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Significant Risks Affecting Quality Performance in Road Widening Projects: Evidence from A Probability–Impact Matrix Analysis

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ABSTRACT: Ensuring quality performance in road widening projects remains a significant challenge due to various risks encountered during construction. This study aims to identify significant quality-related risks in road widening projects using a Probability–Impact Matrix (PIM). The research is based on a case study of the Taktakan–Gunung Sari–Anyer road widening project in Banten Province, Indonesia. Risks were identified through interviews with experienced practitioners and a review of relevant literature, followed by expert validation. Nine risks were evaluated in terms of probability and impact using expert judgment and mapped using the PIM. The results reveal three dominant risks with very high significance: material supply delays, equipment breakdown, and material price escalation. These risks indicate that quality performance is strongly affected by operational and procurement-related issues during construction. The study highlights the practical usefulness of PIM as a straightforward and transparent tool for prioritizing quality risks in road projects. The findings provide practical guidance for improving quality risk management in road widening projects, particularly in developing country contexts.

KEYWORDS: Road widening project, Quality risk, Probability–impact matrix, Construction management, Case study

I. INTRODUCTION

Road infrastructure plays a critical role in supporting economic growth, regional connectivity, and social mobility, particularly in developing countries experiencing rapid urbanization and increasing transportation demand. Road networks not only facilitate the movement of goods and people but also serve as key enablers of logistics efficiency, productivity, and regional competitiveness. However, poor quality performance in road construction continues to be a persistent challenge despite the strategic importance of such infrastructure.

In many construction domains, especially road projects, risk management practices are fundamental to achieve successful project outcomes. Risk events, defined as uncertainties with potential negative effects on project objectives, are widely acknowledged to impact project performance, including cost, schedule, safety, and quality (Abdelhalim, 2025). Qualitative risk analysis has been emphasized as an essential process for assessing risks based on both their likelihood and impact, especially where quantitative data are limited and expert judgment is crucial (Abdelhalim, 2025).

Road widening works present unique challenges compared to new alignments because they must be executed under live traffic conditions, constrained workspace, and existing infrastructure constraints. These project characteristics increase the vulnerability to various risks that can influence the quality of workmanship, material performance, and compliance with specification requirements. Despite this, much of the existing literature on road construction risk has focused predominantly on time and cost performance, with less explicit focus on quality-related risks, particularly within the context of road widening projects.

Semi-quantitative risk assessment tools like the Probability–Impact Matrix (PIM) are widely applied in construction risk management to prioritize risks based on their probability of occurrence and magnitude of impact. The PIM is a deterministic tool that classifies risks in a two-dimensional space of likelihood and consequence, enabling practitioners to visually and systematically prioritize risk responses (Asaa, 2025).

While advanced probabilistic approaches exist, the PIM remains valuable for practical risk prioritization when expertise and project data are limited.

A systematic review of risk assessment and scheduling in highway construction highlights the continued use of traditional techniques such as the Probability–Impact (P-I) matrix in evaluating uncertainties in highway projects, while also noting opportunities for integrating more advanced hybrid methods (Zhasmukhambetova, Evdorides & Davies, 2025).

This demonstrates that PIM continues to be relevant in contemporary risk management practice, especially in projects where immediate prioritization of actions is necessary.

However, the application of PIM in road widening projects has been underrepresented in academic research,

particularly in terms of identifying which quality risks are most significant and deserve managerial attention. Existing studies on risk management in construction underline that risks are diverse and project-specific, and that prioritization based on probability and impact is crucial for effective mitigation planning (Zhasmukhambetova, Evdorides & Davies, 2025).

There is still a lack of empirical evidence on how PIM can be used to pinpoint the critical quality risks that should be prioritized in road widening works.

To address this gap, this study aims to identify and prioritize significant risks affecting quality performance in road widening projects using a Probability–Impact Matrix (PIM) analysis. The research is based on empirical evidence obtained from a road widening project on the Taktakan–Gunung Sari–Anyer corridor in Banten Province, Indonesia, where increasing traffic demand and constrained site conditions present significant risk management challenges. By concentrating on risks that have both high likelihood and high impact on quality, the study offers insights that are directly applicable to project management practices, particularly in developing-country contexts where data constraints and execution complexities are common.

II. METHODOLOGY

2.1 Research Design and Approach

This study adopts a qualitative–quantitative mixed approach using a single case study design to identify and prioritize risks affecting quality performance in road widening projects. The methodological framework follows established construction risk management principles, where expert judgment is combined with a Probability–Impact Matrix (PIM) to determine risk significance (Project Management Institute [PMI], 2021; Asaa, 2025).

The overall research process consists of four main stages:

(1) risk identification,

(2) expert validation,

(3) probability–impact assessment, and

(4) risk evaluation using the PIM framework, which has been widely applied in construction risk studies (Kassem & Hamzah, 2019).

2.2 Case Study Description

The empirical analysis was conducted on a road widening project along the Taktakan–Gunung Sari–Anyer corridor in Banten Province, Indonesia. This project involves pavement widening under live traffic conditions, coordination with multiple suppliers, and intensive quality control activities—characteristics that are commonly associated with quality risks in road infrastructure projects in developing regions (Willar et al., 2023).

The case study approach allows for in-depth investigation of context-specific risks while maintaining methodological transferability to similar road widening projects (Zhasmukhambetova et al., 2025).

2.3 Risk Identification

Initial risk identification was conducted using two complementary sources:

(1) semi-structured interviews with construction practitioners experienced in road projects, and

(2) a structured literature review of recent studies on quality risks in road construction.

The use of open-ended interviews enabled respondents to freely articulate risks encountered during construction activities, a technique commonly recommended to capture tacit professional knowledge in construction risk research (Ibironke et al., 2013). Literature-based risks were integrated to ensure completeness and consistency with previous empirical findings (Nyoman, 2019; Willar et al., 2023).

2.4 Expert Validation of Risks

To enhance contextual relevance, the preliminary risk list was validated by five senior practitioners with more than fifteen years of experience in road construction projects. Expert validation was conducted using a five-point Likert scale to assess the importance of each risk, following approaches proposed by Ibironke et al. (2013) and adapted by Kassem and Hamzah (2019).

Risks with a mean importance score below 3.0 were excluded from further analysis, ensuring that only risks with meaningful implications for quality performance were retained.

2.5 Probability–Impact Assessment

Validated risks were assessed using the Probability–Impact Matrix (PIM), a semi-quantitative technique widely used in construction risk prioritization (Asaa, 2025). Experts evaluated each risk in terms of probability of occurrence and impact on quality using a five-point ordinal scale.

Mean probability and impact scores were calculated for each risk and subsequently plotted within a 5×5 PIM, allowing systematic comparison and prioritization of risks (Kassem & Hamzah, 2019).

2.6 Risk Evaluation and Significance Criteria

Risk evaluation was performed by mapping risks into predefined PIM zones, classified as low, medium, high, and very high-risk levels. Risks positioned within the high and very high zones were classified as significant risks, consistent with standard risk evaluation practices in construction management (PMI, 2021).

These significant risks constitute the primary output of the study and serve as the basis for discussion and managerial implications.

2.7 Reliability and Ethical Considerations

Reliability was enhanced through the use of multiple expert respondents and aggregation of judgments using mean values, reducing individual bias (Hillson & Murray-Webster, 2017). Ethical considerations included voluntary

participation, anonymity of respondents, and exclusive use of data for academic purposes.

III. RESULTS

3.1 Identified and Validated Risks

The initial risk identification process generated a total of 21 potential risks affecting quality performance in road widening projects, derived from practitioner interviews and a structured literature review. Following expert validation, nine risks were retained for further analysis after excluding risks with a mean importance score below the threshold of 3.0.

This validation step ensured that only risks with direct and substantial relevance to construction quality were analyzed, consistent with expert-based risk screening practices recommended in construction risk management literature (Ibironke et al., 2013; Kassem & Hamzah, 2019).

3.2 Probability–Impact Assessment Results

The validated risks were evaluated using the Probability–Impact Matrix (PIM) based on expert judgments regarding the likelihood of occurrence and the severity of impact on quality performance. Mean probability and impact scores were calculated for each risk and plotted on a 5×5 PIM grid, allowing systematic comparison of risk significance.

Table 1 summarizes the mean probability and impact scores for the nine validated risks.

Table 1. The Mean Probability and Impact Scores

No.	Risk Description	Mean Impact (I)	Mean Probability (P)
1	Unskilled labor	1.4	3.1
2	Heavy equipment breakdown	4.9	5.0
3	Material supply delays	5.0	4.9
4	Fluctuation in material quality from suppliers	3.4	1.8
5	Poor work methods / incorrect construction methods	2.4	2.6
6	Material price escalation	4.8	4.9
7	Limited availability of construction equipment	1.9	4.3
8	Inadequate quality supervision	2.4	2.5
9	Technical design errors	2.7	2.8

The results show clear differentiation among risks, with several risks clustering in the high and very high zones of the PIM, indicating elevated concern for quality outcomes. The use of mean-based aggregation reduces individual expert bias and provides a stable representation of collective professional judgment (Hillson & Murray-Webster, 2017).

3.3 Significant Risks Identified

Based on the PIM evaluation criteria, three risks were classified as significant, as they were positioned within the very high (dark red) risk zone, reflecting a combination of high probability and high impact on quality performance. These risks are:

1. Equipment breakdown,
2. Delay in material supply, and
3. Material price escalation.

The positioning of these risks in the upper-right quadrant of the PIM indicates that they pose the most critical threats to achieving the required quality standards in road widening projects. Similar findings have been reported in previous studies, where disruptions in equipment availability and material supply chains were found to strongly influence construction quality outcomes (Willar et al., 2023; Asaa, 2025).

3.4 Relative Risk Characteristics

Among the significant risks, ***material supply delays*** exhibited the highest combined probability and impact scores, indicating frequent occurrence and direct consequences for construction quality. Practitioners noted that delayed material delivery often leads to work acceleration, compromised workmanship, and deviations from quality specifications.

Equipment breakdown ranked second in significance, primarily due to its immediate effect on construction continuity and the quality of pavement operations. Equipment-related disruptions frequently require adjustments in work sequencing, which can negatively affect compaction quality and construction consistency.

Material price escalation, while categorized as a significant risk, primarily affects quality indirectly. Experts emphasized that price volatility may encourage material substitution or reduced material usage, potentially compromising compliance with technical specifications. This indirect pathway aligns with findings in prior studies on cost-driven quality risks in infrastructure projects (Kassem & Hamzah, 2019).

3.5 Summary of Key Findings

Overall, the PIM analysis demonstrates that quality performance in road widening projects is most vulnerable to risks associated with material supply and equipment availability, rather than purely technical design issues. The results highlight the importance of focusing quality risk management efforts on supply chain reliability and equipment management during project execution.

The identification of these significant risks provides a focused empirical basis for developing targeted mitigation strategies, which are discussed in the subsequent section.

IV. DISCUSSION

4.1 Interpretation of Significant Risks

The findings of this study indicate that quality performance in road widening projects is primarily affected by operational and supply-chain-related risks, rather than purely technical or design-related factors. The identification of equipment breakdown, material supply delays, and material price escalation as significant risks suggests that construction quality is highly sensitive to disruptions occurring during the execution phase.

This result reinforces the perspective of modern construction risk management frameworks, such as those outlined by Project Management Institute (2021), which emphasize that risks with high likelihood and high impact should be prioritized regardless of whether they originate from technical or non-technical sources.

4.2 Material Supply Delays as the Dominant Quality Risk

Among the identified significant risks, material supply delays emerged as the most critical threat to quality performance. This finding aligns with recent empirical studies indicating that delays in material delivery often force contractors to accelerate construction activities, reduce curing periods, or compromise workmanship to recover lost time (Willar et al., 2023; Asaa, 2025).

In road widening projects conducted under live traffic conditions, such as the case study corridor in Banten Province, delayed material availability can disrupt carefully planned work sequences and increase the likelihood of quality deviations. This supports prior findings that supply chain reliability is a key determinant of quality outcomes in road infrastructure projects in developing regions (Zhasmukhambetova et al., 2025).

4.3 Equipment Breakdown and Construction Continuity

The second most significant risk identified is equipment breakdown, which directly affects construction continuity and the consistency of pavement operations. Equipment failures often necessitate changes in construction methods, interruptions in compaction or paving processes, and extended idle times, all of which can adversely affect quality performance.

This observation is consistent with the findings of recent road construction quality studies, which highlight the strong linkage between equipment availability, process stability, and final construction quality (Willar et al., 2023). From a risk management perspective, this result underscores the importance of preventive maintenance and equipment readiness as integral components of quality assurance, rather than being treated solely as operational concerns.

4.4 Indirect Quality Effects of Material Price Escalation

While material price escalation was classified as a significant risk, its influence on quality performance is largely indirect. Experts indicated that price volatility may lead contractors to seek alternative materials, reduce material quantities, or delay procurement decisions, thereby increasing the risk of non-compliance with technical specifications.

This finding supports previous studies suggesting that cost-related risks can translate into quality risks through managerial decision-making pathways rather than immediate technical failure (Kassem & Hamzah, 2019). The result highlights an important insight: risks that do not directly affect construction processes may still significantly influence quality outcomes through strategic and procurement-related decisions.

4.5 Implications for Quality Risk Management Practice

The dominance of operational and supply-chain risks in the PIM results suggests that quality risk management in road widening projects should extend beyond traditional technical controls. While design accuracy and workmanship remain important, proactive management of logistics, procurement, and equipment reliability appears to be equally critical for maintaining quality performance.

This finding is consistent with recent interpretations of ISO 31000:2018, which emphasizes the need for integrated risk management across organizational, operational, and technical domains. By focusing on high-priority risks identified through the PIM, project stakeholders can allocate quality control resources more effectively and improve decision-making under uncertainty.

4.6 Contribution to Existing Literature

This study contributes to the existing body of knowledge by providing empirical evidence from a real road widening project in Indonesia, demonstrating how the Probability–Impact Matrix can be used as a practical and transparent tool to identify quality-critical risks. Unlike studies that combine multiple risk analysis techniques, this paper shows that PIM alone is sufficient to highlight dominant quality risks when supported by expert validation.

The findings complement recent international studies that advocate for focused, practitioner-oriented risk prioritization methods in infrastructure projects, particularly in contexts where data availability is limited but expert knowledge is abundant (Asaa, 2025; Zhasmukhambetova et al., 2025).

CONCLUSIONS

This study investigated significant risks affecting quality performance in road widening projects using a Probability–Impact Matrix (PIM) approach supported by expert validation. Based on empirical evidence from the Taktakan–Gunung Sari–Anyer road widening project in Banten Province, the analysis identified three dominant quality-related risks: material supply delays, equipment breakdown, and material price escalation.

The findings demonstrate that operational and supply-chain-related risks pose a greater threat to construction

quality than purely technical or design-related risks. Among the identified risks, material supply delays emerged as the most critical due to their high likelihood and direct influence on construction sequencing and workmanship quality. Equipment breakdown was found to significantly disrupt construction continuity, while material price escalation affected quality indirectly through procurement and managerial decision-making.

From a methodological perspective, this study confirms that the Probability–Impact Matrix, when combined with expert judgment, provides a practical, transparent, and effective tool for prioritizing quality risks in road infrastructure projects. The results suggest that even without advanced quantitative simulations, PIM-based analysis can yield actionable insights for quality risk management, particularly in contexts where data availability is limited but practitioner experience is substantial.

Practically, the study highlights the need for project stakeholders to integrate quality management with logistics planning, equipment management, and procurement strategies, rather than focusing exclusively on technical specifications and workmanship control. By prioritizing high-risk areas identified through PIM, contractors and project owners can allocate resources more effectively and strengthen quality assurance during project execution.

Despite its contributions, this study is limited to a single road widening project and focuses solely on risks affecting quality performance. Future research may extend this approach to multiple project cases, compare different risk prioritization techniques, or explore the interaction between quality, cost, and schedule risks. Nonetheless, the findings provide contextualized empirical evidence that supports the use of PIM as a robust decision-support tool for managing quality risks in road widening projects.

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