Risk Management Strategy In The Implementation Of Maintenance Of Tukad Ayung In Denpasar City: An Integrated Qualitative Analysis

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ABSTRACT

The maintenance of the Ayung River aims not only to maintain the cleanliness and smooth flow of the river itself, but also as part of a broader environmental conservation effort to create a more environmentally friendly and sustainable city. This study aims to identify and assess risks in the implementation of the Tukad Ayung river maintenance project, determine dominant risks and their acceptance levels, and formulate appropriate mitigation and risk ownership strategies to minimize potential impacts on project cost, time, and quality. The study employed a mixed-method approach combining qualitative risk identification with quantitative risk assessment using probability-impact analysis based on ISO 31000:2018. Brainstorming and questionnaires were selected as data collection techniques, with 26 respondents selected using purposive sampling. The results identified 15 valid risks consisting of 9 unacceptable risks (60%) and 6 undesirable risks (40%). The dominant risk was tidal seawater conditions in downstream areas, which obtained the highest probability-impact score of 25 and was categorized as an unacceptable risk requiring immediate mitigation measures. The mitigation strategies implemented included risk reduction, risk transfer, and risk avoidance approaches. Mitigation for this dominant risk involves obtaining tidal seawater level data from Benoa Harbor to optimize downstream work scheduling and implementing a combination of concrete culvert and cyclope concrete foundations to enhance structural resistance in estuary areas. The largest allocation of risk ownership is assigned to the contractor, covering 8 identified risks. The findings contribute to improving risk mitigation planning and decision-making for urban river maintenance projects in Indonesia.

Keywords: Ayung River, Risk Assessment, Risk Management, Risk Mitigation, Risk Ownership.

1. INTRODUCTION

Government Regulation of the Republic of Indonesia Number 38 of 2011 concerning rivers defines a river as a natural and/or artificial water channel or reservoir, consisting of a water flow network and its contents, extending from upstream to estuary, bounded on the right and left by a boundary line. Rivers provide water for household needs, environmental sanitation, agriculture, industry, tourism, sports, defense, fisheries, power generation, transportation, and other needs. Flood control in the Tukad Ayung Watershed utilizes foundations. This is done considering the high flood discharge and the high destructive power caused by the steep slope of the riverbed. The steep slope impacts the adjustment of foundation construction to prevent sliding in certain areas, which could cause the collapse of the water storage tank (retaining wall) structure. Furthermore, the rubber dam structure used as the water intake for the Regional Water Company (RWC) can affect RWC water production if damaged and not promptly addressed. This structure is highly sensitive, given its function as raw water supply for the Denpasar City area. Any problems with it could impact drinking water customers in the area. Upstream bank reinforcement in the form of a retaining wall is necessary to maintain the stability of the cliffs surrounding residential areas. Furthermore, the downstream portion of the river also requires attention, as this area contains Hindu places of worship used for prayers, ritual purification, and other religious activities. If damage downstream is not addressed, it will impact the river mouth, which will be eroded by river and seawater, impacting religious buildings and land owned by residents in the estuary area. The downstream retaining wall construction plan must be reconsidered, given the estuary's conditions, which are affected by river and tidal conditions, as well as high waves that also occur on the coast, to prevent construction failures during maintenance.[1]

River maintenance in urban areas is a complex challenge that requires integrated mitigation strategies to handle erosion and flood risks effectively [2]. The maintenance work for the Tukad Ayung Watershed river structures was conducted through a tender process conducted by the PPK OPSDA III Bali Penida, which is responsible for maintaining the watershed network, including the watershed drainage system (Retaining wall) structures, rubber weirs, and coastal structures. The maintenance of the retaining wall and rubber weirs in Tukad Ayung uses funds from the central government and the state budget (APBN) disbursed through the Ministry of Public Works, Directorate of Water Resources, and the Bali Penida River Basin Office.

The project implementation process, from planning to execution, faced several challenges, including cost, quality, and time. While the planning objectives, such as cost and time, were not fully achieved, problems typically arose, such as cost overruns or delays in implementation. The complex problems encountered during the maintenance work were due to the location being submerged and the impossibility of blocking the water flow. Difficult access to the project site prevented heavy equipment from entering, necessitating manual work.[1]

Based on the problems above, it indicates that the implementation of the watershed river maintenance project in the form of DPT and rubber dam construction needs to be given serious attention regarding the risk of failure by the parties involved in this project. This is because the impact of the risks that arise can hinder and harm the project implementers, both in terms of cost and time. Risks with dominant categories (major risks) are prioritized, so that appropriate solutions are obtained to overcome the risk problems that arise. In this case, to be able to minimize the risks and losses that arise related to the implementation of the river maintenance, an integrated identification, analysis, and mitigation strategy is needed for possible risks in the Network Maintenance Work in the form of Tukad Ayung Watershed River Maintenance.

Previous studies have mainly discussed risk management in building construction, irrigation systems, and general infrastructure projects. However, limited studies specifically address integrated risk management strategies for urban river maintenance projects in Indonesia, particularly those involving mitigation and risk ownership allocation based on ISO 31000:2018. Unlike previous studies that mainly focus on building or general infrastructure projects, this study specifically examines risk management strategies in urban river maintenance projects using an integrated qualitative risk assessment approach. The novelty of this research lies in the combination of risk identification, risk acceptance analysis based on ISO 31000:2018, mitigation strategy formulation, and risk ownership allocation within the context of Tukad Ayung river maintenance in Denpasar City. Therefore, this study aims to identify and assess risks in the implementation of the Tukad Ayung river maintenance project, determine dominant risks and their acceptance levels, and formulate appropriate mitigation and risk ownership strategies to minimize potential impacts on project cost, time, and quality.

2. THEORY AND METHODS

2.1 Theory

Risk is the potential for loss or failure due to uncertainty in the future.[3] Every activity is inherently associated with risk, with the possibility of adverse or detrimental consequences. Therefore, proper planning for identified risks and even a system to minimize risk to an acceptable level is necessary.[4]

Hegger et al. [5] state that risk management in water infrastructure should focus on building governance resilience, acknowledging that adverse consequences cannot always be entirely avoided through traditional methods. Sisto et al. [6] suggest that risk in urban river management is a multi-dimensional concept involving uncertainty and the potential for loss. Their study emphasizes that risk perceptions among stakeholders are crucial for developing effective management strategies in complex river systems.

Risk management is the process of identifying, analyzing, and responding to risks in a project. Risk management can also be defined as a procedure for controlling and reducing risk levels [7]. Project risk management provides better control going forward and can significantly increase the chances of achieving project targets. Risk management aims to identify sources of risk and uncertainty, determine their impact, and determine appropriate.[8]

O'Donnell and Thorne [9] describe a modern risk management process framework for making decisions regarding river infrastructure risks, emphasizing resilience-based stages: source identification, classification, and evaluation of consequences through analytical techniques.

2.2 Methods

The research was conducted on the maintenance work of the Tukad Ayung River structure in Denpasar City. This study employed a mixed-method approach combining qualitative risk identification with quantitative risk assessment to capture the complexity of risk factors in the Tukad Ayung maintenance project. This approach aligns with recent studies on risk management in infrastructure projects within the Bali region, which emphasize the importance of local context in risk identification. The respondents consisted of contractors, supervisory consultants, project managers, site engineers, and technical personnel directly involved in the implementation of the Tukad Ayung river maintenance project. All respondents were selected using purposive sampling and had a minimum of five years of professional experience in construction and river infrastructure maintenance projects. Data collection was carried out through interviews and questionnaire surveys to obtain expert opinions and respondent assessments regarding potential risks that may occur during the implementation of the Tukad Ayung River structure maintenance project in Denpasar City.[10]

The research used primary and secondary data to achieve the final objectives of the research.

a. Primary data is project data, such as data obtained from respondents through questionnaires completed by parties involved in the maintenance work on the Tukad Ayung River in Denpasar City.[11]
b. Secondary data is data obtained through literature review from journals on risk management research to obtain initial risk identification. Initial risk identification was carried out by reviewing previous studies related to this research.

2.2.1 Research Framework

The research framework was developed to systematically identify, assess, and mitigate risks in the implementation of the Tukad Ayung river maintenance project in Denpasar City. The research process began with a literature review and preliminary risk identification based on previous studies and field conditions. Furthermore, brainstorming sessions and expert validation were conducted to confirm the identified risks. Data collection was carried out through questionnaires distributed to respondents involved in the project. The collected data were then tested for validity and reliability using SPSS 22.0. Risk analysis was performed using probability and impact assessment based on ISO 31000:2018, followed by risk acceptance analysis, mitigation strategy formulation, and risk ownership allocation. The overall research framework is illustrated in Figure 1.

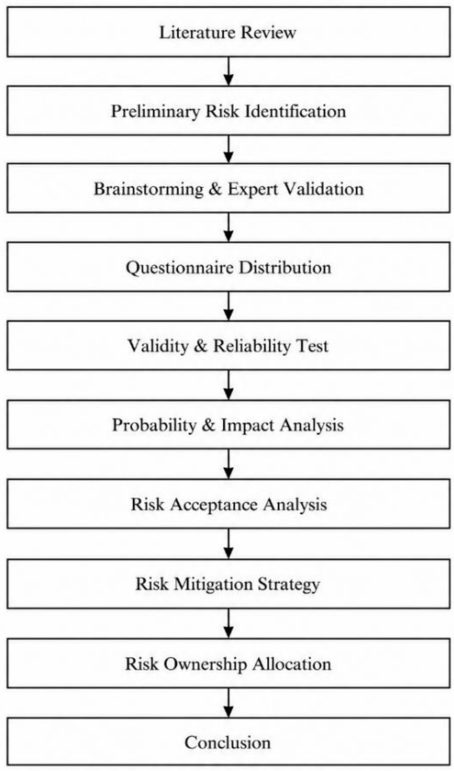

Figure 1. Research Framework Flowchart

2.2.2 Research Procedure

Data plays a crucial role in this research, as it represents the variables being studied. The validity of the data largely determines its quality, depending on the instrument used, namely whether it meets the principles of validity and reliability.

Validity Test

Validity indicates the extent to which a measuring instrument measures what it is intended to measure. In this study, the validity test used was construct validity, which involved asking respondents questions and then conducting a correlation test between the scores on each question item and the total questionnaire score. The statistically obtained product-moment correlation value must be compared with the critical value of the correlation table, r, with degrees of freedom (df) = N-2, and a significance level of 5%. If the calculated r value is greater than the table r value, the measurement is valid. However, if the calculated r value is less than the table r value, the measurement is invalid. The product-moment correlation value can also be calculated using SPSS 22.0.[12]

Reliability Test

Reliability is a measuring tool used to indicate the extent to which data are unbiased and to ensure consistent measurement across various items and time periods within a research instrument [6]. The method used to test the reliability of the questionnaire in this study was SPSS 22.0 software using the reliability function. The minimum reliability requirement for a measuring instrument is based on the criteria established in [12], which is ≥0.6.

2.2.3 Data Analysis

Risk Assessment

The risk assessment in this study was conducted in accordance with the ISO 31000:2018 international standard for risk management. Data obtained through the questionnaire were processed to determine the likelihood and consequence modes for each identified risk, following the risk evaluation criteria defined in the ISO guidelines.[13] The mode in quantitative data indicates the most frequently occurring value, while for qualitative data, the mode indicates the most frequently occurring characteristic or condition. The mode value in this study can be determined from the number of respondents' most frequently selected answers to the identification results. This mode value can represent respondents' opinions regarding the identified risks. The resulting mode value also has two values: the mode for frequency statements and the mode for consequences. The mode values for each frequency and consequence statement are multiplied to determine the type of risk acceptance, allowing mitigation measures to be taken for the dominant risk acceptance.

Risk Acceptance

From the scores given by respondents for each identified risk, the mode of the data can be determined, representing respondents' opinions regarding the identified risks. The mode is the set of data that appears most frequently or with the highest frequency. Risk acceptability analysis is determined based on the risk value obtained by multiplying the likelihood by the risk consequence. Risks that require control measures are all risks classified as Very High Risk and High Risk.

Risk Mitigation

Based on the results of risk acceptance, the risk management or mitigation measures to be implemented are determined. Risks that must be mitigated are those classified as Very High Risk and High Risk. Risk mitigation is conducted through interviews with experts to determine the appropriate management measures for unacceptable risks.

Risk Ownership Assessment

The next step after risks have been identified and classified is allocation to the various parties involved. This allocation is based on an assessment of the relationships between the parties involved and the risk. Determining risk ownership in this study follows the modern risk allocation principles for water infrastructure projects as suggested by O'Donnell and Thorne [9]:

a. Which party has the best control over the event that gives rise to the risk.
b. Which party can handle the risk if it occurs.

c. Which party assumes responsibility if the risk is uncontrolled.

d. If the risk is beyond the control of all parties, it is assumed to be a shared risk.

3. RESULTS AND DISCUSSION

Risk Source Identification

According to Suripin et al. [14], identifying the sources of risk is a critical stage in urban river management to ensure the effectiveness of flood reduction and maintenance strategies. This process involves categorizing risks based on their origin and potential impact on the project's sustainability. Types of risk sources based on activities include political, planning, project, technical, environmental, safety, natural, economic, criminal, human, and financial. In the Tukad Ayung River Maintenance Project in Denpasar City, the risk sources identified were based on activities, as shown in Figure 2.

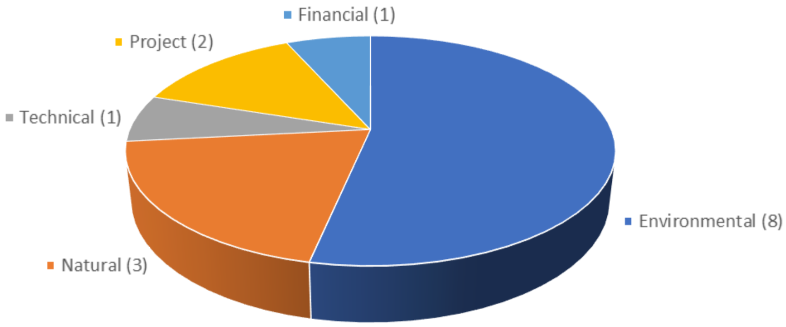

Figure 2. Number of Risks Based on Risk Source

Figure 1 shows that of the 15 (fifteen) identified risks, project, natural, technical, financial, and environmental risks accounted for the largest number, at 8 (eight) risks (53.33%). The largest risk was environmental risk, which involved difficulty in drilling due to sandy soil in the downstream area.

Respondent Assessment Analysis

Data analysis of the Tukad Ayung Maintenance Work in Denpasar City to identify significant risks was conducted using statistical analysis based on the likelihood and consequences identified from respondents' assessments in the questionnaire. The frequency of respondents' assessments of the likelihood of risk occurrence is shown in Figure 3.

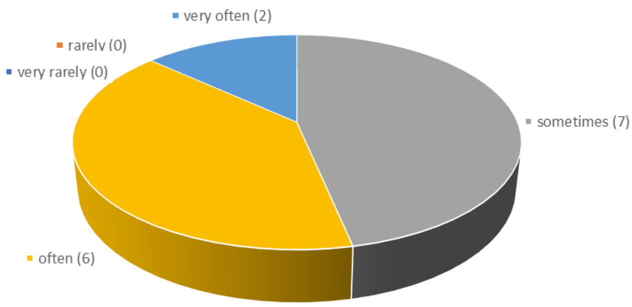

Figure 3. Frequency of Risk Likelihood

Based on the respondent response patterns, as shown in Figure 3, the following results were obtained:

a. Frequency scale 1 (very rare) : 0

b. Frequency scale 2 (rare) : 0

c. Frequency scale 3 (sometimes) : 7
d. Frequency scale 4 (often) : 6
e. Frequency scale 5 (very often) : 2

Based on the data, it appears that risks tend to be at a frequency scale of 4 (often). This indicates that the identified risks occur frequently. For the scale (sometimes), respondents stated that seven risks rarely occur, one of which is a falling tree hitting a construction site still under maintenance.

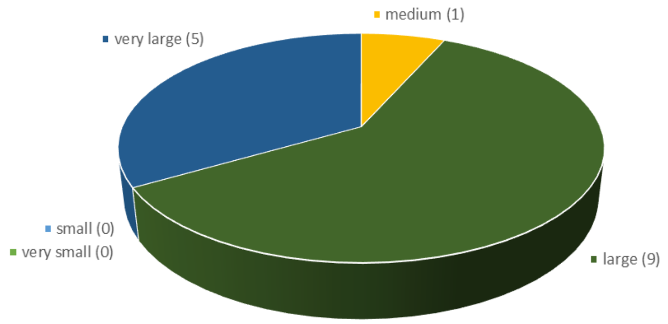

Figure 4. Frequency of Risk Consequences

Based on the respondent's response patterns, as shown in Figure 4., the following results were obtained:

1. Consequence scale 1 (very small) : 0
2. Consequence scale 2 (small) : 0
3. Consequence scale 3 (moderate) : 1
4. Consequence scale 4 (large) : 9
5. Consequence scale 5 (very large) : 5

Based on the data above, the highest risk frequency is at scale 4 (large). This indicates that the identified risks have a significant impact on the project. For scale 3 (moderate), there is one risk with a moderate impact on the project: maintenance on the Tukad Ayung rubber DAM, which results in no flow to the PDAM (Regional Water Company). This risk is considered to have a relatively moderate impact because the impact of the disruption does not significantly disrupt river maintenance. However, these risks must be avoided so that the contractor does not arrive late, which could impact the smooth running of the project.

Dominant Risks (Major Risks)

It can be seen that all risks within the risk acceptance level are dominant risks. This indicates many unacceptable risks in the river maintenance project that could negatively impact both costs and project implementation time. These dominant risks require special attention from competent parties responsible for the risks' occurrence so that mitigation measures can be implemented to reduce the negative impacts.

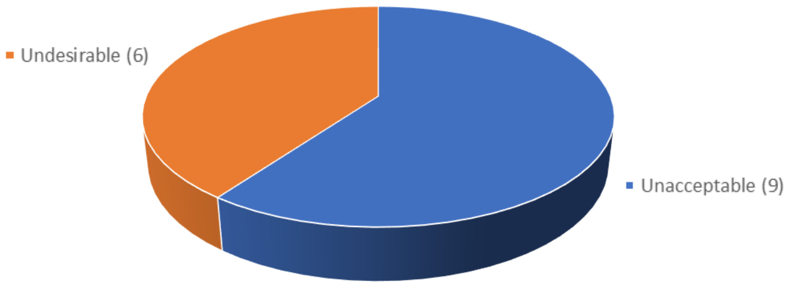

Figure 5. Risk Acceptability

Based on the risk acceptance level as shown in Figure 5., the percentage of risk acceptance levels is as follows:

1. Unacceptable : 9 risks (60.00%)
2. Undesirable : 6 risks (40.00%)
3. Acceptable : 0
4. Negligible : 0

Based on the 15 identified risks, the research results above show that all of them are major risks. Therefore, it can be concluded that the Tukad Ayung River Maintenance Project in Denpasar City is a high-risk project. This is because all identified risks are dominant risks, requiring increased attention.

Based on the data and percentages above, the identified major risks are grouped into the Unacceptable and Undesirable categories. Mitigation measures will then be implemented by the responsible parties.

Distribution of Risk Acceptance for Each Risk Source

Based on the analysis of respondents' risk assessment methods based on risk source, the distribution of risk acceptance can be outlined in Table 1.

Table 1. Distribution of Risk Acceptance for Each Risk Source

Source of Risk	**Risk Identification**		**Risk Acceptance Level**							
			Unacceptable		***Undesirable***		***Acceptable***		***Negligible***	
	qty	**%**	**qty**	**%**	**qty**	**%**	**qty**	**%**	**qty**	**%**
Political	0	0,00	0	0,00	0	0,00	0	0	0	0
Marketing	0	0,00	0	0,00	0	0,00	0	0	0	0
Environmental	8	53,33	4	26,67	4	26,67	0	0	0	0
Planning	0	0,00	0	0,00	0	0,00	0	0	0	0
Economic	0	0,00	0	0,00	0	0,00	0	0	0	0
Finance	1	6,67	1	6,67	0	0,00	0	0	0	0
Natural	3	20,00	2	13,33	1	6,67	0	0	0	0
Projects	2	13,33	1	6,67	1	6,67	0	0	0	0
Human	0	0,00	0	0,00	0	0,00	0	0	0	0
Technical	1	6,67	1	6,67	0	0,00	0	0	0	0
Criminal	0	0,00	0	0,00	0	0,00	0	0	0	0
Safety	0	0,00	0	0,00	0	0,00	0	0	0	0
Number	15	100	9		6		0	0	0	0
Percentage	100.00			60,00		40,00		0		0

Table 1 shows that nine risks (60.00%) fall into the unacceptable category. One of the risks with an unacceptable risk acceptance level is limited access to the site due to steep cliffs. These nine risks have the highest risk rating, considered unacceptable by those competent in river maintenance work. Six risks (40.00%) fall into the undesirable category. The identification of risks in Tukad Ayung reflects common barriers found in integrated river basin management, where technical and environmental factors often become the primary enablers of project uncertainty [15].

Risk Prioritization

Based on the results of the probability and impact assessment, the identified risks were ranked according to their risk scores to determine the dominant risks requiring priority mitigation measures. The ranking results are presented in Table 2.

Table 2. Risk Prioritization Results

Rank	Risk	Probability	Impact	Score	Category
1	Tidal seawater conditions in downstream areas	5	5	25	Unacceptable
2	Schedule for opening and closing the Oongan weir gate	5	4	20	Unacceptable
3	Changes in field work volume due to design drawing revisions	4	5	20	Unacceptable
4	Difficulties in drilling work caused by sandy soil conditions in downstream areas	4	5	20	Unacceptable
5	Project progress not in accordance with the planned schedule or negative deviation affecting payment term withdrawal	4	5	20	Unacceptable

Table 2. shows that tidal seawater conditions in downstream areas represent the highest-ranked risk with a probability-impact score of 25, categorized as an unacceptable risk. This condition significantly affects project implementation because fluctuations in seawater levels can disrupt construction activities, reduce work effectiveness, and increase operational difficulties in estuary areas. Furthermore, tidal fluctuations may limit effective working hours and require adjustments to construction schedules, potentially causing project delays. Additional operational costs may also arise due to the implementation of protective measures and specialized foundation systems required to maintain structural stability and construction quality in estuary areas. Therefore, this risk requires priority mitigation measures and continuous monitoring during project execution. These findings are consistent with previous studies on river infrastructure and flood control projects, which found that environmental and hydrological risks significantly influence project performance due to tidal fluctuations, unstable soil conditions, and uncertainty in water level conditions during construction activities.

Risk Matrix Analysis

To visualize the distribution and prioritization of identified risks, a 5×5 risk matrix was developed based on probability and impact assessment results. The matrix categorizes risks into acceptable, undesirable, and unacceptable risk levels according to ISO 31000:2018 principles. The risk matrix is presented in Figure 6.

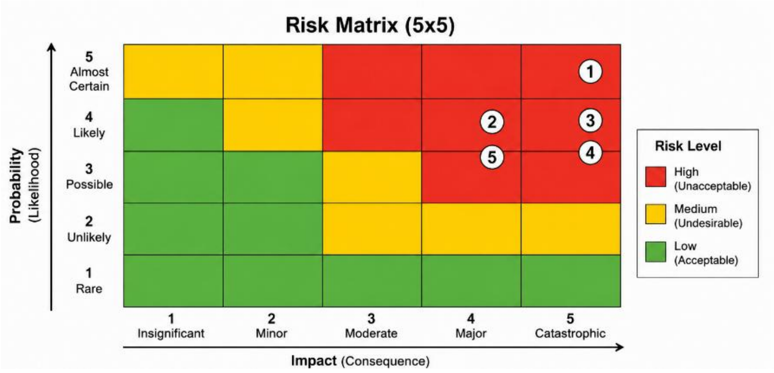

Figure 6. Risk Matrix 5x5

Figure 6. shows that several identified risks are categorized as unacceptable risks due to their high probability and impact values. The dominant risk, namely tidal seawater conditions in downstream areas, is located in the highest risk zone with a score of 25. This indicates that the risk requires immediate mitigation measures and continuous monitoring during project implementation.

Risk Mitigation

The presence of major risks will significantly impact the implementation of the Tukad Ayung maintenance project in Denpasar City. To reduce the negative impact of these risks, risk mitigation measures are implemented. For risks categorized as unacceptable, 15 mitigation measures were implemented. Meanwhile, one of them is a mitigation action for the risk of the water opening and closing schedule in the Oongan Dam that does not match the maintenance work schedule. Mitigation actions can be carried out in the form of coordination with the Denpasar City government, the Denpasar City PUPR Office in order to adjust the opening and closing schedule with the foundation work schedule so that there is no water shortage in the P3A and does not flood the work area during foundation installation, the risk of fallen trees hitting construction that is still under maintenance can be mitigated by using the maintenance guarantee provided by the contractor to repair the damage that occurs. In the implementation of Tukad Ayung maintenance, it is mitigated by reducing these risks. Mitigation actions for Unacceptable risks are carried out by reducing the impact (Risk Reduction), transferring risks (Risk Transfer) and avoiding risks (Risk Avoidance) as many as 10 mitigation actions from risks in the Tukad Ayung River foundation maintenance work. Meanwhile, the risk is classified as undesirable, 7 (seven) mitigation actions are carried out, one of which is the risk of an increase in water discharge due to flooding impacting the implementation of maintenance mitigated by requesting information from BMKG regarding the weather to anticipate an increase in water due to flooding when work begins, the risk of limited access to the location due to steep river banks is mitigated by preparing a borrow area as a temporary base for heavy equipment when work is completed.

Risk Ownership

Responsibility and risk ownership of related parties in the implementation of the Tukad Ayung maintenance project in Denpasar City, namely the Owner (PPK Water Resources of the Bali Penida River Basin Center), Supervisory Consultant and contractor as the project implementer. Risk ownership is carried out to control and handle existing risks properly by the responsible parties. Based on the results of the study, it shows that the risk ownership for the dominant risk (major risk) belongs to the contractor as the project implementer with 4 unacceptable risks and 4 undesirable risks. The greatest risk ownership is the contractor's responsibility because the identified risks related to the Tukad Ayung maintenance project in Denpasar City are the difficulty of carrying out drilling work due to sandy soil in the downstream area, the occurrence of fallen trees that hit the construction that is still under maintenance so that if the contractor does not carry out proper handling of these risks, it will have a negative impact on costs, quality and time.

Practical Implications

The findings of this study can support contractors and local governments in improving preventive planning and risk mitigation strategies for river maintenance projects, particularly in downstream and estuary areas affected by tidal seawater conditions.

Managerial Implications

Project managers and supervisory consultants should prioritize environmental and hydrological risk control during project implementation, especially in areas with tidal fluctuations and unstable soil conditions. Proper scheduling adjustments based on tidal seawater data and continuous monitoring are essential to minimize delays, operational difficulties, and additional project costs.

Academic Implications

The integrated risk analysis framework based on ISO 31000:2018 proposed in this study can be adapted for similar urban river infrastructure and maintenance projects in other regions. The study also contributes to the development of qualitative and quantitative integrated approaches in construction risk management research.

4. CONCLUSIONS

This study identified 15 risks in the implementation of the Tukad Ayung river maintenance project in Denpasar City, covering financial, project, technical, natural, and environmental risk categories. Using probability-impact analysis based on ISO 31000:2018, tidal seawater conditions in downstream areas were established as the dominant risk with the highest score of 25, categorized as unacceptable risk, due to its significant disruption to construction activities and limited working time. Mitigation was prioritized through risk reduction, risk transfer, and preventive planning approaches, including the utilization of tidal level data from Benoa Harbor and the application of concrete culvert and cyclope concrete foundation systems in downstream areas, with the contractor identified as the party bearing the largest proportion of risk ownership responsibilities. These findings contribute to improving risk mitigation planning for urban river maintenance projects, although the study remains limited to the Tukad Ayung watershed with a restricted number of respondents, suggesting that future research should integrate quantitative simulation methods such as Monte Carlo simulation or Fuzzy AHP to enhance risk prediction and prioritization accuracy.

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