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Analysis of Influence Optimization Factors of Risk Management Strategies in Infrastructure Projects

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Abstract

This study examines the risk factors that influence the optimization of risk management strategies in infrastructure projects through a quantitative survey of 31 professionals. The research highlights common risks, including poor planning, financial issues, and changes in client requirements, which significantly impact project schedules and budgets. Risk identification, assessment, and response practices were initially surveyed using a straightforward questionnaire that included rating scale items and space for open-ended comments. The collected data were then analyzed in SPSS, where a correlation was discovered between stakeholder engagement and risk responses. These findings suggest that effective risk management relies on early planning, evidence-based decision-making, and effective coordination. The study bridges theoretical frameworks with practical insights, offering recommendations for enhancing risk management strategies in infrastructure projects.

Keywords
Risk Management, Infrastructure Projects, Risk Factors, Stakeholders

1. Introduction
Risk management is a key to the success of an infrastructure project (Khatib 2022; Owili, Paul, and Lango 2025). The

risk management project aims to increase the probability and impact of positive events and reduce the likelihood and impact of adverse events, which can be detrimental to the project (Alhammadi et al. 2021). The effectiveness of risk management strategies is crucial in infrastructure projects, as they enable the identification, assessment, and mitigation of risks that can impact a project's schedule, budget, and overall success (Rasheed et al. 2022). However, challenges such as inadequate risk assessment, poor stakeholder coordination, and reactive approaches often result in cost overruns and delays, underscoring the need for optimized risk management strategies. This study analyses risk factors that influence the effectiveness of risk management strategies through a structured questionnaire survey distributed to industry professionals. The aim is to enhance decision-making and ensure sustainable project outcomes grounded in empirical evidence.

Many infrastructure projects have recently failed because risks are improperly assigned or managed (Osei-Kyei, Narbaev, and Ampratwum 2022). Poor planning, lack of clear responsibility, and weak communication often cause cost overruns and delays (Daoud et al. 2023; Omran et al. 2023). These problems are compounded by unpredictable external factors, such as climate change, supply chain disruptions, and changing regulations, which complicate risk management. Projects remain vulnerable to preventable failures without a systematic strategy to address these challenges. Therefore, identifying and optimizing key factors influencing risk management effectiveness is critical to ensuring infrastructure resilience and long-term viability.

To address this challenge, this study uses a structured questionnaire survey targeting professionals (e.g., project managers, engineers) to collect quantitative data on the risk management strategies in infrastructure projects. The questionnaire survey is designed for professionals directly involved in infrastructure development, including project managers, engineers, consultants, and contractors, who can offer valuable insights based on their practical experience. It is designed to gather insights into their experiences with risk identification, assessment, allocation, and mitigation. The responses will be analyzed using SPSS software to identify significant risk factors, the relationships between different variables. The results will provide evidence-based recommendations to optimize risk management strategies and improve the overall success of infrastructure projects.

The questionnaire method was chosen because it can gather diverse insights directly from professionals working across various organizational levels, capturing authentic, real-world perspectives on risk management practices. It proved effective in generating empirical data by reflecting practitioners' actual experiences and perceptions, which is critical for drawing robust, evidence-based conclusions (Rufat et al. 2022). To ensure the survey was relevant and comprehensive, its design was informed by a thorough review of current literature and refined with expert feedback. This approach adheres to widely accepted research standards, emphasizing the importance of well-structured questionnaires for collecting reliable data and facilitating meaningful analysis.

In conclusion, this study aims to contribute meaningful insights to the broader discussion on improving risk management in infrastructure projects. By identifying and analyzing the practical risk factors that influence the optimization of risk management strategies, the research provides a clearer understanding of what supports or hinders their effectiveness. These findings are intended to help various stakeholders, including project managers, engineers, consultants, and contractors, by offering concrete, evidence-based recommendations that can be applied to real-world projects. Furthermore, this paper bridges the gap between academic research and field practice by combining theoretical perspectives from the literature with data collected from professionals through the questionnaire. The outcomes of this study will likely support the development of more effective, responsive, and sustainable risk management strategies in the infrastructure sector.

2. Literature Review

In infrastructure projects, risk factors significantly impact cost, time, quality, and overall success. Addressing these risks effectively involves not only allocating them to the appropriate stages of the project but also evaluating their level of influence on critical parameters such as cost, quality, and time (Lapidus et al. 2022). Highlight the potential factors that influence the duration of the projects and the estimated cost for infrastructure projects. Identify all related risk factors and identify scenarios that can lead to technical accidents (Fošner et al. 2024). Therefore, risk factors are crucial in optimizing risk management strategies for an infrastructure project, enabling the identification of risks and their impact on the project.

Various approaches have been explored in recent literature to enhance the effectiveness of risk management in infrastructure projects. One such strategy involves integrating advanced technologies such as Building Information

Modelling (BIM) and Digital Twin (DT), which enable real-time monitoring, simulation, and forecasting across a project's life cycle (Yang et al. 2025). These tools contribute to early risk detection and proactive mitigation by providing visual and data-driven insights into project performance (Revolti et al. 2024). In addition to technological innovations, collaborative risk management frameworks emphasizing stakeholder engagement and adaptive governance have gained attention. These frameworks promote shared responsibility, transparent communication, and flexibility in responding to evolving risks, particularly in complex or uncertain environments (McNaught 2024). Moreover, analytical methods such as questionnaire surveys and quantitative risk assessments provide a strong theoretical foundation by collecting direct insights from experts and stakeholders, and identifying key factors that influence risk outcomes. Collectively, these approaches highlight a shift toward more proactive, integrated, and data-informed risk management strategies in the infrastructure sector.

Risk factors in infrastructure projects refer to any conditions or events that have the potential to hinder the achievement of project objectives, whether in terms of cost, time, quality, or operational sustainability. Major risk factors for construction projects include inefficient planning, execution constraints, external and client-induced issues, partner experience, lack of project management knowledge, and organizational culture (Deep et al. 2022; Sikhupelo and Amoah 2024). Understanding these risk factors is crucial for preventing delays, cost overruns, and quality deficiencies in infrastructure projects. Consequently, a structured and proactive risk management approach should be embedded throughout all phases of project planning and execution to ensure efficiency and long-term sustainability.

In infrastructure projects, various risk factors have been identified as the major causes of delays and cost overruns. Factors such as the contractor's financial difficulties, late payment by the project owner, design change during construction, and inadequate project management are significant factors linked to time and cost overruns of Saudi Arabian construction projects (Kumi et al. 2024). Moreover, changes in design, client-induced modifications, strict project deadlines, lack of skilled labor, and faulty work execution are the key risk factors shaping the success of construction projects in the Dominican Republic (Fernández-Valderrama et al. 2024). These findings underscore the importance of identifying and mitigating risks throughout the planning phase to ensure the effectiveness and viability of infrastructure projects.

Recent literature has begun to explore how digital tools, such as BIM and digital twins, are often adopted in infrastructure risk management through structured surveys. For example, a study introduced a Structural Equation Modelling (SEM) framework, based on a questionnaire of project team members, to assess readiness factors and success drivers for BIM–DT integration in sustainable construction (Alnaser et al. 2024). Likewise, a recent questionnaire survey involving infrastructure professionals examined the application of digital twin technology across various domains, including transportation and utilities, using Likert-scale-based questionnaires to capture practitioner perceptions (Awodele et al. 2025). Building on this body of research, this study employs a structured questionnaire survey targeting professionals involved in infrastructure development, including project managers, engineers, consultants, and contractors. The survey examines respondents' experiences with risk identification, monitoring, and coordination, focusing on the perceived benefits (e.g., early failure detection, cost savings, faster decision-making) and common barriers (e.g., limited digital skills, system issues, stakeholder resistance). The collected data will be analyzed using SPSS software to identify statistically significant factors and examine the relationships between key variables. This analysis will help determine how digital innovation can be effectively leveraged to optimize risk management strategies in infrastructure projects.

The reviewed literature emphasizes that effective risk management is crucial to the success of infrastructure projects, particularly in terms of cost control, timely delivery, and quality assurance. A wide range of internal and external risks, including poor project planning, financial instability, and stakeholder-related challenges, have been identified as key contributors to project delays and cost overruns. To address these challenges, recent studies have emphasized the importance of integrating advanced digital technologies and collaborative frameworks that support real-time monitoring, proactive risk mitigation, and stakeholder engagement. Furthermore, quantitative approaches such as questionnaire surveys and SEM analysis have proven effective in identifying the most influential risk factors and evaluating their impact. These insights underscore a growing shift toward more data-driven, adaptive, and integrated strategies for optimizing risk management in the infrastructure sector.

2.1 Risk Factors Affecting Project Optimization

Successful management in infrastructure projects demands careful attention to some factors that play an important role in key objectives, specifically cost, time, and quality (Namazian 2025). Several causes of delays, such as those listed in the following table, can influence risk factors (Table 1).

Table 1. Risk Factors and Cause of Delay

Risk Factors	Cause of Delay
Design Changes or Variation	Change in orders, delay in approval of drawings, and mistakes and discrepancies in drawings (Arantes and Ferreira 2021).
Financial Problem	Financial constraints on the contractor's part, delays in payment progress by the client, and changes in the price of materials (Yap et al. 2021).
Deficient Planning	Infrastructure governance. Improper planning and scheduling, construction mistakes, and unrealistic contract schedules and specifications (Obi et al. 2021).
Variations by the Client	Slow decision-making by the client, frequent changes in client requests, and client dissatisfaction (Kamal et al. 2022).
Deficient Work Management	The nature of complexity and uncertainty in construction projects, combined with poor management (Guo and Zhang 2022).
Climate Conditions	Weather conditions and natural disasters (Zhang et al. 2023)

Delays in infrastructure projects are often attributed to a complex of risk factors (Elshamy, Elghaish, and Brooks 2025). Technical problems, such as design changes, financial difficulties like delayed payments, and extreme weather conditions, can all cause disruptions. For example, a study of construction projects in Central Aceh, Indonesia, found that poor cost estimation and the rushed adoption of new technologies were major contributors to project delays (Rauzana and Usni 2020). Similar issues were also identified in Peru, where inaccurate site data and slow approval of design changes frequently pushed timelines off track (Julca-Varas et al. 2025).

In addition to technical and financial issues, how a project is managed and the broader environment in which it operates can significantly impact its schedule. Weak planning, ineffective communication, and shortages in skilled labor are significant challenges in Egypt's large-scale construction projects (Daoud et al. 2023). In Ethiopia, researchers highlighted how political instability and broader economic conditions added serious uncertainty to infrastructure delivery (Mekonen et al. 2025). Similarly, a study focusing on construction projects in Indonesia identified land acquisition delays, poor planning, and inadequate coordination among stakeholders as significant contributors to project delays, especially in public-sector developments (Susanti et al. 2021). These challenges suggest that successful project execution isn't just about engineering; it's also about leadership, coordination, and adaptability to change.

The complexity and interdependence of risk factors necessitate comprehensive and proactive risk management strategies. Traditional methods, while valuable, may not sufficiently address the dynamic nature of modern infrastructure projects. Innovative approaches, such as data-driven risk modelling using artificial intelligence, have been proposed to enhance the identification and assessment of risks throughout a project's lifecycle (Erfani 2023). Moreover, adopting integrated simulation platforms can aid in analyzing the resilience of interconnected infrastructure networks, thereby informing more effective risk mitigation strategies (Balakrishnan and Cassottana 2022).

To truly optimize risk management in infrastructure, project teams must take a holistic view, looking beyond individual risks to understand the broader landscape of challenges they may face. Embracing new technologies, improving stakeholder communication, and being ready to adapt quickly are all essential. Doing so can enhance the likelihood of finishing on time and within budget, as well as the overall quality and sustainability of infrastructure projects.

2.2 Role of Stakeholders

Stakeholders' involvement significantly influences the effectiveness of risk management strategies in infrastructure projects. These projects typically involve various stakeholders, including project teams, government agencies, local communities, and private companies. Each group has different goals, knowledge, and opinions about risk (Rodrigues et al. 2024). The diversity (heterogeneity) and sometimes clashing priorities (incongruence) among stakeholders can

result in differing judgments about which risks should be prioritized and how to manage them. These differences often lead to discrepancies both between and within stakeholder groups, especially during critical project stages such as handover to operations (Rodrigues et al. 2024).

Engaging stakeholders early and consistently throughout a project is widely recognized as a powerful way to improve risk management (Osemeike Gloria Eyieyien et al. 2024). Social network analysis helps gather insights from diverse individuals, making it easier to spot risks that might otherwise be missed. For instance, a method that combines feedback from various stakeholders with social network tools has proven helpful in identifying which team interactions may cause problems during construction. Engagement with stakeholders also helps share knowledge, build skills, and ensure everyone understands the goals, especially in asset-intensive sectors like public utilities.

However, insufficient stakeholder participation can increase project vulnerability, such as delays, cost overruns, and stakeholder conflicts (Julca-Varas et al. 2025). Research in public infrastructure projects shows that excluding key groups or not using their knowledge often leads to missed risks and poor accountability (Sikhupelo and Amoah 2024). Inclusive and transparent stakeholder processes, which bring together technical teams, users, and policy entities, are crucial for capturing a broader range of risk inputs and fostering shared ownership of mitigation measures. Without such collaboration, risk management strategies risk misalignment with stakeholder needs and miss opportunities for resilience and innovation.

3. Methods

This research employs a quantitative approach, utilizing a structured questionnaire survey, to identify and analyze risk factors that influence the optimization of risk management strategies in infrastructure projects. The objective of this approach is to evaluate risk management practices in civil engineering projects based on the direct experiences of professionals actively involved in infrastructure project implementation, such as project managers, engineers, consultants, and contractors.

The survey instrument was developed based on a literature review that covered key aspects of risk management, including systematic risk identification, stakeholder engagement, the use of historical data, the application of quantitative risk assessment tools (e.g., a 1–5 Likert scale), and the effectiveness of mitigation strategies. In addition to closed-ended questions, the questionnaire also included open-ended questions to capture qualitative insights regarding common risk factors and suggestions for improving risk management strategies.

The collected data were analyzed using the Statistical Package for the Social Sciences (SPSS) software. The analysis techniques employed included descriptive and inferential statistics, as well as factor analysis, to identify relationships between variables and the dominant factors influencing risk management practices. This approach provides a strong foundation for developing evidence-based recommendations to improve the effectiveness of risk management in infrastructure project management optimization by integrating the real-world perspectives of professionals.

4. Data Collection

The data collection process was conducted through an online questionnaire distributed using the WhatsApp platform, targeting professionals active in infrastructure projects in Batam City. This distribution medium was chosen due to ease of access and the broad reach of respondents from various project types, such as roads, bridges, and dams.

The questionnaire consisted of two main sections: (1) closed-ended questions based on a Likert scale to measure the level of agreement with risk variables, and (2) open-ended questions to elicit respondents' opinions and experiences regarding the risk management challenges they face in the field. The questionnaire was developed based on a literature review and underwent a limited pilot test to ensure clarity and relevance.

A total of 31 respondents successfully completed the questionnaire, with varying work experience ranging from less than 5 years to more than 20 years. Data collection took place over a period of three weeks. All respondents were informed that participation was voluntary and that the data provided would be kept confidential. This was done to maintain data integrity and encourage openness in answering questions.

5. Results and Discussion

This study examined the risk factors that influence the optimization of risk management strategies in infrastructure projects through a comprehensive survey of 31 professionals in Batam City, Indonesia. The research employed a quantitative approach, utilizing structured questionnaires and statistical analysis via SPSS, to identify significant risk factors and their relationships to effective risk management practices.

5.1 Participant Demographics and Professional Representation

The survey successfully captured a diverse cross-section of infrastructure project professionals, ensuring comprehensive representation across various experience levels and professional roles. The demographic analysis revealed that the largest proportion of respondents (42%) were aged 25-30 years, representing early to mid-career professionals who are actively engaged in contemporary infrastructure projects. This age distribution suggests that the findings reflect current industry practices and modern risk management challenges (Figure 1).

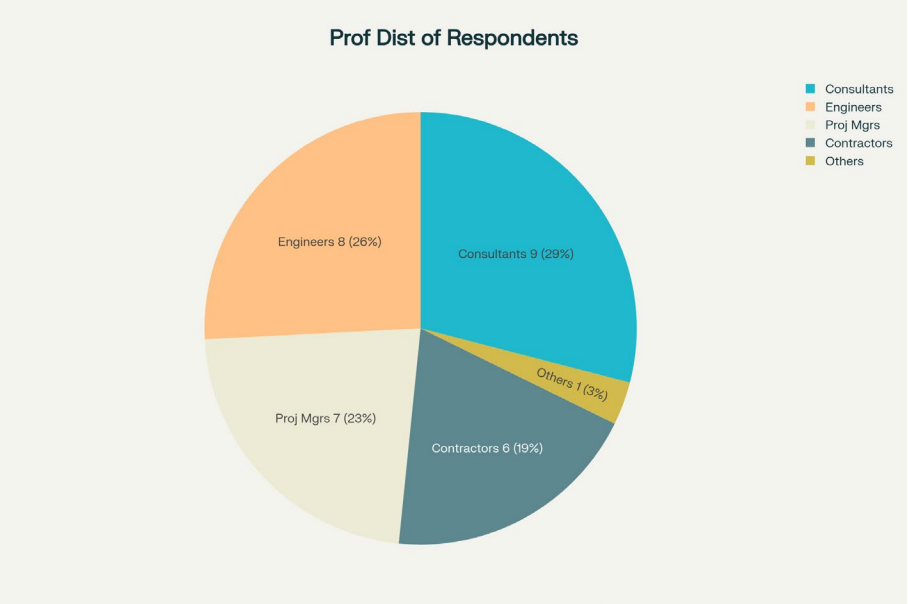

Figure 1. Professionals of the respondents

The professional composition of respondents demonstrated strong representation across key infrastructure project roles. Consultants comprised the largest group at 29% (9 respondents), followed by engineers at 26% (8 respondents), project managers at 23% (7 respondents), and contractors at 19% (6 respondents). This distribution is particularly significant as it encompasses the primary stakeholders involved in infrastructure risk management, from planning and design through implementation and execution phases. Regarding work experience, the survey captured professionals across all experience levels, with the largest group (38%) having 5-10 years of experience, followed by equal representation (23% each) of highly experienced professionals with 11-20 years and more than 20 years of experience[1]. This experience distribution provides a balanced perspective that combines contemporary practices with seasoned insights from veteran professionals.

5.2 Risk Factor Identification and Analysis

The thematic analysis of risk factors identified by respondents revealed clear patterns in the types of risks most encountered in infrastructure projects. When asked to identify the three most frequently encountered risks in their professional practice, respondents consistently highlighted internal management and coordination issues as primary concerns (Figure 2).

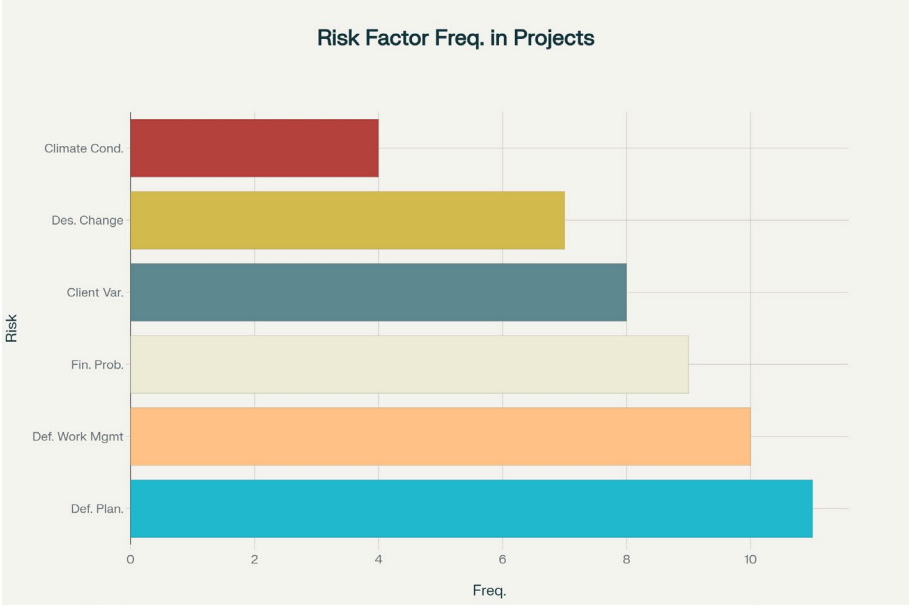

Figure 2. Frequency of Risk Factors Identified by Infrastructure Project Professionals

1. **Deficient Planning** emerged as the most frequently cited risk factor, identified by 11 respondents (35.5% of the sample). This finding aligns with existing literature that emphasizes the critical importance of comprehensive project planning in infrastructure development. The prevalence of planning-related risks suggests that, despite advances in project management methodologies, fundamental planning deficiencies persist in infrastructure projects in the region.
2. **Deficient Work** Management ranked as the second most common risk factor, cited by 10 respondents (32.3%). This category encompasses issues such as miscommunication, lack of coordination between teams, and scheduling inaccuracies. The high frequency of work management issues indicates that operational coordination remains a significant challenge in infrastructure project execution.
3. **Financial Problems** were identified by nine respondents (29.0%), reflecting concerns about cost overruns, material price fluctuations, and payment delays. This finding is consistent with global trends in infrastructure project management, where financial risks persist as a significant challenge across various geographical contexts.
4. **Client Variations emerged** as a notable risk factor, cited by eight respondents (25.8%). This category includes uncertainty stemming from client-induced changes, design modifications, and policy direction changes during project implementation. The prominence of client-related risks highlights the importance of stakeholder management and clear communication protocols in infrastructure projects.
5. **Design Changes or Variations** were identified by seven respondents (22.6%), typically referring to modifications made during the construction phase that can disrupt project implementation processes. While less frequent than planning and management issues, design-related risks remain significant concerns for project success.
6. **Climate Conditions** were mentioned by only four respondents (12.9%), indicating that while environmental factors have an impact, they are not currently perceived as primary risks among professionals in the study region. This relatively low ranking may reflect the specific geographical and climatic characteristics of the study area, or suggest that climate-related risks are currently underestimated in risk management practices.

5.3 Statistical Correlation Analysis

The Pearson correlation analysis conducted using SPSS revealed several statistically significant relationships between risk management practices, providing important insights into the factors that contribute to effective risk management optimization. The strongest correlation identified was between the existence of a documented risk response plan and the clarity of risk response strategies ($r = 0.916$; $p < 0.01$). This very strong positive correlation suggests that when organizations develop formal risk response plans, the development of mitigation strategies becomes more transparent and systematic. This finding supports the theoretical framework that emphasizes the importance of structured documentation in risk management processes.

A significant correlation was found between risk prioritization processes based on likelihood and impact and the use of structured quantitative assessment tools ($r = 0.710$; $p < 0.01$). This relationship confirms that data-driven decision-making and quantitative methods play a crucial role in developing more objective and measurable risk rankings. The finding aligns with contemporary risk management literature that advocates for evidence-based approaches to risk assessment.

Another important correlation was identified between regular risk monitoring in project meetings and the provision of regular risk information updates to the team ($r = 0.765$; $p < 0.01$). This relationship highlights the importance of maintaining ongoing communication and conducting regular evaluations to manage the dynamic nature of risks throughout the project lifecycle. The correlation supports the stakeholder engagement theory that emphasizes continuous communication as a critical component of effective risk management. The analysis also revealed that early stakeholder involvement in projects was positively correlated with the tendency to use historical data in the risk assessment process. This finding reflects the importance of experience-based approaches as a foundation for identifying and understanding potential risks, suggesting that stakeholder engagement facilitates knowledge transfer and learning from past experiences.

5.4 Discussion of Findings

The findings of this study provide several important insights for optimizing risk management strategies in infrastructure projects. The dominance of internal management factors (deficient planning and work management) in risk identification suggests that infrastructure projects in the study region are primarily vulnerable to controllable, internal factors rather than external uncertainties. This pattern indicates significant opportunities for improvement through enhanced project management practices and organizational capabilities. The strong correlations identified in the statistical analysis demonstrate that effective risk management is fundamentally dependent on systematic approaches that integrate documentation, quantitative assessment, and continuous communication. The strong correlation between documented risk response plans and strategy clarity ($r = 0.916$) suggests that formalizing risk management processes is crucial for achieving consistent and effective risk responses.

The findings also highlight the interconnected nature of risk management practices. The correlation between risk prioritization and quantitative tools ($r = 0.710$) suggests that organizations that invest in structured assessment methods are more likely to develop effective risk prioritization systems. Similarly, the relationship between regular monitoring and information updates ($r = 0.765$) suggests that systematic communication practices are essential for maintaining risk awareness throughout project lifecycles.

5.5 Implications for Practice

The study results suggest several practical recommendations for infrastructure project organizations. First, the prominence of planning-related risks indicates that organizations should prioritize investment in comprehensive project planning processes, including risk identification workshops, stakeholder engagement sessions, and scenario planning exercises. Second, the strong correlation between documented risk response plans and strategy clarity suggests that organizations should develop formal risk management documentation systems that clearly articulate response strategies for identified risks.

The findings also emphasize the importance of quantitative risk assessment tools in improving prioritization accuracy. Organizations should consider implementing structured risk assessment methodologies that incorporate both likelihood and impact assessments, supported by historical data and stakeholder input. Ultimately, the correlation between monitoring and communication indicates that regular risk review meetings and systematic information-sharing protocols are crucial for maintaining risk awareness and facilitating proactive responses.

5.6 Limitations and Future Research

While this study provides valuable insights into risk management optimization factors, several limitations should be acknowledged. The sample size of 31 respondents, although appropriate for exploratory research, may limit the generalizability of the findings to broader geographical contexts or different types of infrastructure projects. Additionally, the focus on professionals in Batam City may reflect regional characteristics that differ from other infrastructure development contexts.

The study's reliance on self-reported data regarding risk management practices may introduce response bias, as participants may overestimate the effectiveness of their risk management approaches. Future research could benefit from incorporating objective measures of risk management effectiveness, such as project performance outcomes or comparative case studies. The relatively low emphasis on climate-related risks (cited by only four respondents) warrants further investigation, particularly given the increasing importance of climate change adaptation in infrastructure development. Future studies should explore whether this finding reflects actual risk conditions or potential gaps in risk awareness among professionals.

5.7 Contribution to Knowledge

This study contributes to the infrastructure risk management literature by providing empirical evidence of the relationships between specific risk management practices and their effectiveness. The strong correlations identified between documentation, quantitative assessment, and communication practices offer evidence-based guidance for optimizing risk management strategies in infrastructure projects[1]. The findings also bridge the gap between theoretical risk management frameworks and practical implementation by demonstrating how specific practices contribute to overall risk management effectiveness. The research provides a foundation for future studies exploring risk management optimization in infrastructure projects, particularly in developing country contexts where infrastructure development is rapidly expanding. The methodology employed, combining demographic analysis, thematic risk identification, and correlation analysis, offers a replicable approach for similar studies in different geographical or sectoral contexts.

6. Conclusion

This empirical study has provided valuable insights into the factors influencing the optimization of risk management strategies in infrastructure projects, through a comprehensive analysis of the experiences of 31 professionals in Batam City, Indonesia. The research employed a structured quantitative approach utilizing questionnaires and statistical analysis to identify significant risk factors and their relationships to effective risk management practices. The study revealed that infrastructure projects in the study region are predominantly vulnerable to internal management-related risks rather than external uncertainties. Deficient planning emerged as the most critical risk factor, identified by 35.5% of respondents, followed by deficient work management (32.3%) and financial problems (29.0%)[1]. These findings suggest that the primary challenges in infrastructure project risk management stem from controllable organizational factors, indicating substantial opportunities for improvement through enhanced internal capabilities and systematic approaches. The statistical correlation analysis revealed several significant relationships that provide evidence-based guidance for optimizing risk management. The strongest correlation identified was between documented risk response plans and strategy clarity ($r = 0.916$; $p < 0.01$), highlighting the critical importance of formal documentation in risk management processes. Additionally, significant correlations were found between risk prioritization and quantitative assessment tools ($r = 0.710$; $p < 0.01$), and between regular risk monitoring and information updates ($r = 0.765$; $p < 0.01$).

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