudin[2]; Adnan Fadjar[2]

[1,2] Master Program in Civil Engineering, Graduate School, Tadulako University, Palu 94148, Indonesia

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Abstract: Infrastructure projects located in disaster-prone areas of Palu City face significant occupational safety risks due to the interaction between construction hazards and natural disaster threats, including earthquakes, tsunamis, liquefaction, floods, landslides, and extreme weather events. This study aims to identify construction worker safety risks, analyze and evaluate their risk levels, and formulate appropriate mitigation strategies based on the AS/NZS ISO 31000:2018 Risk Management framework. A mixed-methods approach was employed by distributing questionnaires to 39 respondents representing project owners, supervising consultants, and contractors across three infrastructure projects in Palu City. The quantitative data were complemented by interviews, field observations, and document reviews. Risk analysis was conducted using the Likelihood × Consequence risk matrix. The findings identified six major categories of occupational safety risks. The highest risk in the Palu IV Bridge Approach Project was mass worker fatalities caused by a tsunami, with a risk score of 20 (Extreme). In the Electrical Engineering Laboratory Project of Tadulako University, the highest risk was worker fatalities resulting from earthquakes, also with a risk score of 20 (Extreme). Meanwhile, the Palu Riverside Park Project recorded the highest risk of earthquake-related worker fatalities, with a risk score of 21 (Extreme). The study concludes that implementing AS/NZS ISO 31000:2018, supported by the hierarchy of risk controls, early warning systems, evacuation routes, disaster preparedness training, and the proper use of personal protective equipment (PPE), can significantly enhance the effectiveness of occupational safety risk management in infrastructure projects located in disaster-prone areas.

Keywords: *AS/NZS ISO 31000:2018; Occupational Safety and Health (OSH); Risk Management; Infrastructure Projects; Disaster-Prone Areas.*

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I. INTRODUCTION

Infrastructure development plays a strategic role in supporting economic growth and improving public services. However, infrastructure projects are inherently characterized by high levels of complexity and uncertainty, particularly when implemented in disaster-prone regions. Palu City is one of Indonesia's most disaster-vulnerable areas due to its susceptibility to earthquakes, liquefaction, tsunamis, and flooding. These hazards present substantial challenges to maintaining occupational safety and health during construction activities (BNPB, 2021; Widodo et al., 2023).

Infrastructure projects undertaken in disaster-prone regions possess unique characteristics that distinguish them from projects located in relatively safe environments. These characteristics include unstable geological conditions, limited emergency access, sudden changes in the working environment, and a high dependence on natural factors (Xiang et al., 2020). In Palu City, the presence of the active Palu-Koro Fault and the history of major natural disasters expose infrastructure projects to considerable residual risks, despite the implementation of engineering standards and occupational safety procedures (Syamsuddin et al., 2021).

Risk management based on AS/NZS ISO 31000:2018 provides a comprehensive framework for systematically identifying, analyzing, evaluating, and treating risks while integrating risk management into organizational processes (ISO, 2018). The standard emphasizes the importance of establishing the risk context, effective communication and consultation, as well as continuous monitoring and review, making it particularly suitable for infrastructure projects in disaster-prone environments.

In the context of Palu City, non-structural mitigation measures are especially important because natural hazards cannot be completely eliminated through physical engineering solutions alone. Therefore, applying AS/NZS ISO 31000:2018 with an emphasis on non-structural risk

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management strategies is expected to enhance workers' preparedness and resilience against disaster-related risks.

Previous research conducted by Asnudin et al. (2024) evaluated disaster risks and mitigation strategies for post-disaster permanent housing within the Palu-Koro Fault Zone. The study identified and assessed earthquake, tsunami, and liquefaction hazards, concluding that several zones remained within unacceptable risk levels and required both structural and non-structural mitigation measures.

Similarly, Nugroho and Purwanto (2024) analyzed occupational safety and health risk management in bridge construction projects based on ISO 31000:2018. Their study identified 39 risk variables consisting of four owner-related risks, eleven contractor-related risks, four design consultant risks, four supervising consultant risks, and sixteen worker-related risks.

The novelty of the present study lies in the application of the AS/NZS ISO 31000:2018 framework across three infrastructure projects exposed to different dominant disaster hazards. This approach enables the development of mitigation strategies that are specifically tailored to the dominant risks associated with each project location.

Accordingly, this study aims to: (1) identify occupational safety risks in infrastructure projects located within disaster-prone areas of Palu City based on the AS/NZS ISO 31000:2018 risk management framework (2) analyze and evaluate occupational safety risk levels through likelihood and consequence assessments using the AS/NZS ISO 31000:2018 risk matrix; and (3) formulate risk mitigation strategies based on the hierarchy of risk controls to reduce occupational safety risks in infrastructure projects located in disaster-prone areas.

The findings are expected to contribute to the advancement of construction safety risk management based on AS/NZS ISO 31000:2018 and to serve as a practical reference for project owners, contractors, consultants, and other stakeholders in improving occupational safety performance in disaster-prone infrastructure projects.

II. MATERIALS AND METHODS

➤ *Research Design*

This study employed a mixed-methods approach, integrating quantitative and qualitative research methods. The quantitative approach was used to identify, analyze, and evaluate occupational safety risks based on respondents' perceptions obtained through questionnaires. Meanwhile, the qualitative approach involved semi-structured interviews, field observations, and document reviews to validate the quantitative findings and formulate appropriate risk mitigation strategies based on the AS/NZS ISO 31000:2018 risk management framework.

➤ *Study Area and Research Period*

The study was conducted at three infrastructure projects located in disaster-prone areas of Palu City, Central Sulawesi, Indonesia, namely: Palu IV Bridge Approach Construction Project, Electrical Engineering Laboratory Project, Tadulako University, and Palu Riverside Park Project These projects were selected because they represent different types of infrastructure exposed to various natural hazards, including earthquakes, tsunamis, floods, and unstable geological conditions. Data collection was carried out over a three-month period.

➤ *Population and Sample*

The study population consisted of stakeholders directly involved in the implementation of the infrastructure projects, including project owners, supervising consultants, and contractors. A purposive sampling technique was employed to select respondents based on their knowledge and involvement in project implementation. A total of 39 respondents participated in this study, with 13 respondents representing each project.

➤ *Research Variables and Indicators*

The research variables were developed according to the risk management process described in AS/NZS ISO 31000:2018. A total of 26 occupational safety risk indicators were identified and classified into six major risk groups associated with construction activities and disaster hazards at each project site.

Each indicator was evaluated using a five-point Likert scale for both Likelihood and Consequence, where higher scores indicate a greater probability of occurrence and more severe impacts.

➤ *Data Collection Techniques*

Primary data were collected through questionnaire surveys distributed to the respondents.

To enhance the validity of the findings, the questionnaire data were complemented by: semi-structured interviews, field observations, and reviews of relevant project documents and supporting literature.

The integration of multiple data sources enabled a more comprehensive assessment of occupational safety risks across the three infrastructure projects.

➤ *Instrument Validity and Reliability*

The validity of the questionnaire was examined using the Pearson Product-Moment Correlation test with the assistance of IBM SPSS Statistics Version 25.

The analysis showed that all questionnaire items had correlation coefficients exceeding the critical r-table value of 0.316, indicating that every indicator was statistically valid.

The reliability of the instrument was evaluated using Cronbach's Alpha, and the results demonstrated a high level of internal consistency, confirming that the questionnaire was reliable and suitable for data collection.

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➢ *Data Analysis*

Data analysis followed the risk management process prescribed by AS/NZS ISO 31000:2018, which consists of: Risk Identification; Risk Analysis; Risk Evaluation; and Risk Treatment.

The risk level for each indicator was determined using the following equation:

R = L × C

where:
R = Risk Score
L = Likelihood
C = Consequence

The calculated risk scores were subsequently plotted on the AS/NZS ISO 31000:2018 Risk Matrix to classify each risk into four categories: Low, Moderate, High, Extreme.

These classifications served as the basis for formulating appropriate mitigation measures using the Hierarchy of Risk Controls.

III. RESULTS AND DISCUSSION

➢ *Overview of the Study Area*

This study was conducted on three infrastructure projects located in disaster-prone areas of Palu City: the Palu IV Bridge Approach Construction Project, the Electrical Engineering Laboratory Project at Tadulako University, and the Palu Riverside Park Project.

These projects were selected because they are situated in areas highly susceptible to earthquakes, tsunamis, floods, and unstable soil conditions, making them representative case studies of infrastructure development in disaster-prone environments.

The study involved 39 respondents, with each project represented by 13 respondents (33.3%), comprising project owners (Commitment-Making Officials/PPK), supervising consultants, and contractors.

➢ *Respondent Characteristics*

The demographic characteristics indicate that 82% of the respondents were male, while 18% were female.

Based on age, respondents were predominantly within the 31–40 years age group (41%), followed by 20–30 years (28%), 41–50 years (18%), and over 50 years (13%).

Regarding educational background, most respondents held a Bachelor's degree (77%), while 10% had a Diploma qualification and 13% possessed postgraduate degrees (Master's or Doctoral).

In terms of work experience, the majority had 10–20 years of professional experience (51%), followed by 5–10 years (26%), more than 20 years (13%), and 1–5 years (10%). These findings indicate that the respondents possessed sufficient professional competence to assess occupational safety risks accurately.

The respondents represented various professional positions, with the largest proportions consisting of Inspectors (18%), Site Supervisors (15%), and PPK Staff (13%). Other respondents included Commitment-Making Officials (PPK), Site Managers, Occupational Safety Specialists, Quality Control Engineers, Safety Officers, General Superintendents, Project Managers, and Company Directors.

➢ *Risk Analysis*

Risk analysis was performed by calculating the product of Likelihood (L) and Consequence (C) for each identified occupational safety risk using the AS/NZS ISO 31000:2018 risk assessment matrix. The resulting risk scores were then classified into four categories: Low, Moderate, High, and Extreme.

The analysis revealed that the three infrastructure projects exhibited different dominant occupational safety risks, reflecting the influence of their respective disaster characteristics.

Table 1. Risk Assessment Results for the Palu IV Bridge Approach Construction and Tsunami-Affected Area Revitalization Project

Risk Indicator	Risk Score	Risk Category
Tsunami has the potential to cause mass worker fatalities	20	Extreme
Tsunami waves may cause severe injuries to workers	19	High
Earthquakes may result in worker fatalities	16	High

The results indicate that tsunami-related hazards represent the most critical occupational safety risk for the Palu IV Bridge Approach Project. This finding is closely associated with the project's location within the coastal area affected by the 2018 Palu tsunami, where future tsunami events remain a significant threat to construction workers. Consequently, disaster preparedness measures should become an integral component of occupational safety management throughout the project lifecycle.

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Table 2. Risk Assessment Results for the Electrical Engineering Laboratory Project, Tadulako University

Risk Indicator	Risk Score	Risk Category
Earthquakes may cause worker fatalities	20	Extreme
Earthquake shaking may lead to scaffold collapse	19	High
Unstable ground conditions increase the risk of workers falling	18	High

Table 3. Risk Assessment Results for the Palu Riverside Park Project

Risk Indicator	Risk Score	Risk Category
Earthquakes may cause worker fatalities	21	Extreme
Tsunamis have the potential to cause mass worker fatalities	20	Extreme
Tsunami waves may seriously injure workers	20	Extreme

Among the three case studies, the Palu Riverside Park Project exhibited the highest overall occupational safety risk. Both earthquake and tsunami hazards were categorized as Extreme, indicating that workers are exposed to multiple high-impact disaster threats during construction activities.

The project's proximity to the coastline significantly increases its vulnerability to tsunami hazards, while the regional seismic activity further elevates the probability of earthquake-related accidents. These combined hazards highlight the importance of integrating disaster risk reduction into occupational safety planning.

➢ *Risk Evaluation and Mitigation*

Risk evaluation demonstrated that the majority of occupational safety risks across the three infrastructure projects fell within the High and Extreme categories according to the AS/NZS ISO 31000:2018 risk matrix.

The highest-risk scenario identified in the Palu IV Bridge Approach Project was mass worker fatalities caused by tsunami events, with a risk score of 20 (Extreme).

In the Electrical Engineering Laboratory Project, the most significant risk was worker fatalities caused by earthquakes, also classified as Extreme with a risk score of 20.

Meanwhile, the Palu Riverside Park Project recorded the highest risk level among all case studies, where earthquake-induced worker fatalities achieved a risk score of 21 (Extreme).

These findings demonstrate that occupational safety risks are strongly influenced by the dominant natural hazards associated with each project location. Consequently, disaster characteristics should be incorporated into occupational safety risk assessments rather than focusing solely on conventional construction hazards.

The consistently high risk levels indicate that traditional occupational safety management practices are insufficient when infrastructure projects are undertaken in disaster-prone environments. Instead, project safety management should integrate disaster risk reduction measures throughout project planning and execution.

Risk mitigation strategies were formulated based on the Hierarchy of Risk Controls, emphasizing engineering controls, administrative controls, and personal protective equipment (PPE).

The recommended engineering controls include: installation of disaster early warning systems; provision of clearly marked emergency evacuation routes; regular inspection of temporary structures and construction equipment; and improvement of emergency access facilities.

Administrative controls involve: periodic emergency response drills; disaster preparedness training programs; development of emergency response procedures; continuous supervision of occupational safety implementation; and strengthening safety communication among project stakeholders.

At the individual level, workers are required to use appropriate Personal Protective Equipment (PPE) consistently throughout construction activities.

The implementation of these mitigation measures is expected to reduce occupational safety risks while improving the resilience of infrastructure projects against disaster-related hazards.

➢ *Research Synthesis and Implications*

This study demonstrates that the implementation of AS/NZS ISO 31000:2018 provides a comprehensive framework for systematically identifying, analyzing, evaluating, and treating occupational safety risks in infrastructure projects located in disaster-prone areas.

Unlike conventional occupational safety assessments, which primarily focus on construction-related hazards, this study confirms that disaster hazards substantially influence the overall occupational safety risk profile.

A key contribution of this research is the comparative analysis of three infrastructure projects exposed to different dominant disaster threats. The findings reveal that each project possesses a distinct risk profile depending on its geographical location and hazard characteristics. Therefore, occupational safety management strategies should be tailored to site-specific disaster conditions rather than relying on a uniform approach.

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The proposed mitigation framework may serve as a practical reference for project owners, contractors, supervising consultants, and government agencies responsible for improving occupational safety performance in disaster-prone infrastructure projects.

➢ *Study Limitations*

This study is limited to three infrastructure projects located in Palu City, involving a total of 39 respondents. Therefore, the findings cannot be generalized to all construction projects in disaster-prone areas.

Furthermore, the risk assessment was primarily based on respondents' perceptions obtained through questionnaires, which were supported by interviews, field observations, and document reviews. Consequently, the results may reflect the specific conditions of the projects during the period in which the study was conducted.

Future studies are recommended to involve a larger number of infrastructure projects and respondents from different disaster-prone regions to improve the generalizability of the findings. Additionally, integrating quantitative risk assessment techniques with probabilistic models may provide a more comprehensive understanding of occupational safety risks in disaster-prone construction environments.

IV. CONCLUSION

This study successfully applied the AS/NZS ISO 31000:2018 Risk Management Framework to identify, analyze, evaluate, and mitigate occupational safety risks in infrastructure projects located in disaster-prone areas of Palu City.

The findings identified six major categories of occupational safety risks associated with both construction activities and natural disaster hazards. Risk evaluation revealed that the dominant risks across the three case-study projects were classified as High to Extreme, indicating that immediate and systematic mitigation measures are required to protect construction workers.

The Palu IV Bridge Approach Project exhibited the highest tsunami-related risk, where the potential for mass worker fatalities was classified as Extreme with a risk score of 20. In the Electrical Engineering Laboratory Project, earthquake-induced worker fatalities represented the highest risk, also classified as Extreme with a score of 20. Meanwhile, the Palu Riverside Park Project recorded the highest overall risk level, with earthquake-related worker fatalities reaching a risk score of 21 (Extreme).

These findings demonstrate that occupational safety risks are influenced not only by construction activities but also by the dominant natural hazards associated with each project location. Therefore, disaster characteristics should be incorporated into occupational safety risk assessments to ensure that mitigation measures are responsive to site-specific conditions.

Risk mitigation strategies developed in this study were based on the Hierarchy of Risk Controls, including engineering controls, administrative controls, and the proper use of Personal Protective Equipment (PPE). Recommended measures include the installation of early warning systems, provision of emergency evacuation routes, routine inspection of temporary structures and construction equipment, implementation of disaster preparedness training, emergency response simulations, and strict enforcement of PPE compliance.

Overall, the implementation of AS/NZS ISO 31000:2018 provides a systematic and effective approach for improving occupational safety risk management and strengthening the resilience of infrastructure projects located in disaster-prone areas.

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