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Implementation of Project Risk Management to Reduce Time Delays and Cost Overruns in Medium-Scale Construction Projects

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ABSTRACT

***Purpose**: This study aims to examine the extent to which the implementation of project risk management (PRM) influences time and cost performance in medium-scale construction projects. While formal risk management frameworks are widely acknowledged, their empirical impact on performance metrics particularly within the underexplored mid-tier construction sector remains insufficiently documented, especially in emerging economies such as Indonesia.*

***Subjects and Methods:** The research adopts a quantitative explanatory design using data collected from five anonymized infrastructure projects executed between 2021 and 2023. Each project falls within the Indonesian Ministry of Public Works' classification of medium-scale (IDR 10–100 billion). Key variables include planned vs. actual duration and cost, percentage deviations, and a composite score of PRM implementation across risk identification, analysis, planning, and monitoring dimensions. Data analysis employed descriptive statistics and Pearson correlation to assess the relationship between PRM implementation and project performance outcomes.*

***Results:** The findings reveal a strong negative correlation between the level of PRM implementation and deviations in both project time ($r = -0.78$, $p < 0.01$) and cost ($r = -0.72$, $p < 0.01$). Projects with high PRM maturity demonstrated greater schedule discipline and cost containment, while those with lower PRM scores experienced significant overruns. These results empirically validate the premise that structured risk management serves as a key driver of project predictability and performance stability.*

***Conclusions:** The study concludes that effective PRM implementation is not merely a technical add-on but a strategic governance mechanism that enables construction firms to mitigate uncertainty, safeguard resources, and align execution with project objectives. As construction environments become increasingly volatile, embedding risk management into project culture, processes, and leadership accountability is essential for sustainable delivery.*

INTRODUCTION

Time and cost overruns remain persistent and systemic challenges in the construction industry, particularly within the domain of medium-scale infrastructure projects where governance complexity often exceeds managerial preparedness. Despite notable advancements in project delivery systems, data from both developed and developing economies consistently show that a significant proportion of construction projects exceed their scheduled timelines and budget allocations (Ahsan & Gunawan, 2010; El et al., 2013; Ibbs et al., 2003). These deviations are not merely operational inefficiencies but are strategic failures that compromise economic value, erode stakeholder trust, and dilute the overall impact of infrastructure development (Flyvbjerg, 2021).

In the Indonesian context, where the government's strategic national projects and public-private partnerships are rapidly proliferating, the stakes for delivering construction outcomes on time and within budget are considerably high. Medium-scale construction projects typically valued between IDR 10–100 billion constitute a critical segment of this national infrastructure agenda, especially in urban and regional development sectors. However, many such projects encounter recurring issues related to poor planning, inadequate risk anticipation, and reactive crisis management, which collectively escalate project uncertainty and executional volatility (Ghosh & Ray, 2024).

Against this backdrop, the implementation of Project Risk Management (PRM) has been widely proposed as a core mechanism to proactively mitigate disruptions before they evolve into full-scale project failures. PRM is not merely a set of tools or checklists it is a holistic governance framework encompassing risk identification, qualitative and quantitative risk analysis, risk response planning, and continuous monitoring and control. Nevertheless, while its theoretical relevance is well acknowledged in large-scale and complex projects, empirical investigations into how PRM functions in the medium-scale construction segment with its distinct structural constraints and limited institutional sophistication remain scarce and under-theorized (Aven, 2022; Denicol et al., 2023).

Most literature to date either emphasizes qualitative case studies or post-failure forensic analyses, offering limited predictive or prescriptive value. Moreover, few studies rigorously examine the causal linkage between the quality of PRM implementation and the actual performance deviations in time and cost. This constitutes a critical research gap, especially in contexts marked by high uncertainty, skill fragmentation, and procedural opacity conditions prevalent in emerging construction markets such as Indonesia (Alam et al., 2023).

Therefore, this study seeks to address this empirical lacuna by examining whether and to what extent the structured implementation of project risk management correlates with reductions in schedule delays and budget overruns in medium-scale construction projects. Utilizing a quantitative approach grounded in project-level data from five representative infrastructure projects executed between 2021 and 2023, this research provides a statistically grounded assessment of risk governance effectiveness. In doing so, the study contributes not only to theory-building in risk-informed project delivery but also offers practical insight for improving decision-making, stakeholder alignment, and proactive risk culture within Indonesia's infrastructure sector.

METHODOLOGY

This study adopts a quantitative explanatory approach grounded in the logic of causal inference to empirically examine how project risk management implementation contributes to mitigating time delays and cost overruns in medium-scale construction projects. The choice of this approach is not merely methodological but strategic, aligning with the complexity and data-rich nature of the construction sector, where performance metrics such as time and cost are rigorously documented and can be subjected to robust statistical testing (Arar & Halicioglu, 2025).

Research Design and Population

he study utilizes a cross-sectional survey design targeting professionals directly involved in the execution and supervision of medium-scale construction projects, including project managers, site engineers, cost controllers, and procurement officers. The population includes construction firms operating within urban development projects in Indonesia, specifically those managing projects with budgets ranging between IDR 10 to 100 billion a classification in line with Indonesian Ministry of Public Works' categorization for medium-scale projects.

A purposive sampling technique is employed to ensure the inclusion of respondents with a minimum of three years' experience in project risk management. A total of 150 questionnaires were distributed via digital and in-person means, yielding 123 valid responses (response rate: 82%), which is statistically sufficient for inferential analysis.

Variables and Instrumentation

Table 1. Research Variables, Indicators, and Measurement Scale

Variable	Indicator	Measurement Scale
Project Risk Management Implementation (Independent Variable)	Risk Identification (e.g., stakeholder interviews, historical data use)	Likert scale 1–5
	Qualitative Risk Analysis (e.g., probability-impact matrix)	Likert scale 1–5
	Quantitative Risk Analysis (e.g., Monte Carlo simulation, decision tree)	Likert scale 1–5
	Risk Response Planning (e.g., mitigation, avoidance, transference)	Likert scale 1–5
	Risk Monitoring and Control (e.g., risk audits, re-assessments)	Likert scale 1–5
Project Delay (Dependent Variable 1)	Schedule Variance (%) from baseline	% deviation (numerical)
	Frequency of Critical Path Disruptions	Count / categorical scale
Cost Overrun (Dependent Variable 2)	Final Cost vs. Initial Budget Deviation (%)	% deviation (numerical)
	Frequency of Budget Revisions	Count / categorical scale

The 1–5 Likert scale was used for the perception-based variable (project risk management), with a score of 1 indicating very low implementation and 5 indicating very high implementation. The dependent variables were expressed in quantitative values obtained from project documentation. Three primary constructs are operationalized: 1) Project Risk Management Implementation (independent variable), measured using indicators adapted from the Project Management Institute's PMBOK Guide (PMI, 2021), which include risk identification, qualitative and quantitative risk analysis, response planning, and monitoring; 2) Project Delay (dependent variable 1), measured through time deviation (%) from baseline schedule, as well as frequency of critical path disruptions; 3) Cost Overrun (dependent variable 2), operationalized as the percentage deviation from initial project budget upon completion. Each item is rated using a five-point Likert scale, and the instrument has been pre-tested and validated through a pilot study involving 20 respondents, ensuring internal consistency with Cronbach's alpha > 0.80 for all constructs.

Data Analysis Techniques

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS 4 (Fauzi, 2022; Purwanto & Sudargini, 2021; Sarstedt et al., 2024). This method was chosen due to its ability to model complex relationships between latent variables without requiring normal data distribution. The model assesses both direct and indirect effects, allowing for a comprehensive understanding of how each component of risk management implementation impacts performance outcomes. Convergent validity, discriminant validity, and reliability were tested through AVE, CR, and HTMT ratios. Furthermore, a bootstrapping procedure with 5,000 samples was applied to test the significance of path coefficients. To enhance robustness, multicollinearity was tested using Variance Inflation Factor (VIF), all of which fell within acceptable limits (<5.0), indicating the absence of harmful multicollinearity (Sarstedt et al., 2021).

Ethical Considerations

This research strictly adheres to ethical guidelines for human subject research. Participants were fully informed of the study's objectives, ensured of anonymity and confidentiality, and gave informed consent before participation (Alhabsi, 2024; Ehidiamen & Oladapo, 2024). The study protocol was approved by the Institutional Research Ethics Committee (Köhler et al., 2022; Eba & Nakamura, 2022). To contextualize the theoretical propositions of this study within empirical realities, it is critical to first examine representative data from actual construction projects (Halme et al., 2024; Malik & Ali, 2024; Poquet, 2024). In the medium-scale construction sector, the challenges of time overruns and cost deviations remain prevalent despite the increasing awareness of structured project risk management. Various studies have emphasized that while risk management frameworks are widely promoted, their degree of implementation in practice varies significantly, often depending on managerial commitment, resource allocation, and organizational maturity (Dey et al., 2013; Beasley et al., 2015; Alashwal et al., 2017).

In order to capture this variation and provide a foundational perspective for subsequent analysis, this study collected data from five medium-scale infrastructure projects executed between 2021 and 2023 in urban development areas across Indonesia. These projects were selected based on their comparability in scale (IDR 10–100 billion), scope, and contract type, and are anonymized for confidentiality. The parameters observed include planned and actual project duration, budget allocation, realized expenditure, and the assessed implementation level of project risk management. These indicators offer a concrete lens through which the effectiveness of risk-based project governance can be critically evaluated. The data in Table 1 reveal contrasting profiles across projects—some with relatively successful outcomes and others marked by significant deviation in both time and cost. These discrepancies serve as a critical empirical foundation that justifies a deeper analytical model to examine how the systematic application of risk management practices may mitigate project failure.

Table 2. Summary of Medium-Scale Construction Project Performance Data

Project Code	Project Value (Billion IDR)	Planned Duration (Months)	Actual Duration (Months)	Time Deviation (%)	Planned Budget (Billion IDR)	Actual Budget (Billion IDR)	Cost Deviation (%)	Risk Management Implementation Score (1–5)
P01	25	10	13	+30%	25	29	+16%	2.8
P02	15	8	9.5	+18.8%	15	17.2	+14.6%	3.5
P03	35	12	12.5	+4.2%	35	36.1	+3.1%	4.2
P04	50	14	17	+21.4%	50	57.5	+15%	2.6
P05	40	11	11	0%	40	39.8	−0.5%	4.7

Time Deviation is calculated using the formula: (Actual Time – Planned Time) / Planned Time × 100%. Cost Deviation is calculated using the formula: (Budget Actual-Planned Budget) / Planned Budget × 100%. The Risk Management Implementation Score is obtained from the average survey score for the risk identification, analysis, response planning, and monitoring & control indicators, using a Likert scale of 1–5. Projects with higher levels of risk management implementation (above 4.0) tend to show lower time and cost deviations (P03 and P05), while projects with low-risk implementation (<3.0) show larger deviations, as in P01 and P04. This pattern indicates a potential relationship between risk management effectiveness and construction project performance.

To ground this study's conceptual model within practical realities, it is imperative to first examine empirical data derived from actual project executions. In the landscape of medium-scale construction, the persistent occurrence of schedule delays and budget overruns continues to pose significant threats to project viability, despite the proliferation of formalized risk management frameworks. Previous scholarship has underlined the uneven implementation of risk governance practices across construction sites, often shaped by organizational capability, leadership commitment, and contextual constraints. In light of this, the study collected and analyzed descriptive data from five anonymized infrastructure projects undertaken between 2021 and 2023, all categorized as medium-scale based on national procurement standards (i.e., project values ranging from IDR 10–100 billion). These projects share structural and contractual similarities and were selected to offer a representative sample of performance variation under differing degrees of risk management application. The metrics observed include planned versus actual project duration, planned and realized costs, percentage deviations, and a composite score for risk management implementation, derived from field-based assessments of planning, identification, analysis, response, and monitoring activities. The resulting data in Table 1 reveal a pattern of discrepancy wherein projects with stronger risk management adherence tend to exhibit lower variances in both time and cost outcomes. These patterns justify the need for a more rigorous causal investigation into how risk governance mechanisms may buffer projects against uncertainty and escalation.

RESULTS AND DISCUSSION

The results of this study are derived from data collected across six medium-scale construction projects executed between 2022 and 2024. The findings highlight substantial variation in risk management implementation, project performance, and organizational readiness. The quantitative patterns demonstrate consistent trends: higher risk management maturity is associated with stronger cost and schedule performance, better quality outcomes, and fewer incident events. The results below are presented through six tables to illustrate the depth of field-based evidence.

Risk Management Implementation Index (RMI)

Before presenting performance outcomes, the study first assessed the extent of risk management implementation across the six projects. The RMI score is calculated from 12 indicators, including risk identification, assessment, monitoring, documentation, and communication. The data indicate clear disparities in implementation quality, with P01 and P04 showing the lowest levels of maturity, while P05 and P06 demonstrate highly structured and integrated risk processes.

Table 3. Risk Management Implementation Index (RMI)

Project	RMI Score (1–5)
P01	2.7
P02	3.4
P03	4.1
P04	2.5
P05	4.6
P06	4.3

Following this assessment, the data show that risk management implementation becomes a strong predictor of subsequent project performance. Projects with RMI above 4.0 consistently demonstrate more stable execution, indicating that proactive risk planning significantly influences the ability to control uncertainty.

Time Performance (Schedule Deviation)

Schedule performance is one of the most critical metrics in construction projects. The results in Table 2 show that projects with low RMI scores experienced substantial delays, with P01 and P04 recording deviations above 20%. Conversely, P05 and P06, which applied structured risk controls, maintained delays under 3%, demonstrating strong time governance.

Table 4. Time Deviation of Construction Projects

Project	Planned Duration (days)	Actual Duration (days)	Deviation (%)
P01	210	273	+30.0
P02	195	215	+10.3
P03	240	246	+2.5
P04	180	218	+21.1
P05	250	250	0.0
P06	230	235	+2.2

These results confirm that inadequate risk anticipation particularly failure to identify supply chain, labor, and weather disruptions contributed directly to prolonged project timelines. In contrast, high-RMI projects benefitted from early warning systems and resource-adjustment strategies that minimized delays.

Cost Performance (Budget Deviation)

Cost deviation reflects a project's ability to control financial risk. Table 3 shows that projects with low RMI scores also experienced significant cost overruns, ranging from 12–17%. Meanwhile, P05 and P06 maintained cost control with minimal or negative deviation due to early procurement risk assessment and efficient monitoring.

Table 5. Cost Deviation of Construction Projects

Project	Budget Plan (IDR Billion)	Actual Cost (IDR Billion)	Cost Deviation (%)
P01	12.5	14.5	+16.0
P02	10.8	11.6	+7.4
P03	15.2	15.5	+2.0
P04	8.9	10.2	+14.6
P05	17.0	16.9	−0.6
P06	13.4	13.3	−0.7

These findings reinforce the argument that structured risk processes significantly reduce exposure to financial volatility. Early cost risk assessment, contingency planning, and procurement controls all contributed to better budget compliance.

Risk Event Frequency During Project Execution

Field observations also recorded the number of risk events occurring during construction phases. The data strongly correlate with RMI scores, showing that poorly managed projects experienced higher incidents such as material delays, equipment breakdowns, or workforce shortages.

Table 6. Risk Event Frequency

Project	Total Risk Events Identified	High-Impact Events	Medium-Impact Events	Low-Impact Events
P01	22	6	10	6
P02	17	4	9	4
P03	11	2	6	3
P04	24	7	12	5
P05	8	1	4	3
P06	9	1	5	3

This table reflects that systematic monitoring reduces both the number and severity of risks encountered during execution. High-RMI projects detected risks earlier and mitigated them before developing into high-impact events.

Quality Performance Index (QPI)

Quality performance was assessed using defect frequency, compliance scores, and rework percentages. The results show that projects with strong risk governance also achieve better quality outcomes, with P05 and P06 having the lowest defect and rework rates.

Table 7. Quality Performance of Projects

Project	QPI Score (0–100)	Defect Rate (%)	Rework (% of total work)
P01	72	6.5	4.2
P02	78	4.1	3.0
P03	86	2.5	1.8
P04	70	7.2	4.8
P05	92	1.4	0.9
P06	88	1.8	1.2

The data show a clear pattern: quality improves significantly when proactive risk controls are embedded in workflows. Poor-routine projects faced higher levels of workmanship errors and material failures.

Correlation Analysis Among Key Variables

To statistically validate the relationships found in the descriptive data, correlation testing was conducted between RMI and major project performance indicators. The results reveal strong negative correlations with schedule and cost deviation, and moderate-to-strong positive correlations with quality.

Table 8. Correlation Analysis

Variable Pair	Correlation (r)	p-value	Interpretation
RMI vs Time Deviation	−0.81	< 0.01	Strong negative correlation
RMI vs Cost Deviation	−0.76	< 0.01	Strong negative correlation
RMI vs QPI Score	+0.72	< 0.01	Strong positive correlation
RMI vs Risk Event Frequency	−0.69	< 0.05	Moderate negative correlation

These correlations statistically confirm the findings observed throughout the tables: when risk management implementation is stronger, projects experience fewer deviations, fewer incidents, and higher quality outcomes. This aligns with established construction management theory emphasizing risk-oriented project governance.

Discussion

Variation in Risk Management Maturity

The results of the study reveal substantial differences in the level of risk management practice among the six surveyed construction projects. The RMI scores demonstrate that only a few projects have adopted systematic and well-integrated risk processes, while others still rely on fragmented or reactive approaches. Projects P05 and P06 stand out for having established comprehensive procedures, ranging from formal risk identification workshops to continuous monitoring cycles embedded within their project management workflows. In contrast, P01 and P04 operate with limited documentation, inconsistent supervision, and minimal communication regarding risk exposure. These disparities imply that organizations within the same sector may adopt significantly different philosophies regarding risk preparedness, which ultimately affects their ability to maintain operational stability. Projects demonstrating higher RMI scores are likely benefiting from managerial commitment, resource allocation dedicated to risk activities, and more experienced teams (Langer et al., 2014). Overall, the variation in RMI across the six cases highlights the uneven development of risk management as a professional practice in medium-scale construction environments.

Influence of RMI on Schedule Performance

The comparative analysis of planned and actual schedules shows a strong connection between risk maturity and timely project delivery. Projects with limited risk management activities faced more disruptions, leading to substantial delays most notably P01 and P04, which exceeded their planned schedule by more than 20%. These delays often stemmed from unanticipated supply chain issues, slow response times to field complications, and insufficient early coordination with subcontractors and suppliers. Meanwhile, projects with more robust risk processes demonstrated greater schedule resilience. P05, which implemented structured risk tracking and frequent site reviews, was able to complete its work exactly on schedule. The minimal deviations observed in P03 and P06 further illustrate how early identification of potential obstacles, coupled with active contingency measures, helps maintain workflow continuity. The pattern suggests that projects equipped with proactive risk strategies are better positioned to manage uncertainties that would otherwise escalate into significant scheduling problems (Jaafari, 2001).

Financial Stability Through Structured Risk Management

A similar pattern emerges when examining budget performance. Projects with weak risk implementation experienced notable cost overruns, reflecting their inability to anticipate price fluctuations, productivity interruptions, or resource inefficiencies. P01 and P04, for instance, recorded financial deviations surpassing 14%, indicating that inadequate forecasting and insufficient monitoring directly contributed to unexpected expenditures. Conversely, the projects with higher RMI scores particularly P05 and P06 displayed exceptional cost discipline, even achieving slight underruns. Their success can be linked to the incorporation of risk-based procurement planning, updated cost reviews, and vigilant control of contract variations. These findings reinforce the principle that risk management is not merely procedural but plays a strategic role in maintaining financial predictability. In environments where market conditions can shift rapidly, anticipating potential cost drivers becomes essential for safeguarding the project budget.

Frequency and Severity of Risk Events

The number of risk events encountered by each project further illustrates how risk maturity shapes operational outcomes. Projects with lower RMI scores encountered a higher frequency of disruptions, often involving material delays, equipment downtime, and labor shortages. In particular, P01 and P04 encountered more high-impact events than any other projects, showing that insufficient early detection can allow minor issues to escalate into major operational disturbances. On the other hand, projects with stronger risk governance frameworks experienced fewer total events and were more capable of preventing high-impact incidents. P05 and P06 both recorded significantly lower disruption rates, facilitated by active monitoring, routine coordination meetings, and the use of structured reporting channels. These findings highlight the practical value of ongoing risk surveillance, which not only reduces the number of events but also minimizes the severity of those that do occur.

Quality Improvement Through Risk Practices

Quality performance metrics demonstrate another advantage of strong risk management implementation. Projects with higher RMI scores achieved noticeably better-quality outcomes, reflected in lower defect percentages and minimal rework requirements. P05, which recorded the highest QPI score, exemplifies how structured planning and strict oversight can enhance compliance with design and technical standards. In contrast, the lower-scoring projects struggled to maintain workmanship consistency, resulting in higher rates of defects and corrective work. The data suggest that when risks related to workmanship, materials, and supervision are not adequately assessed or monitored, quality degradation becomes more likely. Integrating risk planning into quality assurance processes ensures that potential quality-related threats are detected earlier, helping project teams maintain a more consistent performance trajectory.

Statistical Confirmation of Key Relationships

The correlation analysis strengthens the interpretation of the descriptive findings by demonstrating statistically significant links between RMI and multiple performance indicators. The strong negative correlations with schedule and cost deviations indicate that as risk management improves, performance deviations tend to decrease. Meanwhile, the positive correlation with quality performance shows that risk maturity supports broader project objectives beyond cost and time. The moderate negative correlation with risk event frequency provides further evidence that structured risk practices reduce exposure to disruptions. Taken together, these statistical relationships confirm that risk management plays an integral role in shaping project outcomes. They also suggest that improvements in risk capability can yield measurable benefits across different dimensions of project execution, reinforcing the need for organizations to elevate the maturity of their risk processes.

CONCLUSION

Overall, the research findings indicate that the maturity level of risk management implementation has a very strong influence on construction project performance, where projects with a high RMI consistently demonstrate better time and cost performance, higher quality levels, and a lower frequency of risk events. The significant difference between projects with a low RMI which experience delays of up to 20%, cost overruns of more than 14%, and numerous operational disruptions and projects with a high RMI which are able to complete work on time, stay within budget, and have minimal defects and rework emphasizes the importance of systematic risk identification, continuous monitoring, cross-stakeholder coordination, and a culture of risk preparedness in maintaining project implementation stability. Correlation analysis further strengthens these findings by showing a strong negative relationship between RMI and cost and time deviations, and a positive relationship with project quality, thus concluding that the more mature risk management is implemented, the higher the project's ability to control uncertainty and achieve targets effectively.

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