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Research Paper

A Risk Management Analysis to Planning of Oesapa Besar Bridge Replacement in Kupang City

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ABSTRACT : *The construction of the Oesapa Besar Bridge Replacement in Kupang City must be conducted due to a significant decline in structural quality. The planning stage is dealing with many risks stemming from technical, financial, environmental and social factors. Therefore, this study aims to analyze the potential risks which may arise during the planning stage and evaluate the effectiveness of the proposed mitigation strategies to reduce these risks.*

The selected method to be applied in this study is Failure Mode and Effect Analysis (FMEA) method to identify potential failures and evaluate risks. The instrument in the form of a questionnaire with 13 risk indicators was distributed to 35 respondents. The results showed all risk variables experienced a decrease for their RPN value after the mitigation strategy was implemented. The total RPN value before mitigation was 2,394.63, has a decrease to 1,504.26 after mitigation, or equivalent to a decrease of 890.37 (37.18%). There are three main risks showed a significant decrease: (a) Innacurate cost estimation, (b) Budget innefficiency due to government policy, and (c) Inadequate water channel outlets. However, there are also several risks that remained in the high category after mitigation had been performed, such as: changes in traffic patterns, water pollution, land acquisition and negatively affected livelihoods.

KEYWORDS: *Risk Management, Failure Mode Effect Analysis,Mitigation Strategy, RPN Value, Bridge.*

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I. INTRODUCTION

The Oesapa Bridge was built in 1984 with a construction style of Callender Hamilton Bridge, a steel truss bridge whose components can be easily connected and separated. Unfortunately, insufficient width of the bridge to accomodate the traffic flow makes road congestion unavoidable, since the Oesapa Besar Bridge only 6 meters wide while the national road width should be 9 meters wide.

According to the detailed bridge inspection report made by INVI J application dated on March 10, 2024 as carried out to identify the current condition of the Oesapa Besar Bridge, there were a number of damages, especially on level 5 element where it has the highest detail level in the classification of bridge components. The damages were listed as: (1) Type of damage in the flexible road pavement has wavy surface layer or rutting with damage point of 14,5m2 out of 29 m2, (2) Damage to the retaining wall as evident in the presence of missing and broken parts with damage of 1.35 m2 out of 16.4 m2, and (3) The concrete of the sidewalk has porous with a moderate damage condition level, and (4) Blocked drainage within the drainage channels with a moderate damage condition level.

In addition, as referred to the following letters of: Official Memorandum of the Director of Bridge Construction, Directorate General of Highways, Ministry of Public Works and Public Housing dated February 22, 2022 Subject: RBU or Callender Hamilton Type Bridge Reinforcement Program for the 2022 Fiscal Year and Letter from the Director of Bridges, Directorate General of Highways, Ministry of Public Works and Public Housing dated July 31, 2018 concerning the Reinforcement of Callender Hamilton (CH) Bridges throughout Indonesia, instructing that taking into account of the substructure condition of the bridge, there will be a program to replace the top/superstructure of bridge with steel box girders.

Planning is a crucial stage in bridge replacement. Project planning consists of several stages where include budget and cost control systems, work schedules, human resources, WBS (Work Breakdown Structure), project results testing plans, documentation plans, site review plans and project results implementation plans.

Unlike planning, the construction stage focuses more on the implementation of the prepared plan where at this stage, the bridge is already built according to the established design by carrying out technical aspects such as construction implementation, supervision, and monitoring work progress. The success of this stage is highly dependent on the quality of the planning that has been done in prior time. [1]

Mistakes during planning stage have caused failure in many bridge replacement projects in Indonesia. Incorrect planning can lead to numerous problems, both technical and non-technical. Poor planning can lead to bridge failures and pose safety risks to bridge users and the surrounding community. Risk analysis method such as Failure Mode and Effect Analysis (FMEA) can play a major role for bridge replacement planning because it is very useful for identifying and mitigating risks that may arise during the project planning process.

So far, discussions related to Risk Management Analysis in the Planning for the Replacement of the Oesapa Besar Bridge in Kupang City – East Nusa Tenggara have not been carried out by many researchers, therefore the problems raised in this study are (1) What are the potential risks that occur in the planning for the replacement of the Oesapa Besar Bridge? (2) What is the level of potential risk identified in the planning for the replacement of the Oesapa Besar Bridge? (3) What risk mitigation strategies can be implemented to reduce the impact of possible risks?

II. LITERATURE REVIEW

2.1. Risk Management

According to Darmawi risk has several meanings, such as: 1) Risk is the chance of loss; 2) Risk is the possibility of loss; 3) Risk is uncertainty; 4) Risk is the difference between actual and expected results; and 5) Risk is the probability of a result different from the expected. [2]

Further definition can be stated as risk is a situation that carries the potential for unexpected loss and there are three conceptual terms related to risks:

1. Peril (Disaster, Calamity) Peril is an event that causes loss.
2. Hazard (Danger)
   Hazard is a condition that can cause or elevating the loss or damage caused by a peril. Hazard has four forms:
   a. Physical Hazard is a condition stemming from physical characteristics than can increase the occurrence of peril.
   b. Moral Hazard is a condition stemming from the mental attitude, outlook on life, and habits of the person concerned which able to increase the occurrence of peril.
   c. Morale Hazard is a condition stemming from the person carelessness that able to increase the occurrence of loss.
   d. Legal Hazard is a condition where regulations that protect the public are ignored, thus increasing the occurrence of a peril.

According to Wideman, risks can be divided into several types of:

1. Unpredictable external risks, such as project failure, natural disasters such as floods, earthquake and heavy rains, changes in law and regulations and other factors.
2. Predictable external risks, such as inflation, operational risks after project completion, currency fluctuation, and tax changes.
3. Internal risks that are generally controllable, such as delays in project implementation, cost overrun, and construction work management. [3]

When analysing these sources as the root causes, there are several types of risk sources that must be given serious attention. These risk sources are:

1. Political Situation
   The political situation in a country often becomes a major factor triggering risk, where policy changes, public opinion, legitimacy issues, and chaos caused by terrorism, riot and war can bring significant impact to the project implementation. Political risks are not difficult to predict, especially by examining track records of leadership candidates, community leaders, and religious figures, since they are the decision-makers at the national or regional level.
2. Environment
   Risks originating from environment often closely related to business activities (for example as internal company policy that can cause discomfort for employees. Also, the impact of pollution that affects health can also be a source of risk from outside the business environment.
3. Incorrect Planning
   Improper planning will impact your business. Companies that are not careful enough in their planning tend to face very serious risks.

4. Economy Problems
   Inflation in a country is difficult to be predicted in accurate way. However, a reliable analytical skill can help mitigate the risks arising from an economic recession.
5. Natural Disasters
   Disasters are physical risks that often heading to a major issue since it can take various forms such as fires, volcanic eruptions, pandemics, and personal accidents, all stemming from natural factors. Companies often must deal with significant challenges due to the impact of these natural disasters. [4]

According to Yim et al., types of risk events which able to arise in a project can be vary, depending on the project classification. It suggests that risk management plans can be tailored from outset based on the existing classification, thereby increasing the project's chances of success. There are eight risk classifications:

Table 1. Risk classification [5]

Risk Classification	Risk Category
Natural risk	Act of God
	Losses due to fire or accident
Design risk	Changes in scopes
	New technology
	Specification
	Missing or late because of different site or design changes.
Logistic risk	Delay and material damage
Financial risk	Fund sufficiency, cashflow, exchange rate and inflation
	Late in time
Law and order risk	Licence and Permit problem, contract failure, rule changes
Political risk	Loss or delay because of war; revolution at site, changes in the trade law
Environment risk	Ecological damage, pollution, waste management
Construction risk	-

Moreover, there are also risk category where RBS is not be taken for use:

Table 2. Risk category [6]

Risk Classification	Risk Category
Technical Risk	Definition of scope
	Definition of requirements
	Estimation, assumption and constraints
	Technical process
	Technology
	Interface technical
Management Risk	Project management
	Program management
	Operational management
	Organization
	Resources
	Communication
Commercial Risk	Terms and requirement of contract
	Internal procurement
	Supplier and vendor
	Subcontract
	Client stability
	Partnership and joint venture
External Risk	Regulations and law
	Exchange rate
	Location or facilities
	Environment and weather
	Competition
	Rules

2.2. Failure Mode and Effect Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is a systematic method for identifying and preventing product problems before they occur. It focuses on defect prevention, improving safety, and enhancing customer satisfaction. The goal of FMEA is to identify all possible failures in a process or product. [7]

Evaluation of the failure process in FMEA is carried out by considering three main indicators: Severity (S), Occurrence (O), and Detection (D). To determine the priority level of a failure mode, the author multiply three relevant indicators, which then produces a Risk Priority Number (RPN). This RPN reflects the priority level of a failure mode based on the analysis conducted on the process being studied. The higher the RPN value obtained, the higher the priority for improvement. The RPN is calculated using a predetermined formula. [8]

$$\text{RPN} = \textit{Severity} \times \textit{Occurrence} \times \textit{Detection} \quad \textit{(1)}$$

According to Mc Dermott, the ranking criteria of FMEA assessor consists from:

1. Severity rating criteria
   The severity rating calculation includes safety, production continuity, scrap loss, etc. The following table is presenting the level of severity:

Table 3. Criteria of severity level [8]

Severity Probability	Criteria	Rank
Failure to Meet Safety and/or Regulatory Requirements	Potential failure modes affect the safe operation of the vehicle and/or involve non-compliance with government regulations *without* warning	10
	Potential failure modes affect the safe operation of the vehicle and/or involve non-compliance with government regulations *with* warnings	9
Loss or Decline of Primary Function	Loss of primary function (vehicle cannot be operated, does not affect the safe operation of the vehicle)	8
	Primary functional impairment (vehicle can still be operated, but at a reduced performance level)	7
Loss or Decline of Secondary Function	Loss of primary function (vehicle cannot be operated, but comfort/convenience functions cannot be operated)	6
	Primary functional impairment (vehicle cannot be operated, but comfort/convenience functions are at a reduced performance level)	5
Distrubances	Appearance or Audible Noise, vehicle is operable, item is not suitable and noticed by most customers (>75%)	4
	Appearance or Audible Noise, vehicle is operable, item does not match and is noticed by many customers (50%)	3
	Appearance or Audible Noise, vehicle is operable, item is not suitable and noticed by a discerning customer (<25%)	2
Insignificant	No Apparent effect	1

2. Occurence rating criteria
   The probability of a failure occurring during the system lifetime is expressed in terms of potential occurences per unit time. The failure mode probability is classified into different levels through logical approaches. The occurrence ranking criteria is presented in the following table (Table 4).

Table 4. Criteria of occurence level [8]

Occurence Probability	Criteria	Rank
Very High	New technology/new design without history	10
High	Failures are inevitable with new designs, new applications, or changes in duty cycle/operating conditions	9
	Failures may occur due to new designs, new applications, or changes in duty cycle/operating conditions	8
	Failure is uncertain with new designs, new applications, or changes in duty cycle/operating conditions	7
Moderate	Frequent failures associated with similar designs or in simulation and testing of designs	6
	Occasional failures related to similar designs or in simulation and testing of designs	5
	Isolated failures associated with similar designs or in simulation and testing of designs	4
Low	Only isolated failures related to nearly identical designs or in simulation and testing of designs	3
	No failures were observed in relation to the nearly identical designs or in simulation and testing of the designs	2
Very Low	Failures are eliminated through preventive controls	1

3. Detection rating criteria
   In detection ranking, the probability that a failure mode will be detected based on existing controls is assessed. The probability of detection is ranked in reveerse order. The detection rating criteria is listed in the following tabel (Table 5).

Table 5. Detection rating criteria [8]

Detection Probability	Criteria	Rank
Almost Possible	No current design control; Unable to detect or not analyzed.	10
Very Far	Design analysis/detection control has weak detection capabilities; Virtual Analysis (e.g., CAE, FEA, etc.) does not correlate with the actual expected operating conditions.	9
Far	Product verification/validation after design freeze and before launch with pass/fail testing (Subsystem or system testing with acceptance criteria such as ride and handling, delivery evaluation, etc.).	8
Very Low	Product verification/validation after design freeze and with testing to failure (Subsystem and before launch or system testing to failure, system interaction testing, etc.).	7
Low	Product verification/validation after design freeze and before launch with degradation testing (Testing of subsystems or systems after endurance testing, e.g. function checks).	6
Moderate	Product validation (reliability testing, development, or validation testing) prior to design freeze using pass/fail testing (e.g., acceptance criteria for performance, function checks, etc.).	5

Detection Probability	Criteria	Rank
Quite High	Product validation (reliability testing, development testing or validation) prior to design freeze uses trials to failure (e.g., to leak, yield, crack, etc.).	4
High	Product validation (reliability testing, development testing or validation) prior to design freeze using degradation testing (e.g., data trends, before/after values, etc.)	3
Very High	Design analysis/detection control has strong detection capabilities; Virtual Analysis (e.g., CAE, FEA, Correlation, etc.) is highly correlated with actual or expected operating conditions prior to design freeze.	2
Almost Certain	The cause of failure or failure mode cannot occur because it is completely preventable through a design solution (e.g., applicable; proven design standards, best practices or common materials, etc.).	1

III. RESEARCH METHOD

3.1. Research Location

The location of this study is on Terusan Timor Raya Street, Oesapa, Kelapa Lima District, Kupang, East Nusa Tenggara, in particular site of Oesapa Besar Bridge, with geographical coordinate points mentioned as -10.149563, 123.638229.

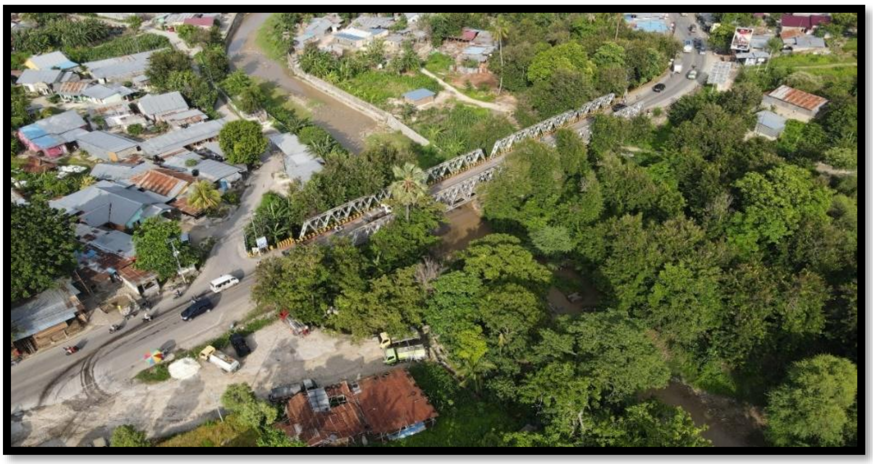

Figure 1. Aerial view of Oesapa Besar Bridge

3.2. Data Source

There are two types of data: the primary and secondary data, where both were very important to support a comprehensive analysis and conclusion achievable in this research.

1. Primary Data
   A questionnaire is a data collection technique that involves providing list of questions to respondents. The purpose in administering questionnaire is to obtain information from respondents regarding the research problem of this study, where these questions was aimed at planning consultants within the NTT National Development Planning Agency (BPJN) and consultants with ample experiences in Bridge planning.

2. Secondary Data
   The secondary data for this study was obtained from the Planning Committee (PPK) on the NTT National Development Planning Agency (BPJN). The following secondary data were necessary to be taken: 1) Project Data (plan drawing, AHS, environmental documents); 2) Literature Review (journal, article, books).

3.3. Technique of Tabulation Data and Data Analysis

This study was performing an analysis using Failure Mode and Effect Analysis (FMEA) methods as an attempt to answer the study problem of this research:

1. Risk identification
   Here, the risk identification is carried out in planning phase with target for replacing the Oesapa Besar Bridge, as sorted from various factors such as technical factor, financial factor, environmental factor and social factors.
2. Risk potentiality identification
   The next stage is to identify potential risks that may arise in the planning for replacing the Oesapa Besar Bridge.
3. Rating Severity (S) determination
   The severity rating represents the level of seriousness of the consequences of a potential failure. The higher the severity value, the greater the potential impact. The severity rating scale ranges from 1 to 10, depending on the level of seriousness or danger. These results were obtained through questionnaires and interviews conducted with respondents who have required experience and related education.
4. Rating Detection (D) determination
   Detection Rating is performed by measuring the ability to detect or control failures. The detection rating scale ranges from 1 to 10. These results were obtained through questionnaires and interviews conducted with respondents who have required experience and related education.
5. Rating Occurrence (O) determination
   The occurrence rating is the frequency level where a specific failure cause occurs, resulting in a specific type of failure. The occurrence rating scale ranges from 1 (almost never) to 10 (almost always). These results were obtained through questionnaires and interviews with respondents who have required experience and related education.
6. Calculation of RPN value
   The next step is calculating the RPN value, which aims to determine the order of importance of potential failures in the FMEA method. The RPN value is obtained by multiplying the SOD (Severity, Occurrence, and Detection) values.

   RPN = *Severity* (S) x *Occurrence* (O) x *Detection* (D)

7. Determination of RPN value category
   The next step is calculating the RPN value, which aims to determine the order of importance of potential failures in the FMEA method. The RPN value is obtained by multiplying the SOD (Severity, Occurrence, and Detection) values.

Table 6. Risk level according to RPN Value [9]

Risk Level	Scale of RPN Value
Very Low	x < 20
Low	20 ≤ x < 80
Moderate	80 ≤ x < 120
High	120 ≤ x < 200
Very High	x > 200

IV. RESULT AND DISCUSSION

4.1. Research Design

This study is attempting to analyze risks using the Failure Mode and Effect Analysis (FMEA) method. Each potential risk is evaluated based on three main parameters of Severity (S), Occurrence (O) and Detection (D). The Risk Priority Number (RPN) value inside the FMEA method worksheet has two types of values: (a) RPN value for risk and (b) RPN value for risk mitigation as obtained using the following formula [6]:

$$RPN_{ij} = S_{ij} \times O_{ij} \times D_{ij} \quad (2)$$

Where:
i = Number of risk statement (1 until 13)
j = Number of respondents (1 until 35)

S = Severity Value
O = Occurrence Value
D = Detection Value

With calculation as stated below:

$$RPN_{11} = S_{11} \times O_{11} \times D_{11} = 10 \times 9 \times 1 = 90$$

From the calculation result, it is found that the RPN 11 value was 90, and the result of the RPN calculation for each studied respondent is put in details in the appendix. After obtaining the Risk Priority Number (RPN) for each statement and each respondent, the average RPN value was then be calculated using the following formula:

$$RPN_{mean} = \frac{\sum_{j=1}^{n} RPN_{ij}}{n} \qquad (3)$$

Where:
i = number of risk statement (1 until 13)
j = number of respondents (1 until. 35)
n = total respondents (35)

With calculation as mentioned below:

$$RPNmean\ at\ risk\ variable\ of\ P1 = \frac{\sum_{j=1}^{n} RPN_{ij}}{n}$$
$$= \frac{90+392+216+216+240+128+216+315+180+512+128+\cdots+10+4}{35}$$
$$= 188{,}83$$

The mean Risk Priority Number (RPN) value for risk variable P1 is found to be 188.83. The average Risk Priority Number (RPN) value for risk can be seen as follows:

Table 7. The average RPN Value for risks

Risk	Average RPN Value of Risk	Risk Level
P1	188.83	High
P2	187.26	High
P3	228.71	Very High
P4	150.80	High
P5	195.57	High
P6	232.66	Very High
P7	230.51	Very High
P8	194.97	High
P9	137.43	High
P10	148.31	High
P11	190.91	High
P12	144.86	High
P13	163.80	High

From the above table, then the average Risk Priority Number (RPN) value can be found which listed in the following explanation:

1. Risk Variable P6 with the risk of less accurate cost estimation obtained an average Risk Priority Number (RPN) value of 232.66 and categorized into a very high-risk level.
2. Risk Variable P7 with the risk budget efficiency from government policy obtained an average Risk Priority Number (RPN) value of 230,51 and categorized into a very high-risk level.

3. Risk Variable P3 with the risk of inadequate water outlet planning obtained an average Risk Priority Number (RPN) value of 228,71 and categorized into a very high-risk level.
4. Risk Variable P5 with the risk of ineffective traffic diversion obtained an average Risk Priority Number (RPN) value of 195,57 and categorized into a very high-risk level.
5. Risk Variable P8 with the risk of water pollution obtained an average Risk Priority Number (RPN) value of 194,97 and categorized into a high-risk level.
6. Risk Variable P11 with the risk of land acquisition obtained an average Risk Priority Number (RPN) value of 190,91 and categorized into a very high-risk level.
7. Risk Variable P1 with the risk of not taking into account changes in future traffic patterns obtained an average Risk Priority Number (RPN) value of 188,83 and categorized into a very high-risk level.
8. Risk Variable P2 with the risk of innefective temporary path planning obtained an average Risk Priority Number (RPN) value of 187,26 and categorized into a very high-risk level.
9. Risk Variable P13 with the risk of ineffective relocation or eviction obtained an average Risk Priority Number (RPN) value of 163,80 and categorized into a very high-risk level.
10. Risk Variable P4 with the risk of unfriendly design pavement for disability people obtained an average Risk Priority Number (RPN) value of 150,80 and categorized into a high-risk level.
11. Risk Variable P10 with the risk of air pollution obtained an average Risk Priority Number (RPN) value of 148,31 and categorized into high risk level.
12. Risk Variable P11 with the risk of livelihood becomes negatively influenced obtained an average Risk Priority Number (RPN) value of 144,86 and categorized into high risk level.
13. Risk Variable P9 with the risk of noise pollution obtained an average Risk Priority Number (RPN) value of 137,43 and categorized into high risk level.

4.2. Determination of Sample and Respondents of the Study

A method of Failure Mode and Effect Analysis (FMEA) was used to conduct a risk management analysis for the Oesapa Besar Bridge Replacement Planning. This study produced two types of Risk Priority Number (RPN) values: RPN before mitigation and RPN after mitigation. RPN value before mitigation reflects the risk severity at the baseline, meanwhile the RPN value after mitigation indicates the remaining risk level after the control strategy is implemented.

Based on the analysis of 13 risk variables, all risks experienced a decrease value in their RPN after the mitigation strategy was implemented. For example, the risk variable P6 (innacurate cost estimation, decreased from RPN 232.66 to 98.51), risk variable P7 (budget efficiency from government policy, decreased from 230.51 to 176.11) and risk variable P3 (inadequate water outlet planning, decreased from 228.71 to 121.89). These decrease values indicate the implemented mitigation strategy had been able to reduce the risk level significantly and effectively, in particular for risks with a critical impact on project continuity.

In total, the total RPN value before mitigation was 2,394.63, while the total RPN value after mitigation was 1,504.26. Thus, there was a decrease in the total RPN of 890.37, with a percentage decrease of 37.18%. This percentage indicates the success of the implementation of the mitigation strategy in reducing the aggregate risk level across all analyzed aspects, including technical, financial, environmental, and social aspects.

However, not all risks experienced a significant reduction. Several risks remained in the high category after mitigation, outside of the three main risks mentioned above. These risks are risk variable P1 (not taking into account changes in future traffic patterns, with an RPN value of 188.83, down to 138.46); risk variable P8 (water pollution, with an RPN value of 194.97, down to 121.31); risk variable P11 (land acquisition with an RPN value of 190.91, down to 130.69); and risk variable P12 (negatively affected livelihoods, with an RPN value of 144.86, down to 120.11). These risks have not been fully controlled due to external factors such as policy changes, community involvement, and coordination with other agencies.

Risk analysis using the FMEA method showed that mitigation strategies significantly able to reduce the RPN value. However, some risks remained with high RPNs after mitigation. Consequently, to ensure the success and smooth construction of the Oesapa Besar Bridge, project management requires continued supervision and give special attention to some risk potentials.

V. CONCLUTION

From the result of the Failure Mode and Effect Analysis conducted in this study, there are several findings obtained that can be put into conclusions as explained below:

1. There are four potential risk factors occuring in the planning stage of the project of replacing the Oesapa Besar Bridge: 1) from technical factor that has 5 risk factors of: not taking into account changes in future traffic patterns, inneffective temporary road planning, inadequate water channel outlet planning, non-friendly sidewalk design for disability people, and ineffective traffic diversion; 2) from financial factor has 2 risks of: innacurate cost estimates and budget efficiency from government policies; 3) environmental factor has 3 risks

of: water pollutions, noise pollution and air pollution; 4) social factor has 3 risks of: land acquisition, negatively affected livelihood and ineffective evictions and relocations.

2. There are 3 main risks with a very high-risk level identified in the planning for the replacement of the Oesapa Besar Bridge, namely risk variable P6 with a description of the risk of inaccurate cost estimates, risk variable P7 with a description of the risk of budget efficiency from policies and risk variable P3 with a description of the risk of inadequate water channel outlet planning.
3. Strategy of risk mitigation that able to be applied for overcome three main risks (to reduce the impact of possible risks) are: 1) risk variable P6 is subject to risk mitigation such as using the SIPASTI application in cost estimation; 2) risk variable P7 is subject to risk mitigation such as implementing a strict monitoring system to monitor expenditures and ensure that the project remains within the budget and cutting lower RAB values by paying attention to value standards and technical specifications; 3) risk variable P3 is subject to risk mitigation such as conducting outlet analysis by considering capacity, slope and flow direction.

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