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Research Paper

Risk Management Analysis to Construction Project of Liliba Bridge Duplication in Kupang City

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ABSTRACT : *Kupang City is a municipality and capital city of East Nusa Tenggara Province, that currently has a rapid population growth, increasing activities and higher number of travels, therefore, it is necessary to improve road facilities and its infrastructure. The implementation of Liliba Bridge Duplication work uses APBN funding source through the Regional Road of Presidential Instruction (Impres) program with a work contract value of Rp. 72.413.655.000, -. The construction work of Liliba Bridge Duplication is unavoidable will cause many risks along its implementation, especially this construction will take place on an active route in the city center crossing with very dense traffic and large use of heavy equipment and sophisticated machinery.*
The selected method that will be used in data management and initial data exploration of this study was the Work Breakdown Structure which divided into two methods of ISO 31000 and House of Risk (HOR) to identifity, assess, mapping, classifying and mitigating the risks.
Based on the identification results, there were 134 risks identified and can occur during the Liliba Bridge Duplication project. Verification using the first questionnaire distributed to 30 respondents revealed 84 relevant risks and further action (the analysis) succeeded to identify 11 risk agents at the highest level. From the 11 risk agents, their ARP value were calculated using House of Risk (HOR) Stage 1, resulting in 6 dominant risk agents with the highest values: (1) A10 with ARP value of 279, (2) A11 with ARP value of 252, (3) A8 with ARP value of 225, (4) A9 with ARP value of 144, (5) A6 with ARP value of 130, and (6) A7 with ARP value of 120. Three main mitigation strategies for risk mitigation were found, such as wearing appropriate personal protective equipment (PPE) such as gloves, safety shoes, safety helmets or safety googles and safety belts (PA1), held training related to Occupational Safety and Health (OSH) (PA2), and ensuring cafeful material procurement planning (including listing of type, quantity, and time of delivery), tracking material deliveries to guarantee timely arrival and preparing a sufficiently large and organized material storage area (PA3).

KEYWORDS: *Construction Project, Risk Management, House of Risk, Work Breakdown Structure, Bridge.*

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I. INTRODUCTION

The implementation of Liliba Bridge Duplication Construction Project was funded by APBN source from Regional Road program as mandated by Presidential Instruction through task force of National Road Implementation Region I of East Nusa Tenggara Province; the National Road Implementation Center of East Nusa Tenggara Province with a work contract of Rp. 72.413.655.000, - (seventy-two billion four hundred thirteen million six hundred fifty-five thousand rupiah). This construction project uses a Multiyear Contract (MYC) scheme with work implementation period lasting to 360 calendar days. Liliba Bridge Duplication will become a helping hand for the smoothness of traffic flow for supporting the economic sector, supporting more capacity of land transportation and facilitating the logistic routes and land transportation mobility in East Nusa Tenggara Province. The Liliba Bridge Duplication Project in Kupang City is one of the construction projects with high level of risk and work accidents since there are large number of workers involved, and the use of sophisticated machines that require special method and expertise, and must be supervised in their use.

The construction of Liliba Bridge Duplication work inevitably will heading to many risks since the construction is carried out on an active route at the city center with very heavy traffic. Risk is a possibility of something unexpected happening that will be detrimental and can affect the overall project completion in terms of time, cost, and quality. [1]

II. LITERATURE REVIEW

2.1. Risk Management

According to Purdy, ISO 31000 is a qualitative approach to risk assessment. It is a risk management process adapted from AS/NZS 4360:2004, with a purpose to demonstrate the relationship between the standard clauses that describe the process. The risk management process schematic using ISO 31000 method is described below:

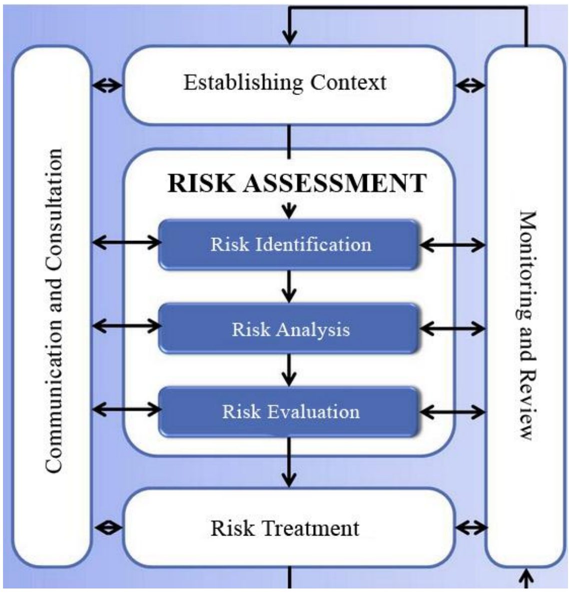

Figure 1. Scheme of risk management process. [2,3]

After completing stages of process as displayed above, then, analysis to the potential risks and determine what mitigation measures should be implemented can be conducted. The stages are defined in the following explanation:

1. Establish the context: defined as the external and internal parameters that must be put into consideration by the organization during their action in managing risks.
2. Risk Assesment: based on ISO 31000, consisted of three steps: risk identification, risk analysis and risk evaluation.
   a. Risk identification: Risk identification requires the application of a systematic process to understand what could happen, how, when, and why.
   b. Risk analysis: Risk analysis is concerned with developing an understanding about each risk, its consequences, and the likelihood of those consequences.
   c. Risk evaluation: Risk evaluation then involves making decisions about the level of risk and priority of attention through the application of criteria developed when the context was established.
3. Risk Treatment: the process where the existing control are enhanced or new controls are developed and implemented. This process involves evaluating and selecting from options, including analyzing cost and benefits, and assessing the potential new risks for each option may pose, the giving priority and implementing the selected treatment through a planned process.
4. Communication and Consultation: between the organization and its stakeholders. This dialogue is ongoing and iterative, since it is a two-way communication process that involves sharing and receiving information about risk management. Once communication and consultation are complete, decision are made and direction is set by the organization, not by stakeholders.
5. Monitoring and review: monitoring has a meaning of supervise and continuously examine and critically observe, it means determining the current status and assessing whether expected performance level being achieved or not. Meanwhile, reviewing involves reviewing risk management policies and plans, including risk criteria, risk treatment, risk management control, risk assessment processes, and others.

2.2. Risk Survey

According to Yin, the question of ‘what’ has a focus on exploratory matters typically for utilize survey, case study and experimental approaches. Whereas the question of ‘what’ (in the form of ‘how many’ and ‘how big’), ‘who’, and ‘where’ questions are more appropriate to be used for approach of survey and archival analysis. This approach brings advantage if the research objective is to describe the frequency of occurrence, the level of influence of an event or incident, or to predict a definite outcome. Whereas 'how' and 'why' questions provide more explanatory information and probability about definite matters, so the suitable approaches are case studies, history, and experiments. Due to the nature of some questions that related to how something works, it requires more in-depth research than measuring the occurrence frequency or impact it causes. Based on the discussion above and types of questions in the research question/RQ, this study uses a survey method based on a questionnaire filled out by respondents that consisted from project heads, field implementers, and site office engineers at PT X. [4]

2.3. Risk Potential Measurement

In conducting evaluation process, Godfrey dan Halcrow provide benchmark for determining the probability and consequence level of a risk. The following table shows the probability and consequence level of a risk:

Table 1. The level of risk probability [5]

Probability	
Description	**Explanation**
Very Often	Occuring very frequent or multiple times during the project implementation period (indicator 100/T)
Often	Frequently occurs during the project implementation period. (indicator 10/T)
Sometimes	It can occur several times and at various times during the project implementation period. (indicator 1/T)
Seldom/Rarely	The probability of occurrence is small (e.g., one in ten occurrences) during project implementation. (indicator 1/10T)
Very Seldom	Very unlikely to happen so it can be assumed that it will not happen or cannot happen. (indicator 1/100T)
T = Project Time	

Table 2. The level of risk consequences [5]

Consequences	
Description	**Explanation**
Dangerous	Death, system loss, criminal error, bankruptcy
Critical	Work that threatens injury or illness, major damage, substantial damage
Serious	Damage to project equipment or supplies (dredging machine), requires an insurance claim
Small	Injuries or illnesses that only require first aid at work, minor damage that can wait for routine care
Ignorable	So small as to be considered without consequence

For calculating a risk, the following formula is suitable to be used:

$$R = P \times I \quad (1)$$

Where:
R = Risk level
P = Probability level
I = Impact level

A Likert Scale is used in this evaluation process for measuring the probability and consequence levels of potential risks that able to occur. The following evaluation scale is employed and ranges from 1 to 5:

Table 3. Evaluation scale of probability level

Probability	Scale
Very Often	5
Often	4
Sometimes	3
Seldom/Rarely	2
Very Seldom/Rarely	1

Table 4. Evaluation scale of consequence level

Consequence	Scale
Dangerous	5
Critical	4
Serious	3
Small	2
Avoidable	1

After the evaluation process completed, the next step is creating a risk map. In this stage, the identified risks can be identified as low, moderate and high risk. The following risk map will be used.

Table 5. Risk map [3]

Consequence Likelihood	*Insignifant (1)*	*Minor (2)*	*Moderate (3)*	*Major (4)*	*Catastrophic (5)*
Almost Certain (5)	*Medium (5)*	*High (10)*	*High (15)*	*Very High (20)*	*Very High (25)*
Likely (4)	*Medium (4)*	*Medium (8)*	*High (12)*	*High (16)*	*Very High (20)*
Possible (3)	*Low (3)*	*Medium (6)*	*High (9)*	*High (12)*	*High (15)*
Unlikely (2)	*Low (2)*	*Low (4)*	*Medium (6)*	*Medium (8)*	*High (10)*
Rare (1)	*Low (1)*	*Low (2)*	*Medium (3)*	*Medium (4)*	*High (5)*

2.4. House of Risk

The House of Risk (HOR) model is a development of the Failure Modes and Effects Analysis (FMEA) method and the Quality Function Deployment (QFD) method. This model is divided into two phases: the risk identification phase and the risk mitigation phase. This model aims to reduce the occurrence of risk causes which can directly prevent the possibility of risk events from occurring. [6,7]

Pujawan and Gerardin explain that in FMEA method, the probability level and severity level are associated with risk events while in the HOR model, it assigns a probability level to the risk cause and a severity level to the risk event. Since a single risk cause able to lead to multiple risk events, it is crucial to calculate the aggregate risk value to determine the potential of risk occurrence. The following is the formula for calculating aggregrate risk value according to Pujawan and Gerardin [6,7]:

$$ARP_j = O_j \& S_i R_{ij} \quad (2)$$

Where:
Oj = Probability of risk source occurrence (j)
Si = Magnitude of impact when risk occurs (i)
Rij = Correlation between risk (i) and source of risk (j)

Further, Pujawan and Gerardin (2009) added, HOR is divided into two: HOR I and HOR 2. HOR 1 has an aim to determine which risk sources will be prioritized for preventive action, whereas HOR 2 aims to determine effective actions for these priorities. [7]

In the HOQ model, Pujawan and Gerardin connect the requirements (what) and responses (how), where each response can fulfill one or several requirements. The correlation level then can be classified as follows [7]:

0 = no correlation
1 = low correlation
3 = moderate correlation
9 = high correlation

In adopting these procedures, HOR 1 is developed through the following steps:

1. Identification of potential risk events using a scale of 1 – 10, and 10 becomes the greatest impact.
2. Identification of risk causes (agents) using a scale of 1 – 10, with 10 as the greatest number of occurences.
3. Develop a correlation matrix using a scale of 0,1, 3 and 9, with 9 as the highest correlation number.
4. Calculate the aggregate value.
5. Make a rank of risk causes based on the aggregate risk value from the highest to the lowest number.

Table 6. House of risk stage 1 [7]

Business processes	Risk event (E_i)	Risk agents (A_j) A_1	A_2	A_3	A_4	A_5	A_6	A_7	Severity of risk event i (S_i)
Plan	E_1	R_{11}	R_{12}	R_{13}					S_1
	E_2	R_{21}	R_{22}						S_2
Source	E_3	R_{31}							S_3
	E_4	R_{41}							S_4
Make	E_5								S_5
	E_6								S_6
Deliver	E_7								S_7
	E_8								S_8
Return	E_9								S_9
Occurrence of agent j		O_1	O_2	O_3	O_4	O_5	O_6	O_7	
Aggregate risk potential j		ARP_1	ARP_2	ARP_3	ARP_4	ARP_5	ARP_6	ARP_7	
Priority rank of agent j									

HOR 2 is used to determine which actions should be taken first, by considering the varying effectiveness, the resources involved, and the degree of difficulty involved. In ideal condition, companies should choose a set of actions which are not too difficult to be implemented but can effectively reduce the likelyhood of risk agent occuring. The steps are explain in the following paragraph:

1. Choose a number of risk factors with a high priority ranking using Pareto analysis from ARPj.
2. Identify actions which consider relevant for preventing the risk factors.
3. Determine the relationship between each preventive action and each risk agent (Ejk) using a scale of 0,1,3 and 9, where 9 is the highest correlation.
4. Calculate the total effectiveness of each action with the following equation:

$$TE_k = \text{J} \& ARP_j E_{jk} \quad (3)$$

5. Assess the level of difficulty in performing each action (Dk), which can be represented using a Likert Scale or similar.
6. Calculate the total effectiveness to difficulty ratio.
7. Rank the prioriry for each action (Rk) with a rank of 1 will be given to action with the highest ETDk value.

Table 7. House of risk stage 2 [7]

To be treated risk agent (A_j)	Preventive action (PA_k)					Aggregate risk potentials (ARP_j)
	PA_1	PA_2	PA_3	PA_4	PA_5	
A_1	E_{11}					ARP1
A_2						ARP2
A_3						ARP3
A_4						ARP4
Total effectiveness of action k	TE_1	TE_2	TE_3	TE_4	TE_5	
Degree of difficulty performing action k	D_1	D_2	D_3	D_4	D_5	
Effectiveness to difficulty ratio	ETD_1	ETD_2	ETD_3	ETD_4	ETD_5	
Rank of priority	R_1	R_2	R_3	R_4	R_5	

III. RESEARCH METHOD

3.1. Research Design

This research is a case study type by using expert judgment, and process of selecting experts who will be used as expert panels (general superintendent, technical manager, quality manager, roadwork and maintenance implementer, and construction K3 expert) unfortunately was not working according to study plan, from potential respondents that researcher has identified, no assurance from the experts to become the respondents. Therefore, there may be changes in respondents that will be adjusted based on the willingness of the experts. Research method employed in this study for data management and initial data exploration section was the Work Breakdown Structure (WBS) and two additional methods (ISO 31000 and House of Risk (HOR) stage 1 and stage 2. ISO 31000 method is applied for analyzing and evaluating risks that may occur, also for mapping the risks that have been analyzed to determine whether the risk is classified in the low risk, moderate risk, or high-risk category. Meanwhile, the HOR method is used to determine the appropriate steps or method for risk mitigation based on the source of risk causal so the provided mitigation suggestions are objective and can be targeted according to each source of the risk cause.

3.2. Determination of Sample and Respondents of the Study

The construction of Liliba Bridge Duplication project is located in the Liliba area of Kupang City, East Nusa Tenggara. The bridge is built on El Tari Raya Road STA 05 + 525 crossing the Liliba River.

Figure 2. Location of Liliba Bridge Duplication construction

3.3. Data Collection

The researchers collected study data from the National Road Implementation Center of East Nusa Tenggara Province, which later, after obtaining the project data, the researchers conducted a direct survey at the project site to obtain a general overview of the field condition. In addition, the researchers conducted a literature review from sources of books, references from internet, documents from Department of Public Works regulations along with other regulations that could serve as reference and supplementary materials for this study. The following data was collected:

1. Primary Data
   Total number of respondents were 30 individuals and divided into five population as follows:
   a. The Work Unit of National Road Implementation for Region 1, NTT Province as the Budget User (10 individuals).
   b. Commitment Making Officer 1.1, NTT Province (7 Individuals).
   c. Implementer Contractor (5 individuals).

   d. Supervisory Consultants (5 individuals)
   e. Academic Experts (3 individuals)
2. Secondary Data
   The Secondary data collecting process involving direct surveys from the relevant agencies or companies.

3.4. The Research Flowchart

In this research, data analysis was carried out to answer the problems that had been established, namely:

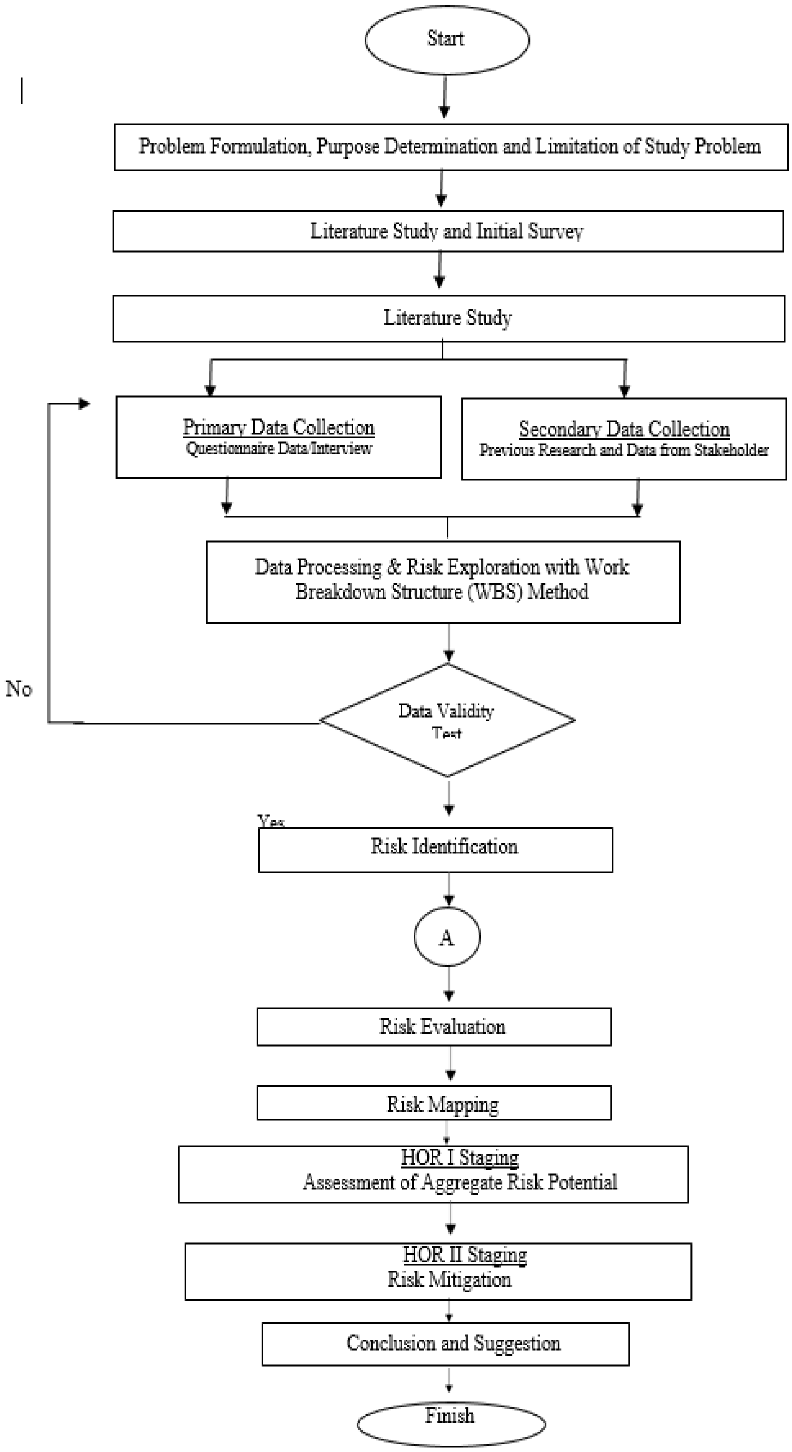

Figure 3. Research flowchart

IV. RESULT AND DISCUSSION

4.1. Analysis of Risk identification

Once the work identification using the Work Breakdown Structure method was completed, the researcher began to identify risks based on the activities (work items) that had been identified in the WBS and found result of 134 identified risks which able to occur in 27 activities (work items) in 8 existing work divisions. Then, the researcher conducted a risk survey from the result of risk identification by distributing the first stage questionnaire to 30 (thirty) respondents in order to obtain relevant risk agents or focus on existing work items and obtained result of 84 (eighty-four) relevant risks. Moreover, from result of the relevant risk survey, the researchers used it as a basis for distributing the second stage of questionnaire and had passed the validity and reliability test. It has a function for determining the risk evel also mapping the riks according to the AS/NZS 4360:2004 method. From the measurement result of risk level and risk staging, the level of riks was classified into: (a) low risk with 2 (two) risks with a weight of 2 %, (b) medium risk level with 73 (seventy-three) risks with a weight of 77 %, (c) high risk level with 8 (eight) risks with a weight of 19 %, and (d) very high-risk level with 3 (three) risks with a weight of 4 %.

4.2. Result Analysis of House of Risk (HOR) Stage 1

House of Risk Stage 1 was used to determine the dominant risk agent to be addressed, where the priority risk agents were determined using Aggregate Risk Potential (ARP) calculation with the variable used were the severity, occurrence, and correlation scores of each risk agent. According to the ARP processing results, six dominant risk agents were obtained out of a total of 11 risk agents. This was determined based on the ARP value, where the higher the ARP value, the greater the risk agent's influence. The following list are the dominant risk agents obtained from this study.

1. Improper use of Personal Protective Equipment and less proper training (A10) gained the highest ARP score of 279.
2. Poor compliance with safety procedures, lack of training and education, poor physical condition from the workers, and the use of unsafe equipment (A11) gained the second highest ARP score of 252.
3. Innacurate use of Personal Protective Equipment and lack of beneficial training (A8) gained the third highest ARP score of 225.
4. Factory stock shortages (A9) gained an ARP score of 140.
5. Inadequate regular equipment maintenance (A6) gained an ARP score of 130.
6. Use of substandard electrical equipment, failure to use personal protective equipment, and weather factor (A7) gained the sixth highest ARP score of 120.

4.3. Result Analysis of House of Risk (HOR) Stage 2

After the dominant risk agent was identified, the next step to prevent the risk from occurring was to provide the proposed treatment. This risk mitigation strategy is obtained using the House of Risk Stage 2 in which the mitigation strategy will be sorted from the highest ETD value to the lowest ETD value. The variables used are the degree of difficulty and correlation between risk agents to determine the effectiveness of the treatment. From six (6) dominant risks, there are seven (7) mitigation strategies were obtained that are suitable and can be implemented to provide treatment. The following is the priority order of the proposed mitigation strategies:

Table 8. Rank of priority of mitigation strategy

Code	Mitigation	Rank
PA1	Wear appropriate personal protective equipment (PPE) such as gloves, safety shoes, safety helments, or safety googles.	1
PA2	Conducting training related to the Occupational Safety and Health (OSH) principles.	2
PA3	Ensure careful planning of material procurement, including type, quantity, and delivery time. Track material delivery to guarantee timely arrival and prepare adequate and organized material storage area.	3
PA5	Regular heavy equipment checks.	4
PA6	Performing routine maintenance on heavy equipment.	5
PA7	Good traffic management, use of clear traffic signs and placement of traffic officers at the project locations.	6

Code	Mitigation	Rank
PA4	Held training sessions and certification program for the operator.	7

When the priority order of the proposed mitigation strategies had been obtained, then a Pareto diagram was employed to determine the main mitigation strategy by conforming the 80:20 Pareto concept (selecting 80 % of the mitigation strategies which expected to produce the 20 % of the effective mitigation strategies). The following explanation is a Pareto diagram of the proposed mitigation strategy:

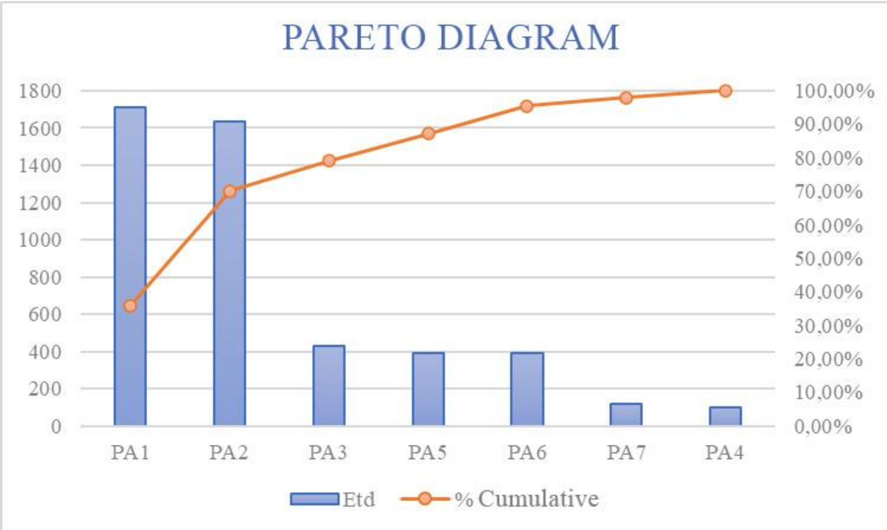

Figure 4. The Pareto Diagram

Figure 4 is displaying the proposed mitigation on a Pareto diagram, by considering effectiveness of mitigation strategies in the implementation. There are four (4) main mitigation strategies obtained and can be implemented from seven (7) priority mitigation strategies which resulted in an effectiveness of 79.11 %. The following explanation consists of three (3) main mitigation strategies that can be chosen to be used in work implemetation:

1. The first strategy has ETD value of 1712, by using appropriate personal protective equipment (PPE) such as gloves, safety shoes, safety helments, or safety goggles and safety belts (PA1) to minimize or even avoid work accidents during work implementation.
2. The second strategy has ETD value of 1633, by conducting training that related to the Occupational Safety and Health (OSH) Principles (PA2) to increase awareness of the importance of safety and health in the workplace, as well as provide the knowledge and skills needed to create a safe and healthy work environment.
3. The third final strategy with an ETD value of 432 in ensuring careful material procurement planning, by listing or including the type, quantity and delivery time. Tracking material delivery to gurantee timely arrival and preparing a sufficiently large and organized material storage area (PA3). This can be done because the steel frame production process sometimes delayed due to order queue/ limited stock so that it can affect production scheduling or planning.

There are three (3) priority of main mitigation strategies obtained in this study with several field actions that can be implemented in the real situations such as:

4. Wearing appropriate personal protective equipments (PPE) such as gloves, safety shoes, a safety helmet, or safety googles and a safety belt (PA1). Actions that can be taken based on this mitigation strategy include preparing all PPE facilities according to procedures and carefully checking the use of PPE regularly by workers and all directors involved in the work construction.
5. Held a training related to Occupational Safety and Health (OSH) principles (PA2). Action that can be taken based on this mitigation strategy are identifying training needs, determining target participants, selecting a certified training institution that meets the criteria and conducting regular training to maintain OSH/K3 awareness and understanding among workers.
6. Ensure careful material procurement planning, including the type, quantity and delivery time. Track material deliveries to guarantee timely arrival and prepare a sufficiently large and organized material storage area (PA3).

Actions that can be taken based on this mitigation strategy are to place orders or pre-orders after determining the plan before starting work, using e-purchasing technology through E-catalog procurement system that able to search the reliable supplier who can produce the material from all parts of Indonesia.

V. CONCLUTION

According to the result analysis in this study, the researchers compose several conclusions as listed in the following:

1. From the identification result, there are 134 (one hundred and thirty-four) risks were found that could occur in the implementation of Liliba Bridge Duplication Project. Then, after verification by using the first questionnaire which distributed to 30 (thirty) respondents, there are 84 (eighty-four) relevant risks were found.
2. From the analysis result, 11 risk agents were obtained at the highest level (the high-risk level and very high-risk level). Then, from 11 risk agents, the ARP value was calculated using the House of Risk method Stage 1, resulting in 6 dominant risk agents with the highest value: (1) A10 with ARP value of 279, (2) A 11 with a value of 252, (3) A8 with a value of 225, (4) A9 with a value of 144, (5) A6 with a value of 130, and, (6) A7 with a value of 120.
3. The risk mitigation strategy was obtained based on six dominant risks agents and resulted in seven (7) mitigation actions. From the seven mitigation actions presented, also by considering the effectiveness of the mitigation actions in their implementation, there are three main mitigation strategies were obtained, such as wearing appropriate personal protective equipment (PPE) such as gloves, safety shoes, safety helments or safety googles and safety belts (PA1), held training according to Occupational Safety Health (OSH) principles (PA2), and ensuring careful material procurement planning, including the type, quantity, and time of delivery, Tracking material delivery to guarantee timely arrival and preparing a sufficiently large and organized material storage area (PA3).

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