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DOI: doi.org/10.64780/jeims.v1i1.7

Journal of Engineering Innovation and Management Science Vol 1 No 2. (2025)

Research Article

Integrating Job Safety Analysis (JSA) into Railway Construction Projects: A Risk Based Safety Framework from the Branti Tegineneng Railway Upgrade in Indonesia

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Received : 15 August 2025 | Revised : 11 September 2025 | Accepted : 02 October 2025 | Online : 30 December 2025

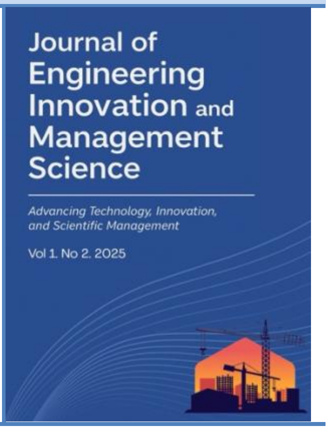
Abstract

This study investigates the integration of Job Safety Analysis (JSA) into railway construction projects as a proactive strategy to enhance occupational safety and risk control. Focusing on the Branti Tegineneng segment of the Tarahan Tanjung Enim railway upgrade in Indonesia, the research addresses the urgent need for structured risk mitigation in complex, high risk infrastructure development. A mixed method approach was applied, involving field observations, document analysis, and quantitative risk assessment based on the AS/NZS 4360:2004 risk management guideline. Forty eight construction activities were systematically analyzed using the JSA framework, which included identifying hazards, evaluating the likelihood and severity of potential accidents, and mapping risk levels using a risk matrix. Findings revealed that a significant number of activities posed medium to high risks, with the most critical hazards associated with manual handling, excavation, material transportation, and improper use of personal protective equipment (PPE). The implementation of JSA led to improved safety awareness, the establishment of control measures such as safety briefings (safety morning), enforcement of PPE use, and the application of work permits and incident response protocols. This study contributes to the development of a practical and adaptable risk based safety framework for infrastructure projects. It demonstrates that JSA not only reduces the probability of accidents but also enhances on-site safety culture. The framework is particularly relevant for developing countries aiming to align construction practices with international safety standards.

Keywords: *Hazard Identification; Job Safety Analysis; Occupational safety; Railway Construction*

How to Cite:

Ashruri, Zakaria, A., & Haviz, M. (2025). Integrating Job Safety Analysis (JSA) into Railway Construction Projects: A Risk-Based Safety Framework from the Branti Tegineneng Railway Upgrade in Indonesia. *Journal of Engineering Innovation and Management Science*, *1*(2), 78–90.



Journal of Engineering Innovation and Management Science

Advancing Technology, Innovation, and Scientific Management

Vol 1. No 2. 2025

INTRODUCTION

Construction projects, particularly those within the infrastructure domain, are consistently identified as high risk environments due to their complex operations and involvement of multiple stakeholders (Hartono et al., 2019; Liu, 2023; Onubi et al., 2019). Among these, railway construction projects are distinguished by their unique challenges, which stem from the simultaneous execution of various technical activities such as track installation, ground stabilization, structural works, and mechanical integration (Ashimova et al., 2023; Cheng et al., 2024). These tasks often require the use of heavy equipment within confined and linear work zones, exposing workers to heightened safety risks (Magfirona et al., 2025; Oswald et al., 2020). Additionally, fluctuating site conditions, time constraints, and the presence of live operational tracks further contribute to the overall hazard potential (Cheng et al., 2024; Guo et al., 2024; Wang et al., 2022). In regions where the enforcement of occupational safety regulations remains partial or inconsistent, such as in many developing countries, the risk of accidents and disruptions becomes even more pronounced (Adhikari & Giri, 2024; Gong et al., 2021; Nurimbetov & Zikriyoev, 2019). Consequently, there is an urgent need for structured safety interventions that are not only responsive but also embedded into the daily workflows of construction teams. This calls for the adoption of proactive safety management frameworks that can detect, assess, and control risks before actual incidents occur. Similar findings on site-specific environmental risks in linear infrastructure zones were reported by (Ardianti et al., 2024) in a noise impact study on motor vehicle traffic near a university corridor.

Indonesia has positioned railway development as a strategic pillar in its national infrastructure agenda, aimed at improving inter regional connectivity and stimulating economic growth (Fadlilah et al., 2024; Prinanda & Prasodjo, 2023; Shabani & Safaie, 2018). One prominent example is the Tarahan Tanjung Enim railway upgrade, particularly the Branti Tegineneng segment, which encompasses a wide array of high-risk construction activities. These include excavation (Wu et al., 2024), lifting of heavy structural components (Folkman et al., 2020), placement of sleepers and rails (Olugbenga et al., 2019), and site preparation under varying terrain conditions (Yu-xiang et al., 2022). Given the dynamic and hazardous nature of such work, the implementation of an effective safety strategy becomes essential to protect both human resources and project timelines. Job Safety Analysis (JSA) emerges as a vital method in this context, offering a structured, step-by-step approach to identifying potential hazards at each phase of a task (Billah et al., 2023; Pramitasari et al., 2021; Rahayu, 2023; Soesilo, 2023). Unlike general safety protocols, JSA provides a task-specific perspective that allows for real-time hazard anticipation and mitigation planning. In practice, this approach can significantly enhance situational awareness, ensure clearer communication between site personnel, and serve as a practical guide for implementing control measures. The core strength of JSA lies in its ability to dissect individual work tasks into sequential operations, allowing stakeholders to examine risks at the micro level and introduce appropriate safeguards accordingly (Djunaidi & Umami, 2024; Hasheminejad et al., 2022). By doing so, JSA fosters a culture of safety ownership, encouraging both management and workers to engage collaboratively in preventing workplace incidents. Furthermore, it enables project supervisors to make informed decisions regarding resource allocation, timing, and procedural adjustments to reduce the likelihood of accidents. Despite the widespread recognition of JSA’s benefits in manufacturing, energy, and general construction sectors, its structured application in railway infrastructure projects especially in developing countries remains limited (Magfirona et al., 2025). Existing safety management frameworks in such contexts often prioritize compliance documentation over operational integration, resulting in gaps between planning and practice. Consequently, many construction teams continue to rely on reactive measures rather than preventive strategies (Al-Bayati, 2021; Tripathi & Mittal, 2024). Addressing this gap requires empirical investigation into how JSA can be effectively adapted and embedded into railway project environments, where the nature of risk is both evolving and localized.

Although the general application of JSA has been reported across various sectors (*Application of the job safety analysis (JSA) method to assessment occupational risk at the workplace of the laser cutter operator*, 2021; Ghasemi et al., 2023; Mahaboon et al., 2022), its usage within construction has largely focused on isolated activities such as scaffolding or workshop operations (Mulyaningsih, 2020; Nudin & Andesta, 2023). On the other hand, research on railway projects has tended to center around broader themes such as environmental safety, cost related risk modeling, and macro level risk frameworks (Wang et al., 2022), with limited emphasis on task-specific safety protocols. Furthermore, emerging approaches like lean risk management or AI-assisted safety assessment highlight innovation in risk management but lack integration with fundamental procedural tools like JSA. This gap is particularly evident in developing countries, where safety tools must be both contextually adaptable and operationally feasible. This study seeks to investigate the incorporation of Job Safety Analysis into a railway construction project in Indonesia, using the Branti–Tegineneng segment as a case. The objective is to develop a risk-based safety framework that facilitates detailed hazard identification, assigns appropriate mitigation strategies, and supports improved safety performance in similar infrastructure development contexts.

METHODS

This research employed a qualitative-quantitative case study approach to examine the implementation of *Job Safety Analysis* (JSA) in a high-risk infrastructure project. The selected case was the railway upgrade project on the Branti Tegineneng segment in Lampung Province, Indonesia, a site characterized by intensive and multi-stage construction activities involving both civil and track works. The complexity and risk profile of the project made it a suitable context for evaluating hazard identification and risk control mechanisms through JSA.

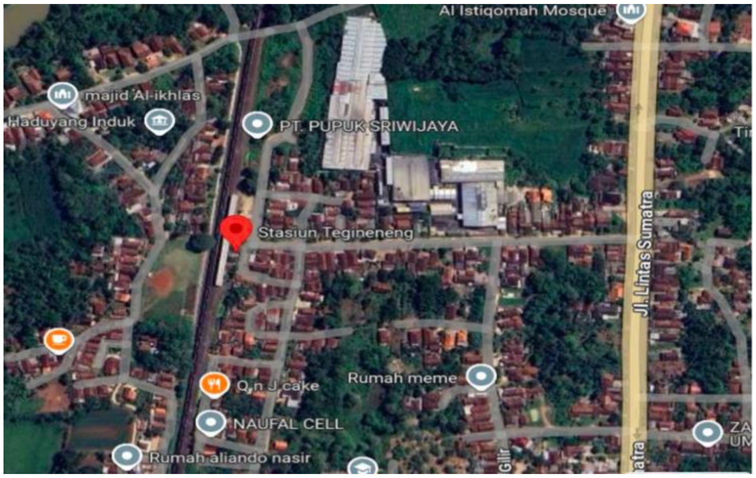


Figure 1. Project location of the Branti Tegineneng segment on the Tarahan–Tanjung Enim railway line (*Source*: Google Earth, 2024).

Data collection was conducted through both primary and secondary sources to ensure a comprehensive understanding of site conditions and safety practices. Primary data were obtained through direct field observations, structured interviews with project personnel, and administration of questionnaires to construction workers and site supervisors. These instruments were designed to capture perceptions of risk likelihood and potential impacts associated with specific tasks. Photographic documentation of construction activities was also carried out to support visual analysis. Secondary data included project planning documents, safety protocols, and national regulations relevant to occupational health and safety, which provided essential context for interpreting field findings.

Job Safety Analysis was applied as the main framework to identify and evaluate hazards at each step of the selected job tasks. A total of 48 construction activities were analyzed by breaking them down into smaller, sequential operations to facilitate targeted risk assessment. Each step was evaluated using a standardized matrix adapted from the AS/NZS 4360:2004 Risk Management Guidelines, which combines the probability of occurrence with the severity of potential consequences. Risk levels were categorized as low, moderate, high, or very high, based on the resulting risk scores. This classification enabled prioritization of safety measures in accordance with the level of urgency and exposure.

The analysis process involved quantifying both likelihood and impact scores using a Likert-type scale ranging from 1 to 5. The overall risk level for each activity was computed by multiplying these two values, producing a composite score that guided the development of appropriate control measures. Tasks identified as high or very high risk were further examined to determine the most effective interventions, which included engineering controls, procedural modifications, and the enforcement of personal protective equipment (PPE) usage. All results were interpreted through descriptive analysis to map the distribution of risks across work categories and to highlight critical points requiring immediate managerial attention.

RESULT AND DISCUSSIONS

Risk Identification

The implementation of Job Safety Analysis (JSA) on 48 job tasks within the Branti–Tegineneng railway upgrade project revealed various potential hazards. These included physical injuries from falling objects, risk of entrapment during excavation, musculoskeletal strain due to repetitive movements, and hazards related to welding and high-temperature materials. Additional risks were attributed to external factors such as uneven ground, poor visibility, and climate variability, which affect the continuity and safety of operations. These findings affirm that railway construction involves multi-layered risks, arising from both operational procedures and environmental dynamics. By breaking down tasks into detailed steps, the JSA method enabled more precise identification of when and where hazards are most likely to occur. This approach provided a baseline for evaluating risk levels and planning interventions accordingly. It also ensured that worker input and real-world site conditions were incorporated into the assessment process. The next phase involved quantifying risk likelihood and severity to categorize the overall risk level for each task.

Risk Level Classification

To assess the probability of hazard occurrence, workers and supervisors were surveyed using a structured questionnaire. Their responses were tabulated into likelihood categories, as shown below:

Table 1. Likehood of Risk Occurrence Based on Questionnaire Responses

Likehood Category	Frequency (Respondents)	Score	Description
Rare (JT)	13	1	My occur under specific conditions
Occasional (KT)	17	2	May occur but infrequent
Possible (DT)	10	3	Reasonably expected
Likely (ST)	-	4	No data reported
Almost Certain (HPT)	40	5	Very likely under normal conditions

The dominant response indicated that hazards were almost certain (HPT), with a likelihood score of 5. Similarly, risk severity was evaluated based on the potential consequences of each hazard:

Table 2. Severity of Risk Impact Based on Questionnaire Responses

Severity Category	Frequency (Respondents)	Score	Description
Insignificant (TS)	10	1	No injury loss
Minor (K)	11	2	Minor injury or small loss
Moderate (S)	19	3	Serious injury, non permanent disability
Major (BR)	-	4	No data reported
Catastrophic (BN)	40	5	Fatality or permanent disruption

From the responses, the most common severity score was also 5, indicating catastrophic risk potential. Based on the AS/NZS 4360:2004 guideline, the final risk score was calculated as:

Risk Score = Likelihood x Severity = 5 x 5 = 25

According to the standard, this falls under the "Very High Risk" category, which requires immediate action and strong managerial oversight.

Risk mapping and Interpretation

The quantitative analysis showed that over half of the tasks fell into the medium to very high-risk categories. Particularly, manual handling, lifting precast components, welding track joints, and working at elevated platforms were classified as high-risk operations. These activities not only involve high energy or mechanical hazards but also depend heavily on human behavior, coordination, and equipment reliability. The risk matrix developed during analysis provided a visual tool to prioritize interventions and monitor hazard exposure throughout the construction phases. It also enabled the project team to identify "hotspots" in the workflow, such as during mobilization and installation, where risk levels consistently spiked. These findings emphasize that safety planning must be dynamic and integrated with actual work sequences, not merely attached as procedural compliance.

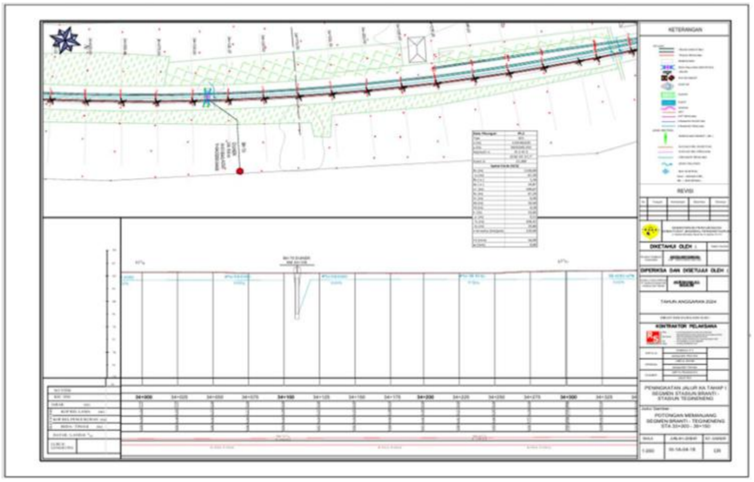


Figure 2. Longitudinal section of the railway track in the Branti-Tegineneg Segment (*Source*: Project Document, 2024)

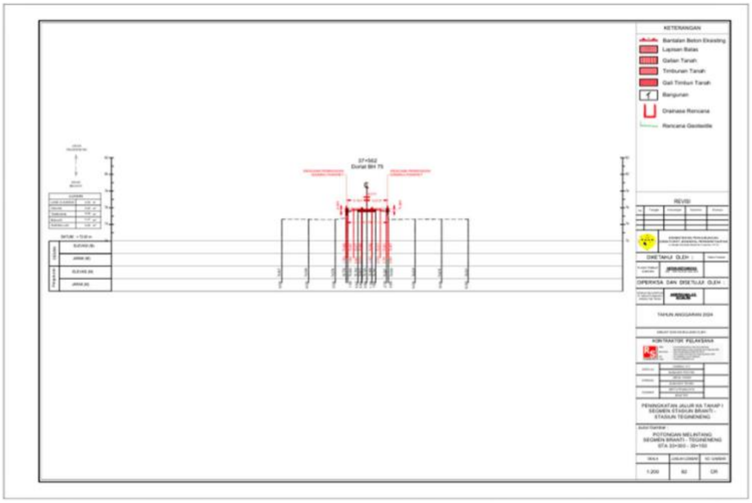


Figure 3. Cross sectional profile of the railway track in the Branti-Tegineneg segment (*Source*: Project Document, 2024)

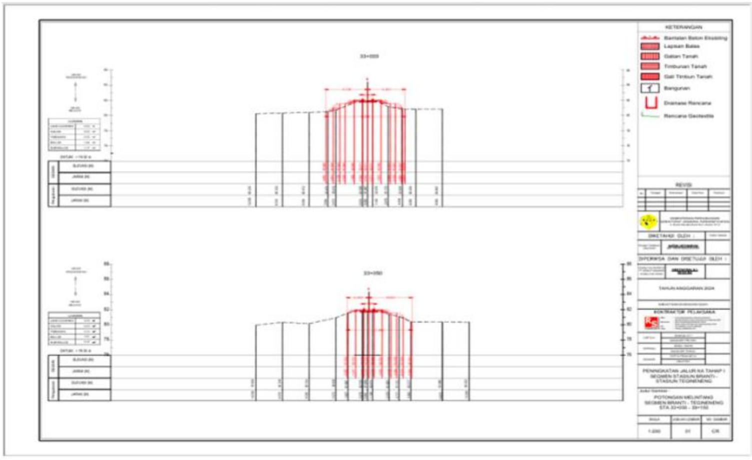


Figure 4. Cross sectional profile of the railway track in the Branti-Tegineneng segment (*Source*: Project Document, 2024)

Implications for Safety Management

The application of JSA throughout the project improved not only hazard detection but also safety awareness among field personnel. Daily "safety morning" briefings, reinforced by the findings from JSA, became a regular platform for communicating risks and procedures. Furthermore, the use of structured documentation, such as accident-fatality harm forms and work permits, contributed to a more disciplined and traceable safety culture. However, the findings also highlighted that the effectiveness of JSA depends on consistent application, timely updates, and full engagement of both management and workers. In dynamic infrastructure projects like railways, where work environments shift frequently, JSA should be treated as a living document that evolves with task progression. As such, JSA serves not only as a risk assessment tool but also as a catalyst for continuous safety improvement embedded within the construction cycle.

Discussion

The findings from the Job Safety Analysis (JSA) conducted on the Branti–Tegineneng railway upgrade project demonstrate that a significant proportion of construction activities fall within medium to very high-risk categories, with tasks involving manual handling, machinery operation, material lifting, and welding identified as the most critical. The predominance of "almost certain" likelihood scores combined with "catastrophic" severity ratings highlights the urgent need for proactive and continuous safety interventions. Risk mapping revealed that hazard exposure peaks during specific stages such as material mobilization, track alignment, and structural installation, where both operational complexity and human factors converge to elevate accident probability. These results underscore the importance of integrating JSA not merely as a compliance tool but as a dynamic element of safety management that evolves alongside the project's progress. The structured breakdown of tasks enabled precise hazard detection, fostering targeted control measures including engineering modifications, administrative controls, and mandatory use of personal protective equipment (PPE). Furthermore, the incorporation of daily safety briefings and formalized work permits reinforced safety discipline and facilitated real-time communication between supervisors and workers. However, the study also indicates that the effectiveness of JSA is contingent upon consistent application, periodic review, and strong engagement from all stakeholders to adapt to changing site conditions. Consequently, embedding JSA into the operational fabric of railway construction projects offers not only a reduction in incident rates but also a sustainable improvement in safety culture across the workforce.

Implication

The outcomes of this study carry substantial implications for both practice and policy in occupational safety management within railway infrastructure projects. By evidencing the effectiveness of Job Safety Analysis (JSA) in systematically identifying hazards and prioritizing risk control measures, the findings provide a practical framework that can be adopted by contractors, project managers, and regulatory bodies to enhance on-site safety performance. The integration of JSA into routine project operations has the potential to shift safety management from a reactive, incident-driven model to a proactive, prevention oriented approach, thereby reducing the frequency and severity of accidents. For policymakers, the results underscore the need to formalize JSA requirements within national safety regulations and to ensure their consistent enforcement across infrastructure projects. Moreover, the emphasis on worker participation and real-time hazard communication demonstrated in this study highlights the value of fostering a safety culture that extends beyond compliance, embedding risk awareness into daily work practices. From an industry perspective, applying the JSA framework can improve resource allocation by directing safety investments toward activities with the highest risk exposure, ultimately enhancing productivity while safeguarding the workforce. In the broader context, these implications suggest that embedding structured risk assessment methods such as JSA in railway construction can serve as a replicable model for other high-risk sectors in developing economies.

Limitation and Suggestion for Further Research

This study is subject to certain limitations that should be acknowledged when interpreting its findings. The analysis was confined to a single railway construction project within a specific geographical and regulatory context, which may limit the generalizability of results to other infrastructure settings or countries with different safety governance structures. Furthermore, the reliance on self-reported data from questionnaires introduces the possibility of response bias, particularly in assessing likelihood and severity scores, which could influence the accuracy of risk classification. The study also adopted a cross-sectional design, capturing hazard profiles at a specific point in time, thus not accounting for changes in risk exposure as project phases progressed. Future research should consider multi-site and longitudinal approaches to capture the dynamic nature of safety risks and evaluate the sustained impact of Job Safety Analysis (JSA) over the lifecycle of construction projects. Incorporating quantitative performance metrics, such as incident rates before and after JSA implementation, alongside qualitative assessments of safety culture, could provide a more comprehensive evaluation. Additionally, comparative studies across different sectors or countries would help to refine and adapt the JSA framework to diverse operational environments. Such efforts would contribute to building a more robust evidence base for integrating structured hazard assessment methods into global occupational safety practices.

CONCLUSION

The application of *Job Safety Analysis* (JSA) in the Branti–Tegineneng railway upgrade project has demonstrated its effectiveness as a structured and proactive tool for hazard identification, risk prioritization, and the development of targeted control measures in high risk infrastructure environments. The study revealed that a substantial proportion of construction tasks fell into medium to very high risk categories, particularly during operationally complex stages such as material mobilization, track alignment, and structural installation. By embedding JSA into daily operations, supported by safety briefings, work permits, and consistent use of personal protective equipment (PPE), the project achieved improved risk visibility and enhanced communication between management and workers. These outcomes underscore the potential of JSA not only to reduce incident rates but also to foster a safety-oriented culture that extends beyond regulatory compliance. However, the findings also highlight the necessity of continuous review and adaptation of JSA to address evolving site conditions and maintain its relevance throughout the project lifecycle. While the results are context-specific, the approach outlined in this study offers a replicable model that can be adapted to other railway and high-risk construction projects, particularly in developing economies. Ultimately, the integration of JSA into formal safety management systems represents a strategic pathway toward sustainable improvements in occupational safety performance.

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AUTHORS CONTIBUTIONS STATEMENT

All authors contributed substantially to the conception and design of the study, as well as to the analysis and interpretation of the data. Ashruri led the conceptualization of the research framework, coordinated field data collection, and prepared the initial manuscript draft. Ahmad Zakaria was responsible for developing the methodology, conducting statistical analyses, and interpreting the findings in the context of existing literature. Muhammad Haviz contributed to the acquisition of project documentation, facilitated stakeholder engagement, and provided critical revisions to enhance the intellectual content. All authors participated in refining the manuscript, approved the final version for submission, and agree to be accountable for all aspects of the work, ensuring the integrity and accuracy of the reported results.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this manuscript. All contributions were conducted independently and without any financial, commercial, or institutional influence that could be perceived as a potential conflict. The research was carried out solely for academic and professional purposes.

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