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Research Paper

A Risk Management Analysis on the Construction Of*duwet Krajan* Bridge in Malang Regency by House of Risk (Hos) Model Application

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Abstract
Malang Regency is one of many regencies in East Java province with a topographical condition composed from highland areas surrounded by several mountains and lowland areas with an altitude of 250-500 meters above sea level. These vast geographical region rimmed by mountains and lowlands require the existence of adequate number of well-structured bridges to ensure an effective and efficient land transportation system run well. The bridge construction work may have potential threat to pose many types of risks that able to affect its quality or quantity, without exception to the DuwetKrajan Bridge work in Malang Regency. This research aimed to identify risks of bridge construction projects also to find the type of response to handle the risks. It is a descriptive research with a case study approach with the research method applied was the House of Risk (HOR). The House of Risk method is a model used as a framework functions to manage the supply chain risks in proactive responses. In this study, a risk analysis will be carried out to describe the potential risks and the mitigation strategies for the work implementation of DuwetKrajan bridge construction. The final step of this research was to control the most dominant risk, and the form of control will be carried out on dominant risks is preventing these risks to occur in order to minimize loss of the project that could be increase.
Keywords: *risk identification, risk management, bridge construction, House of Risk*

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I. INTRODUCTION

Malang Regency is one of many regencies in East Java province with a topographical condition composed from highland areas surrounded by several mountains and lowland areas with altitude of 250-500 meters above sea level. These vast geographical regions rimmed by mountains and lowlands necessitate the existence of adequate number of well-structured bridges to ensure an effective and efficient land transportation system togo well. Work of construction bridges may have potential threat to pose diversion or different kind of risks which able to affect its quality or quantity.

As one of the mandatory public infrastructures in Indonesia, a bridgehas an important role in land transportation system since it functionsto be a connector from one to another area that geographically are separated by rivers, valleys or canyons. It also linking two roads which are disconnected due to difficult geographical conditions. Apart from its connection to roads, bridgeis crucial,for it is the lifeblood of the economy from a region. A robust bridge will guarantee the undisruptive process of an effective and efficient land transportation system. This smooth circulation system affects the mobility of people and goods/products in this area, ifthe people and good's mobility running strong, then, the economic life from the community will develop as well. Furthermore, many products can be more affordable because of cheaper transportation cost due to a well circulated land transportation system.

Similar to other construction projects, bridge construction work also pose various types of risks that affect its quality or quality. A construction work is one type of work that pose high risk especially during the construction implementation stage, without execption to bridge construction work(DirjenBinaMarga, 2006)**.**

A construction work planning must be prepared through several estimations and assumptions during the plan was made,in which sometimes occur a discrepancy between plans that have been arranged and those plans that will be implemented. Many risks can affect productivity, performance, quality also cost of a project. Although workplan has been constructed as best as possible, there is no guarantee of the plan will work completely. Work accidents, material scarcity or others are the risks that may occur in a construction work and have potentials for slowing down the project completion, create cost overrun in the construction budget and make the work quality less than optimum.

Therefore, it is necessary to take preventive and mitigation measures in a form of risk management. It is a management measure to find out, analyze and control any risks exist in each activity as well as serves to manage risks to minimize the bad consequences that may arise from the implemented project activities. A risk management in construction works often be ignored or overlooked despite it able to help to increase the likelihood of project success. Risk management aimed to reduce risks resulting project loss, so that, by reducing potential risks, the higher profits can be earned.

One of the most recognizable risk management is the House of Risk (HOR) method. This method uses principles from Failure Mode and Error of Analysis (FMEA) to measure risk in quantitative way and combined with model of the House of Quality (HOQ) for finding risk agents that must be prioritized as a basis for selecting the most effective actions to reduce potential risks generated by the risk agents. It will be followed by mitigation action for the selected risk agentswhich arranged based on total ratio of the effectiveness of the difficulty level, also from which mitigation action that able to reduce risk agents with high risk potential.

II. LITERATURE REVIEW

A. A Construction Project

A construction project is a series of civil engineering work activities in scopes of major civil engineering work and architectural work. Primary civil engineering works are the feasibility study, design engineering, procurement and construction resulted in a construction of bridges, buildings, ports, highways, and others.The activities of a construction project have complexity in nature because the project work will be lasted for long period of time and also require certain allocation of funds for achieving the predetermined target. With many activities and parties involved for an implementation of construction project, it can make some complex problems (Ismael, 2013). Further, Ervianto (2005) in Zuhdi, *et.al.* (2022) explained about the parties involved in a construction project as depicted in Figure 1 below.

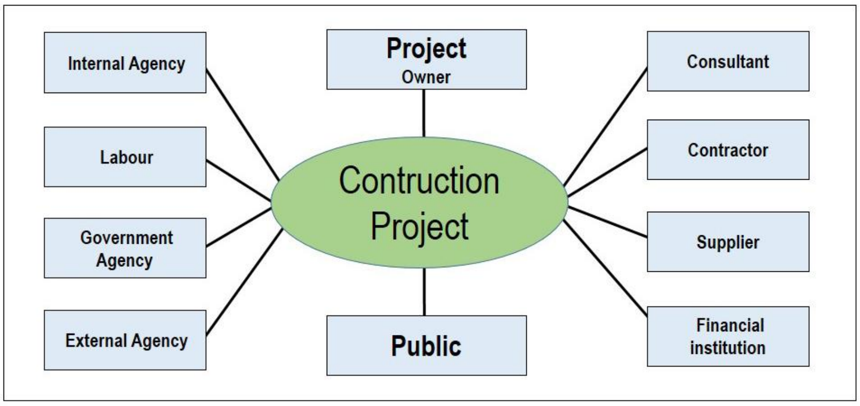

Figure2.1. Parties involved in A Construction Project
Source: Ervianto, 2005, inZuhdi, et.al. 2022.

B. A Risk Management

A risk management is a process stage systematically carried out to overcome and minimize also avoid potentials for the emergence of a risk. It covers several stages from risk identification, risk assessment, risk acceptance, risk mitigation and risk ownership allocation (Jaya, *et.al.*,2019). A risk management is an integral part of a project activity which aimed to improve the project workperformancefrom the initial stage until project completion by identifying, evaluating and controlling aspects that have potential to become a risk in a project implementation. Flanagan & Norman (1995) also added, risk management is a decision-making process related to ways to manage risks as it called the Risk Management System. It consisted of five stages; risk identification, risk classification, risk analysis, attitude to risk, and response to risk.

1. Risk Identification and Risk Classification

A risk identification is a process to recognize and categorize many risks according to their source or impact on the project, where afterward an analysis will be carried out to determine type of response to the risk and its mitigation action. The following explanation will present several risk categorizations.

According to Jaya, *et.al.* (2019) risks potentials are identified and categorized as follow:

- Difficult road access to reach the project site.

- Unsafe surrounding environment.
- Road access is restricted.
- Delay in mobilizing heavy equipments.
- The type of soil that is not in accordance with the project drawings.
- The excavation elevation is different from the drawings.
- Inflation occurred and causing price increases
- Reprimand from the local community
- Material quality that does not meet specifications
- Restriction of heavy equipment operating hours
- Conflict between human resources/labour workers
- Differences in specifications in the RKS image
- Lack of supervision during the project implementation
- Wrong placement of workers who do not match their skills.
- Work accidents caused by sharp objects or hazardous substances.
- Lack of personal protective equipment (ADP)
- Some material specifications that are difficult to find on the market.
- Longer time for some materials procurement because these materials must be ordered in advance (indented) or imported from abroad.
- Type, size and colour from materials which have not been determined by the project owner.
- Noise produced by the use of heavy equipments.
- Air pollution due to the project implementation.
- Differences found in image size to the field conditions.
- Innacurrate scheduling.
- Discrepancies of numbers and capacities of worklabours in the project implementation.
- Out of sync design drawings between structural, architectural and MEP drawings.
- Lack of details or undetailed drawings from the planning consultants.
- Slow decision making in selecting brands and material specifications by the owners.
- Design changes that affect material specifications.

C. House Of Risk Model

This model is an extension of FMEA and QFD methods developed by Pujawan and Geraldin (2009). In general, this model consists of two primary parts; a risk identification and a risk mitigation phases. This model development intended to be a precautionary measure against risks that may occur in the network of supply chain activities. By minimizing the occurrence of risk agents, it will be impacted on reduction of the level of possibility from those risk events (Pujawan and Geraldin, 2009). Risks in general can create more than one type of risk causes.

In contrast to FMEA method which the likelihood of occurrence and the level of impact (both of them) related to the risk event, HOR provides the possibility value for each risk cause and able to give an impact assessment on each risk (Geraldine &Pujawan, 2009). Since each risk can lead into more than one risk cause, able to quantify risk aggregate from each risk event becomes a very important action. Pujawan and Geraldine (2009) contribute calculation for the aggregate value as stated below:

$$ARP_j = O_j \sum S_i R_{ij}$$

Where:

- O_j = the likelihood of occurrence of the cause from risk source (j)
- S_i = magnitude of impact if risk (i) occurs
- R_{ij} = correlation between risk (i) and the cause of risk source (j)

In their research, Geraldine and Pujawan (2009) suggested HOR consists of HOR 1 and HOR 2. The function of HOR 1 is determining which risk cause becomes a priority for prevention meanwhile the HOR 2 functions to determine the effective steps for these priorities.

In the HOQ model, there is a link creates to connect the necessities (*what)* to responses (*how)* where each response requires one or several requirements. The degree of correlation is generally defined in numbers as follows:

- 9= strong correlation
- 3=moderate correlation
- 1=weak correlation

- 0= no correlation

Each requirement has a gap to be fulfilled, thus, as an adaptation for these requirements, HOR stage 1 built through the following steps:

1. Identifies risk events that able to occur in the supply chain business processes and provides assessment on a scale of 1–10 where 10 stated to be having the greatest impact.
2. Identifies the risk cause and provides an assessment of its number of occurences on a scale of 1-10 where 10 stated to be having the largest number of events.
3. Constructs a correlation matrix in a scale of 0,1,3 and 9, where 9 indicates the highest correlation.
4. Calculates the aggregate value of potential risk agent (ARPj).
5. Put the risk causes into an order based on their potential aggregate value from the biggest to the smallest value.

The result from these calculations then inserted into Table 2.1as displayed below.

		Risk Agents (*Aj*)							
Business Processes	**Risk Event (*Ei*)**	A1	A2	A3	A4	A5	A6	A7	**Severity of Risk Event *i* (*Si*)**
Plan	E1	R11	R12	R13	...	...	...	...	S1
	E2	R21	R22	...	...	...	..	..	S2
Source	E3	R31	...	...	...	...	...	...	S3
	E4	R41	...	...	...	...	...	...	S4
Make	E5	...	...	...	...	...	...	...	S5
	E6	...	...	...	...	...	...	...	S6
Deliver	E7	...	...	...	...	...	...	...	S7
	E8	...	...	...	...	...	...	...	S8
Return	E9	...	...	...	...	...	...	Rij	S9
Occurrence of Agent *j*		O1	O2	O3	O4	O5	O6	O7	
Aggregate Risk Potential *j*		ARP1	ARP2	ARP3	ARP4	ARP5	ARP6	ARP7	
Priority Rank of Agent *j*									

Table 2.1. The Calculation of HOR 1

Source: Pujawan and Geraldine in Sibuea and Saragi (2019).

For HOR stage 2, this model is used to explain which step must be done firsthand based on the level of effectiveness and the difficulties in the project implementation. The company (ideally) should select steps which are not difficult to do but have impact to provide effective results in reducing the risk cause occurrence. These are steps in building HOR stage 2:

1. Choose a number of risk causes with high priority ranking, which conducted generally by Pareto analysis from ARPj.
2. Identify the relevant step to prevent the risk cause occurrences.
3. Describe the relationship from each prevention effort and each risk cause (Ejk) by values of 0,1,3,9, where 9 indicates the highest correlation.
4. Calculate the total effectiveness of each step by the following formula:

$$TEk = \sum_{i} ARPj\ Ejk$$

5. Assign a value (*Dk)* to the level of difficulty when carrying out each step, and able to be represented in certain scale such as Likert scale or other relevant scales.
6. Calculate the total effectiveness of the difficulty ratio.
7. Give a rank to the priority of each step (*Rk)* where rank 1 is given to the step with the highest ETD*k.*

After the steps have conducted, then the result of HOR stage 2 are displayed on Table 2.2

	Preventive Action (PAk)					
To be treated risk agent (Aj)	PA1	PA2	PA3	PA4	PA5	Aggregate Risk Potentials (ARPj)
A1	E11	E12	E13	...	...	ARP1
A2	E21	E22	...	...	...	ARP2
A3	E31	...	...	...	...	ARP3
A4	...	...	...	...	...	ARP4
A5	...	...	...	...	Ejk	ARP5
Total efectiveness of action k	TE1	TE2	TE3	TE4	TE5	
Degree of difficulty performing action k	D1	D2	D3	D4	D5	
Effectiveness to difficulty ratio	ETD1	ETD2	ETD3	ETD4	ETD5	
Rank of priority	R1	R2	R3	R4	R5	

Table 2.2. The Calculation of HOR 2
Source: Pujawan and Geraldine in Sibuea and Saragi (2019).

III. RESEARCH METHOD

3.1 The Data Type

There are two types of data involved in this research; primary data and secondary data types.

a. Primary data is the data that obtained in direct. In this research the primary data was obtained from questionnaires given to research respondents.

b. Secondary data is the data that obtained from relevants journals, articles or books to support this research.

3.2 The Research Operational Variables

Research variables which going to examine in this research are:

a. The level of risk impact (Severity)

Level of risk impact will show how much disruption caused by a risk event to the process of the construction work.

b. The level of risk emergence (Occurence)

This variable represents level of opportunity for the occurrence frequency of a risk agent will cause one or several risk events to emerge in which able to present disruption to the process of carrying out the construction work.

c. The level of relationship

This variable represents level of relationship between risk events to the risk agents on the process of construction work.

3.3 The Analysis of House of Risk (HOR)

a. House of RiskStage 1

The analysis of HOR stage 1 focuses on the rank determination of the Aggregate Risk Potentials (ARP) which divided into three factors, the occurrence factor, severity factor and interrelationship factor. HOR stage 1 is conducted by following phases:

1) Identify risk events(E) that may occur in the construction project of *DuwetKrajan* Bridge.

2) Identify the risk agent (A) in the construction project of *DuwetKrajan* bridge.

3) Measure the severity (S) level. The value will state about how much disruption is caused by a risk event to the construction project and the severity level is scaled from 1 to 5, with scale 1 indicates an insignificant impact to scale 5 indicates a disaster impact that able to ruin target achievement of the construction project.

4) Measure the probability of occurrence from risk agents. This is important to seek the possibility about the emergence of risk agents which have significant impact on the construction process of the *DuwetKrajan*bridge. The probability of occurences will be rated on a scale of 1-5. Scale 1 indicates ‘no appearance of occurences’ and scale 5 indicates ‘certainty (high) appearance of occurrence’from a risk agent.

5) Measure correlation/relationship values between the risk agents and risk events. The higher the correlation value, the stronger the relationship between the two risks. If the correlation value is high, it can be concluded a risk agent has big potential to cause a risk event.

6) Calculate the Aggregate Risk Potentials to determine occurrence level of the risk agent also the impact caused by the risk event by applying equation:

$$ARP_j = O_j \sum_i S_i R_{ij}$$

7) Put a rank on risk agents according to the ARP values.

b. House of RiskStage 2

An analysis to House of Risk Stage 2 aimed to identify and determine response or risk mitigation. Responses of risk is taken based on criteria that are easy to implement and able to reduce the possibility of risk agent appearance. The House of Risk Stage 2 is carried out in the following phases:

1) Choose a risk agent with high priority level according to the output from HOR stage 1.
2) Identify the relevant actions to prevent the occurrence of risks.
3) Determine the relationship or correlation between each preventive action on each risk agent. The higher the correlation value, the more effective the preventive action for the risk agent.
4) Determine the effectiveness level from each preventive action.
5) Measure the difficulty level by representing each action taken.
6) Calculate the total effectiveness to determine ratio.
7) Conduct a priority scale starts from the highest value to the lowest value from the ETD (*Effectiveness to Difficulty).*

3.4 The Research Flowchart

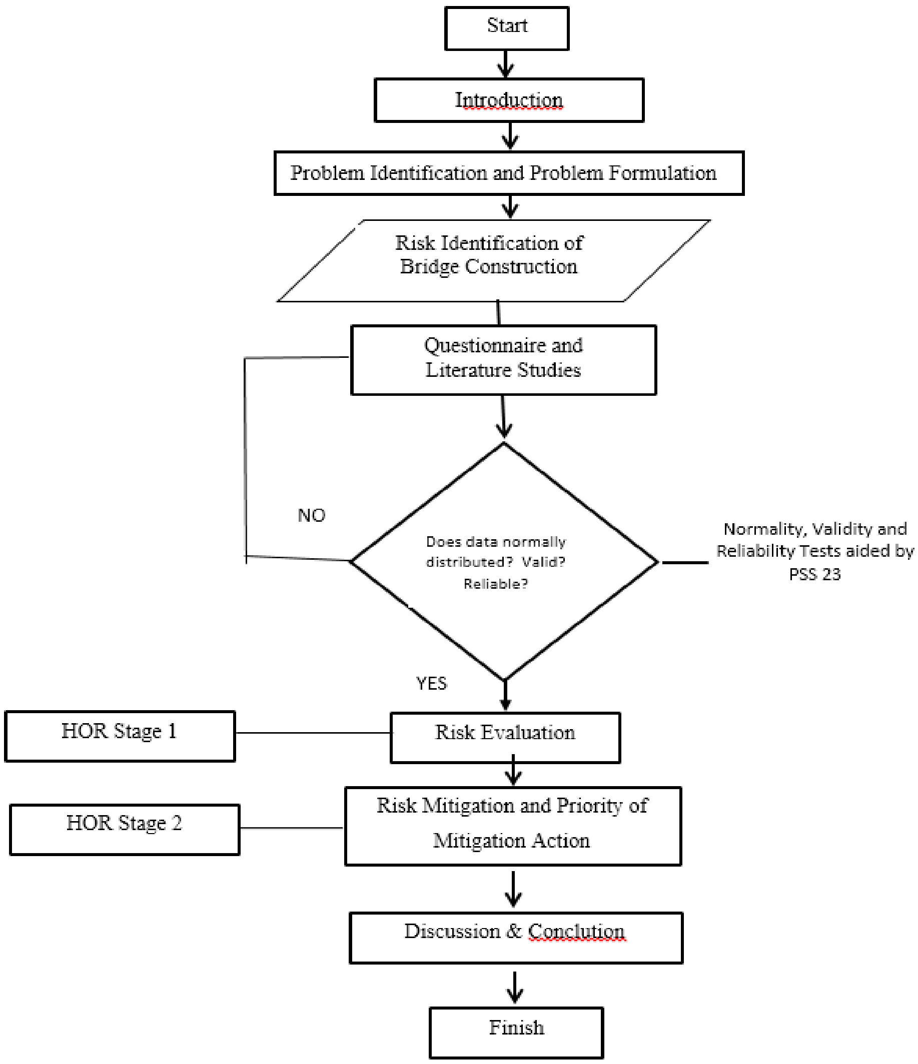

Figure 3.1. The Research Flowchart

IV. RESULT AND DISCUSSION

4.1. Analysis of The House of Risk

A. House of Risk Stage 1

House of Risk stage 1 is a risk management phase focuses on rank determination of Aggregate Risk Potentials (ARP). The ARP calculation carried out by considering three aspects; the occurrence, severity and relationship between the risk agent and the risk event. Prior to calculation of correlation between the risk agent and risk event, there is a correlation matrix that must be made between the two risks. A calculation to obtain the correlation strength of risk agent and risk event will be carried out using the Product Moment formula, then summed to produce the Aggregate Risk Potentials (ARP) of each risk agent. The following explanation are phases and results calculation from the House of Risk Stage 1.

a. Measure the Severity Value

The severity value is obtained from questionnaire filled by research respondents. It states the range (how much) disruption caused by a risk event in the construction project of DuwetKrajan bridge, where it will be put in to an assessment on a scale of 1-5 to represent the severity level with scale 1 shows an insignificant impact while scale 5 shows disaster impact that able to thwart the target achievement of the construction project. The severity level from the risk event will be presented below.

Table 4.1. Measurement Result of Severity Risk Event Level

No.	***Risk Event***	**Average*Severity***
1	Dissapearance of materials on the site location	1,08
2	Damage to existing materials on the site location	1,17
3	Delay in the Work Implementation	3,75
4	Damage to the Construction Structure that has been implemented	1,08
5	The implemented work is not carried out according to the specifications	4,17
6	Lack of work volume on the site location	2,42
7	Cost overrun in the Implementation Cost	3,25
8	An excavation collapses	4,08
9	Unprecise (lack of) placement from the Bridge’s axles	3,17
10	Lack of Bore Pile excavation according to the workplan	4,17
11	Misalignment of bridge abutments	3,50
12	Idle Equipments on the construction site	1,75
13	Idle workers on the construction site	1,58
14	Installed formwork (*bekisting)* collapses	3,83
15	Wrong order of work execution	4,58
16	Workers buried in the ground	1,17
17	Workers fell down	1,50
18	Workers hit or struck down by construction materials	1,33
19	Construction materials do not meet specifications Material	4,42
20	Road congestion happens around the construction site	1,50
21	Incorrect iron build-up assembly	4,58
22	Uneven/imbalance compaction (density) during casting	4,75
23	Deflection occurs in structural beams	2,00
24	Structure tilts/slants after attaining certain height	1,25
25	The failure of the contractor to start the construction project according to the schedule	4,42
26	Other unexpected and unavoidable fees	4,67
27	Use of untested designs	4,00
28	Experiencing difficulty in using technology	1,33
29	Too high water surface	1,17
30	Unstable soil conditions	1,50
31	Unavailability of certain materials	1,17
32	Difficult access for heavy equipments to the construction site	1,08
33	Fraudulence or embezzlement of project’s assets	4,67
34	Security disturbances at the construction site	1,25
35	Disabled equipments due to interference	1,25
36	Change of priority in the working program	1,25
37	Specification Changes	1,58
38	Environmental protest due to disturbance caused by the project	1,67
39	Unsuitable equipments for the site conditions	2,75

b. Measure the Probability of Risk Agent Occurrence

Probability of occurrence also can be obtained from questionnaire distributed to research respondents. This activity is conducted to seek the probability of occurrence that able to bring certain impact on the construction process of *DuwetKrajan* bridge, and it will be assessed on a scale of 1-5 where scale 1 indicates ‘never occurred’ whereas scale 5 indicate ‘certainty of occurrence’. The following explanation is the measurement result from the probability of occurences.

Table 4.2. The Probability of Occurences of The Risk Agent

No.	Risk Agent	Occurrence
	Material Risk	2,5
1	A delay in material delivery	2,1
2	A delay in ordering material activity	1,3
3	Insufficientspace for material storage	1,4
4	An increase in Material Prices	1,8
	Equipment Risk	2
5	Shortfall or lack of certain number of equipments	2
6	Lack of maintenance of tools or heavy equipments	1,3
7	Working equipments/tools are not according to specifications	1,5
	Labor Risk	1,5
8	Lack of labour/workforce capability	4,5
9	Lack of labourers or manpower	1,8
10	Low labor productivity	1,6
	Implementation Risk	4,5
11	Lack of communication and coordination	1,2
12	Changes in construction methods	1,5
13	Lack of control over the schedule of work implementation	4,8
14	An inappropriate selection of construction method	1,4
15	Changes in construction projects including replacement, reduction, addition or removal of work after the signed contract.	1,5
16	Incorrect or incomplete design	1,3
17	Lack of supervision during work implementation	4,7
	Environmental Risk	1,4
18	Nature topography/weather condition	1,5
19	Poor condition of the site location	1,4
	Financial Risk	4,5
20	No consideration ofunexpected costs / any contingencies	2,5
21	Innacurate of cost estimation	2,1
22	Poorly timing in payment time (not punctual)	1,3
	Occupational Safety and Health (OSH/K3) Risk	1,4
23	Lack of K3 application usage	1,8
24	Workers' awareness in implementing OSH	2
25	Lack of Budget for OSH	2

c. Create a Rank According to The Risk Agent

After the ARP value of each risk agent is obtained, the researchers ranking each risk agent with a calculation as presented in the following formula:

$$ARP_j = O_j \Sigma S_i R_{ij}$$

From the calculation result, ARP rank successfully obtained as follow:

Table 4.3. The ARP Ranks

No	Risk Agent	ARP Rank
A17	Lack of supervision during work implementation	89
A11	Lack of communication and coordination	49,52
A21	Innacurate of cost estimation	34,84
A25	Lack of Budget for OSH	12,69
A14	An inappropriate selection of construction method	11,88
A4	An increase in Material Prices	1,52
A7	Working equipments/tools are not according to specifications	0,19
A18	Nature topography/weather condition	-2,58

d. Make The Pareto Chart

The finished ranking process of risk agents then entered into the Pareto chart to determine scale priority about which risk agent that must be addressed. The following stages in creating a Pareto chart are explained as follow:

1) Arrange the ARP values from the highest to the lowest value.

2) Calculate the *Cummulative Count*

*Cummulative count*is a calculation of ratio percentage from each risk agent to the data cumulative value with the ARP total value of all risk agents.

Table 4.4Pareto Chart of *Aggregate Risk Potentials* (ARP) Values

RISK AGENT	ARP	CUMULATIVE COUNT
A_17	89,00	44,58
A_11	49,52	69,38
A_21	34,84	86,84
A_25	12,69	93,19
A_14	11,88	99,14
A_4	1,52	99,90
A_7	0,19	100,00
A_18	- 2,58	100,00

e. Arrange The Pareto Chart

A Pareto analysis is a statistical technique for decision making which used to select number of tasks that produce a significant overall effect. It is an analysis method that was developed by economists by the usage of Pareto principle where states that most problems (80%) are caused by a few primary causes (20%). Here, a Pareto Risk Agent Chart is presented below.

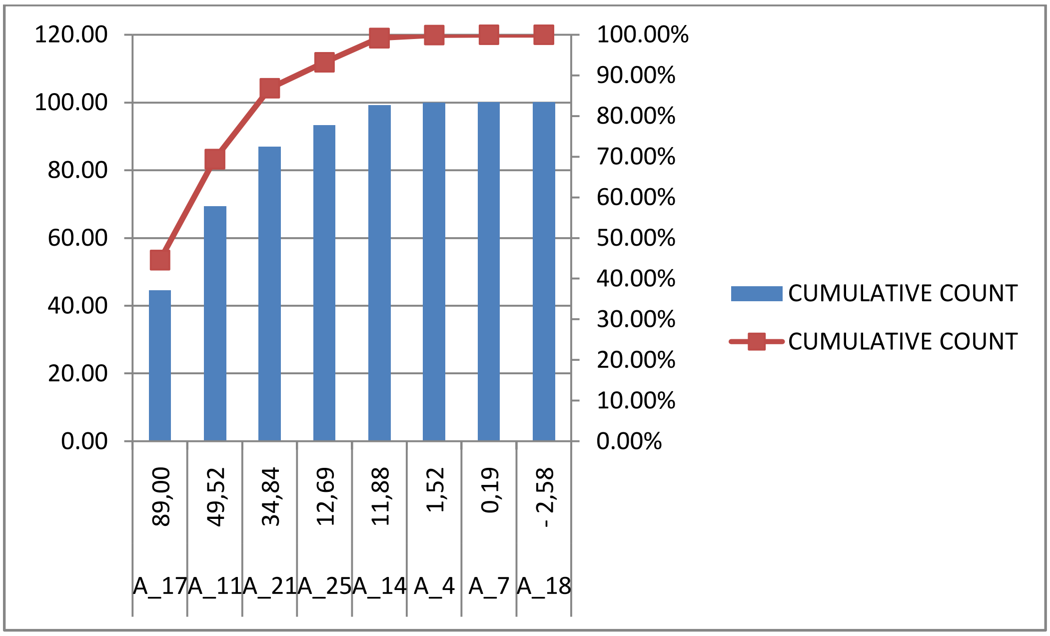

Figure 4.1 The Pareto Chart
Source: Data Analysis (2022)

According to the Pareto principle which stated 80 % of problems are caused by 20 % of the causes, from the research chart above, it is evident that risk agent variables of A17, A11 and A21 were stationed outside of 80 % area of the Pareto chart. For this reason, the risk agent number 17,11, and 21 were considered as the cause of 80 % of problems occurred in the project and becomes the top priority for resolution.

B. The Calculation of ETD in The House of Risk Stage 2

The focus of HOR stage 2 is how to find a response or mitigating the arriving risks. On mitigating these risks, this act must be easy to do and able to minimize the occurrence of risk agent. The phases in HOR stage 2 are explained as follow:

a) Choose risk agents that have a highest priority

There are 3 risk agents with the highest priority for mitigation as evident from the Pareto chart of HOR stage 1.These risk agents are risk agent A17 (lack of supervision during work implementation), risk agent A11 (lack of communication and coordination) and risk agent A21 (innacurate cost estimation).

b) Identify relevant actions for mitigation.

The identification of mitigation measures is carried out by applying same procedure as identification phase of risk agent and risk event (through stages of literature review and field observation). From the literature review and observations, some mitigation measures were obtained for each risk agent as stated below:

Table 4.5The Mitigation Action

No	Risk Agent	Preventive Action
A17.	Lack of supervision during work implementation	• Arrange an SOP for work supervision that includes supervision scopes and scheduling.
		• Adding supervisor/ workers' overseers
A11	Lack of communication and coordination	• Make a periodicaltable for scheduling coordination with parties related to the project development.
		• Publication of the work process in the mass media.
A21	Innacuratecost estimation	• Improve control of financial quality on the project implementation
		• Arrange the cost estimation by inserting unexpected aspects such as inflation, increasing price of material and others.

c) Determine any relationship or correlation between each preventive action.
Each preventive action that has been identified then assembled into a questionnaire. The questionnaire were given to 12 respondents and it will be put into answer scale ranging from scale 1(very unappropriate), scale 2 (not appropriate), scale 3 (hesitate/doubtful), scale 4 (appropriate), and scale 5 (very appropriate).
In the same questionnaire, the respondents also asked to determine the difficulty level from each preventive action by scaling the answers starts from scale 3 (indicating a low level of difficulty), scale 4 (indicating a medium level of difficulty) and scale 5 (indicating a high level of difficulty).

After the respondents' answers about preventive actions of each risk agent had been obtained, a correlation calculation is performed with the occurrence level of related risk agent taken from the previous questionnaire. The respondents' answers and the occurrence of risk agents presented in tabel 4.6 below.

Table 4.6. Respondents' Answers to Preventive Action

No. Risk Agent	A17		A11		A21		Occurrence Risk Agent No.		
No PA	1	2	3	4	5	6	17	11	21
1	5	2	4	3	4	5	5	5	5
2	5	3	4	3	4	5	5	5	4
3	5	2	5	3	4	5	5	5	5
4	4	2	4	2	4	5	3	5	4
5	4	3	5	3	4	4	5	5	5
6	5	3	4	3	4	4	4	3	5
7	4	3	4	3	4	4	5	4	4
8	5	2	5	3	5	4	5	4	5
9	4	3	4	2	3	5	5	4	5
10	5	2	4	3	4	4	5	5	4
11	4	1	4	3	4	4	5	5	5
12	4	3	4	2	5	5	5	4	5

Then, a correlation calculation between two values is performed by applying Pearson Product Moment formula.

Table 4.7The Correlation Values of Preventive Actions

Number of Preventive Action	Correlation Values
1	0,14
2	0,05
3	0,15
4	0,15
5	0,12
6	0,00

d) Determine the effectiveness level from each preventive actions.
This phase is a calculation activity of the effectiveness level from each preventive action by applying the following formula.

$$TE_k = \sum ARP_j.E_{jk}$$

Whereas the calculation results are presented in the table 4.8 below.

Table 4.8. The Effectiveness Level of Preventive Actions

Number of Preventive Action	Level of Effectiveness
1	12,46
2	4,87
3	7,38
4	7,38
5	4,16
6	0,00

e) Measure the level of difficulty (D) from each action

From questionnaire filled out by research respondents, average level of difficulty from each preventive action according to the respondents was obtained.

Table 4.9.The Average Value of The Difficulty Level

Number of Preventive Action	Level of Difficulty (D)
1	3,25
2	4,17
3	3,17
4	4,33
5	3,50
6	4,33

f) Calculate the*Effectiveness Preventive Action* (ETD) value.

Total value of ETD was obtained by applying the formula as presented below:

$$ETD_k = TE_k/D_k$$

Where

ETD : Effectiveness to Difficulty Ratio.

TE : Total effectiveness.

D : Degree of Performing an Action.

Then, the total value of ETD will be displayed in table 4.10 below.

Table 4.10. ETD *Preventive Action*

Number of Preventive Action	ETD
1	3,83
2	1,17
3	2,33
4	1,70
5	1,19
6	0,00

g) Determine the priority scale from the EDT (Effectiveness to Difficulties) Value.

The EDT priority scale is obtained by sorting the values and put into order from the highest value to the lowest EDT value as displayed in table 4.11 below.

Table 4.11The Order of ETD Preventive Actions

Number of Preventive Action	ETD
A17	3,83
A11	2,33
A21	1,19

Furthermore, the explanation of House of Risk Stage 2 will be displayed in table 4.12 below.

Table 4.12. ETD Calculation of HOR Stage 2

Risk Agent To Be Treated	Menyusun SOP pengawasan pekerjaan yang mencakup ruang lingkup dan jadwal pengawasan.	Menambah jumlah pengawas pekerjaan	Membuat jadwal koordinasi secara periodik dengan pihak-pihak terkait terkait perkembangan proyek	Publikasi proses pekerjaan di media massa	Meningkatkan kontrol kualitas keuangan pada pelaksaan proyek	Menyusun estimasi biaya pekerjaan dengan mempertimbangkan aspek-aspek seperti inflasi dll	ARP
	Preventive Action						
	PA_1	PA_2	PA_3	PA_4	PA_5	PA_6	
A_17	0,14	0,05					89,00
A_11			0,15	0,15			49,52
A_21					0,12	0,00	34,84
TE	12,46	4,87	7,38	7,38	4,16	0,00	
D	3,25	4,17	3,17	4,33	3,50	4,33	
ETD	3,83	1,17	2,33	1,70	1,19	0,00	
Rank	1	5	2	3	4	6	

Where :TE = Total of Effectiveness of Action
D = Degrees of difficulty performing action
ETD = Effectiveness to Difficulty ratio

From the result of EDT calculation, it is evident that preventive action number 1 obtained the highest ETD value. This value showed the effectiveness value from preventive action 1 (preparing SOP for work supervision must include scopes and schedules of supervisions) becomes a priority scale which must be carried out to mitigate type of risk from a lack of supervision during the work implementation or construction work. The preventive action 1 is the priority scale to implement, aimed to prevent the occurrence of risk agent A17 (lack of supervision). This finding confirmed result of Ederzon and Sukirman (2020) research. In their research, they found a surveillance factor is also a priority preventive action that must be implemented. Further, this is in line with result of research conducted by Indriani, Widyana, and Laintarawan (2019) which stated the supervisory factor is a variable with the highest value. These findings showed that supervision plays a very important role in the success of a construction work or project.

To overcome the risk agent A11 (lack of communication and coordination), it concluded to do the preventive action number 3, states to make a coordination schedule periodically with related parties involved to a project development can be the most appropriate mitigation action to deal with risk agent 11. Type of risks caused by coordination and communication lackness also found in the research of Wijaya and Nugraha (2017) where in their research a lack or unsufficient communication and coordination between project planners and the implementers greatly affect the project work's quality. Thus, there must be an effective risk mitigation action to weaken it. Align with these findings, Ardian (2021) also identified some risks arose due to lack of communication and coordination between related parties in his research on a risk management of housing project.

Meanwhile, for the risk agent A21(innacurate cost estimation) can be mitigated through preventive action number 5, stated to improve the quality control of financial aspect in the project implementation. These findings are strengthening the result of research conducted by Adyana (2017), where reported inaccuracy of cost estimation is a risk that must be mitigated, and one way of mitigation action for minimizing the risk occurrence is to ascertain the financial quality control by having consultation to experienced project teams, identify and learn some special provisions that have big impact to cost budgets also carried out reviews to every calculation that have been made in the project.

V. CONCLUTION

There are 39 risk events and 25 risk agents identified in this research based on the literature studies and the field observation. The research measurements were conducted through questionnaire filled out by research respondents to determinethe level of severity and probability of occurrence. From the two measurement types, the research material were ready to enter the House of Risk Stage 1.

According to Pareto Chart which was a part of House of Risk Stage 1, it was found 3 risk agents needed to be prioritized to prevent their occurences or, maybe, must do a preventive measure to avoid their emergence on:

a. Lack of supervision during work implementation (A17),

b. Lack of communication and coordination (A11)
c. Innacurate cost estimation (A21).

Since the three priority risk agents had been obtained, House of Risk Stage 2 will be conducted with the aim to identify type of effective preventive action/measures to be taken. Based on the analysis of House of Risk Stage 2, the following precaution actions are obtained:

a. Developing a Standard Operation Procedure (SOP) for the work supervision which include range of scopes and schedule of the work supervision. It is an effective action in preventing the occurrence of risks that related to lack of supervision during work implementation.

b. Making a periodically coordination schedule with related parties in the project. This action is able to prevent risk arising due to lack of communication and coordination.

c. Improving the quality control of financial aspect in the project implementation. This action is considered effective in preventing the occurrence of risk related to innacurate cost estimation.

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