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Risk Identification and Response Strategies for Urban Road Maintenance: A Case Study of Jakarta's Routine Maintenance Task Force

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ABSTRACT: Urban road-maintenance activities play a central role in sustaining mobility, service reliability, and infrastructure performance in dense metropolitan environments. This study aims to identify significant risks affecting routine road-maintenance operations in Jakarta, a megacity that relies heavily on rapid-response systems driven by citizen reporting. The research adopts a structured risk-identification and evaluation approach based on the ISO 31010 Probability–Impact Matrix (PIM). An initial set of fifty-two risks was identified through literature review and expert interviews, then refined to thirty-six validated risks following expert assessment. These risks were subsequently evaluated using a quantitative survey in which practitioners rated the probability and impact of each risk on a five-point scale. Mean probability and impact values were plotted directly into the PIM adapted from Kaseem and Hamzah (2019), producing a color-coded visualization of risk significance. Ten risks were classified as significant, occupying the red-zones (light and dark) of the matrix. The most dominant risks derive from three primary domains: (1) environmental exposure, notably heavy and extreme rainfall, which severely disrupts workflow and increases defect volumes; (2) resource limitations, including shortages of materials, damaged equipment, and insufficient personnel; and (3) operational challenges related to dense traffic, public non-cooperation, and inaccuracies in citizen-reporting data from the CRM platform. These findings highlight the complex operational landscape of Jakarta's maintenance ecosystem, shaped by climatic variability, resource constraints, and urban-behavioral factors. The identified significant risks offer a practical basis for prioritizing improvements in resource planning, public engagement, and maintenance coordination. The study contributes empirical insights for enhancing resilience and responsiveness in urban road-maintenance management, with relevance for other rapidly growing cities facing similar infrastructural pressures.

KEYWORDS: Urban road maintenance, risk identification, probability–impact matrix, operational risk, Jakarta

I. INTRODUCTION

Urban road networks play a vital role in supporting mobility, economic productivity, and social connectivity in metropolitan areas. As cities grow denser and more complex, the functionality of urban road infrastructure depends heavily on continuous routine maintenance, not only on large construction projects. Routine maintenance activities often face operational constraints, unpredictable field conditions, and the growing expectations of urban residents for rapid service response. These challenges make risk identification a critical step in improving the reliability of municipal maintenance operations (Strong, 2012).

Jakarta, Indonesia's capital and one of the world's largest megacities, is undergoing rapid transformation in its effort to become a competitive global city. Achieving this vision requires modern, reliable, and well-maintained road infrastructure, which supports economic activity, human mobility, and urban services. With a road network exceeding 6.5 million m², Jakarta faces significant challenges due to heavy traffic load, urban density, and environmental factors such as flooding and extreme rainfall. The responsibility for routine road maintenance lies with the Dinas Bina Marga and its operational workforce, the *Penyedia Jasa lainnya Perorangan* (PJLP), who perform direct field repairs daily.

In parallel with infrastructure modernization, Jakarta has adopted citizen-centric reporting mechanisms to increase transparency and responsiveness. The Citizen Relationship Management (CRM) platform enables residents to submit reports on potholes, damaged sidewalks, and malfunctioning streetlights. Such digital platforms have been widely recognized for improving governance and community participation, but also introduce a larger and more unpredictable workload for maintenance teams (Asada et al., 2022). By 2023, CRM recorded thousands of infrastructure reports, reflecting increasing public expectations for immediate responses. The volume of these reports intensifies the operational pressure on PJLP teams, making the identification of significant risks essential for ensuring service effectiveness.

Literature on infrastructure risk management commonly focuses on construction projects, long-term maintenance contracts, deterioration modeling, or major infrastructure failures. Studies specifically addressing routine municipal road maintenance—particularly in dense urban settings of developing countries—remain limited. Even research on citizen-report-driven maintenance systems tends to emphasize digital governance rather than operational risks encountered by field technicians. Strong (2012) emphasizes that operational road maintenance involves complex risk factors related to traffic exposure, inadequate equipment, and environmental conditions—factors highly relevant to Jakarta's context.

Furthermore, unlike performance-based contracts or contractor-driven maintenance systems, municipal maintenance teams operate under unique constraints. These include limited resources, shifting priorities due to CRM reports, and varied working conditions across densely populated urban environments. Several studies show that urban maintenance risks may include material shortages, limited equipment availability, hazardous traffic conditions, and workforce-related issues such as insufficient training or uneven manpower distribution (Sahoo et al., 2020). Environmental factors such as drainage failure, extreme weather, and road aging also contribute to recurring risks in urban maintenance operations (Asada et al., 2022).

These factors indicate a clear research gap, particularly concerning which risks are most significant in the daily operations of municipal road maintenance in megacities. A structured and data-driven identification of significant risks is crucial to improving maintenance performance. As highlighted by international studies, robust risk identification enhances decision-making, resource allocation, and overall maintenance planning (Adnyana, 2019).

Given these challenges, this study aims to identify significant risks in Jakarta's routine road maintenance operations, focusing specifically on the risks faced by the PJLP task force. This research does not propose mitigation strategies but builds a foundational understanding of significant operational vulnerabilities. Identifying these risks is an essential first step toward improving Jakarta's maintenance effectiveness and supporting the city's broader vision of becoming a globally competitive metropolis.

This paper is structured as follows. The Methods section presents the risk assessment approach based on probability–impact scoring. The Results section provides the list of identified risks and highlights the significant ones. The Discussion interprets these findings in relation to international literature on urban maintenance risks. The Conclusion summarizes key insights and proposes opportunities for future research.

II. METHODOLOGY

This study applies a descriptive qualitative and quantitative risk-assessment approach designed to identify the significant risks that affect routine road maintenance operations conducted by PJLP under Dinas Bina Marga DKI Jakarta. The research design adheres to the ISO 31000:2018 framework and its derivative ISO 31010:2019, ensuring that risk identification and analysis follow a structured, systematic, and internationally recognized procedure. Consistent with the research flowchart presented in the Figure 1, the methodology integrates literature review, expert validation, field-based surveys, and probability–impact analysis as the main pillars of the research process.

This study adopts a structured risk-assessment methodology consisting of sequential stages that begin with risk identification and progress toward determining significant risks using the Probability–Impact Matrix (PIM). The methodological flow is grounded in established risk management references, particularly Ibironke et al. (2013) and Kaseem & Hamzah (2019), whose frameworks integrate expert-based assessment and matrix-based risk evaluation.

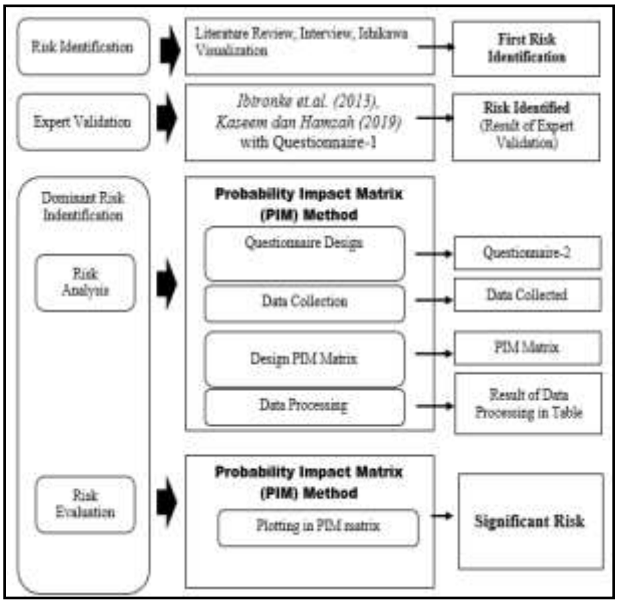

Figure 1. Flowchart Metodhology

The research process began with literature review and expert interviews to compile an initial list of potential risks associated with routine urban road maintenance. This preliminary stage ensured that the risk universe reflected both theoretical knowledge and field realities. Literature sources related to urban infrastructure maintenance, operational risks, and construction management were reviewed, while expert interviews contributed contextual insights from practitioners directly involved in maintenance operations. This combined approach aligns with recommendations in prior maintenance risk research, which emphasize the importance of merging literature-based and experience-based risk identification (Ibironke et al., 2013).

The initial set of risk variables was then subjected to expert validation, conducted through the first questionnaire (Questionnaire-1). Experts assessed the relevance and clarity of each identified risk, and only variables that were confirmed as valid and contextually significant were advanced to the next stage. The outcome of this step was a refined list of risks representing practitioner-verified operational challenges. Validation through expert judgement is consistent with methodological standards outlined by Kaseem & Hamzah (2019), who highlight that expert consensus is a crucial filter before quantitative scoring.

After completing the expert validation stage, the refined list of risk variables was assessed through a structured questionnaire designed to capture the probability and impact of each risk event. Respondents evaluated every validated risk using a five-point Likert scale for each dimension, following the principles of the Probability–Impact Matrix (PIM) method widely used in infrastructure and maintenance risk studies (Kaseem & Hamzah, 2019).

In this assessment, the probability dimension represented how likely a risk was to occur during routine road-maintenance operations, while the impact dimension captured the extent of operational disruption that could arise if the risk materialized. All responses were collected and the probability and impact values for each risk were averaged across respondents, generating representative mean scores for both dimensions.

These mean probability and impact values were then plotted directly into the Probability–Impact Matrix (PIM) adapted from Kaseem & Hamzah (2019). The matrix positions probability along one axis and impact along the other, producing a two-dimensional mapping of risk conditions. Unlike approaches that rely on calculating a composite risk score, this study emphasizes the visual classification of risks based solely on their plotted positions in the matrix, which aligns with qualitative risk-evaluation practices recommended in maintenance-risk literature (Sakai, 2008).

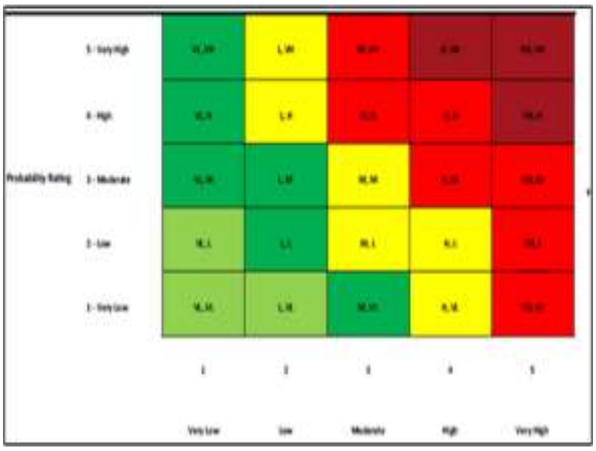

Figure 2. PIM Matrix (Kaseem & Hamzah, 2019)

The PIM used in this study contains color-coded zones that represent increasing levels of risk significance. Risks falling within the red-zones (light and dark) of the matrix were classified as significant risks, as these represent scenarios where both the likelihood of occurrence and operational impact are elevated. Risks plotted in lower-intensity color zones—such as yellow or green—were categorized as moderate or low risks, and thus did not form the focus of this study.

By emphasizing plotting rather than numerical scoring, this approach prioritizes interpretability and aligns with the matrix-based evaluation techniques frequently used in operational-risk management, where visual zone-classification is considered sufficient to establish risk significance for managerial decision-making (Strong, 2012). This method ensures clarity in identifying which risks require immediate attention and provides a robust foundation for discussing the dominant risks that affect routine urban road-maintenance activities.

III. RESULT AND DISCUSSION

The Probability–Impact Matrix (PIM) assessment generated a clear visualization of the distribution of risks associated with routine road-maintenance operations in Jakarta. From the 36 validated risks assessed through the survey, several risks were positioned in the High (pink) and Very High (dark red) significance zones of the matrix. These zones represent combinations of higher probability and higher operational impact, indicating risks that significantly disrupt maintenance workflows, workforce efficiency, and response times.

Based on the plotted results, ten risks were identified as significant. These risks originate from environmental conditions, resource limitations, operational constraints, and social–urban interactions. Table 1 summarizes all significant risks.

Table 1. PIM Matrix (Kaseem & Hamzah, 2019)

No.	Risk Code	Description of Significant Risk	PIM Zone	Level of Significance
1	R.01	Public indifference during ongoing maintenance work	Red Zone (dark)	Very High
2	R.02	Heavy rainfall / extreme rainy season	Red Zone (dark)	Very High
3	R.06	Limited availability of maintenance materials	Red Zone (light)	High
4	R.09	Inability to complete work due to weather conditions	Red Zone (light)	High
5	R.18	Damage to tools and maintenance equipment	Red Zone (light)	High
6	R.20	Heavy traffic conditions during maintenance activities	Red Zone (light)	High
7	R.25	Unequal distribution	Red	High

		of workload among teams	Zone (light)	
8	R.30	Insufficient number of maintenance personnel	Red Zone (light)	High
9	R.32	Delayed reporting from the public	Red Zone (light)	High
10	R.33	Inaccurate location information in citizen reports (CRM)	Red Zone (light)	High

The distribution of risks within the PIM reveals several thematic clusters that reflect systemic operational challenges in Jakarta's routine road-maintenance environment.

1. Environmental and Weather-Related Risks

Weather-related risks (R.02 and R.09) represent the most severe category, occupying the Very High and High zones. Seasonal heavy rainfall and extreme weather conditions significantly disrupt field operations by delaying work, creating rework, and reducing mobility. This is consistent with Sakai (2008), who emphasized that weather variability is one of the most influential external factors affecting urban-road maintenance efficiency. In tropical megacities such as Jakarta, rainfall amplifies defect occurrence (potholes, subsidence) while simultaneously reducing the operational window for field teams.

2. Resource-Availability Risks

Material shortages (R.06), equipment failures (R.18), and limited personnel availability (R.30) emerged prominently in the High zone. These findings align with international studies (Sahoo et al., 2020), which note that insufficient materials and inadequate funding often lead to cascading delays and inefficient task sequencing. The operational readiness of the maintenance force heavily depends on consistent material supply and equipment reliability; disruptions in these areas prolong repair cycles and influence overall service quality.

3. Operational Constraints in Urban Context

Dense traffic conditions (R.20) and uneven distribution of workload among teams (R.25) highlight the complexity of carrying out maintenance work in a densely populated metropolitan environment. Traffic congestion increases safety risks and limits the feasibility of lane closures, while workload imbalance reduces overall productivity. These observations are consistent with findings from Strong (2012), which show that urban maintenance teams often experience delays due to traffic hazards and inefficient task allocation.

4. Social and Community-Interaction Risks

Public indifference toward ongoing maintenance work (R.01) represents a Very High risk and underscores the social dimension of maintenance challenges. Non-cooperative behavior can compromise worker safety and hinder operational efficiency. This aligns with literature noting that public behavior significantly affects urban maintenance operations, particularly in high-density areas.

5. Risks Related to the Citizen-Reporting System (CRM)

Two significant risks (R.32 and R.33) stem directly from the characteristics of Jakarta's CRM digital reporting platform. Delayed reports slow down the initiation of maintenance responses, while inaccurate location information increases verification time and dispatch inefficiency. Similar issues have been documented in smart-city maintenance systems worldwide, where citizen-generated data require verification and sometimes introduce operational noise rather than clarity.

The combined results indicate three overarching themes:

a. Environmental exposure (rainfall, weather disruptions)
→ These are unavoidable but must be proactively managed.

b. Internal resource constraints (equipment, materials, manpower)
→ These are systemic and require long-term planning and budget alignment.

c. Urban-operational complexity (traffic, citizen reports, worker-public interaction)
→ These require behavioral, procedural, and regulatory solutions.

The convergence of these themes reflects Jakarta's position as a megacity with intense mobility demands, climatic vulnerability, and heavy reliance on public-reporting mechanisms. The risks identified offer an evidence-based foundation for redesigning maintenance strategies, optimizing resource allocation, and improving CRM integration within operational workflows.

CONCLUSIONS

This study identified and analyzed significant risks that affect routine road-maintenance operations in Jakarta using a Probability–Impact Matrix (PIM) approach. From an initial list of validated risks, ten risks were classified within the High and Very High zones of the matrix, indicating elevated levels of both likelihood and operational impact. These risks primarily fall into three clusters: environmental exposure, resource limitations, and urban-operational challenges. Weather-related factors such as heavy rainfall emerged as the most severe, significantly disrupting maintenance schedules and increasing defect occurrences. Resource-related risks—including shortages of materials and equipment, as well as insufficient personnel—were found to contribute substantially to delays and inefficiencies in field operations. Additionally, social and urban-interaction factors such as traffic congestion, public non-cooperation, and inconsistencies in citizen-reporting data further hinder effective service delivery.

The findings highlight that Jakarta's routine road-maintenance system operates within a complex risk environment shaped by climatic conditions, resource constraints, and dense urban dynamics. Addressing these significant risks will require an integrated strategy that strengthens resource management, enhances operational coordination, and improves public-engagement mechanisms. The insights produced in this study can support policymakers, infrastructure agencies, and urban-maintenance managers in designing more resilient and responsive maintenance frameworks. Future research may incorporate predictive modelling, cost–benefit analysis, or simulations to explore mitigation pathways and evaluate their potential effectiveness.

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