

Risk Management In The Flood Control Project Of Tukad Unda, Klungkung Regency

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ABSTRACT

The Tukad Unda Flood Control Project was implemented to support river normalization and spatial planning efforts aimed at reducing flood risks in Klungkung Regency. However, the project faces significant challenges due to its location in flood-prone, swamp, and coastal areas, which increase the likelihood of risks during construction. This study aims to identify potential project risks, assess risk acceptance levels, develop appropriate mitigation strategies, and allocate risk ownership among stakeholders. A mixed-method approach combining quantitative and qualitative descriptive analysis was employed. Primary data were collected through surveys and group discussions, while secondary data were obtained from relevant literature. Respondents were selected using purposive sampling based on their professional roles and experience in the project, representing owners, consultants, and contractors. A total of 37 risk variables were identified and analyzed using validity and reliability tests to ensure data consistency. The results indicate four levels of risk acceptance: unacceptable (2.70%), undesirable (37.84%), acceptable (37.84%), and negligible (21.62%). Fifteen dominant risks were identified, requiring mitigation through risk avoidance and risk reduction strategies. These findings highlight the importance of experience-based risk assessment in improving the effectiveness of construction project management.

Keywords: risk management; flood control project; construction risk;

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1. INTRODUCTION

Flood control and river normalization programs are fundamental strategies in watershed management to reduce flood hazards and improve river system resilience. The development and normalization of the Tukad Unda River in Klungkung Regency represent an important effort to improve river capacity and minimize flood risk in surrounding areas. Flood disasters remain one of the most significant natural hazards affecting urban and rural regions worldwide, particularly in areas experiencing rapid environmental change. Increasing climate variability has intensified hydrological extremes, resulting in more frequent and intense rainfall events that increase flood risk in many regions [1]. Consequently, infrastructure development aimed at flood mitigation must consider both environmental uncertainties and construction-related risks.

Risk management is therefore essential to control uncertainties and ensure project objectives related to time, cost, and quality are achieved. It involves systematic identification, analysis, and mitigation of risks to reduce their impact and support better decision-making throughout the project lifecycle.[2]. Risk management

is essential to ensure construction projects meet targets for time, cost, and quality. It includes identifying, analyzing, and responding to risks while continuously monitoring them throughout the project lifecycle. Effective integration of these processes helps minimize negative impacts, improve performance, and support better decision-making in complex project environments.[3].

Recent studies in infrastructure and water resource engineering have emphasized the importance of proactive risk assessment in flood control and river engineering projects. Environmental uncertainty, hydrological variability, and geological conditions are frequently identified as dominant risk factors affecting construction activities in river infrastructure projects [4]. Research also indicates that climate-related uncertainties can significantly influence project implementation, particularly in coastal or river basin environments where water dynamics and environmental conditions change rapidly [5]. Therefore, The systematic identification of hazards and implementation of risk control measures are essential to support occupational safety and ensure the successful execution of flood control projects. [6].

Several studies have investigated risk management in construction projects, particularly focusing on cost and schedule risks, project delays, and environmental uncertainties. For example, Aarthipriya et al. [2] developed a framework for managing schedule and cost risks in construction activities, while Gunda et al. [7] proposed a risk assessment framework for infrastructure development under environmental uncertainty. In addition, research by Rezakhani [8] emphasized that systematic risk identification and prioritization are essential for improving decision-making in construction project management. These studies demonstrate the importance of integrating structured risk management approaches in infrastructure development.

Although previous studies have addressed risk management in construction projects, limited research has specifically examined the integration of risk identification, risk acceptance levels, mitigation strategies, and risk ownership in flood control projects located in river basins with complex environmental conditions. In particular, studies addressing risk identification, risk acceptance distribution, mitigation strategies, and risk ownership allocation in flood control projects in Indonesia remain limited. This gap highlights the need for more context-specific research that considers environmental characteristics, construction conditions, and stakeholder responsibilities within flood control infrastructure projects.

Based on this research gap, this study aims to identify potential risks during the construction phase of the Tukad Unda flood control project in Klungkung Regency, particularly dominant risks (major risks). Furthermore, the study analyzes risk levels, evaluates risk acceptance distribution, proposes mitigation strategies, and determines risk ownership among project stakeholders. The findings of this research are expected to contribute to improving risk management practices in flood control construction projects and provide practical insights for similar infrastructure development projects in river basin areas.

2. RESEARCH METHOD

This research employed a mixed-method approach that integrates quantitative and qualitative analysis to examine risk management in the Tukad Unda Flood Control Project located in Klungkung Regency, Bali. The mixed-method approach enables researchers to evaluate measurable risk levels through numerical assessment while also providing descriptive explanations of risk conditions encountered during project implementation. Such an approach is widely applied in construction management studies because it allows comprehensive analysis of both statistical data and contextual project conditions [9]–[12].

2.1. Data Collection

Data were collected using survey and brainstorming techniques involving 20 respondents selected based on their roles and experience in the project. The survey was conducted through direct observation of construction activities related to the flood control works along the Tukad Unda watershed to identify potential risks during project implementation.

In addition, brainstorming sessions were carried out with project stakeholders, including contractors, supervision consultants, and technical personnel, where participants shared their experience and professional judgment to identify potential risks associated with project activities.. Brainstorming is commonly used in risk identification because it facilitates collaborative analysis among project stakeholders and enables the identification of risks that may not be captured through observation alone [13], [14].

The risks identified from field surveys, brainstorming sessions, and previous related studies were compiled into a risk register. This list of risks was then used to develop a structured questionnaire distributed to selected respondents involved in the project [15],[16].

2.2 Instrument Testing

Prior to conducting the main analysis, the collected questionnaire data were evaluated through validity and reliability testing. Validity testing was conducted to ensure that each question item accurately represented the variables being measured, while reliability testing aimed to determine the consistency of responses among

respondents. These procedures were necessary to guarantee that the collected data were suitable for further analysis and could represent the actual conditions of the project environment [17], [18].

2.3 Risk Analysis

Risk analysis in this study was conducted using a qualitative risk assessment approach, which evaluates potential risks based on their likelihood of occurrence and the magnitude of their possible impacts on project performance. This approach is widely applied in construction project management because it enables researchers and practitioners to systematically identify and prioritize risks that may significantly affect project objectives, including cost efficiency, project schedule, construction quality, and safety performance [19].

The evaluation process was performed using data obtained from questionnaires distributed to project stakeholders, including contractors, supervision consultants, and technical personnel involved in the flood control project. Each identified risk was assessed using a rating scale representing the probability of occurrence and the severity of its potential consequences. The risk score for each variable was calculated using the formula Risk Score = Probability × Impact, where probability reflects the likelihood of occurrence and impact represents the severity of consequences. This calculation provides a quantitative measure of the relative importance of each risk and its potential influence on project implementation [3].

The resulting risk scores were then interpreted to determine the level of risk acceptance, which indicates the extent to which a particular risk can be tolerated during project execution. Based on established risk management frameworks, risks were categorized into four levels of acceptance: unacceptable, undesirable, acceptable, and negligible. Risks classified as unacceptable and undesirable require priority attention and mitigation due to their significant potential impact on project performance. In contrast, acceptable risks may be tolerated within defined limits, while negligible risks have minimal impact and generally do not require specific mitigation measures. This classification provides a practical basis for stakeholders in prioritizing appropriate risk response strategies, as presented in Table 1 [14].

Table 1. Risk Acceptance Scale

Risk Acceptance Level	Risk Score Range
Unacceptable	$x \geq 15$
Undesirable	$5 \leq x < 15$
Acceptable	$3 \leq x < 5$
Negligible	$x < 3$

2.4 Risk Mitigation

Risk mitigation refers to strategic actions implemented to reduce the likelihood of occurrence or the potential impact of identified risks. In this study, mitigation measures were primarily developed for risks categorized as unacceptable and undesirable, as these risks have the greatest potential to disrupt project implementation [13], [20]. The mitigation strategies were determined based on expert judgment obtained through brainstorming sessions with project stakeholders and supported by findings from previous studies in construction risk management [21], [22].

Several mitigation approaches were applied according to the characteristics of each identified risk. The mitigation strategies used in this study include[23]:

1. Risk Avoidance – eliminating the source of risk by modifying work methods, construction procedures, or project design to prevent the risk from occurring.
2. Risk Reduction – minimizing the likelihood or potential impact of risks through improved planning, stricter supervision, and enhanced quality control during project implementation.
3. Risk Transfer – shifting the responsibility for certain risks to other parties through contractual arrangements, insurance mechanisms, or subcontracting to specialized organizations.
4. Risk Acceptance – accepting risks with relatively low impact that can still be tolerated within project constraints while maintaining regular monitoring.
5. Risk Sharing – distributing the responsibility for managing risks among project stakeholders, such as owners, contractors, and consultants, through agreed contractual arrangements.

2.5 Risk Ownership Allocation

After mitigation strategies were determined, the next stage involved assigning risk ownership to relevant stakeholders involved in the project implementation. Risk ownership refers to the responsibility assigned to a particular party for managing and responding to a specific risk [24].

In construction projects, risk allocation should consider which party has the greatest ability to control or manage the risk source. According to established risk allocation principles, risks should be assigned to the

party that has the most capability to prevent or mitigate their occurrence. If a risk cannot be controlled by any single party, it may be shared among multiple stakeholders involved in the project [25].

Through this stage, the dominant risks identified in the Tukad Unda flood control project were allocated to the responsible parties, particularly the contractor and the supervision consultant, in order to ensure effective risk management throughout the project lifecycle [26].

3. RESULTS AND DISCUSSION

3.1. Risk Identification

Risk identification is the first step in this study, aimed at identifying what risks may occur, as well as how and why they arise during project implementation. The identification process was conducted through field surveys and brainstorming with several respondents involved in the project. Field surveys were carried out by directly observing construction activities at the project site and compiling a list of potential risks. Brainstorming sessions were also conducted with project stakeholders to discuss potential project risks. Based on the results of brainstorming and previous studies, a total of 37 risks were identified, originating from political, environmental, economic, financial, natural, project, technical, human, and safety aspects in the Tukad Unda flood control project.

3.2. Risk Assessment and Risk Acceptance

Risk acceptance analysis was determined based on the risk value, calculated from the multiplication of the mode values of respondents' answers for risk frequency and risk consequences. This analysis was used to determine the level of risk acceptance in the Tukad Unda flood control project. The results of the risk assessment and acceptance analysis are presented in Table 2.

Table 2. Risk Assessment and Risk Acceptance

No.	Risk Identification	Frequency Mode	Consequence Mode	Risk Value	Risk Acceptance
I	Political Risks				
1	Negative news coverage in electronic or printed media.	3	1	3	<i>Acceptable</i>
2	Rejection from communities around the project location.	2	2	4	<i>Acceptable</i>
II	Environmental Risks				
3	River water and groundwater near the project site become polluted by waste.	3	3	9	<i>Undesirable</i>
4	Difficulty in accessing the project site.	2	2	4	<i>Acceptable</i>
III	Economic Risks				
5	Increase in tax costs.	1	2	2	<i>Negligible</i>
6	Increase in material prices.	2	2	4	<i>Acceptable</i>
7	Increase in fuel prices during the construction period.	1	2	2	<i>Negligible</i>
IV	Financial Risks				
8	Increase in operational and maintenance costs.	3	2	6	<i>Undesirable</i>
9	Delay in payment from the owner to the contractor.	2	2	4	<i>Acceptable</i>
V	Natural Risks				
10	Unstable soil conditions that may cause landslides.	4	3	12	<i>Undesirable</i>
11	Occurrence of tidal waves.	5	2	10	<i>Undesirable</i>
12	Unpredictable weather conditions during project implementation.	3	3	9	<i>Undesirable</i>
13	Flood occurrence.	3	5	15	<i>Unacceptable</i>
14	Coastal erosion.	2	2	4	<i>Acceptable</i>
15	High groundwater level.	4	2	8	<i>Undesirable</i>
VI	Project Risks				
16	Incomplete supporting equipment facilities for operation and maintenance.	2	2	4	<i>Acceptable</i>
17	Incomplete work implementation requirements.	2	2	4	<i>Acceptable</i>
18	Project execution not complying with established standards.	2	2	4	<i>Acceptable</i>
19	Lack of quality control during project implementation.	1	2	2	<i>Negligible</i>
20	Contractor's limited experience with similar projects.	2	1	2	<i>Negligible</i>

No.	Risk Identification	Frequency Mode	Consequence Mode	Risk Value	Risk Acceptance
21	Complicated administrative systems that hinder project progress.	2	1	2	<i>Negligible</i>
22	Inaccurate soil data.	2	4	8	<i>Undesirable</i>
23	Subcontractor work not in accordance with the contract.	2	2	4	<i>Acceptable</i>
VII Technical Risks					
24	Heavy equipment breakdown that delays project implementation.	3	2	6	<i>Undesirable</i>
25	Delay in procurement of equipment and materials.	2	1	2	<i>Negligible</i>
26	Planned specifications not matching the implementation results.	2	2	4	<i>Acceptable</i>
27	Material specifications not meeting field implementation requirements.	3	2	6	<i>Undesirable</i>
28	Incomplete shop drawings.	3	3	9	<i>Undesirable</i>
29	Field measurements for determining coordinates and elevations not matching the drawings.	4	2	8	<i>Undesirable</i>
30	Settlement or displacement of installed panels.	3	3	9	<i>Undesirable</i>
31	Landslides occurring in excavation areas.	4	2	8	<i>Undesirable</i>
32	Design changes due to adjustments to existing site conditions.	3	3	9	<i>Undesirable</i>
VIII Human Risks					
33	Workers lack competence in their assigned tasks.	2	2	4	<i>Acceptable</i>
34	Worker fatigue leading to decreased work quality.	3	1	3	<i>Acceptable</i>
IX Safety Risks					
35	Workers buried by sand or stone materials.	1	2	2	<i>Negligible</i>
36	Workers swept away by coastal currents.	1	2	2	<i>Negligible</i>
37	Occupational health and safety (OHS) not receiving sufficient attention during project implementation.	2	2	4	<i>Acceptable</i>

Based on the risk assessment results, four levels of risk acceptance were identified: unacceptable (1 risk), undesirable (14 risks), acceptable (14 risks), and negligible (8 risks). The concentration of risks within the undesirable and acceptable categories indicates that most risks have moderate to high significance and require careful management. This pattern reflects the inherent complexity of flood control projects, where technical and environmental factors are closely interconnected and significantly influence overall project performance.

Flood occurrence was identified as the most dominant risk due to its high probability and significant impact on construction activities. The project's location within a river basin and its proximity to swamp and coastal areas make it highly sensitive to fluctuations in water discharge and tidal conditions. In addition, external factors such as rainfall intensity and upstream flow are difficult to control, increasing uncertainty during construction. These conditions can disrupt work schedules, damage temporary structures, and reduce productivity, making flood risk a critical factor that must be prioritized in mitigation planning.

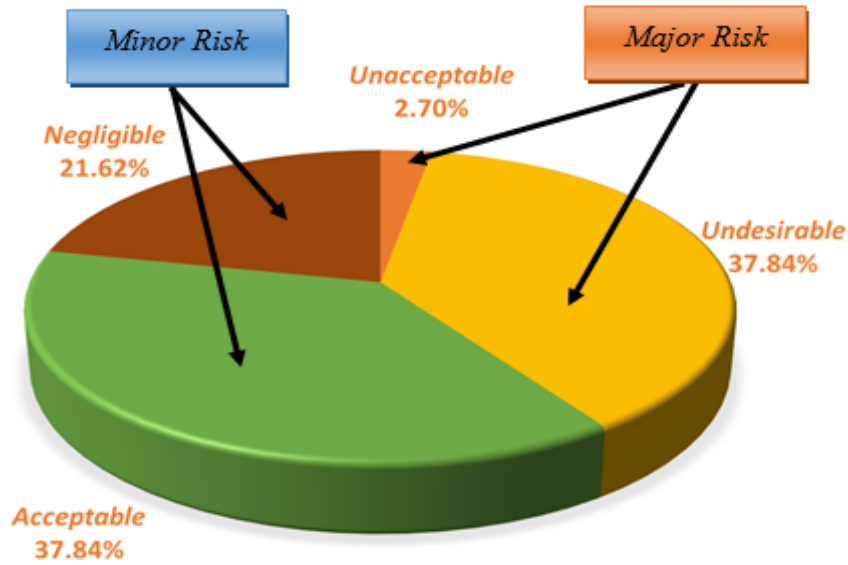


Figure 1. Percentage of Risk Acceptance

In percentage terms, the distribution of risk acceptance (Figure 1) indicates that undesirable and acceptable risks dominate, each accounting for 37.84% of the total identified risks. This suggests that most risks fall within a moderate level that still requires active management rather than being fully tolerable. Meanwhile, unacceptable risks represent a relatively small portion (2.70%), but they demand immediate attention due to their high impact, whereas negligible risks (21.62%) have limited influence on overall project performance.

3.3. Dominant Risks

Dominant risks (major risks) are risks that fall into the unacceptable and undesirable categories, which require appropriate mitigation measures and clear allocation of risk ownership. Based on their sources, the risks categorized as dominant risks (major risks) can be described as follows.

Table 3. Dominant Risks Based on Their Sources

No.	Risk Source	Risk Category	
		Unacceptable	Undesirable
1	Environmental Risk		1 risk
2	Financial Risk		1 risk
3	Natural Risk	1 risk	4 risks
4	Project Risk		1 risk
5	Technical Risk		7 risks

3.4. Risk Mitigation

Risk control or mitigation refers to actions taken to reduce the impact of risks after they have been identified. Risk mitigation is particularly required during the project implementation stage, especially for risks categorized as unacceptable (risks that cannot be accepted) and undesirable (risks that are not expected). Risks categorized as acceptable and negligible do not require specific mitigation measures. The mitigation actions for the identified dominant risks are presented in Table 3.

Table 4. Risk Mitigation

No.	Risk Identification	Risk Identification	Risk Identification	Risk Identification
II	Environmental Risk			
3	River water and groundwater near the project site are polluted by waste	9	Undesirable	Risk Avoidance Do not dispose of waste into rivers or other water sources; do not discharge leftover concrete wash water from mixer trucks into the river; conduct environmental management and monitoring around the project area.
IV	Financial Risk			
8		6	Undesirable	Risk Reduction

No.	Risk Identification	Risk Identification	Risk Identification	Risk Identification
	Increase in operational and maintenance costs			Improve efficiency in operational and maintenance costs; perform more detailed cost estimation to prevent cost escalation.
V Natural Risk				
10	Unstable soil conditions leading to landslides	12	Undesirable	Risk Avoidance Construct retaining walls in landslide-prone areas; create terracing to reduce soil pressure and prevent landslides..
11	Occurrence of tidal waves	10	Undesirable	Risk Avoidance Construct higher protective embankments to prevent tidal waves.
12	Unpredictable weather conditions during project implementation	9	Undesirable	Risk Reduction Use weather forecasts for the Klungkung area and Tukad Unda watershed as a guideline for scheduling activities; intensify construction work when weather conditions are favorable to compensate for delays caused by bad weather.
13	Flood occurrence	15	Unacceptable	Risk Avoidance Build temporary embankments such as kist dams higher than the flood water level to prevent water overflow that may disrupt construction activities.
15	High groundwater level	8	Undesirable	Risk Avoidance Continuously pump water from the work area to prevent disruption to construction activities.
VI Project Risk				
22	Inaccurate soil data	8	Undesirable	Risk Reduction Conduct additional soil investigations under the supervision of the project consultant to obtain accurate soil data.
VII Technical Risk				
24	Heavy equipment breakdown delaying project implementation	6	Undesirable	Risk Reduction Conduct periodic maintenance of heavy equipment and monitor equipment validity periods.
27	Material specifications not meeting field requirements	6	Undesirable	Risk Reduction Conduct material inspections by the Quality Surveyor and supervising consultant to ensure compliance with specified standards.
28	Incomplete shop drawings	9	Undesirable	Risk Avoidance Assign competent drafters to prepare shop drawings; consultants should review shop drawings carefully before construction begins.
29	Field measurements for determining coordinates and elevations do not match the drawings	8	Undesirable	Risk Reduction Deploy professional surveying teams experienced in difficult terrain; perform re-measurements to verify coordinate positions and elevation accuracy.
30	Settlement or displacement of panels after installation	9	Undesirable	Risk Avoidance Develop appropriate installation methods for unstable soil conditions. Risk Reduction Compact the soil beneath the panel foundation before installation to prevent settlement or displacement.
31	Landslides occurring in excavation areas	8	Undesirable	Risk Reduction Construct kist dams around excavation areas to prevent landslides.
32	Design changes due to adjustments to existing site conditions	9	Undesirable	Risk Reduction Conduct additional site surveys to align the design drawings with the existing field conditions.

3.5. Risk Ownership Determination

At the stage of determining risk ownership, the risks categorized as dominant risks (major risks) are allocated to the parties involved in the project implementation. Based on the results of the study, the allocation

of risk ownership shows that the Supervision Consultant is responsible for 4 risks, while the Contractor is responsible for 15 risks.

As the party bearing the largest portion of risks, the Contractor is required to manage and handle these risks effectively by implementing proper management of project cost, quality, and schedule during the execution of the project.

4. CONCLUSION

This study identified 37 potential risks in flood control projects, with 15 dominant risks classified as unacceptable and undesirable, indicating their significant influence on project performance. The findings reveal that risks in flood control construction are not solely driven by technical factors but are largely dominated by environmental and hydrological uncertainties. This highlights that river-based infrastructure projects, particularly those located in complex environments such as river basins connected to coastal areas, exhibit a distinct and higher-risk profile compared to conventional construction projects.

The main contribution of this study lies in its integrated framework, which combines risk identification, risk acceptance assessment, mitigation strategy formulation, and risk ownership allocation into a unified analytical approach. This framework provides deeper insight into the relationship between project characteristics and dominant risks, while emphasizing the critical role of contractors in implementing risk avoidance and risk reduction strategies. Beyond the specific case, this study offers a transferable approach that can be applied to flood control and other water infrastructure projects facing high environmental uncertainty, thereby strengthening both practical risk management and decision-making processes.

CONFLICT OF INTEREST STATEMENT


The Authors state no conflict of interest.

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