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# Analysis of Factors that Influence the Optimization of Risk Management Strategies in Infrastructure Projects

# Analisis Faktor-Faktor yang Mempengaruhi Optimalisasi Strategi Manajemen Risiko pada Proyek Infrastruktur

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***ABSTRACT***

*Infrastructure projects frequently experience challenges such as cost overruns and schedule delays, which are often linked to ineffective risk management practices. These issues are particularly prominent in developing regions, where regulatory complexity, limited coordination among stakeholders, and organizational constraints intensify project risks. Effective risk management is therefore essential to improving project performance and ensuring successful project delivery. This study aims to identify and analyze the key risk factors that influence the optimization of risk management strategies in infrastructure projects, focusing on professional practices in Batam City, Indonesia. This study employs a quantitative approach, with data collected through an online questionnaire distributed to infrastructure professionals, including project managers, engineers, consultants, and contractors. Using purposive sampling, 31 valid responses were obtained from practitioners with direct experience in infrastructure project implementation. The questionnaire assessed perceptions of common risk factors, risk management practices, and indicators related to the optimization of risk management strategies. Data analysis was conducted using SPSS, employing descriptive statistics and correlation analysis to examine the relationships between risk management practices and optimization outcomes. The results indicate that internal risk factors, particularly inadequate planning and ineffective work management, have a more significant influence on risk management performance than external risks such as climatic conditions. Financial instability, frequent design changes, and client-driven variations were also identified as major contributors to project risk. Furthermore, the findings reveal a positive correlation between proactive stakeholder involvement, systematic risk identification, and the effectiveness of risk response strategies. The use of historical project data and formal risk documentation was found to support improved risk mitigation outcomes. This study concludes that optimizing risk management strategies in infrastructure projects requires an adaptive and evidence-based approach, emphasizing early planning, stakeholder collaboration, and continuous risk monitoring. The findings provide practical insights for practitioners and decision-makers seeking to enhance risk management practices in similar infrastructure project contexts.*

## 1. Introduction

Risk management is key to the success of infrastructure project [1], [2]. The risk management project tries to improve the possibility and impact of positive events while decreasing the likelihood and impact of negative events that can harm the project [3]. The effectiveness of risk management strategies is critical in infrastructure projects, because they enable the detection, assessment, and mitigation of risks that might damage a project's schedule, budget, and overall success [4], [5]. However, challenges in infrastructure projects remain significant. Several infrastructure projects have lately collapsed due to inappropriate risk assignment or management. These problems are often caused by poor planning, lack of clarity of responsibilities and weak communication [6], [7], [8]. As a result, projects often experience cost overruns and delays. Unpredictable external factors like climate change, supply chain issues, and changes in the law make these internal problems worse. Without a clear way to deal with these problems, projects are likely to fail even though it could have been avoided.

To address this issue, previous academic research has focused on the development of theoretical frameworks and advanced digital models, such as BIM and Digital Twin [9]. However, there is a gap between these theoretical models and their implementation in the infrastructure projects. This research aims to bridge the gap by offering insights drawn directly from professionals.

In Indonesia, infrastructure projects particularly those in the public sector continue to struggle with recurring issues such as cost overruns and schedule delays. Previous studies indicate that these problems are commonly driven by inadequate upfront planning, poor coordination among project stakeholders, land acquisition difficulties, and limited financial capacity [10]. Such risks are further compounded by complex regulations, lengthy administrative processes, and challenging site conditions. Although infrastructure development has accelerated in recent years, risk management practices in Indonesia tend to be applied in a reactive and fragmented manner. This situation underscores the importance of context-specific, practice-based research that explores how risk management strategies can be strengthened and optimized at the project level [11].

This study therefore focuses on examining practical risk factors that affect the optimization of risk management strategies, aiming to deepen understanding of factors that either enhance or constrain their effectiveness. The results are intended to support infrastructure practitioners by delivering evidence-based insights applicable to real-world project implementation [12].

The scope of this research is specifically focused on achieving these objectives. The study uses a quantitative approach through a questionnaire survey. The data are limited to the perceptions and practical experiences of 31 infrastructure professionals including project managers, engineers, consultants, and contractors currently working on various projects in Batam. The analysis focuses on key variables such as risk factors (e.g., deficient planning, financial problems) and management practices (e.g., stakeholder engagement) to generate locally relevant, evidence-based recommendations.

## 2. Literature Review

Risk factors are crucial elements in infrastructure projects due to their significant impact on cost, time, and quality. Optimizing a risk management strategy requires an approach that goes beyond simple identification. This process should include in-depth analysis, such as evaluating the impact of each risk on key project parameters, identifying specific factors affecting duration, cost, and mapping potential scenarios for technical accidents [13], [14], [15]. Thus, a detailed understanding of risk factors provides a strategic foundation for mitigating negative impacts and ensuring project success.

To improve the effectiveness of risk management, recent literature highlights several integrated approaches. Advanced technologies such as Building Information Modeling (BIM) and Digital Twin (DT) have a direct impact on risk identification by enabling real-time simulations to detect potential design conflicts or delays early [16]. Through visual and data-driven representations of project performance, these technologies enable early risk detection and more proactive mitigation efforts [17]. This technological approach is reinforced by a collaborative framework that leverages stakeholder engagement to broaden the scope of risk identification, capturing perspectives that might otherwise be overlooked [18]. This strategy is then validated through analytical methods such as questionnaire surveys, which provide quantitative data to prioritize the most critical risk factors based on expert insights [19]. The collective impact of these integrated methods is a shift from reactive problem-solving to proactive, data-driven strategies that provide a much more comprehensive understanding of project risks.

In infrastructure projects, risk factors are any circumstances or occurrences that could make it more difficult to accomplish project goals, whether the factors are related to cost, time, quality, or operational sustainability. Understanding these issues is critical for reducing delays, cost overruns, and quality flaws. These key risk factors include internal issues such as inefficient planning, implementation constraints, inadequate understanding of project management and corporate culture, as well as external issues [20], [21]. For example, a study in Saudi Arabia highlighted contractor financial difficulties, late payments by the project owner, and inadequate project management as significant factors [22] Similarly, research in the Dominican Republic identified design changes, client-requested modifications, and lack of skilled labor as key risks [23]. Therefore, to ensure project efficiency and sustainability, a disciplined and proactive risk management approach must be used throughout the planning and execution phases.

Recent studies have examined the adoption of digital tools, such as Building Information Modeling (BIM) and Digital Twin, in infrastructure risk management through structured survey-based approaches. A study applied a Structural Equation Modeling (SEM) method using questionnaires distributed to project team members to evaluate preparation criteria and success determinants for BIM-DT integration in sustainable construction [24]. A recent survey involving infrastructure professionals investigated the application of digital twin technologies across various sectors, including transportation and utilities, by employing Likert-scale questionnaires to assess professional perspectives [25]. These studies emphasize the importance of professional empirical data in the use of digital tools that can be effectively integrated into infrastructure risk management practices.

The existing literature indicates that infrastructure project failures, including schedule delays and cost overruns, are commonly driven by a variety of risks, such as inadequate planning, financial instability, and challenges related to stakeholder coordination. To address these challenges, recent studies highlight a shift toward more data-driven, adaptive, and integrated strategies to optimize risk management. These approaches typically combine advanced digital technologies and collaborative frameworks that support real-time monitoring and stakeholder engagement, alongside quantitative techniques such as questionnaire-based surveys to identify and assess the most critical risk factors. Although advanced digital tools are discussed in literature, this study primarily focuses on managerial and organizational risk factors as perceived by professionals.

## 2.1 Risk Factors Affecting Project Optimization

Effective infrastructure project management depends on a thorough understanding of the factors that substantially impact key objectives, including cost, time, and quality [26], [27]. Various factors contributing to delays, as outlined in the subsequent table, can affect risk factors.

Table 1. *Risk Factors and Causes 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 [28]. |
| Financial Problem | Financial constraints on the contractor's part, delays in payment progress by the client, and changes in the price of materials [29]. |
| Deficient Planning | Infrastructure governance. Improper planning and scheduling, construction mistakes, and unrealistic contract schedules and specifications [30]. |
| Variations by the Client | Slow decision-making by the client, frequent changes in client requests, and client dissatisfaction [31]. |
| Deficient Work Management | The nature of complexity and uncertainty in construction projects, combined with poor management [32]. |
| Climate Conditions | Weather conditions and natural disasters [33][34]. |

Infrastructure project delays are frequently caused by a variety of risk factors [35]. Poor cost estimation and the early adoption of new technology were found to be significant drivers to project delays in a study of building projects in Central Aceh, Indonesia [36]. Similar problems were also found in Peru, where schedules were regularly delayed due to inaccurate site data and delayed acceptance of design modifications [37].

A project's schedule can be greatly impacted by management practices and the larger context in which it functions, in addition to technical and financial concerns. Large-scale building projects in Egypt face serious difficulties due to poor planning, poor communication, and a lack of competent workers [7]. Researchers in Ethiopia emphasized how the delivery of infrastructure was seriously unclear due to instability in politics and general economic difficulties [38]. Similarly, research on building projects in Indonesia found that poor planning, inadequate coordination among stakeholders, and delays in land acquisition were major causes of project delays, particularly in public-sector developments [39]. These difficulties imply that effective project management requires more than simply engineering; it also requires coordination, leadership, and flexibility. While these studies have successfully identified various risk factors across different geographic contexts, there remains a gap in research that quantitatively analyzes how these factors influence the optimization of risk management strategies, particularly from the perspective of professionals in Batam. Therefore, this study aims to address this gap by offering locally relevant, data-driven recommendations.

Comprehensive and proactive risk management solutions are required due to the complexity and connection of risk factors. Despite the benefits they provide, traditional approaches might not adequately handle the dynamic character of contemporary infrastructure projects. Various strategies have been proposed to improve the detection and evaluation of risks at every stage of a project's execution, such as data-driven risk modeling with artificial intelligence [40]. Additionally, the use of integrated simulation platforms can support resilience assessments in interconnected infrastructure networks by providing insights into more effective risk mitigation strategies [41]. These risk minimization strategies often include early stakeholder engagement to establish shared responsibility for mitigation measures, leveraging historical, and implementing adaptive strategies to effectively respond to challenges.

Project teams must adopt a comprehensive approach, going beyond specific risks to comprehend the wider range of difficulties likely to be encountered, to genuinely maximize risk management in infrastructure. It is crucial to embrace new technology, enhance stakeholder communication, and be prepared to quickly adjust. By doing this, infrastructure projects' overall quality and sustainability can be improved, as well as their chances of being completed on schedule and under budget.

### 2.2 Role of Stakeholders

Effective risk management techniques in infrastructure projects are greatly influenced by stakeholders' participation. Various stakeholders, such as project teams, governmental organizations, local communities, and private businesses, are frequently involved in these initiatives. Every organization has distinct objectives, levels of expertise, and perspectives on risk [42]. Differences of opinion about which risks prioritizing and how to manage them can arise from diverse and sometimes conflicting priorities among stakeholders. This variation often leads to disagreements within and between stakeholder groups, especially during crucial project phases such as handover to operations [42].

It is commonly acknowledged that one of the most effective ways to enhance risk management is to involve stakeholders early on and continuously throughout a project [43]. Social network analysis facilitates the collection of perspectives from a variety of people, making it simpler to identify risks that could otherwise go undetected. For example, a technique that integrates social network tools with feedback from multiple stakeholders has been useful in identifying team relationships that could be problematic during construction [44]. Particularly in asset-heavy industries like public utilities, engaging with stakeholders improves sharing of information, talent development, and goal understanding.

Insufficient stakeholder participation may increase project vulnerability leading to delays, cost overruns, and conflicts among stakeholders [37]. Studies on public infrastructure projects indicate that the exclusion of significant stakeholders or the failure to leverage their expertise frequently results in overlooked risks and reduced accountability [20]. Stakeholder processes that are inclusive and transparent, involving technical teams, users, and policy entities, are crucial for gathering a wider range of risk inputs and developing collective ownership of mitigation strategies. In the absence of collaboration, risk management strategies may become misaligned with stakeholder needs and overlook opportunities for resilience and innovation.

## 3. Methodology

This study employed a quantitative research approach using a structured questionnaire survey to identify and analyze risk factors influencing the optimization of risk management strategies in infrastructure projects. A quantitative approach was selected to enable systematic measurement of professional perceptions and statistical analysis of relationships among variables.

The respondents consisted of infrastructure professionals, including project managers, engineers, consultants, and contractors, who were actively involved in infrastructure projects in Batam City, Indonesia. The questionnaire was distributed online to practitioners working on various types of infrastructure projects, such as roads, bridges, and dams. A total of 31 valid responses were collected using purposive sampling to ensure that all participants possessed relevant professional experience.

The questionnaire design was informed by an extensive review of prior research addressing risk factors and risk management practices in infrastructure projects. The independent variables include common risk factors and risk management practice indicators, such as inadequate planning, financial issues, design changes, client-driven variations, stakeholder involvement, utilization of historical project data, and the effectiveness of risk response strategies. The dependent variable is the optimization of risk management strategies, which is defined as the perceived consistency and effectiveness of risk management practices throughout the project lifecycle. Although project performance outcomes related to cost, time, and quality are acknowledged, this study specifically emphasizes professionals' perceptions of how risk management strategies are applied in practice.

Responses were measured using a five-level Likert scale, where values ranged from strong disagreement to strong agreement. The collected data was processed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistical techniques were employed to summarize respondent profiles and identify dominant risk factors, followed by Pearson correlation analysis to evaluate the relationships between risk variables and risk management optimization.

## 4. Results and Discussion

The findings of this study are derived from questionnaire data collected via an online survey platform. A total of 31 infrastructure professionals participated in the study, providing empirical insights into factors influencing the optimization of risk management strategies within infrastructure development projects.

The data analysis was carried out using SPSS software, focusing on examining correlations between key risk factors. Descriptive statistics were used to summarize response characteristics and highlight the most frequently identified risks. The analysis revealed that financial problems, design changes, deficient planning, and client-driven variations are among the most significant concerns. These findings are discussed with existing studies, offering insights into how risk management strategies can be strengthened in infrastructure projects.

Table 2. *Age of Respondent*

| Numbers | Age of Respondents | Number of Responses | Percentage (%) |
|---|---|---|---|
| 1 | 25-30 Years | 13 | 42 |
| 2 | 31-35 Years | 3 | 10 |
| 3 | 36-40 Years | 5 | 16 |
| 4 | 41-45 Years | 5 | 16 |
| 5 | Above 45 Years | 5 | 16 |
| | TOTAL | 31 | 100 |

Based on the data presented in Table II of 31 respondents, a significant finding indicates that most participants (42%) are in the 25-30 age group. The remainder are evenly distributed among the more senior age groups (36 and above), indicating that the survey captured perspectives from a variety of experience levels.

Table 3. *Work Experience of Respondent*

| Numbers | Years of Experience | Number of Responses | Percentage (%) |
|---|---|---|---|
| 1 | <5 Years | 5 | 16 |
| 2 | 5-10 Years | 12 | 39 |
| 3 | 11-20 Years | 7 | 22 |
| 4 | >20 Years | 7 | 23 |
| | TOTAL | 31 | 100 |

Respondent's work experience data revealed significant findings. Most respondents, 39% (12 people), had between 5 and 10 years of work experience. This group likely possesses a balanced understanding of theory and practical application in the field. Furthermore, it is important to note that nearly half of respondents (45%) had more than 11 years of experience (22% with 11-20 years and 23% with more than 20 years). The presence of this large number of senior professionals enriches the research data with strategic insights and long-term perspectives based on decades of experience navigating various project risks. This combination demonstrates that the research findings are based on a comprehensive and in-depth perspective.

Table 4. *Professional Backgrounds of Respondents*

| Numbers | Profession | Number of Responses | Percentage (%) |
|---|---|---|---|
| 1 | Project Manager | 7 | 23 |
| 2 | Engineer | 8 | 26 |
| 3 | Consultant | 9 | 29 |
| 4 | Contractor | 6 | 19 |
| 5 | Other | 1 | 3 |
| | TOTAL | 31 | 100 |

The respondents in this survey came from various professional backgrounds. The largest group (29%) of participants, 9 people, were consultants. Engineers followed closely, representing 26% of the total of 8 people. Project managers accounted for 23% of respondents, or 7 people, while contractors comprised 19% of respondents, or 6 people. A small portion, about 3% 1 person, came from other fields. In total, 31 individuals with diverse work experience contributed to the survey results.

Table 5. *Risk Factors of the Respondents*

| Numbers | Risk Factor | Frequency |
|---|---|---|
| 1 | Design Change or Variation | 12 |
| 2 | Financial Problem | 11 |
| 3 | Deficient Planning | 30 |
| 4 | Variations by the Client | 9 |
| 5 | Deficient Work Management | 16 |
| 6 | Climate Conditions | 15 |

To classify the risk factors, 31 professionals in infrastructure projects were asked to list three key risks they frequently encounter. The risk systematically grouped into six categories: Design Change or Variation (e.g., modification during construction), financial problems, (e.g., cost overruns), variations by client (e.g., policy changes), deficient work management (e.g., safety issues), and climate conditions (e.g., extreme weather). This categorization was based on recurring response themes that align with common industry risk frameworks. For instance, delays due to miscommunication were classified under deficient planning, while material cost fluctuations fell under financial problems.

The findings present the distribution of risk factors as identified by respondents involved in infrastructure projects. The most prevalent risks are Deficient Planning (30 occurrences) and Deficient Work Management (16 occurrences), indicating significant challenges in project coordination, communication, and execution. Design Changes or Variations (12 occurrences) and Climate Conditions (15 occurrences) appear less frequently but still warrant attention, especially in projects sensitive to environmental or design fluctuations. Financial problems (11 occurrences) and client-related variation

(9 occurrences) also emerge as critical concerns, reflecting external dependencies and budgetary constraints.

The results indicate weaknesses in internal project management, such as inadequate planning and inefficient work processes, rather than external factors like weather conditions. Organizations should prioritize strengthening project coordination, improve resource management, and foster clearer communication channels to mitigate these risks. Addressing financial and client-related uncertainties through proactive stakeholder engagement and contingency planning can further enhance project resilience. By focusing on these areas, teams can reduce disruptions and improve project outcomes.

The strategic recommendations proposed in this study, such as strengthening coordination, improving communication, and engaging stakeholders, align with findings from various previous studies. For example, the emphasis on strong planning and coordination echoes research findings in Egypt and Indonesia, which identified weak planning and inadequate coordination as significant challenges. Similarly, the importance of proactive stakeholder engagement, also supported by the correlation findings in this study, is validated by the literature, which consistently recognizes stakeholder engagement as an effective means of improving risk management and reducing project vulnerability. This alignment demonstrates that although this study focuses on the local context of Batam, the identified internal management challenges and mitigation strategies have broader relevance and reflect fundamental issues in the infrastructure sector globally.

**Correlations**

| | | Risiko diidentifikasi secara sistematis di setiap tahap proyek | Proses identifikasi risiko melibatkan pemangku kepentingan utama | Data dari proyek sebelumnya bisa digunakan untuk mengidentifikasi risiko yang berpotensi | Identifikasi Risiko (X1) |
|---|---|---|---|---|---|
| Risiko diidentifikasi secara sistematis di setiap tahap proyek | Pearson Correlation | 1 | .405* | .483** | .811** |
| | Sig. (2-tailed) | | .024 | .006 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Proses identifikasi risiko melibatkan pemangku kepentingan utama | Pearson Correlation | .405* | 1 | .161 | .646** |
| | Sig. (2-tailed) | .024 | | .387 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Data dari proyek sebelumnya bisa digunakan untuk mengidentifikasi risiko yang berpotensi | Pearson Correlation | .483** | .161 | 1 | .790** |
| | Sig. (2-tailed) | .006 | .387 | | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Identifikasi Risiko (X1) | Pearson Correlation | .811** | .646** | .790** | 1 |
| | Sig. (2-tailed) | <.001 | <.001 | <.001 | |
| | N | 31 | 31 | 31 | 31 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Figure 1. Correlation Analysis (Risk Identification)

The correlation analysis results for the Risk Identification variable indicate that the three indicators used show strong and significant correlation. The indicator regarding systematic risk identification has the strongest correlation with the total score (r = 0.811), followed by using historical project data (r = 0.790) and stakeholder engagement (r = 0.646). The significance value for all items was recorded at <0.001, which is far below the significance level of 0.05. This indicates that all question items can measure the risk identification construct accurately and consistently.

**Correlations**

| | | Risiko dinilai secara kuantitatif menggunakan alat terstruktur (misalnya matriks risiko) | Prioritas risiko ditentukan berdasarkan dampak dan kemungkinan terjadinya | Faktor eksternal (misalnya kebijakan, cuaca) dipertimbangkan dalam penilaian risiko | Penilaian/Analisis Risiko (X2) |
|---|---|---|---|---|---|
| Risiko dinilai secara kuantitatif menggunakan alat terstruktur (misalnya matriks risiko) | Pearson Correlation | 1 | .295 | .095 | .668** |
| | Sig. (2-tailed) | | .107 | .610 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Prioritas risiko ditentukan berdasarkan dampak dan kemungkinan terjadinya | Pearson Correlation | .295 | 1 | .208 | .654** |
| | Sig. (2-tailed) | .107 | | .262 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Faktor eksternal (misalnya kebijakan, cuaca) dipertimbangkan dalam penilaian risiko | Pearson Correlation | .095 | .208 | 1 | .710** |
| | Sig. (2-tailed) | .610 | .262 | | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Penilaian/Analisis Risiko (X2) | Pearson Correlation | .668** | .654** | .710** | 1 |
| | Sig. (2-tailed) | <.001 | <.001 | <.001 | |
| | N | 31 | 31 | 31 | 31 |

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 2. Correlation Analysis (Risk Assessment)

In the Risk Assessment variable, validity testing was conducted on three statement items. Statistical results show that items related to consideration of external factors (such as policies and weather) have the highest correlation contribution ($r = 0.710$), followed by quantitative risk assessment ($r = 0.668$) and risk prioritization ($r = 0.654$). All items show a significant value of 0.000 ($p < 0.01$), which confirms that this instrument is valid in measuring the dimensions of risk assessment and analysis in projects.

**Correlations**

| | | Terdapat dokumen resmi mengenai rencana tanggapan risiko | Strategi tanggapan (menghindari, mengurangi, atau menerima) telah ditentukan dengan jelas | Tim proyek dilatih untuk merespons risiko tertentu | Perencanaan/Tanggapan Risiko (X3) |
|---|---|---|---|---|---|
| Terdapat dokumen resmi mengenai rencana tanggapan risiko | Pearson Correlation | 1 | .683** | .701** | .893** |
| | Sig. (2-tailed) | | <.001 | <.001 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Strategi tanggapan (menghindari, mengurangi, atau menerima) telah ditentukan dengan jelas | Pearson Correlation | .683** | 1 | .733** | .891** |
| | Sig. (2-tailed) | <.001 | | <.001 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Tim proyek dilatih untuk merespons risiko tertentu | Pearson Correlation | .701** | .733** | 1 | .905** |
| | Sig. (2-tailed) | <.001 | <.001 | | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Perencanaan/Tanggapan Risiko (X3) | Pearson Correlation | .893** | .891** | .905** | 1 |
| | Sig. (2-tailed) | <.001 | <.001 | <.001 | |
| | N | 31 | 31 | 31 | 31 |

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 3. Correlation Analysis (Risk Planning)

The instrument for the Risk Planning/Response variable demonstrated a very high level of validity. All three statement items had very strong correlation coefficients: the availability of official response plan documents ($r = 0.893$), clarity of response strategies ($r = 0.891$), and project team training ($r = 0.905$). With a correlation value approaching 1 and a significance of $<0.001$, this variable has a very solid and reliable measurement indicator to represent risk response readiness.

**Correlations**

| | | Daftar risiko diperbarui secara berkala | Pemantauan risiko dilakukan dalam rapat kemajuan proyek | Pelajaran dari risiko proyek sebelumnya diterapkan pada proyek saat ini | Monitoring/Review Risiko (X4) |
|---|---|---|---|---|---|
| Daftar risiko diperbarui secara berkala | Pearson Correlation | 1 | .511** | .550** | .843** |
| | Sig. (2-tailed) | | .003 | .001 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Pemantauan risiko dilakukan dalam rapat kemajuan proyek | Pearson Correlation | .511** | 1 | .491** | .813** |
| | Sig. (2-tailed) | .003 | | .005 | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Pelajaran dari risiko proyek sebelumnya diterapkan pada proyek saat ini | Pearson Correlation | .550** | .491** | 1 | .814** |
| | Sig. (2-tailed) | .001 | .005 | | <.001 |
| | N | 31 | 31 | 31 | 31 |
| Monitoring/Review Risiko (X4) | Pearson Correlation | .843** | .813** | .814** | 1 |
| | Sig. (2-tailed) | <.001 | <.001 | <.001 | |
| | N | 31 | 31 | 31 | 31 |

**. Correlation is significant at the 0.01 level (2-tailed).

Figure 4. Correlation Analysis (Risk Monitoring)

For the Risk Monitoring variable, correlation analysis results indicate that the risk register updating mechanism, discussions in progress meetings, and implementation of lessons learned are significantly correlated with the construct. The correlation coefficient ranges from 0.813 to 0.843, with the item regularly updating the risk register as the indicator with the highest correlation. Statistical significance at the 0.01 level confirms that this instrument is valid for measuring ongoing risk monitoring activities.

**Correlations**

| | | Praktik manajemen risiko saat ini cukup untuk menghadapi ketidakpastian proyek | Alat teknologi (seperti BIM) membantu optimalisasi manajemen risiko | Budaya organisasi mendukung manajemen risiko yang proaktif | Diperlukan pelatihan tambahan dalam manajemen risiko | Optimalisasi Manajemen Risiko (Y) |
|---|---|---|---|---|---|---|
| Praktik manajemen risiko saat ini cukup untuk menghadapi ketidakpastian proyek | Pearson Correlation | 1 | .405* | .656** | .288 | .805** |
| | Sig. (2-tailed) | | .024 | <.001 | .116 | <.001 |
| | N | 31 | 31 | 31 | 31 | 31 |
| Alat teknologi (seperti BIM) membantu optimalisasi manajemen risiko | Pearson Correlation | .405* | 1 | .245 | .532** | .766** |
| | Sig. (2-tailed) | .024 | | .184 | .002 | <.001 |
| | N | 31 | 31 | 31 | 31 | 31 |
| Budaya organisasi mendukung manajemen risiko yang proaktif | Pearson Correlation | .656** | .245 | 1 | .016 | .646** |
| | Sig. (2-tailed) | <.001 | .184 | | .931 | <.001 |
| | N | 31 | 31 | 31 | 31 | 31 |
| Diperlukan pelatihan tambahan dalam manajemen risiko | Pearson Correlation | .288 | .532** | .016 | 1 | .660** |
| | Sig. (2-tailed) | .116 | .002 | .931 | | <.001 |
| | N | 31 | 31 | 31 | 31 | 31 |
| Optimalisasi Manajemen Risiko (Y) | Pearson Correlation | .805** | .766** | .646** | .660** | 1 |
| | Sig. (2-tailed) | <.001 | <.001 | <.001 | <.001 | |
| | N | 31 | 31 | 31 | 31 | 31 |

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Figure 5. Correlation Analysis (Risk Management Optimization)

The dependent variable, namely Risk Management Optimization, was measured using four indicators. The analysis results showed a positive and significant correlation in all items, with a coefficient range between 0.646 to 0.805. Current risk management practices ($r = 0.805$) and the role of technology/BIM tools ($r = 0.766$) were the dominant factors correlated with optimization. Considering that all Sig. values (2-tailed) were smaller than 0.05, these four statement items were declared valid as a measure of risk management success.

## 5. Conclusion

This study identifies key factors that play a significant role in enhancing risk management strategy optimization within infrastructure projects. The findings emphasize that internal management-related issues, particularly deficiencies in planning and work management, exert a stronger influence on project outcomes than external risks such as climate conditions. By improving planning processes, fostering stakeholder collaboration, and implementing proactive mitigation measures, infrastructure projects can achieve greater efficiency, resilience, and sustainability.

The research bridges the gap between theoretical frameworks and practical applications, offering evidence-based recommendations to project managers, engineers, and contractors. Encouraging collaboration, leveraging historical data, and adopting adaptive strategies can help infrastructure projects mitigate risk more effectively, ensuring timely and sustainable outcomes. Future studies could expand on these findings by exploring the role of emerging technologies and cross-industry best practices in further refining risk management approaches. Lastly, this study aims to contribute meaningful insights to the broader discussion on improving risk management in infrastructure projects.

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