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Risk Management on Infrastructure Projects and Their Impact on Project Financials

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Abstract

This study aims to identify potential risks in infrastructure projects and determine their impact on project costs. The research addresses the financial implications of risk management practices in infrastructure development projects in Indonesia, focusing on operational, political, managerial, and technical risks.The research employs a mixed-method approach, integrating qualitative and quantitative methodologies. Data collection was conducted using questionnaires and semi-structured interviews to describe and verify the study findings. Additionally, the snowball sampling method was applied to gather data from Indonesian engineers working on infrastructure projects with contractors or consultants. Qualitative data was sourced from a comprehensive review of scientific literature related to risk management.Based on a survey of 50 construction practitioners, the study finds that infrastructure projects are highly likely to encounter multiple risks. Among these, the risk of principal insolvency has the most significant impact on infrastructure project costs, with an RII score of 3.04. Empirical findings reveal that only seven risk categories, including building structure risks, complaint and protest risks, contractual risks, approval risks, risks arising from service changes, maintenance risks, and vandalism risks, do not significantly affect infrastructure project costs in Indonesia. These risks can be managed through comprehensive project planning, clear contractual documentation specifying standards and specifications, and the inclusion of adjustment clauses. However, 16 other risk categories significantly impact project costs in the Indonesian infrastructure sector.This study extends the research by Fischer et al. (2010) by empirically testing risk categories to assess their impact on project costs. It adopts both quantitative and qualitative research approaches, focusing on the implementation practices of construction contractors within established project risk management frameworks.The findings provide actionable insights for policymakers, standardization boards, and construction practitioners, offering an empirical foundation for developing integrated and standardized risk management systems. These systems aim to enhance transparency and credibility by providing step-by-step instructions for interconnected subprocesses within the overall structure, improving information dissemination and decision-making accuracy.

Keywords: *Project Risk Management, Project Budget, Infrastructure Project.*

Introduction

Infrastructure projects are critical to Indonesia's development. High-quality infrastructure, such as roads, bridges, ports, and airports, enhances connectivity and facilitates the distribution of goods and services, thereby driving economic growth. However, these projects are fraught with various risks that can lead to significant financial implications. This study explores the financial implications of risk management practices in infrastructure development projects in Indonesia, focusing on operational, political, managerial, and technical risks.

This focus is necessitated by the fact that infrastructure projects are often executed under public-private partnership (PPP) schemes, which require substantial investments, extended project timelines, and are frequently influenced by political conditions (Zhang et al., 2020). These projects, often referred to as large-scale projects, involve significant investments, resources, and time commitments.

A key factor in achieving value for money in PPP projects is optimal risk allocation. The principle of risk allocation in PPP projects posits that risks should be borne by the party best equipped to assess, manage, and mitigate them. However, in practice, PPPs often shift as many risks as possible to private entities, contradicting this principle and sometimes exacerbating risks within a project. Although the criteria for risk

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allocation are straightforward, the decision-making process underlying their application requires thorough consideration (Adafin et al., 2021).

Infrastructure projects are subject to numerous risks, including financial, temporal, personnel, design and technical, contractual, physical, political and regulatory, and safety risks (Ebekozien et al., 2024). These risks can negatively impact the cost, time, and quality of infrastructure projects. Physical risks include extreme weather, earthquakes, floods, fires, and soil subsidence, while political and regulatory risks include government policy instability, expropriation, and corruption. Fischer et al. (2010) identified at least 26 risk categories specific to PPP schemes.

Rudolf and Spinler (2018) identified key risk factors in supply chain risk management for large-scale projects, including supply chain configuration and management, as well as performance and operational risks. While these risks are not unique to large-scale projects, they are pervasive in infrastructure development. The high complexity and value associated with the supply chain sector exacerbate overall risk exposure. Ineffective supply chain risk management has been identified as one of the main causes of failure in large-scale projects. Supply chain risk management is categorized into four main areas: suppliers, supply chain coordination and management, environment, and behavior and collaboration. These categories encompass well-known risk areas such as scope and baseline specifications and supply chain configuration. However, previous research often overlooks critical areas, emphasizing the need for a more comprehensive approach to risk management in large-scale projects.

Infrastructure projects face environmental and economic challenges. On average, 90% of infrastructure projects exceed their anticipated costs by 28% (Ebekozien et al., 2024). Project delays due to financial constraints can reduce project utility periods and increase maintenance costs (Tariq, 2013). In Indonesia, key operational risks identified in infrastructure projects include issues related to contracts between project management companies and government authorities, organizational restructuring, and accidents arising from inadequate safety measures (Sa'dl Issa Alkhawaja & Varouqa, 2023). These risks have been highlighted with a Relative Importance Index (RII) score of 3.04, indicating their significant impact on project success.

Kululanga and Kuotcha (2010) argued that the size of construction contractors, measured by financial turnover, experience, and employee count, significantly influences the adoption and effectiveness of risk management practices. Larger, more experienced contractors tend to implement risk management measures more effectively. Conversely, small and medium-sized contractors, which constitute the majority of the construction industry, are characterized by low implementation rates of these measures. This disparity underscores the importance of contractor size in determining the effectiveness of risk management practices.

The objective of this study is to identify potential risks in infrastructure projects and determine their impact on project costs. Risk is broadly defined as the likelihood of an adverse event occurring. It encompasses the ability of businesses and institutions to recognize and understand each risk they face. Risk can be viewed as a condition that, if it occurs, has a positive or negative effect on project objectives. It can also be seen as exposure to losses or gains, or the probability of occurrence multiplied by the magnitude of the consequences. Additionally, risk is often considered a barrier to success and is linked to the concept of opportunity, such as the probability of loss or failure (Olsson, 2008).

Addressing risks in construction projects involves various steps and techniques. One approach is to develop new interpretative and mitigation frameworks for corporate risk management strategy analysis (Derakhshanfar et al., 2019). It is also critical to systematically identify, analyze, and respond to risks, particularly during challenging times such as floods, fires, earthquakes, and other disasters. Risk analysis techniques, including probability and impact grids, system reliability estimates, fault tree analysis, event tree analysis, sensitivity analysis, and simulation, can be used to determine whether a risk event requires further analysis. Risk evaluation involves decision tree analysis, portfolio management, and multi-criteria decision-making methods. Additionally, reactive and proactive approaches can be employed in risk mitigation to control activities that minimize the adverse impact of unexpected situations.

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This study extends Fischer et al. (2010) by empirically testing risk categories to evaluate their impact on project costs. A quantitative research approach was adopted, focusing on the implementation practices of construction contractors within known project risk management frameworks. The research employed a questionnaire survey based on potential risks in infrastructure projects. This study contributes to the development of knowledge in infrastructure project risk management and recommends the creation of integrated and standardized risk management systems that provide step-by-step guidance for interconnected processes within an overall structure, serving all stakeholders effectively

Literature Review

Risk management is defined as "a technique consisting of risk identification, qualitative and quantitative assessment, response with a system for handling risk acceptance, and finally, risk monitoring" (Yirenkyi-Fianko & Chileshe, 2015). Project risk management, according to Hlaing et al. (2008), is a critical step in procedures aimed at identifying and explaining project hazards. The primary goal of risk management is to prevent losses and capitalize on the opportunities presented by risks. When employing this approach, it is crucial to carefully consider the current conditions and any future modifications that may be required. Identifying and analyzing potential threats, as well as implementing measures to mitigate risks, are essential components of risk management. Employing risk management strategies in upcoming projects yields numerous benefits, as poorly managed risks can lead to project failures (Amoah & Nkosazana, 2022). Risk management is, therefore, a fundamental aspect of "project management."

Risks in infrastructure projects may arise due to various factors affecting the project throughout its lifecycle (Rane et al., 2019). These risks can stem from technical or legal disruptions that impede services, changes in service standards, or the insolvency of key stakeholders, which may result in delays and additional costs. Furthermore, the lack of a systematic approach to risk management in the public sector also contributes to the prevalence of risks in infrastructure projects.

Methodology

Research Approach

Risk management must be examined holistically, and its impact on infrastructure project costs in Indonesia will be thoroughly investigated. This study employs both qualitative and quantitative research approaches. Data collection methods include the use of questionnaires and semi-structured interviews to describe and verify the study's findings. The snowball sampling method was also used to gather data from Indonesian engineers working on infrastructure projects with contractors or consultants. Qualitative data was obtained through an extensive review of scientific literature related to risk management. The study aims to identify the impact of risk management on infrastructure project costs. The sample comprises project-based construction businesses. The study also utilizes self-reported data from contractors to determine how risk management practices influence financial project costs.

A risk management system for infrastructure service projects in Indonesia will be designed, examined, and evaluated as part of this research. Respondents' feedback will be used to generate research data. The impact of infrastructure service risks on financial project costs in Indonesia will be monitored and analyzed using Excel spreadsheets. Detailed instructions provided in the survey questionnaire state: "We intend to investigate the hazards associated with infrastructure services and their potential impact on the financial costs of infrastructure projects in Indonesia as part of our research." The findings from the questionnaires and investigations are expected to be statistically significant.

Additional studies could explore the key and most active aspects influencing the development of visual risk matrices for infrastructure service projects to validate the hypotheses. Politicians, decision-makers, and academics should also be interviewed to establish and construct infrastructure service systems that ensure consistent risk management plans for infrastructure projects.

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Data Collection Method

Risk management and infrastructure project costs in Indonesia were assessed using a combination of qualitative and quantitative approaches. Risk weights and financial costs were incorporated into the research through surveys.

Questionnaire Development

The questionnaire was developed to perform a risk assessment, identifying the most critical risks affecting infrastructure service projects and their impact on financial project costs in Indonesia. The questionnaire included information on respondents' age, gender, ethnicity, nationality, and occupation, as well as plans for infrastructure service projects by the Ministry of Public Works and Housing (PUPR), the Ministry of Transportation, and the National Development Planning Agency (Bappenas).

Risk assessment utilized a qualitative approach, heavily relying on the judgment and expertise of assessors to evaluate risk levels. This process involved a systematic analysis of workplace hazards to determine whether existing safeguards or controls were adequate or if additional measures were necessary. Risks were assessed by multiplying the likelihood of each risk occurrence by its impact level and then classifying these risks into categories based on their severity.

Risks were categorized into 26 risk categories (Table 2), following Fischer (2010). A total of 69 distinct risk indicators associated with infrastructure projects affecting financial project costs were identified. Respondents were asked to evaluate the likelihood and magnitude of each risk using a five-point scale, where 1 represented "very low" and 5 represented "very high." This approach facilitated the assessment of each risk's potential impact on the project. The questionnaire was initially distributed to determine its validity and reliability.

Subsequently, the study employed the Relative Importance Index (RII), as referenced by Sa'dl Issa Alkhawaja and Varouqa (2023), to measure the relative importance of specific quality criteria compared to others. This method helped classify and score risk factors based on their potential impact on infrastructure service projects and contributed to developing risk response strategies. The RII was calculated using the following formula:

$RII=\Sigma WA\times NRII=A\times N\Sigma W$

Where:

- WW represents the weight assigned to each factor by respondents,
- AA is the highest possible weight in the study,
- NN is the total number of respondents.

The more significant a component, the higher its RII value. The risk rankings based on RII values are as follows:

Table 1. RII Ranges and Risk Levels

RII Ranges	Risk Level
$RII < 1.5$	Very Low
$1.5 \leq RII < 2.5$	Low
$2.5 \leq RII < 3.5$	Moderate

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$3.5 \leq RII < 4.5$	High
$RII \geq 4.5$	Very High

Source: Sa'dl Issa Alkhawaja & Varouqa, 2023

Table 2. Risk List in PPP Projects

Risiko	Definisi	Indikator	Kode
Site risks	Factors related to the project location, such as land availability, weather conditions (e.g., frost, windstorms), public perception, environmental issues, and sustainability concerns, negatively impact construction progress, operations, or utilization	1. Changes in weather patterns and worsening climate conditions..	**A1**
		2. Natural disasters (floods, earthquakes, fires).	**A2**
		3. Property damage caused by vandalism or criminal activities	**A3**
		4. Deficiencies in meeting stated and required standards	**A4**
		5. Lack of supporting infrastructure (e.g., stormwater drainage, emergency exits) contributing to disasters.	**A5**
		6. Cracked asphalt on highways due to poor-quality materials	**A6**
Demand risks	Variations in user demand projections in terms of quality, quantity, flexibility, or functionality (e.g., creating excess capacity)	1. Passenger projections are not met due to decreased travel interest or the emergence of new competitors on the same route, potentially impacting airport service revenues.	**B1**
		2. Changes in societal travel patterns, such as a shift in preference from private vehicles to public transportation, may reduce toll road usage, leading to a decline in toll revenue.	**B2**
Subsoil risks	Unknown soil conditions, unexpected findings, or contamination can delay and hinder project progress or lead to increased costs.	1. Uncertainty about geological conditions, such as the presence of hard rock, soft soil, or unstable soil layers, may impede construction processes and increase costs	**C1**
		2. High groundwater levels can create issues during construction, including flooding or soil instability, potentially disrupting the project schedule.	**C2**
		3. Highly mobile or unstable soil, such as expansive clay, can cause settlement, cracking, or structural damage to built structures.	**C3**
		4. The presence of subsurface contaminants, such as hazardous waste, can pose challenges to development and	**C4**

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		significantly increase cleanup costs	
Building structure risks	Variations in assumptions regarding the type or condition of existing buildings or structural components lead to additional requirements, delays, and/or extra costs.	1. The use of poor-quality or non-compliant construction materials can reduce the durability and safety of the structure	**D1**
		2. Errors in construction techniques, such as improper installation, can result in structural issues over time	**D2**
Tendering and awarding risks	Poor consultation, flawed contract documents, inappropriate awarding procedures, insufficient bidders, and process deficiencies can lead to the suspension or delay of the entire awarding process or specific stages, such as during verification/review in the event of deficiencies or objections.	1. Unclear or incomplete tender documents can result in inaccurate bids and issues in project execution	**E1**
		2. Inadequate submissions may lead to non-compliant bids and potential failures to meet project requirements	**E2**
		3. Corruption or nepotism in the selection process may result in the appointment of contractors who do not meet the required quality or experience standards.	**E3**
		4. Low-priced bids made to win the tender may cause financial difficulties for contractors and negatively impact work quality	**E4**
		5. Lengthy tendering processes can delay project implementation, increase costs, and reduce efficiency	**E5**
Complaint and protest risks	Lack of political support and protests can result in early project termination or delays.	1. Local communities may oppose the project due to concerns about environmental impacts, social displacement, or loss of livelihoods.	**F1**
		2. The selection of contractors perceived as non-transparent or unfair may lead to complaints or protests by aggrieved parties.	**F2**
Design risks	Incomplete documents (e.g., technical specifications) and/or planning errors regarding content, processes, workflows, progress, and engineering can result in additional costs or delays.	1. Inaccuracies or deficiencies in structural design may lead to structural failures, such as cracks or collapses.	**G1**
		2. Inconsistencies in design documents	**G2**
Contractual risks	Unclear descriptions of service scope, performance standards or limitations, ambiguous post-termination regulations, and/or	1. Ambiguous or unclear contractual provisions that cause disputes and misunderstandings between the parties involved.	**H1**

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	incomplete documentation of agreed-upon performance can lead to contract conflicts, mediation processes, or litigation proceedings..	2. Contracts lacking realistic provisions for completion timelines.	**H2**
		3. Inadequate payment-related provisions.	**H3**
		4. Lack of clarity in quality standards.	**H4**
Approval risks	Delayed (or non-issued) decisions, permits, and/or approvals required for project execution result in additional costs or delays	1. Prolonged administrative processes by government agencies or relevant authorities	**I1**
		2. Regulatory uncertainties that complicate the approval process	**I2**
Input risks	Faktor produksi yang hanya dapat diperoleh dengan kualitas yang lebih rendah, dalam jumlah kecil, dengan biaya yang lebih tinggi dan/atau mungkin tidak diperoleh pada waktunya.	1. Ketersediaan bahan yang sesuai dengan standar mutu.	**J1**
		2. Kenaikan harga bahan baku	**J2**
		3. Proses pengiriman material ke lokasi proyek.	**J3**
Interface risks	Disruptions during service processing due to the coexistence of the intended performance and the performance of private partners.	1. Inability to coordinate among design, construction, and project management teams, potentially leading to implementation errors.	**K1**
		2. Lack of effective communication among stakeholders, including contractors, subcontractors, and project owners.	**K2**
Management risks	Defective temporal planning and/or inadequate descriptions of competencies, communication channels, personnel applications, resource allocations, or insufficient subcontractor control, as well as neglected control duties and executive functions, result in delays or cost escalations..	1. Project operators, such as administrators and drivers, are required to work multiple shifts.	**L1**
		2. Operational losses for the concession.	**L2**
		3. The potential to minimize accidents and save lives has been overlooked.	**L3**
Tecnical implementation risks	Conversion errors in construction logistics, quality management, error rectification, worker safety, conservation and historic building preservation, art in construction, and/or construction methods lead to the neglect of technical requirements..	1. Operations are hindered by the unavailability of necessary equipment.	**M1**
		2. Ineffective communication and collaboration among relevant authorities.	**M2**
		3. Disruptions in communication among involved parties.	**M3**
		4. Production has decreased due to a lack of routine maintenance on utilized equipment	**M4**
		5. Kebijakan nasional yang National policies supporting infrastructure development are insufficient	**M5**
Technology risks	Technical innovation requires replacing outdated technical	1. The use of inadequate technology, expertise, and	**N1**

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	arrangements and facilities to ensure competitiveness	methods in administration, operations, processing, and infrastructure project development.	
Operation risks	Technical or judicial disruptions to services that impede performance, availability, quality, or quantity of the services to be delivered	1. Accidents occur due to poor safety procedures	**O1**
		2. Current traffic conditions, affecting movement and travel times.	**O2**
Risks arising from change in service standards	Unforeseen changes in service standards (functional spatial programs, space allocation plans, facilities, and users' constructive and operational demands) during construction and operation phases by principals or users necessitate re-planning, reconstruction, or change actions.	1. Involvement of multiple, differing decision-making bodies.	**P1**
		2. Contractual issues between businesses operating on the project and the responsible government entities.	**P2**
		3. Reorganization of corporate structures and processes.	**P3**
Maintenance risks	Incorrect or neglected inspections, maintenance services, or repairs result in secondary damage, increased costs, or delays.	1. Initial construction fails to meet quality standards	**Q1**
		2. Lack of a clear and structured maintenance pla	**Q2**
		3. Absence or inadequacy of monitoring and evaluation systems.	**Q3**
Vandalism risks	Non-operational damages caused deliberately (e.g., theft and vandalism) necessitate additional measures, unforeseen costs, and delays.	1. Theft of materials or heavy equipment by criminal actions.	**R1**
		2. Physical damage to construction projects due to vandalism.	**R2**
Financial risks	Capital intended for introduction (including transportation assets) to finance medium- or long-term projects cannot be raised or fails to meet the planned conditions.	Cash flow and resource management are not properly handled.	**S1**
		Insufficient operational staff, including administrators, technicians, and field workers.	**S2**
		Decline in the cost of necessary equipment has occurred.	**S3**
Inflation risks	Unspecified differences between actual costs and planned costs, or services not commensurate with expenses due to inflation i.	1. Inflation rates in Indonesia.	**T1**
		2. Economic recession.	**T2**
		3. Fluctuations in fuel prices.	**T3**
		4. Inflation must be incorporated into cost planning.	**T4**
Tax risks	Changes in tax laws and increases in tax rates impose additional financial burdens on projects and/or partners.	1. Amendments to the tax system.	**U1**
		2. Adjustments in tax rates	**U2**
Income risks	Revenue generated from usage (e.g., entry fees) deviates from projected revenue, which is critical for user-financed projects (e.g., public restrooms)	1. Usage rates for infrastructure deviate from the planned rates	**V1**

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Risk of the principal insolvency	The principal is unable to settle their debts, or at least fails to do so on time.	1. Delayed or unpaid contractual payments	**W1**
Risks of change in law/standards	Changes in broader legal regulations (e.g., construction laws) and/or norms to be implemented, as well as rules and directives impacting project outcomes.	1. Project funding policies have shifted.	**X1**
		2. Opposition and intervention within the political arena	**X2**
		3. Bribery and corruption.	**X3**
Force majeure	Force majeure events (natural disasters, wars, etc.) damage or destroy the project	1. Natural disasters affecting infrastructure project integrity.	**Y1**
Exploitation risks	Uncertainty regarding the market value of the contractual object at the end of the contract term (whether at the conclusion of the contract period or due to premature termination)	1. Uncertainty in market value	**Z1**

Finding and Discussion

Respondent Demographics

In this section, respondents identified as construction experts were asked three demographic questions. Table 3 reveals their work location, professional experience, and educational background. A total of 56% of respondents work in the public sector or government, while the remaining 44% are employed in the private sector. Regarding educational attainment, only 5% of survey participants hold a master's degree, while 90% possess a bachelor's degree. Additionally, 78% of respondents have over ten years of experience, whereas only 22% have less than ten years of experience.

Table 3. Respondent Demographics

	Category	Frequency	Percentage
Work Location	Public Sector	28	56%
	Private Sector	22	44%
	Non-Governmental Organization	0	-
	International Non-Governmental Organization	0	-
	Donor Agency	0	-
Work Experience	1-5 years	0	-
	5-10 years	11	22%
	> 10 t years	39	78%
Education	Doctorate/PhD	0	-
	Master's Degree	5	10%
	Bachelor's Degree	35	90%
	Diploma	0	-
	High School	0	-
	Junior High School	0	-

Source: Processed Data, 2024

Descriptive Statistics of Risk Categories and RII

A total of 50 completed questionnaires were collected and processed. The initial data presented include descriptive statistics for each risk category and the RII values derived from the 50 study respondents, as shown in Table 4.

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Table 4. Descriptive Statistics of Risk Categories

Category	Code	Mean	RII	Rank	Risk Level
Site Risks	**A1**	1.60	2.70	11	Moderate
	A2	1.88	2.50	21	Low
	A3	1.36	2.36	25	Low
	A4	1.38	2.48	22	Low
	A5	1.92	2.66	13	Moderate
	A6	2.56	2.88	2	Moderate
Demand Risks	**B1**	2.36	2.68	12	Moderate
	B2	2.06	2.58	17	Moderate
Subsoil risks	**C1**	1.58	2.60	16	Moderate
	C2	2.34	2.66	13	Moderate
	C3	2.32	2.82	4	Moderate
	C4	2.36	2.70	11	Moderate
Building structure risks	**D1**	2.40	2.74	9	Moderate
	D2	1.86	2.78	6	Moderate
Tendering and awarding risks	**E1**	2.42	2.68	12	Moderate
	E2	1.48	2.58	17	Moderate
	E3	2.14	2.64	14	Moderate
	E4	2.30	2.66	13	Moderate
	E5	2.36	2.72	10	Moderate
Complaint and protest risks	**F1**	2.50	2.68	12	Moderate
	F2	1.98	2.56	18	Moderate
Design risks	**G1**	2.44	2.70	11	Moderate
	G2	2.12	2.64	14	Moderate
Contractual risks	**H1**	2.00	2.58	17	Moderate
	H2	2.02	2.52	20	Moderate
	H3	1.64	2.56	18	Moderate
	H4	1.46	2.64	14	Moderate
Approval risks	**I1**	1.46	2.56	18	Moderate
	I2	1.38	2.56	18	Moderate
Input risks	**J1**	2.40	2.72	10	Moderate
	J2	2.44	2.84	3	Moderate
	J3	2.26	2.68	12	Moderate
Interface risks	**K1**	2.44	2.76	7	Moderate
	K2	2.26	2.62	15	Moderate
Management risks	**L1**	2.32	2.74	9	Moderate
	L2	2.44	2.75	8	Moderate
	L3	2.42	2.74	9	Moderate
Tecnical implementation risks	**M1**	2.48	2.80	5	Moderate
	M2	2.10	2.62	15	Moderate
	M3	2.14	2.56	18	Moderate
	M4	2.52	2.84	3	Moderate
	M5	2.20	2.56	18	Moderate
Technology risks	**N1**	2.30	2.72	10	Moderate

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Operation risks	**O1**	2.48	2.74	9	Moderate
	O2	2.42	2.74	9	Moderate
Risks arising from change in service standards	**P1**	2.20	2.62	15	Moderate
	P2	2.24	2.72	10	Moderate
	P3	2.24	2.50	21	Low
Maintenance risks	**Q1**	2.34	2.58	17	Moderate
	Q2	2.46	2.70	11	Moderate
	Q3	1.80	2.48	22	Low
Vandalism risks	**R1**	2.10	2.60	16	Moderate
	R2	1.90	2.50	21	Low
Financial risks	**S1**	1.86	2.44	23	Low
	S2	2.14	2.62	15	Moderate
	S3	1.74	2.42	24	Low
Inflation risks	**T1**	2.14	2.70	11	Moderate
	T2	1.74	2.42	24	Low
	T3	2.14	2.84	3	Moderate
	T4	1.54	2.28	26	Low
Tax risks	**U1**	2.08	2.54	19	Moderate
	U2	1.86	2.64	14	Moderate
Income risks	**V1**	2.32	2.80	5	Moderate
Risk of the principal insolvency	**W1**	2.70	3.04	1	Moderate
Risks of change in law/standards	**X1**	2.50	2.62	15	Moderate
	X2	2.16	2.70	11	Moderate
	X3	2.42	2.68	12	Moderate
Force majeure	**Y1**	2.36	2.62	15	Moderate
Exploitation risks	**Z1**	2.46	2.66	13	Moderate

Source: Processed Data, 2024

As shown in Table 3, the infrastructure project pathway and its impact on the financial costs of infrastructure projects in Indonesia are crucial for project success. The identified risk factors were categorized based on Fischer's 21 risk categories (2010) and subsequently scored by respondents according to their potential impact on infrastructure project costs. Based on the mean scores for each indicator and the RII calculation, only 10 risk indicators were classified as low, while the remaining 59 indicators were categorized as having moderate potential impacts on infrastructure development in Indonesia.

The risk of principal insolvency ranked first, emerging as the risk with the most significant impact on infrastructure project costs. When the principal becomes insolvent, the project may need to find a replacement to complete pending work. This process often involves additional costs, both for sourcing a new contractor and for accelerating the completion of delayed tasks. Consequently, this can cause the project budget to escalate significantly.

Validity and Reliability

We used SPSS to test the validity and reliability of the questionnaire before it was distributed to respondents. The results of these tests provided Cronbach's alpha values > 0.7 and AVE > 0.6 for each risk category, indicating that survey responses were highly consistent.

Table 5. Validity and Reliability

	Cron. alpha	**AVE**		**Cron. alpha**	**AVE**
Site Risk	0.786	0.691	Technology Risks	0.815	0.632
Demand Risks	0.727	0.782	Operation Risks	0.857	0.874

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Subsoil Risks	0.773	0.601	Risks Arising from Change in Service Standard	0.754	0.671
Building Structure Risks	0.778	0.754	Maintenance Risks	0.807	0.723
Tendering and Awarding Risks	0.865	0.651	Vandalism Risks	0.848	0.868
Complain and Protests Risks	0.857	0.744	Financial Risks	0.779	0.694
Design Risks	0.850	0.869	Inflation Risks	0.737	0.437
Contractual Risks	0.829	0.662	Tax Risks	0.776	0.617
Approval Risks	0.915	0.922	Income Risks	0.758	0.617
Input Risks	0.892	0.822	Risks of the Principal Insolvency	0.826	0.653
Interface Risks	0.843	0.864	Risks of Change in Law	0.751	0.534
Management Risks	0.859	0.782	Force Majeure	0.824	0.619
Technical Implementation Risks	0.913	0.741	Exploitation Risks	0.765	0.685

Source: Processed Data, 2024

Statistical Analysis

The assessment of potential risks with significant or minimal impacts on infrastructure costs was conducted through statistical analysis using PLS-SEM with the following path equation.

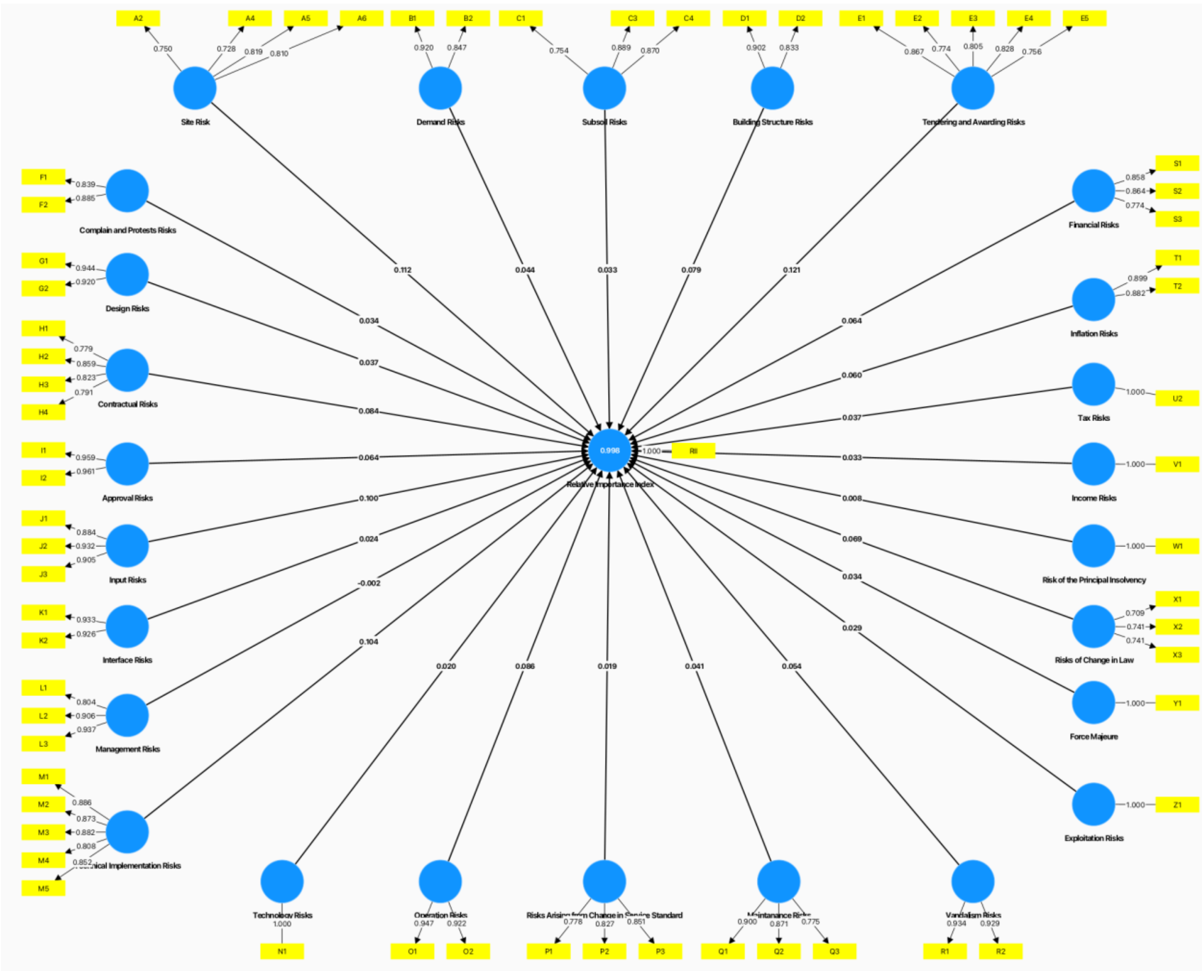

Figure 1. Graphical Output of Path Analysis

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The R-square value in this research model is 0.998, indicating that 99.8% of the variation in the dependent variable can be explained by the independent variables in the model. This demonstrates that the model is highly fitting to the data. The influence test was conducted by examining the t-statistic and p-values. A hypothesis is accepted if the t-statistic > 1.96 and the p-value < 0.05.

Table 5. Impact of Risk Categories on Infrastructure Project Costs

No.	Hubungan	Original sample	t-stat	P values	Keterangan
1	Site Risk → RII	0.086	1.987	0.048	Accepted
2	Demand Risks → RII	0.169	2.083	0.034	Accepted
3	Subsoil Risks → RII	0.003	1.972	0.027	Accepted
4	Building Structure Risks → RII	0.064	**1.342**	**0.185**	**Rejected**
5	Tendering and Awarding Risks → RII	0.005	1.975	0.080	Accepted
6	Complain and Protests Risks → RII	0.014	**0.061**	**0.125**	**Rejected**
7	Design Risks → RII	0.094	2.157	0.045	Accepted
8	Contractual Risks → RII	0.112	**0.554**	**0.580**	**Ditolak**
9	Approval Risks → RII	0.211	**0.843**	**0.394**	**Rejected**
10	Input Risks → RII	0.101	2.176	0.024	Accepted
11	Interface Risks → RII	0.013	2.690	0.049	Accepted
12	Management Risks → RII	0.061	2.264	0.029	Accepted
13	Technical Implementation Risks → RII	0.090	2.767	0.044	Accepted
14	Technology Risks → RII	0.025	2.374	0.018	Accepted
15	Operation Risks → RII	0.119	2.595	0.042	Accepted
16	Risks Arising from Change in Service Standard → RII	0.074	**0.217**	**0.286**	**Rejected**
17	Maintenance Risks → RII	0.066	**0.115**	**0.209**	**Rejected**
18	Vandalism Risks → RII	0.107	**0.412**	**0.681**	**Rejected**
19	Financial Risks → RII	0.026	2.007	0.030	Accepted
20	Inflation Risks → RII	0.199	2.075	0.032	Accepted
21	Tax Risks → RII	0.037	2.026	0.022	Accepted
22	Income Risks → RII	0.086	2.507	0.013	Accepted
23	Risks of the Principal Insolvency → RII	0.169	2.843	0.039	Accepted
24	Risks of Change in Law → RII	0.003	2.163	0.031	Accepted
25	Force Majeure → RII	0.064	2.412	0.027	Accepted
26	Exploitation Risks → RII	0.005	2.047	0.029	Accepted

Source: Processed Data, 2024

(Fischer et al., 2010) categorized risks to provide a foundation for standardization by grouping risk factors into non-redundant risk categories. This grouping was performed in such a way as to minimize or eliminate interdependencies among the various risk groups. An empirical test was then conducted to identify risks influencing infrastructure project costs. Based on the data analysis results (Table 5), seven risks were found to have no significant impact (t-statistic < 1.96 and p-values > 0.05) on infrastructure project costs in Indonesia. The most likely reason is that these risks were deemed to have a low response degree based on survey data.

Building Structure Risks were found to have no impact on infrastructure project costs. These risks are defined as factors related to location, such as project site availability, weather conditions (e.g., frost,

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windstorms), public perception, environmental concerns, and sustainability issues that negatively affect construction progress, operations, or infrastructure utilization. Respondents perceived these risks as not significantly influencing expenditures or budgets for infrastructure projects. When structural planning and design are conducted appropriately, location-related risks such as extreme weather can be minimized. For instance, weather-resistant designs can reduce losses caused by adverse weather conditions.

Complain and Protest Risks relate to public dissatisfaction resulting in protests. While these risks can cause disruptions to project execution, they do not always have a direct impact on project costs. In the Indonesian context, guarantees provided by institutions such as PT Penjaminan Infrastruktur Indonesia (PT PII), a state-owned enterprise (SOE), help mitigate political risk exposure and reassure investors that projects will proceed as planned, even amidst potential public protests. This reduces financing costs and increases private participation in infrastructure projects.

Contractual Risks arise from incomplete contract documents, leading to additional costs or delays. These risks were not deemed impactful on infrastructure project costs because respondents considered them effectively manageable. If contract documents are well-prepared and cover all critical aspects, risks stemming from incompleteness or ambiguity can be minimized. Many contracts also include adjustment clauses that allow for cost renegotiation in specific situations, thereby reducing the financial impact of contractual risks.

Approval Risks, related to delays or uncertainties in obtaining decisions, permits, and approvals, were found to have no significant impact on infrastructure project costs. While such delays can slow project progress, in many cases, they do not directly increase project costs.

Risks Arising from Changes in Service Standards do not significantly affect infrastructure project costs. This is because infrastructure projects are typically supported by contracts that clearly specify the services and standards to be met. If changes in service standards occur, these contracts often include clauses addressing how such changes will be managed, including adjustments to costs or completion timelines.

Maintenance Risks can be avoided if companies are capable of identifying, managing, and mitigating potential risks, including regular maintenance planning and clear procedures, ensuring maintenance risks do not affect infrastructure costs. Many infrastructure projects in Indonesia are covered by insurance, including protection against vandalism. These policies often cover repair or replacement costs for damaged assets, thereby reducing the financial burden on developers.

Risks of Principal Insolvency ranked first as the most significant risk affecting infrastructure project costs.

Conclusion, Limitation, and Implication

This study aimed to identify and determine the impact of infrastructure project risks on infrastructure costs. The impact of these risks was determined by assessing their occurrence frequency based on respondents' survey responses and ranking them using RII ranges. Potential risks in infrastructure projects include financial, time, personnel, design and technical, contractual, physical, political and regulatory, and safety risks. These risks can negatively affect the cost, time, and quality of construction projects. Physical risks include extreme weather, earthquakes, floods, fires, and land subsidence, while political and regulatory risks involve unstable government policies, expropriation, inflation, and taxation.

Empirical findings revealed that seven risk categories have no impact on infrastructure project costs in Indonesia, including Building Structure Risks, Complain and Protest Risks, Contractual Risks, Approval Risks, Risks Arising from Changes in Service Standards, Maintenance Risks, and Vandalism Risks. These risks can be managed and mitigated through comprehensive project planning, clear contract documents specifying standards and specifications, and adjustment clauses. Additionally, Indonesia benefits from guarantees provided by SOEs, reducing exposure to social and political risks.

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Managing risks in infrastructure projects involves several steps, including risk response planning, developing and implementing strategies such as prevention, transfer, and mitigation, as well as ongoing negotiation and risk control to monitor developments and changes.

This study also found a lack of consistent and universally accepted definitions for risks in PPP projects. While substantial research on risk management in PPPs exists, this study highlights the need for standardized risk management processes.

The utility of risk management in this study lies in enhancing transparency by leveraging improved data sources and information distribution. Infrastructure project risks should be effectively managed through a risk management process encompassing identification, analysis, assessment, allocation, control, and monitoring. Advanced risk management techniques will enhance the ability and accuracy of decision-making processes. This will foster credibility and shared understanding of key data, ratios, and reports for all contractual partners.

The findings provide implications for policymakers, standardization boards, and construction practitioners as an empirical foundation for developing integrated and standardized risk management systems aimed at improving transparency and credibility. Such integrated systems offer step-by-step instructions for sub-processes connected within the overall structure, serving all stakeholders by enhancing information distribution and decision-making accuracy.

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