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Risk Analysis in the Implementation of Flood Control Construction Projects in Jambi Province

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Abstract

Flood control construction projects are highly prone to various risks due to technical, environmental, and management factors. While risk management in general construction projects is widely studied, few works focus specifically on flood control infrastructure in flood-prone regions. This study aims to analyze the risks that arise in the implementation of flood control construction projects in Jambi Province. A mixed-methods approach was employed, combining survey data from key stakeholders with quantitative analysis using severity indices and probability-impact matrices and formulate mitigation strategies using the PDCA (Plan – Do – Check – Act) approach. Data were collected through questionnaires distributed to stakeholders and analyzed using risk matrices The results showed that among 39 identified risk variables, one was categorized as moderate-risk, and thirtyeight were categorized as low – risk. Key risks include delays in land acquisition, design changes, weather disruptions, and material shortages. Mitigation strategies include enhanced planning, improved stakeholder communication, and strengthening contractor capabilities. The study contributes theoretically by demonstrating the applicability of PDCA in risk management for flood – prone infrastructure, and practically by providing actionable strategies to enhance project resilience in similar contexts globally. These findings aim to assist practitioners in recognizing and managing key risks to ensure successful project delivery.

Keywords: Construction Risk, Flood Control, Project Management, Jambi Province, Risk Analysis

■1.0 INTRODUCTION

Jambi Province, located in the central part of Sumatra Island, represents a strategic region that plays a pivotal role in driving national economic growth and advancing regional infrastructure development. Geographically, the province covers an area of approximately 50,160.05 km² with a population of 3,631,136 (Jambi Provincial Statistics Agency, 2022). Its geographical position, which borders several other provinces, strengthens its role as a crucial hub in Sumatra's spatial and economic planning. The local economy is largely supported by agriculture, plantations, and fisheries, sectors that not only dominate economic activity but also provide employment for the majority of its inhabitants.

Nevertheless, the rapid pace of demographic growth combined with expanding economic activities has created mounting pressures on land resources and environmental capacity. In particular, the Batanghari Watershed (DAS) the largest watershed in Jambi and the main provider of water for both domestic consumption and industrial purposes has experienced severe ecological stress. Uncontrolled land-use changes, urban expansion, and industrial development have accelerated the degradation of natural resources, thereby intensifying the frequency and magnitude of floods. The hydrological balance of the Batanghari River system has been disrupted by excessive sedimentation, narrowing river channels, and the encroachment of human settlements along its banks. These factors collectively increase the province's vulnerability to flood disasters, with direct implications for public safety, infrastructure resilience, and economic stability.

In response to these escalating challenges, the Jambi Provincial Government, in collaboration with the Sumatra VI River Basin Organization, has initiated a series of flood control construction projects. These initiatives include the construction and improvement of drainage networks, river normalization programs, canal rehabilitation, and the building of embankments. While these projects are crucial to reducing flood risks and protecting socio economic activities, their implementation is far from straightforward. Technical limitations in the field, managerial constraints within project execution, and resistance from affected communities represent persistent barriers. In addition, delays in land acquisition, discrepancies between project designs and actual site conditions, and ineffective communication between stakeholders further complicate the realization of project goals.

Given these complexities, the systematic identification and management of risks become essential in ensuring that flood control projects achieve their intended outcomes. This study, therefore, aims to identify and analyze the dominant risks associated with flood control construction projects in Jambi Province and to propose mitigation strategies grounded in adaptive risk management frameworks.

By doing so, the study not only contributes practical solutions for project stakeholders but also enriches theoretical discussions on risk management in infrastructure development within flood-prone regions. The findings are expected to serve as a valuable reference for policymakers, engineers, and practitioners in enhancing project resilience and sustainability in the face of dynamic socio environmental challenges.

2.0 LITERATURE REVIEW

2.1 Definition and Sources of Construction Risk

Risk in construction projects is generally defined as an uncertain event or condition that, if it occurs, may positively or negatively affect the achievement of a project's objectives (Loosemore, M. et. al., 2012). These risks stem from various sources throughout the project life cycle, which may arise due to unpredictable or poorly managed conditions.

In addition, construction risk is defined as the probability of an uncertain event that can affect project objectives in terms of time, cost, quality, or scope (PMI, 2017). Several studies have emphasized the importance of early risk identification in infrastructure projects. According to Ervianto (2005), poor anticipation of risks often leads to delays and cost overruns in public construction projects.

Flood control construction projects, by nature, involve complex coordination of various elements, including land acquisition, environmental assessments, hydraulic design, and larges – scale excavation and structure works. These components interact in a dynamic setting, often leading to uncertainties and challenges that cannot always be anticipated at the planning stage. The location of the project in a hydrologically sensitive area further compounds the exposure to natural and technical risks. Therefore, without a robust risk management framework, such projects face high potential for delays and budget overruns.

2.1.1 Types of Risk Sources

Construction risks can be categorized into several key domains (Duffield & Trigunarsyah, 1999), including: 1) Technical Risks: Related to design errors, construction methods, technology failure, or discrepancies between design and field execution. 2) Financial Risks: Involving budgeting errors, late payments, inflation, or cash flow shortages. 3) Environmental Risks: Such as adverse weather, natural disasters, and environmental regulations. 4) Legal and Contractual Risks: Including unclear contract clauses, disputes, or delays in land acquisition and permits. 5) Managerial and Human Risks: Related to lack of coordination, poor planning, or limited experience of project personnel.

Risk identification and categorization are essential components of the risk management process. It involves recognizing all potential threats, assessing their probability and impact, and classifying them according to severity levels. By applying tools such as risk matrices, decision-makers can prioritize mitigation efforts and allocate resources more effectively. Fahlevi et al. (2019) emphasized that the success of flood control projects in West Java heavily depended on early identification of logistical and environmental risks. Incorporating such techniques into project planning enhances preparedness and decision – making.

2.1.2 Internal and External Risks

According to Wideman, R. M. (2004) risks in construction are classified as: 1) Internal Risks: Those originating within the project boundaries such as cost overruns, resource unavailability, and scheduling problems. 2) External Risks: Events outside the control of the project team, such as regulatory changes, political instability, or public opposition.

Meanwhile, Flanagan & Norman (1998) in Sofandi (2017) identified more specific risks that commonly occur in construction projects, such as: a. Uncertainty of weather conditions, b. Variations in soil characteristics, c. Delays in obtaining planning drawings or permits, d. Discrepancies between the final project results and the initial design.

Gustavson, S. G., & Trieschmann, J. S. (1995) introduced a classification of risk into two broad categories: pure risk and speculative risk. Pure risk has only two outcomes: loss or no loss, while speculative risk includes the possibility of loss, no loss, or gain.

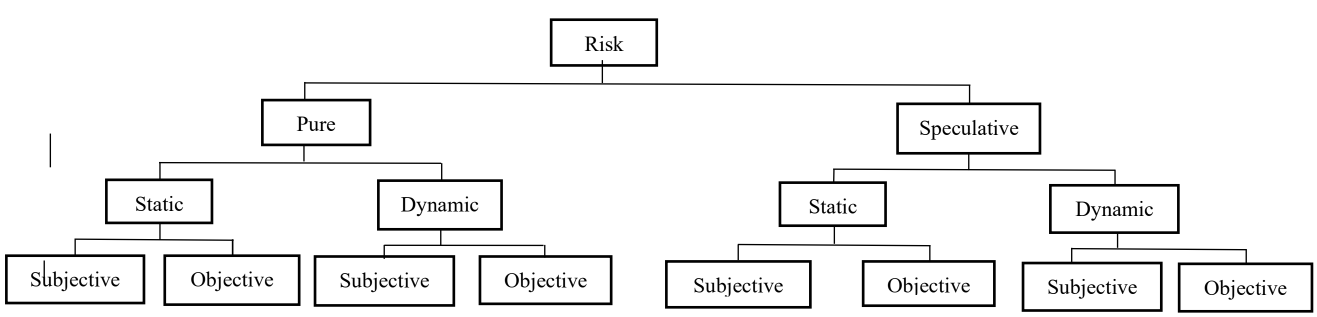

Figure 1 Risk Type Scheme
(Source: Trieschmann & Gustavson, 1995)

2.2 Risk Management Process

ISO 31000 emphasizes the importance of a systematic and integrated approach to risk management in order to support the achievement of organizational objectives and improve resilience in the face of uncertainty. It outlines a series of key stages in the risk management process, consisting of: 1. Risk Management Planning, which involves establishing the approach, resources, and strategies to be used in the risk management process. 2. Risk Identification, which involves recognizing potential events that could impact the achievement of organizational objectives. 3. Risk Analysis, which involves evaluating risk characteristics, including causes, likelihood of occurrence, and potential impacts. 4. Risk Evaluation, which is the process of comparing the level of risk with predetermined criteria to determine the priority of its handling. 5. Risk Treatment, which is the establishment and implementation of the most appropriate actions to reduce, avoid, or transfer risks. 6. Risk Monitoring and Review, which is the ongoing monitoring activity to ensure the effectiveness of the entire risk management process and make improvements when necessary.

By applying the principles of ISO 31000:2009, organizations are expected to be able to face complex and dynamic challenges in a more adaptive and responsible manner.

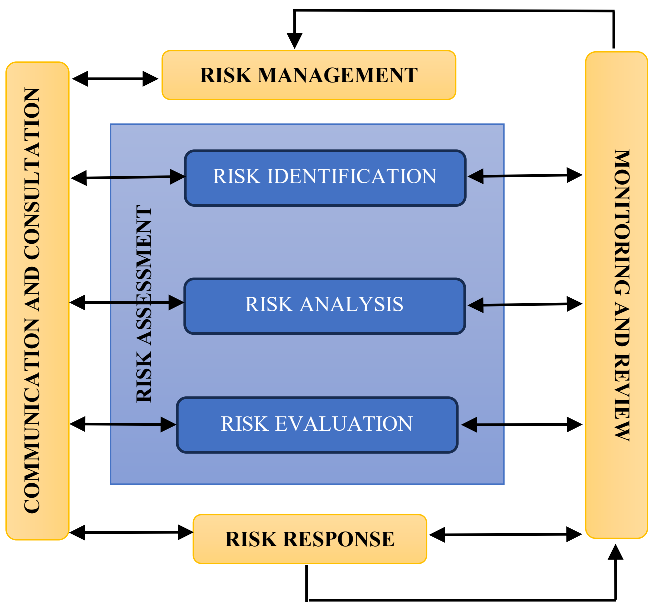

Figure 2 Risk Management Process (ISO 31000:2009)

In the third edition of A Guide to the Project Management Body of Knowledge (PMBOK), the risk management process is described in more detail through a flowchart that illustrates six main steps. These steps include: risk management planning, risk identification, risk analysis covering qualitative and quantitative analysis, risk response planning, and risk monitoring and control. This approach demonstrates how the risk management process is applied systematically throughout the entire project lifecycle.

To manage these risks, the Project Management Institute (PMBOK, 20017) and ISO 31000:2009 propose a structured approach involving the following stages: Risk identification, risk analysis, and risk management. These three stages will run optimally if supported by accurate data and effective and comprehensive communication at all levels of the organization, from top management to field workers. Collaboration and information transparency are important elements in ensuring that potential risks are handled appropriately, thereby minimizing the negative impact on the project.

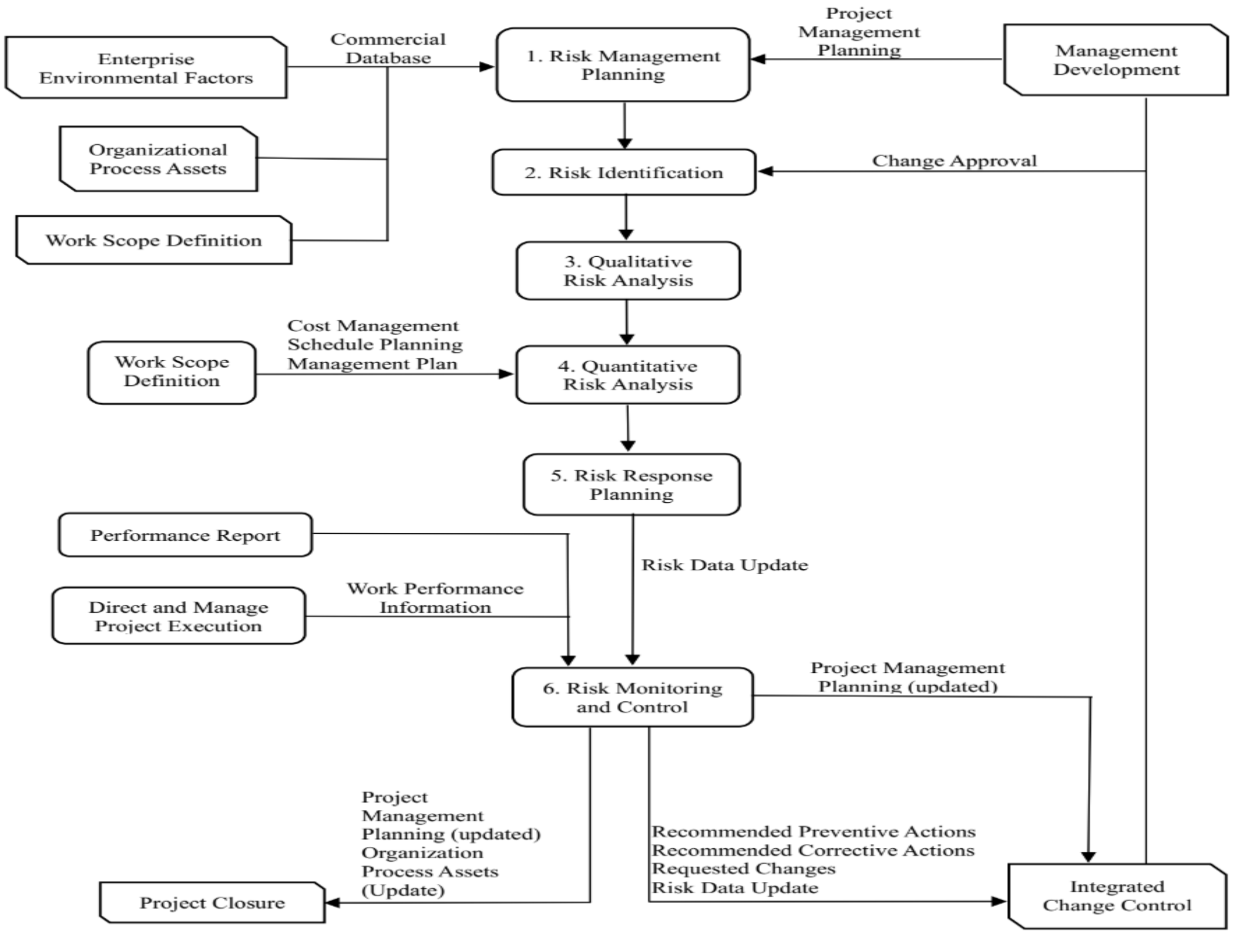

Figure 3 Risk Management Process according to PMBOK
(Source: Project Management Institute, 2017. PMBOK Guide 7th Ed.)

2.2.1 Risk Identification

Risk identification aims to recognize threats that could potentially affect the course of the project and document their characteristics systematically. Given that risks can continue to evolve as the project progresses, this process is ongoing. In general, there are two categories of risk: internal and external. 1. Internal risks are risks that originate from within the company or project itself, such as costs, productivity, contracts, and completion schedules. 2. External risks originate from outside the company or project, such as political conditions, inflation, and other external factors.

Risk identification is carried out by analyzing a series of events from the source of risk to the occurrence of events that can cause losses. This process can be grouped based on two main aspects, namely risk events and risk agents, which are the factors that cause risk events to occur.

2.2.2 Risk Analysis

Risk analysis is an estimate of what will happen if a decision is made. The main factors in choosing a risk analysis technique include the type and scale of the project, available information, analysis costs, available time, and the experience and expertise of the analyst (Smith et. al., 2014). In general, there are two methods for conducting risk analysis: qualitative and quantitative.

Each risk was assessed based on its probability of occurrence and impact level. Techniques such as Severity Index and Probability Impact Matrix were used to quantify and prioritize these risks.

Severity Index (SI) is calculated using the following formula (Dewi & Nurcahyo, 2013).

$$SI = \frac{\sum_{i=0}^{4} a_i x_i}{4\sum_{i=0}^{4} x_i}(100\%)$$

Where:
ai = assessment constant
xi = respondent probability
i = 0, 1, 2, 3, 4, 5,……, n
x0, x1, x2, x3, x4 are respondent probability responses
a0=0, a1=1, a2=2, a3=3, a4=4
x0 = respondent probability of “very low,” then a0 = 0
x1 = respondent probability of “low,” then a1 = 1
x2 = respondent probability of “quite high,” then a2 = 2
x3 = respondent probability of “high,” then a3 = 3
x4 = respondent probability of “very high,” then a4 = 4

Risk categories in the Probability Impact Matrix

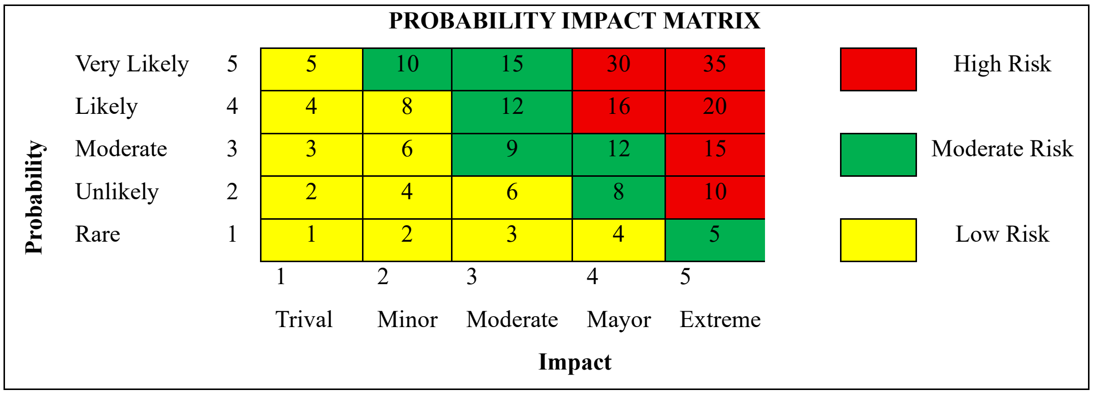

Figure 4 Risk Analysis Matrix (Probability vs Impact)

2.2.3 Risk Evaluation and Treatment

Risk assessment is the process of comparing the estimated level of risk with pre-established risk criteria. The result of this assessment is a risk ranking to identify the priority scale that needs to be managed by management. The purpose of risk assessment is to determine decisions that can impact the company, both decisions that can be implemented and those that need to be eliminated. The results of this evaluation reflect aspects that must be prioritized and require further action (Siahaan et. al., 2024)

There are several approaches commonly used in dealing with risk (Chan et. al., 2013) namely: 1. Risk Retention This is a risk management strategy in which a party consciously chooses to bear the risk. This approach is generally applied when the risk faced is not expected to cause significant losses, has a low probability of occurrence, or the cost of managing it is not commensurate with the benefits obtained. 2. Risk Reduction This is done by taking preventive measures to reduce the likelihood of the risk occurring or its impact. 3. Risk Transfer This strategy involves transferring the risk to another party, for example through an insurance agreement. In this case, the risk is borne by the insurance company in exchange for premium payments by the party seeking protection from the risk. 4. Risk Avoidance This approach involves refusing to engage in activities or projects that involve unacceptable risks. In this context, avoiding risk means not continuing or even starting the project.

2.2.4 Risk Monitoring

Risk monitoring and control is a process that includes overseeing the implementation of agreed risk response plans, reviewing identified risks, and recognizing and analyzing new risks. In addition, this process also aims to evaluate the effectiveness of risk management throughout the project. The benefit of this activity is to ensure that project decisions are based on the latest information regarding overall risk exposure and individual risks within the project. The risk monitoring and control process can be explained through the following diagram.

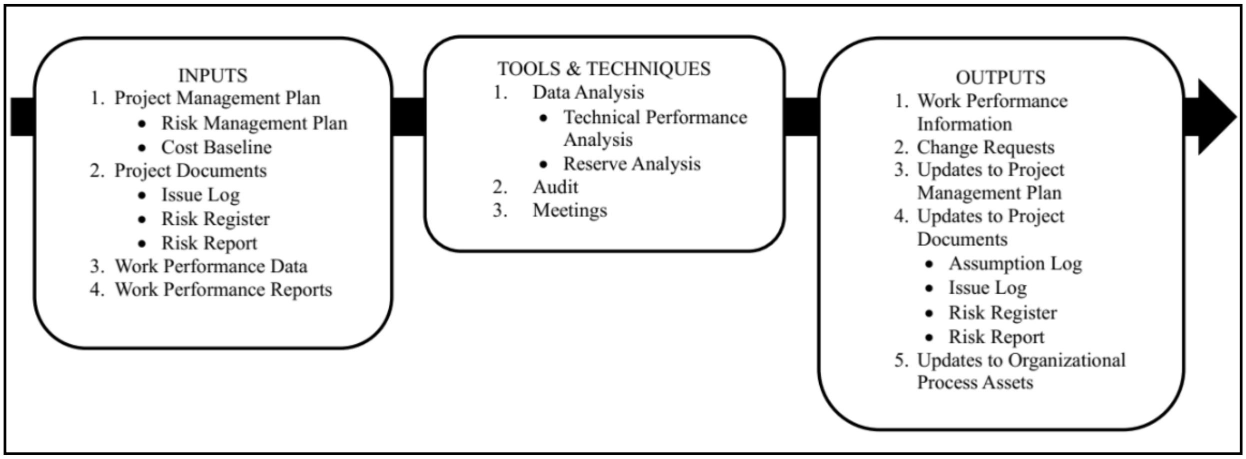

Figure 5 Risk Monitoring and Control (PMBOK, 2017)

Continuous supervision and reevaluation were conducted throughout the project implementation to adjust mitigation actions as needed

2.3 PDCA as a Risk Mitigation Framework

In line with the principle of continuous improvement, Deming (1986) proposed the Plan Do Check Act (PDCA) cycle, which has been successfully applied in risk management across infrastructure projects. In this research, PDCA was utilized to structure mitigation strategies, summarized as follows: 1. Plan: Identify risks, define mitigation targets, and assign responsibilities. 2. Do: Implement planned mitigation strategies on-site. 3. Check: Monitor and evaluate the outcomes of the strategies. 4. Act: Revise and adapt strategies based on findings to prevent recurrence.

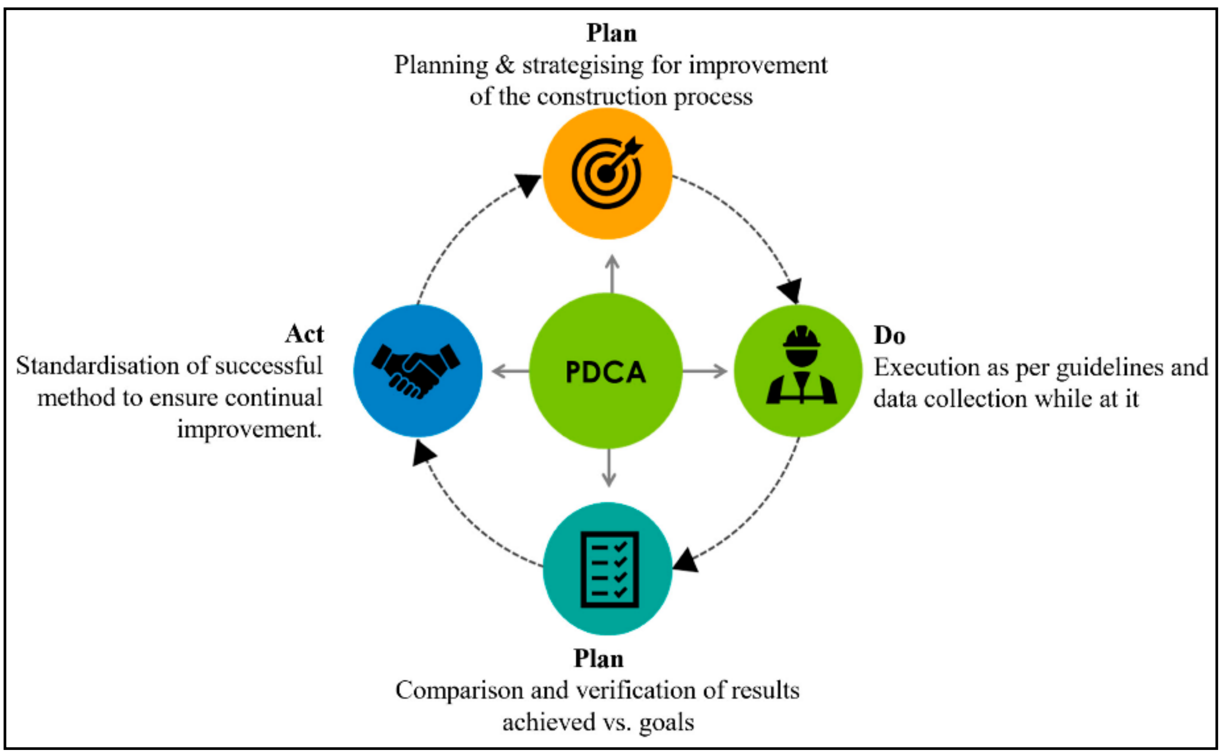

Figure 6 PDCA Cycle Adaptation

3.0 METHODOLOGY

3.1 Research Design

This study adopts a mixed-methods approach combining qualitative and quantitative techniques. A qualitative descriptive design was used to understand the context of flood control construction in Jambi, while quantitative analysis measured the severity of identified risks.

The study employed an exploratory sequential design, where qualitative data were used to explore potential risk indicators which were later quantified and analyzed statistically. This approach was chosen to ensure that the risk assessment captured both technical and contextual challenges encountered during implementation in the field.

3.2 Data Collection

Primary data was obtained through structured questionnaires distributed to stakeholders, including contractors, supervisors, government officials, and local community representatives. A total of 39 risk indicators were formulated from literature review and field observations, covering technical, financial, environmental, legal, and social domains.

Table 1 Factors and Variables

Factor	Code	Variable
Natural Factors (FA)	FA1	Unpredictable weather
	FA2	Natural disasters (floods, landslides, earthquakes, volcanic eruptions, etc.)
	FA3	Unstable soil conditions
Material Factors (FM)	FM1	Increase in material prices
	FM2	Damage or theft of materials
	FM3	Delays in ordering and delivery of materials
	FM4	Poor quality materials
	FM5	Lack of unloading and storage facilities for materials
Equipment Factors (FP)	FP1	Frequent equipment breakdowns
	FP2	Unavailability of spare parts
	FP3	Low productivity and efficiency of equipment
	FP4	Delays in equipment procurement and mobilization
Labor Factors (FTK)	FTK1	Insufficient labor supply on site
	FTK2	Unskilled labor
	FTK3	Low labor productivity
	FTK4	Accidents and occupational safety issues
	FTK5	Labor strikes
Contractual Factors(FK)	FK1	Unclear contractual clauses
	FK2	Different interpretation of specifications between owner and contractor
	FK3	Disputes between owner and contractor
	FK4	Unilateral termination of contract
Design and Technology Factors (FDT)	FDT1	Design errors
	FDT2	Design changes
	FDT3	Incorrect construction methods
	FDT4	Incomplete design data
Management Factors (FMJ)	FMJ1	Inaccurate time estimation
	FMJ2	Inaccurate cost estimation
	FMJ3	Poor communication and coordination
	FMJ4	Poor contractor performance
Financial Factors (FKU)	FKU1	Delayed fund disbursement
	FKU2	Unbalanced cash flow
	FKU3	Embezzlement of funds
	FKU4	Poor financial condition of contractor
Social and Environmental Factors(FSL)	FSL1	Public protests
	FSL2	Noise caused by heavy equipment
	FSL3	Damage to roads and public infrastructure
Political and Regulatory Factors (FPR)	FPR1	Changes in government regulations
	FPR2	Land acquisition issues
	FPR3	Exchange rate instability (inflation)

In addition, interviews were conducted with representatives from Balai Wilayah Sungai Sumatera VI and local project implementers to gain deeper insights into specific risk events and management responses.

Table 2 Research Respondent

No	Position in The Project	Amount
	Project Owner	
1	Budget User Authority	1
2	Commitment Making Officer (PPK)	2
3	Technical Implementer	2
4	Field Supervisor	12
	Contractor	
1	Site Manager	3
2	Field Implementer	4
3	Technical Team	7
	Supervisory Consultant	
1	Team Leader	3
2	*Inspector*	6
	Quantity	**40**

3.2.1 Validity and Reliability Testing

To ensure the accuracy and consistency of the measurement instruments: 1) Validity was tested using the Pearson Product Moment method. An indicator was considered valid if its correlation coefficient exceeded the critical value of 0.361 for N=30 (Sugiyono, 2013). 2) Reliability was tested using Cronbach's Alpha, with a threshold of >0.6 deemed acceptable for social research.

The results confirmed that all risk indicators used in the study were both valid and reliable.

3.2.2 Risk Analysis Techniques

Risk levels were determined using: 1) Severity Index (SI): To quantify the magnitude of impact if a risk occurs. 2)Probability Impact Matrix (PIM): To categorize risks based on their likelihood and severity, assigning them into low, moderate, or high – risk categories.

These tools allowed for prioritizing risks that required urgent mitigation strategies.

3.2.3 Mitigation Strategy Development

Based on the identified high-priority risks, mitigation strategies were formulated using the PDCA (Plan-Do-Check-Act) framework: 1) Plan: Identify and plan responses to critical risks such as budgeting issues or stakeholder resistance. 2) Do: Implement mitigation actions in the field (e.g., budget restructuring, communication forums). 3) Check: Monitor risk indicators through progress reports and feedback mechanisms. 4) Act: Revise project plans and adjust strategies based on evaluation findings.

This method ensured adaptive risk management during implementation.

■4.0 RESULTS

4.1 Identified Dominant Risks

The dominant high – risk variables included delays in land acquisition (score: 20), changes in design (score: 16), extreme weather (score: 15), supply delays in key materials (score: 15), and execution errors during construction (score: 12). These findings are aligned with those of Setiawan (2020), who emphasized the recurrent nature of design-related and procurement issues in government led infrastructure projects. In the Jambi context, delays in land release were exacerbated by overlapping land ownership and slow administrative processes (MoPW, 2019).

Table 3 Dominant Risks Identified Across Projects

FACTORS	CODE	PROBABILITY (P)		CODE	IMPACT (I)		R = P x I SEVERITY INDEX (%)	RISK RANKING	R = P x I (GRADE)	RISK CATEGORY
		SEVERITY INDEX (%)	SCORE		SEVERITY INDEX (%)	SCORE				
FREQUENCY OF NATURAL FACTORS	FFA1	43.38	3	DFA1	44.85	3	19.46	2	9	Moderate
	FFA2	31.62	2	DFA2	53.68	3	16.97	4	6	Low
	FFA3	35.29	2	DFA3	45.59	3	16.09	5	6	Low
FREQUENCY OF MATERIAL FACTORS	FFM1	36.03	2	DFM1	38.97	3	14.04	9	6	Low
	FFM2	35.29	2	DFM2	44.85	3	15.83	7	6	Low
	FFM3	35.29	2	DFM3	58.09	3	20.50	1	6	Low
	FFM4	29.41	2	DFM4	35.29	2	10.38	19	4	Low
	FFM5	26.47	2	DFM5	31.62	2	8.37	23	4	Low
FREQUENCY OF EQUIP MENT FACTORS	FFP1	34.56	2	DFP1	38.24	3	13.21	12	6	Low
	FFP2	27.21	2	DFP2	37.50	3	10.20	20	6	Low
	FFP3	22.79	2	DFP3	33.82	2	7.71	25	4	Low
	FFP4	29.41	2	DFP4	40.44	3	11.89	16	6	Low
FREQUENCY OF LABOR FACTORS	FFTK 1	27.94	2	DFTK 1	37.50	3	10.48	18	6	Low
	FFTK 2	32.35	2	DFTK 2	44.12	3	14.27	8	6	Low
	FFTK 3	27.21	2	DFTK 3	35.29	2	9.60	21	4	Low
	FFTK 4	9.56	2	DFTK 4	19.85	2	1.90	39	4	Low
	FFTK 5	11.03	2	DFTK 5	19.85	2	2.19	38	4	Low
FREQUENCY OF CONTRACTUAL FACTORS	FFK1	14.71	2	DFK1	26.47	2	3.89	35	4	Low
	FFK2	16.91	2	DFK2	26.47	2	4.48	32	4	Low
	FFK3	13.24	2	DFK3	25.74	2	3.41	36	4	Low
	FFK4	12.50	2	DFK4	24.26	2	3.03	37	4	Low
FREQUENCY OF DESIGN AND TECHNOLOGY FACTORS	FFDT1	30.15	2	DFDT1	42.65	3	12.86	13	6	Low
	FFDT2	35.29	2	DFDT2	35.29	2	12.46	14	4	Low
	FFDT3	26.47	2	DFDT3	33.09	2	8.76	22	4	Low
	FFDT4	35.29	2	DFDT4	45.59	3	16.09	5	6	Low
FREQUENCY OF MANAGEMENT FACTORS	FFMJ1	17.65	2	DFMJ1	31.62	2	5.58	30	4	Low
	FFMJ2	25.00	2	DFMJ2	42.65	3	10.66	17	6	Low
	FFMJ3	30.88	2	DFMJ3	43.38	3	13.40	11	6	Low
	FFMJ4	27.94	2	DFMJ4	43.38	3	12.12	15	6	Low
FREQUENCY OF FINANCIAL FACTORS	FFKU1	14.71	2	DFKU1	29.41	2	4.33	33	4	Low
	FFKU2	20.59	2	DFKU2	34.56	2	7.12	27	4	Low
	FFKU3	19.85	2	DFKU3	36.03	2	7.15	26	4	Low
	FFKU4	13.97	2	DFKU4	30.88	2	4.31	34	4	Low
FREQUENCY OF SOCIAL AND ENVIRONMENTAL FACTORS	FFSL1	31.62	2	DFSL1	43.38	3	13.72	10	6	Low
	FFSL2	25.74	2	DFSL2	31.62	2	8.14	24	4	Low
	FFSL3	17.65	2	DFSL3	27.94	2	4.93	31	4	Low
FREQUENCY OF POLITICAL AND REGULATORY FACTORS	FFPR1	20.59	2	DFPR1	33.82	2	6.96	28	4	Low
	FFPR2	36.76	2	DFPR2	51.47	3	18.92	3	6	Low
	FFPR3	17.65	2	DFPR3	34.56	2	6.10	29	4	Low

Extreme weather conditions, such as heavy rainfall and flooding, frequently interrupt excavation and concrete works. This was supported by interviews with contractors who reported needing to halt operations during sudden weather shifts. Respondents also indicated that material availability, especially for aggregates and geotextiles, was inconsistent due to limited suppliers within the region highlighting the logistical vulnerability of remote infrastructure sites (Pertiwi & Anggraeni, 2024; Yuliana & Rani, 2020).

Technical errors during construction, such as inaccuracies in elevation or misplacement of structural elements, were attributed to insufficient supervision and miscommunication between field teams and planners. This matches observations in similar projects discussed by Saputro (2022), who noted the impact of inadequate coordination on quality control outcomes. Respondents suggested that many errors could have been avoided through clearer technical documentation and routine site coordination meetings (Hair, et. al., 2010)

In response to these risks, mitigation strategies were formulated through expert discussions and literature synthesis. For instance, to reduce land acquisition delays, early socialization and legal coordination with stakeholders are proposed, following the model of participatory land release as promoted by the Ministry of Public Works (MoPW, 2019). To prevent design-related risks, the integration of value engineering and peer reviews before execution phases is recommended (Amalia & Khamim 2022; Fatchiyati, 2019).

Additionally, adaptive scheduling methods such as buffer allocation and flexible task sequencing were recommended to cope with weather – related disruptions. For procurement risks, developing a database of qualified suppliers and establishing multi-source supply chains are seen as effective (Xie et al., 2021). Meanwhile, for execution related risks, implementing a QA/QC checklist system and assigning specialized supervisors at critical stages of work can increase oversight and accountability (Molina Azorin, 2012).

The analysis confirms that multi-level risks are interlinked and must be managed holistically. The visualization of these findings through a risk matrix, shown in Table 4, illustrates the relative severity and frequency of the top ten variables. This allows project managers to prioritize which issues demand immediate and sustained attention (Chen et al., 2016; Deming, 1986).

Table 4 Combined Severity – Probability Risk Mapping Matrix

IMPACT		Trival (1)	Minor (2)	Moderate (3)	Mayor (4)	Extreme (5)
PROBABILITY	Very Likely (5)	5	10	15	20	25
	Likely (4)	4	8	12	16	20
	Moderate (3)	3	6 17 variable	9 1 variable	12	15
	Unlikely (2)	2	4 21 variable	6	8	10
	Rare (1)	1	2	3	4	5

4.2 Implementation of Risk Mitigation Strategies

Mitigation strategies that can be applied to minimize the impact of risks that occur in the implementation of flood control construction projects in Jambi Province using the PDCA (Plan-Do-Check-Act) approach are as follows:

1. PLAN (Planning): a. FM3 – Delays in Material Ordering and Delivery: 1) Supply Chain Planning: Develop realistic material procurement schedules that take into account ordering times, delivery times, and potential logistical obstacles. 2) Supplier Selection: Enter into contracts with suppliers who have a track record of timely delivery and good material quality. 3) Buffer Stock: Determine buffer stock requirements for critical materials to anticipate delivery delays; b. FA1 – Unpredictable Weather: 1) Weather Analysis: Use historical data and weather forecasts to plan a flexible work schedule. 2) Temporary Drainage Design: Design a temporary drainage system to manage rainwater and prevent flooding in the work area; c. FPR2 – Land Acquisition 1) Involve local stakeholders from the planning stage. 2) Adopting a social approach with communities surrounding the construction project. 3) Providing transparent and regulation-compliant compensation; d. FA2 – Natural Disasters (Floods, Landslides, Earthquakes): 1. Disaster Risk Study: Conduct a natural disaster risk study at the project site to identify potential threats. 2) Contingency Plan: Develop a contingency plan that includes evacuation, asset protection, and post-disaster recovery; e. FA3 – Unstable Soil Conditions: 1) Geotechnical Investigation: Conduct geotechnical investigations to understand soil characteristics and determine appropriate construction methods. 2) Special Foundation Design: Design foundations suitable for soil conditions, such as the use of piles or soil reinforcement.

2. DO (Implementation) a. FM3: 1) Procurement Schedule Implementation: Implement the material procurement schedule according to plan and conduct regular coordination with suppliers. 2) Delivery Monitoring: Use a tracking system to monitor the status of material deliveries in real time; b. FA1: 1) Work Schedule Adjustments: Adjust the daily work schedule based on actual weather conditions. 2) Use of Weather-Resistant Materials: Use materials that are resistant to extreme weather conditions to reduce the risk of damage; c. FPR2: 1) Implement a participatory communication approach with the community; d. FA2: 1) Contingency Plan Implementation: Implement the contingency plan in the event of a natural disaster, including evacuation and asset protection. 2) Coordination with Local Authorities: Coordinating with local authorities to obtain information and assistance during disasters; e. FA3: 1) Foundation Design Implementation: Constructing foundations in accordance with designs developed for unstable soil conditions. 2) Soil Stability Monitoring: Conducting regular monitoring of soil stability during project implementation.

3. CHECK (Inspection and Evaluation): 1) Internal Audit: Conduct regular internal audits to ensure compliance with the risk mitigation plan. 2) Performance Evaluation: Assess supplier performance, work schedule effectiveness, and community satisfaction in the land acquisition process. 3) Environmental Monitoring: Monitor environmental and soil conditions to detect changes that may affect the project;

4. ACT (Corrective and Preventive Actions): 1) Process Improvement: Identify and implement improvements in procurement, implementation, and risk management processes based on evaluation results. 2) Team Capacity Building: Provide additional training to the project team to enhance their ability to address risks. 3) Updating the Mitigation Plan: Updating the risk mitigation plan to reflect changes in conditions and lessons learned during the project. 4) Re-evaluating the land acquisition approach for future projects by involving mediation.

The results of the mitigation strategy can be summarized as follows in Appendix A.

■5.0 DISCUSSION

5.1 Discussion of the Results of Data Analysis for the First Research Objective

Based on the results of the validity and reliability tests on a total of 39 risk items spread across all factors, it was concluded that:

1. All items were declared valid, because the Pearson correlation value (r count) > r table (0.339) and significant at the 5% level ($p < 0.05$).
2. The Cronbach's Alpha reliability value of 0.960 for risk frequency and 0.973 for risk impact, indicating a very high internal consistency of the instrument.

High instrument validity and reliability indicate that the risk identification process is carried out systematically and representatively. Thus, the results of measuring the frequency and impact of risks can be used validly for the next analysis stage, such as factor analysis, risk priority mapping, or formulating data-based mitigation strategies.

5.2 Discussion of the Results of Data Analysis for the Second Research Objective

This study uses the Severity Index (SI) approach to analyze the frequency and impact of risks in flood control construction projects. Risks are categorized into five levels, ranging from very low to very high. For example, the variable of disturbance due to unpredictable weather has an SI value of 43.38% and is classified as a medium risk, while most other variables are in the low category.

In addition to frequency, the impact of risk is also calculated using the same SI method, indicating that natural factors, materials, equipment, management, and contracts affect the project with different intensities. The results of this analysis are used to compile a Probability Impact Matrix that describes the role of each variable in the overall project.

Furthermore, the risk rating is calculated from the multiplication of frequency and impact (P x I). Although the majority of risks are classified as low, some such as late ordering and material delivery have a high level of risk due to their significant impact on the project. This finding is in line with previous studies that highlight weather as a major risk factor in similar projects.

Risk Level Assessment in Appendix B.

5.3 Discussion of the Results of Data Analysis for the Third Research Objective

Initial implementation of these strategies during the 2022 – 2023 project phases indicated a measurable improvement in budget utilization rates and reduced public complaints. The integration of adaptive planning and community feedback loops proved especially effective in Jambi City.

According to COSO (2004) and Darmawi (2006), the key to successful risk mitigation lies in proactive governance, clear accountability lines, and flexible decision – making all of which were gradually incorporated into the revised project workflows.

Overall, the validation results show that the PDCA-based risk mitigation strategy is not only feasible, but also very suitable for the needs of flood control infrastructure construction projects. Each stage of the PDCA cycle can be carried out systematically, with integration between construction engineering, project management, and community-based social approaches. This finding strengthens previous literature stating that the application of the PDCA cycle in construction project risk management can improve quality, efficiency, and stakeholder satisfaction (Chen et al., 2016; Deming, 1986).

■6.0 CONCLUSION

The flood control construction project in Jambi Province is subject to multiple risks, though none reached a highrisk level. Among the 39 variables, 1 was moderate and 38 were low. Key concerns include delays in land acquisition, execution inconsistencies, weather factors, and material shortages.

This study highlights the importance of early risk identification and structured mitigation planning using frameworks such as PDCA. The proposed strategies can enhance the effectiveness of flood control projects and contribute to sustainable infrastructure development in vulnerable areas.

The findings contribute to both practice and theory by showcasing the application of systematic risk assessment in real world projects, and encouraging adaptive planning in dynamic construction environments.

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Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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APPENDIX A
Risk Mitigation Strategy

RISK IDENTIFICATION	CODE	MITIGATION STRATEGY				RELATED REFERENCES
		PLAN	*DO*	*CHECK*	*ACT*	
Delays in Ordering and Shipping Materials	FM3	1. Supply Chain Planning: Create a realistic schedule for procuring raw materials by considering order times, delivery times, and potential logistical obstacles. 2. Supplier Selection: Sign contracts with suppliers who have a proven track record of timely delivery and high-quality raw materials. 3. Reserve inventory: Determine the reserve inventory requirements for critical raw materials in order to anticipate delivery delays.	1. Procurement Schedule Implementation: Implement the material procurement schedule according to the plan, and coordinate regularly with suppliers. 2. Delivery Monitoring: Use a tracking system to monitor the status of material deliveries in real time.	1. Internal Audit: Conduct regular internal audits to ensure compliance with the risk mitigation plan. 2. Performance Evaluation: Assess supplier performance, work schedule effectiveness, and community satisfaction regarding land acquisition. 3. Environmental Monitoring: Monitor environmental and soil conditions to detect changes that may affect the project.	1. Process Improvement: Identify and implement improvements to the procurement, execution, and risk management processes based on the evaluation results. 2. Team Capacity Building: Provide additional training to the project team to enhance their ability to address risks. 3. Risk Mitigation Plan Update: Update the risk mitigation plan to reflect changes in conditions and lessons learned during the project.	1. Comprehensive planning will form the foundation for project success (PMBOK Guide, PMI, 2021). 2. Use long-term contracts with suppliers, build buffer stock, and implement a digital supply chain management system for stock and logistics monitoring (Mahamid, 2022).
Unpredictable weather	FA1	1. Weather Analysis: Using historical data and weather forecasts to plan flexible work schedules. 2. Temporary Drainage Design: Designing temporary drainage systems to manage rainwater and prevent flooding in work areas.	1. Adjustment of Work Schedule: Adjusting the daily work schedule based on actual weather conditions. 2. Use of Weather-Resistant Materials: Using materials that are resistant to extreme weather conditions to reduce the risk of damage.			1. Develop a construction work schedule based on weather forecasts from the BMKG and develop contingency plans for emergency conditions. The use of real-time weather monitoring technology can help with responsive decision-making (Rahman et al., 2020). 2. Use weather forecast data from the BMKG and take preventive measures in the event of weather changes (Yuliana et al., 2020).
Land acquisition	FPR2	1. Involving local stakeholders from the planning stage 2. Taking a dialogue-based social approach with the communities surrounding the project. 3. Providing transparent compensation in accordance with regulations	1. Implementing a participatory communication approach with the community.			1. In this study, respondents consistently identified the risks that should be shared or borne by users or service providers, with the risks that had the greatest impact on project implementation being the complexity of licensing and land acquisition issues.

Natural Disasters (Floods, Landslides, Earthquakes)	FA2	1. Disaster Risk Assessment: Conduct a natural disaster risk assessment at the project site to identify potential threats. 2. Contingency Plan: Develop a contingency plan that includes evacuation, asset protection, and post-disaster recovery.				1. Risk mitigation for flood risk variables in the construction of temporary embankments to prevent water from entering the project area, as flood risk variables are categorized as high risk (Se)tiayan D, 2023). 2. As a precaution in case of natural disasters, risk transfer can be conducted to a third party by insuring the construction building (Pramudawati et al., 2020; Pertiwi, 2023).
Unstable Soil Conditions	FA3	1. Geotechnical Investigation: Conducting geotechnical investigations to understand soil characteristics and determine appropriate construction methods. 2. Special Foundation Design: Designing foundations that are appropriate for soil conditions, such as the use of piles or soil reinforcement.	1. Foundation Design Implementation: Constructing foundations in accordance with designs that have been developed for unstable soil conditions. 2. Soil Stability Monitoring: Conducting periodic monitoring of soil stability during project implementation.			1. Risk mitigation measures implemented for the risk variable of unstable soil conditions involve improving soil conditions (Fachtiyati, 2019).