International Journal of Marine Engineering Innovation and Research, Vol. 8(4), Dec. 2023. 605-615
(pISSN: 2541-5972, eISSN: 2548-1479)

Risk Evaluation of Ship Repair Delays with The Failure Modes and Effects Analysis (FMEA) Method

Intan Baroroh[1] ,Ndaru Gilang Ramadhan[2] ,Didik Hardianto[3] ,Tri Agung Kristiyono[4]
(Received: 14 November 2023 / Revised: 15 November 2023 /Accepted: 16 November 2023)

***Abstract*—Every ship, that is still actively operating in shipping must pay attention to repair or maintenance in accordance with classification standards. This was needed by management or ship owners to carry out maintenance planning. The shipyards as repair services, there are often obstacles during the repair process that cause the repair time to be longer. This is caused by limited work equipment, delivery of materials that are not in order, and lack of technical equipment. The purpose of research is to evaluate the risk of ship repair delays so there are no failures or delays in ship repair. The method used is the FMEA method (Failure Mode and Effect Analysis) to measure each failure in each activity that affects ship repair. The results showed an assessment score in the form of a Risk Priority Number (RPN) consisting of activities: amount of cutting machines is still limited with a score of 309.83, painting and welding failures at the same time with a score of 267.08, materials that come are remachined to fit the needs with a score of 335.06 and inadequate transportation equipment with a score of 294.16. Improvements made in the form of preparing amount of work tools before the work is carried out, conditioning the order of work according to the schedule and adding backup transportation.**

Keywords—Risk mapping, Failure Mode and Effect Analysis (FMEA), Ship repair, Risk Priority Number (RPN)

I. INTRODUCTION

Repair or maintenance of ships that are still actively operating refers to classification and statutory standards, including BKI (Indonesian classification bureau), BV (bureau veritas), LR (Lloyd's Register), and others. Ship maintenance actions need to be carried out regularly including annual surveys, intermediate surveys, and special surveys. Ship repair activities carried out in each shipyard will vary depending on the classification rules used by the ship and the needs of the ship [10]. The ship repair process according to [4] is divided into 4 processes, namely hull plate repair, electrical and electronic repair process, pipe repair process, and painting work. In general, the ship repair process is described as follows:

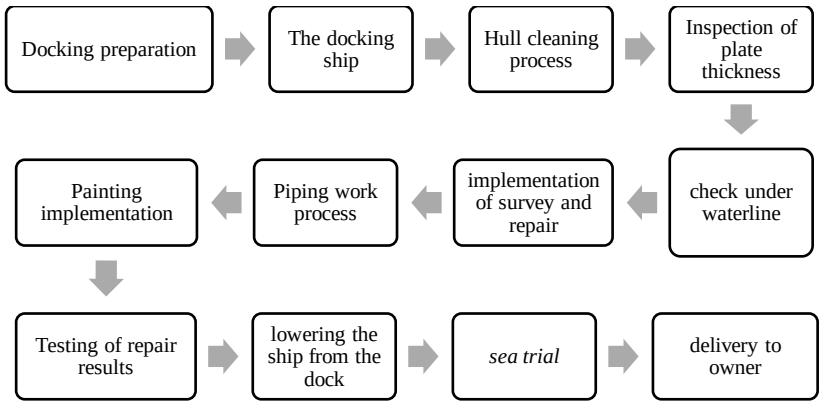

Figure. 1. Hull Plate Repair Process, Electrical, Piping, and Painting (Baroroh, 2023).

This is a need for management or shipowners to carry out periodic repair and maintenance planning. In the implementation of ship repair or repair projects, effectiveness and efficiency are important aspects so that the activity process is well completed starting from the planning process (planning), the process of preparing work plans (scheduling) and the quality control process (monitoring) [11].

Risk management is the process of identifying risks and developing strategies for managing them. Strategies such as measurement, risk analysis, and handling efforts in the risk. [7]. Risk management identification process according to [6] has stages:

Intan Baroroh, Faculty of Science and Marine Engineering, Naval Architecture, Hang Tuah University, Surabaya, Indonesia.
E-mail: intan.baroroh@hangtuah.ac.id
Ndaru Gilang Ramadhan, Faculty of Science and Marine Engineering, Naval Architecture, Hang Tuah University, Surabaya, Indonesia.
E-mail: Gilang.ftik19@hangtuah.ac.id
Didik Hardianto, Faculty of Science and Marine Engineering, Naval Architecture, Hang Tuah University, Surabaya, Indonesia.
E-mail: didik.hardianto@hangtuah.ac.id
Tri Agung Kristiyono, Faculty of Science and Marine Engineering, Naval Architecture, Hang Tuah University, Surabaya, Indonesia.
E-mail: tri.agung@hangtuah.ac.id

1. Risk identification
2. Risk assessment
3. Risk response development
4. Risk response control

The identification of time estimates for each activity comes from the workplace or the experience of workers in carrying out operational processes. This is based on, the weight of the hour budget for each job or activity takes into account the volume and difficulty factors in the work. [3]. Figure 2. shows data on several ship repairs from 2018 - 2022 at PT. YWT. From the data above, there are 9 ships that have made repairs since 2018, with details, namely in 2018 with 1 unit, then in 2019 with 3 units, in 2020 with 1 unit, and 2-unit ships in 2021 and 2022.

Figure 3. shows that in 2018 - 2020 there was a repair of the MV. Berlin Nakroma which experienced delays, in 2019 there was a delay in repairing the KN. Kumba and in 2020 the TB ship. Patra Tunda 3001 also experienced delays. This can be influenced by many external and internal factors.

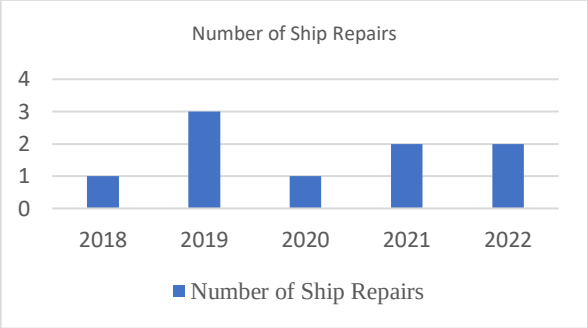

Figure 2 Graph of Ship Repairs in the 2018-2022

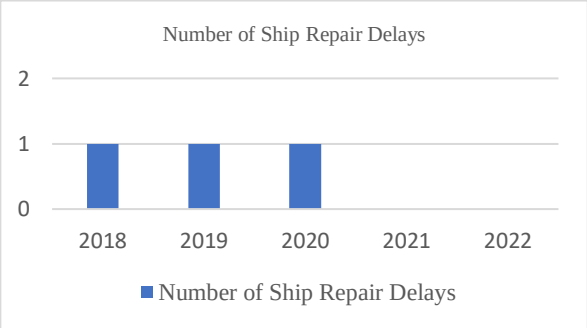

Figure 3 Ship Repair Delay Graph Time Brackets 2018- 2022

TABLE 1.
SHIP DATA OF MV BERLIN NAKROMA

Information	Amount (Meters)
Overall length of the ship (LOA)	47.25
Ship height (H)	3.60
Ship width (B)	12.00
Draft	2.4

Case study research was conducted on the MV. Berlin Nakroma (IMO, 9335472) operated by the government of Timor Leste connecting Dili with Pante Macassar in the Oecusse Exclave of East Timor, and Atauro Island. This passenger vessel has an overall length (LOA) of 47.25 meters, height of 3.6 M, width (B) of 12 meters, and draft of 2.4. This research was conducted because when ship repairs took place at the PT. YWT shipyard there were several obstacles that caused delays from the contract deadline. So it is necessary to evaluate the risk of delay in ship repair using the FMEA (Failure Mode and Effect Analysis) method to see which work process has the highest Risk Priority Number (RPN) value, and then improve the system so that the failure does not recur.

TABLE 2.
LEVEL OF RISK ASSESSMENT

Score	Severity	Occurrences	Detection
1	No impact	Failure never happens	Failure is always prevenred
2 - 3	Small	Frequency of small risks	High enough failure detection
4 - 5	Medium	Risk frequency may occur occasionally	Medium failure detection
6 - 8	Big loss	Frequency of occurrence at work	Low failure detection
9 - 10	Very large loss	Risks that occur are always recurring	Failure cannot be detected

II. METHOD

A. Description

The Failure Modes and Effects Analysis (FMEA) method is a technique for identifying possible failures in planning, to improve reliability and safety [1]. FMEA can identify, define and reduce risks in a design, system, process before it is used. [9] Risk Priority Number (RPN) is done by calculating the average value of severity (S), occurrence (O), and detection (D) from the results of the risk agent questionnaire with the following formula:

$$\text{mean} = \frac{\sum(\text{S}) \text{ or } (\text{O}) \text{ or } (\text{D})}{\sum \text{total number of respondents}} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

So that from the formula above, the average score for each factor causing delay is obtained. [5] Then it is calculated by multiplying the three average values on each risk agent factor. As follows:

RPN = (S) x (O) x (D)……..(2)

Level risk Mapping	**Severity (Impact)**				
Occurance (Probabilities)	1	2 – 3	4 – 5	6 – 8	9 – 10
1	Low	Low	Low	Medium	Medium
2 – 3	Low	Low	Medium	Medium	High
4 – 5	Low	Low	Medium	High	High
6 – 8	Low	Medium	Medium	High	High
9 – 10	Low	Medium	High	High	High

Figure 4. Level Risk Mapping

From the RPN results, each factor causing delay is then grouped into a 5 x 5 risk matrix. This risk matrix method uses two main criteria to prioritize risks, namely severity (impact) and occurance (probability) [2]. The 5 x 5 matrix does not include the detection (D) factor, so not all information from the FMEA analysis is represented in the 5x5 risk matrix. So as to reduce the risk and failure of ship repair projects, which can be applied to the four works. High risk marked in red means that the damage is very high and the probability of failure in a project is very high, this phase has the highest risk. The yellow color is for risks that have moderate impact and likelihood, so they require monitoring procedures, so that more severe failures do not occur. Green risks are low impact but need to be monitored regularly so that failure prevention efforts can be maintained.

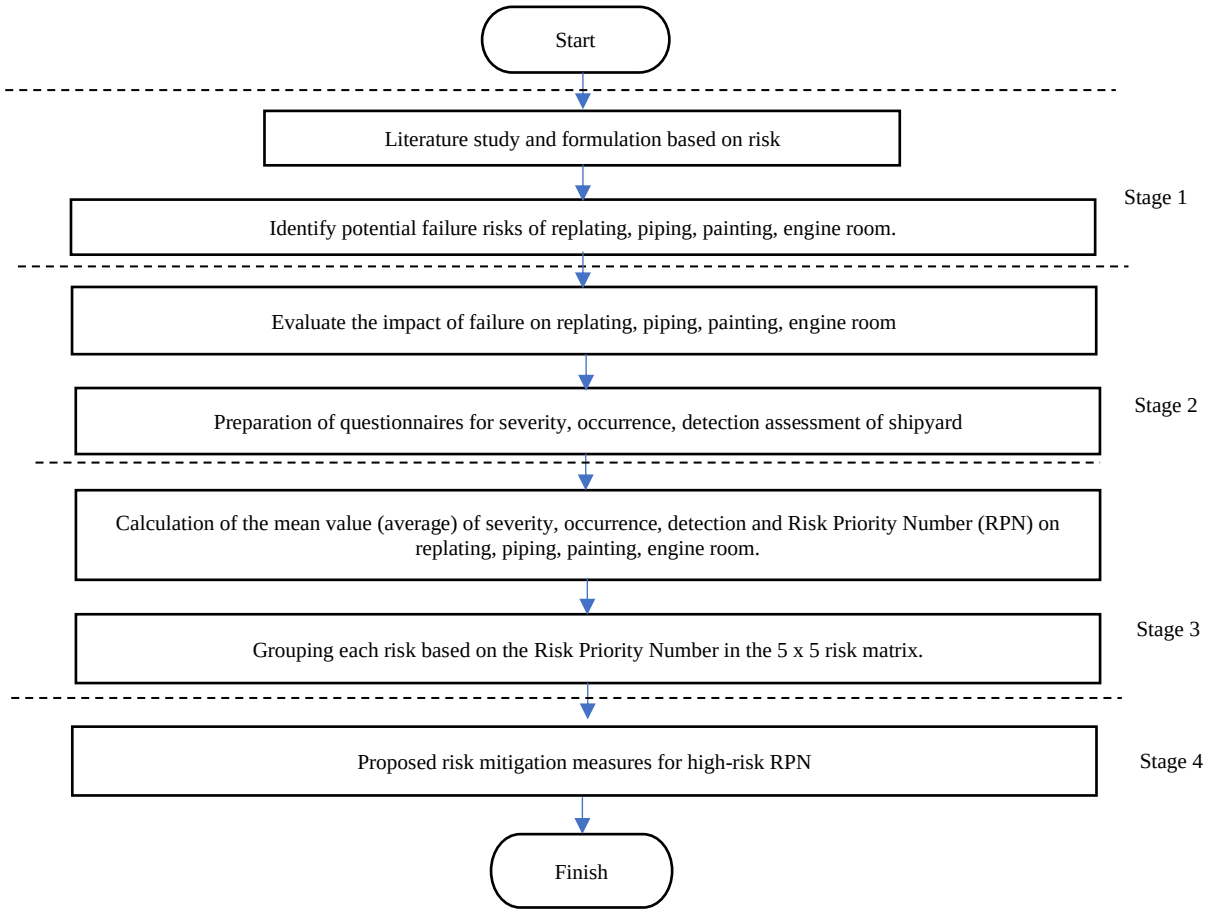

Figure 5. Flow Chart of Research Methodology

Identification of potential risks of ship repair MV. Berlin Nakroma is based on 4 processes, namely replating, piping, painting, engine room. Obtained from the interview process with the owner surveyor who oversees the repair process of MV. Berlin Nakroma.

Research Model

The research model used when researching with primary data research models, namely research using surveys to research subjects in the data collection process. Research Design.

a. FMEA model. to identify risks.
b. Determination of risk factors from the repair work process is based on 4 work processes, namely replating, piping, painting, engine room.
c. Measuring delay factors with FMEA theory.

Data Analysis Technique

The data acquisition technique used in this research is using a field survey. After the data is obtained, then the data will be analyzed using the Failure Modes and Effects Analysis (FMEA).

Risk Matrix

The risk matrix is a grouping of each factor causing delay using two main criteria for prioritizing risks, namely severity (impact) and occurance (probability).

Mitigation Measures

Mitigation measures are taken at the highest RPN, which is the cause of ship repair delays. to minimize the impact.

Conclusion

After analyzing by measuring, ranking risks and controlling the latest risks, conclusions are obtained from the results of the risk analysis of ship repair using the Failure Modes and Effects Analysis (FMEA) method.

III. Results and Discussion

The results of cause identification and interviews revealed a delay in the repair of the MV. Berlin Nakroma, can be seen in Table 3 for replating work, Table 4 for painting work, piping work in Table 5, and Table 6 engine room work. The interview data is then compiled and used as a reference in the questionnaire so that it can be found out how much the severity, occurrence, and detection values are.

TABLE 3.
FACTORS CAUSING DELAYS IN REPLATING WORK

No	Criteria Risk	Risk Event	Code	Risk Agent
1.	Machine support tools	Limited and incomplete work equipment	A1	Work is done alternately due to limited cutting machines
			A2	The number of cutting machines is incomplete
2.	Working method	Plate cutting process is not on schedule	A3	Inappropriate and incomplete work equipment
			A4	Schedule changes due to additional work
			A5	The replating position is difficult to work on
		There is additional work	A6	List of work is not well conveyed
			A7	Workers lack the expertise to carry out their work
3.	Material	Material delivery not as agreed	A8	Late delivery of materials from the owner
			A9	Lack of coordination between the owner and the shipyard regarding the material to be used
4.	Technical workforce	Uncoordinated communication	A10	List of work is not understood by workers
		Non-skilled worker	A11	List of work is not well conveyed
			A12	Workers lack the expertise to carry out their work

TABLE 4.
FACTOR CAUSING DELAYS IN PAINTING WORK

No	Criteria Risk	Risk Event	Code	Risk Agent
1.	Machine support tools	Limited and incomplete work equipment	B1	Work is done alternately due to limited equipment
			B2	Existence of other work processes in the vicinity
2.	Working method	Paint does not stick well	B3	There are still other work processes in the vicinity
			B4	Welding fumes affect the quality of Painting Results
			B5	Plate cleaning is not maximized during the sandblasting process
3.	Material	Material delivery not as agreed	B6	Late delivery of materials from the owner
			B7	Lack of coordination between the owner and the shipyard regarding the material to be used
4.	Technical workforce	Uncoordinated communication	B8	List of work is not understood by workers
		Non-skilled labor	B9	List of work is not well conveyed
			B10	Workers lack the expertise to carry out their work

TABLE 5.
FACTORS CAUSING DELAYS IN PIPING WORK

No.	Risk Criteria	Risk Event	Code	Risk Agent
1.	Machine support tools	Limited and incomplete work equipment	C1	Alternate use of lifting equipment
			C2	Limited amount of equipment
			C3	Alternate use of machines in the workshop
2.	Working method	Pipe unloading and cutting Not on Schedule	C4	Incomplete technician equipment and tools
			C5	Schedule changes due to additional work
			C6	Absence of component care and maintenance
		Work planning not running smoothly	C7	Determination of old job list
			C8	Work order is difficult to understand
			C9	Late delivery of materials from the owner
3.	material	Material delivery not as agreed	C10	Owner's decision on materials needed long time
			C11	Arriving materials are remachined to fit the requirements
			C12	Lack of coordination between owner and shipyard regarding the material to be used
4.	Technical workforce	Uncoordinated communication	C13	List of work is not understood by workers
			C14	Subcon less communicative with owner and Project leader
		Non-skilled labor	C15	Inexperienced subcontractor
			C16	Labor lacks initiative in doing work
			C17	Insufficient human resources required

TABLE 6.
FACTORS CAUSING DELAYS IN ENGINE ROOM WORK

No	Risk Criteria	Risk Event	Code	Risk Agent
1.	machine support tools	Limited and incomplete work equipment	D1	Alternate use of lifting equipment
			D2	Limited amount of equipment
			D3	Alternate use of machines in the workshop
2.	Working method	Component dismantling is not on schedule	D4	Incomplete technician equipment and tools
			D5	Schedule changes due to additional work
			D6	Absence of component care and maintenance
		Work planning not running smoothly	D7	Determination of old job list
			D8	Work order is difficult to understand
			D9	Late delivery of materials from the owner
3.	Materials	Material delivery not as agreed	D10	Owner's decision on materials needed long time
			D11	Materials need to be imported from abroad
			D12	Lack of coordination between the owner and the shipyard regarding the material to be used
4.	Technical workforce	Uncoordinated communication	D13	List of work is not understood by workers
			D14	Subcontractor less communicative with owner and project leader
		Non-skilled labor	D15	Inexperienced subcontractor
			D16	Labor lacks initiative in doing work
			D17	Insufficient human resources required

Table 3, it can be seen that the work on replating there are 4 factors causing delay, 6 forms of failure or failure modes, 12 causes of delay in ship repair projects. From Table 4, it can be seen that the work on painting has 4 factors causing delay, 7 forms of failure or failure modes, 10 causes of delay in ship repair projects. From Table 5, it can be seen that the work on piping has 4 factors causing delay, 6 forms of failure or failure modes, 17 causes of delay in ship repair projects. From Table 6, it can be seen that the work in the engine room has 4 factors causing delay, 6 forms of failure or failure modes, 17 causes of delay in ship repair projects.

The results of distributing questionnaires obtained from respondents were then recapitulated so that the Severity (S), Occurrence (O), and Detection (D) values were obtained for each of the factors causing delays in replating, painting, piping, and machinery room work. From the recapitulation, calculations are carried out so that the mean value for each factor causing delay is obtained.

$$\text{mean} = \frac{\sum(\text{S}) \text{ or } (\text{O}) \text{ or } (\text{D})}{\sum \text{total number of respondents}} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The following is a recapitulation of the average score for each of the factors causing delays in replating, painting, piping, and machinery room.

TABLE 7.
AVERAGE VALUE OF SEVERITY (S), OCCURRENCE (O), DETECTION (D) IN REPLATING WORK

No.	Risk Event	Code	Risk Agent	Average		
				O	D	S
1.	Limited and incomplete work equipment	A1	Work is done alternately due to limited cutting machines	6.60	6.56	6.24
		A2	The number of cutting machines is incomplete	7.20	6.52	6.60
2.	Plate cutting process is not on schedule	A3	Inappropriate and incomplete work equipment	5.88	5.48	5.68
		A4	Schedule changes due to additional work	6.00	6.40	6.16
		A5	The replating position is difficult to work on	6.36	6.40	6.40
3.	There is additional work	A6	List of work is not well conveyed	5.60	5.32	5.52
		A7	Workers lack the expertise to carry out their work	5.32	5.40	5.56
4.	Material delivery not as agreed	A8	Late delivery of materials from the owner	4.72	4.96	5.60
		A9	Lack of coordination between the owner and the shipyard regarding the material to be used	4.16	4.92	4.44
5.	Uncoordinated communication	A10	List of work is not understood by workers	3.88	3.80	3.84
6.	Non-skilled labor	A11	List of work is not well conveyed	3.44	3.88	3.64
		A12	Workers lack the expertise to carry out their work	4.04	3.52	3.36

Table 7 shows the average level of value of each factor number of incomplete cutting machines with an causing delays in replating work. So that the results Occurrence (O) score of 7.20, then Detection (D) 6.52, obtained the highest cause of delay due to the factor of the and Severity (S) 6.60.

TABLE 8.
AVERAGE VALUE OF SEVERITY (S), OCCURRENCE (O), DETECTION (D) IN PAINTING WORK

No.	Risk Event	Code	Risk Agent	Average		
				O	D	S
1.	Limited and incomplete work equipment	B1	Work is done alternately due to limited equipment	6.32	5.96	6.08
		B2	Existence of other work processes in the vicinity	6.48	6.40	6.44
		B3	There are still other work processes in the vicinity	6.24	6.40	6.40
2.	Paint does not stick well	B4	Welding fumes affect the quality of painting	5.64	5.72	5.56
		B5	Plate cleaning is not maximized during the sandblasting process	5.80	6.20	6.12
3.	Material delivery not as agreed	B6	Late delivery of materials from the owner	5.80	6.32	5.68
		B7	Lack of coordination between the owner and the shipyard regarding the material to be used	5.28	5.44	5.24
4.	Uncoordinated communication	B8	List of work is not understood by workers	4.7	3.90	3.70
5.	Non-skilled labor	B9	List of work is not well conveyed	4.04	3.88	3.72
		B10	Workers lack the expertise to carry out their work	4.40	4.16	4.28

Tabel 8 shows the average level of value of each factor existence of other work processes in the vicinity with a causing delays in painting work. So that the results Occurrence (O) score of 6.48, then Detection (D) 6.40, obtained the highest cause of delay due to the factor of the and Severity (S) 6.44.

TABLE 9.
AVERAGE VALUE OF SEVERITY (S), OCCURRENCE (O), DETECTION (D) IN PIPING WORK

No.	Risk Event	Code	Risk Agent	Average		
				O	D	S
1.	Limited and incomplete work equipment	C1	Alternate use of lifting equipment	6.84	6.68	6.24
		C2	Limited amount of equipment	6.96	6.64	6.00
		C3	Alternate use of machines in the workshop	6.80	6.64	6.32
2.	Pipe unloading and cutting not on schedule	C4	Incomplete technician equipment and tools	6.68	6.24	5.56
		C5	Schedule changes due to additional work	6.56	6.32	5.52
		C6	Absence of component care and maintenance	6.24	6.00	5.52
3.	Work planning not running smoothly	C7	Determination of old work list	6.36	5.88	5.68
		C8	Work order is difficult to understand	5.00	4.88	5.00
		C9	Late delivery of materials from the owner	3.92	3.64	3.04
4.	Material delivery not as agreed	C10	Owner's decision on materials needed long time	4.36	3.04	3.36
		C11	Arriving materials are remachined to fit the requirements	7.12	6.84	6.88
		C12	Lack of coordination between owner and shipyard regarding the material to be used	5.08	5.00	4.64
5.	Uncoordinated communication	C13	List of work is not understood by workers	3.12	3.68	2.16
		C14	Subcontractor less communicative with owner and project leader	2.68	2.68	2.32
6.	Non-skilled labor	C15	Inexperienced subcontractor	4.92	2.04	1.96
		C16	Labor lacks initiative in doing work	2.68	1.72	1.64
		C17	Insufficient human resources required	2.48	2.12	2.08

Table 9 shows the average level of value of each factor causing delays in piping work. So that the results obtained the highest cause of delay due to the material factor that comes re-machining to suit the needs with an Occurrence (O) score of 7.12, then Detection (D) 6.84, and Severity (S) 6.88

TABLE 10.
AVERAGE VALUE OF SEVERITY (S), OCCURRENCE (O), DETECTION (D) IN ENGINE ROOM

No.	Risk Event	Code	Risk Agent	Average		
				O	D	S
1.	Limited and incomplete work equipment	D1	Alternate use of lifting equipment	6.4	6.44	5.96
		D2	Limited amount of equipment	6.88	6.48	5.48
		D3	Alternate use of machines in the workshop	6.2	6.44	6.2
2.	Demolition and plate cutting not on schedule	D4	Incomplete technician equipment and tools	6.92	6.56	6.48
		D5	Schedule changes due to additional work	6.6	6.48	6
		D6	Absence of component care and maintenance	5.6	5.44	6.12
3.	Work planning not running smoothly	D7	Determination of old job list	6.56	5.64	5.84
		D8	Work order is difficult to understand	6.56	5.8	5.44
		D9	Late delivery of materials from the owner	4.96	5.36	5.72
4.	Material delivery not as agreed	D10	Owner's decision on materials needed long time	5.92	5.32	5.04
		D11	Materials need to be imported from abroad	5.68	5.36	5.68
		D12	Lack of coordination between the owner and the shipyard regarding the material to be used	5.72	4.96	4.52

Table 10 shows the average level of value of each factor causing delays in engine room work. So that the results obtained the highest cause of delay due to incomplete equipment and technician tools with an Occurrence (O) score of 6.92, then Detection (D) 6.56, and Severity (S) 6.48..

Level risk Mapping	**Severity (Impact)**				
Occurance (Probabilities)	1	2 – 3	4 – 5	6 – 8	9 – 10
1	Low	Low	Low	Medium	Medium
2 – 3	Low	Low	Medium	Medium	High
4 – 5	Low	Low	Medium	High	High
6 – 8	Low	Medium	Medium	High	High
9 – 10	Low	Medium	High	High	High

Figure 5. Scale Level Risk Mapping

Based on Figure 5 above, risk mapping is then carried out based on the severity (impact) and occurance (probability) values. The estimated risk level in the matrix is presented as an integer, so the severity and occurrence values greater than or equal to (≥ 0.5) are rounded up. While decimal values below (< 0.5) are rounded down. Then it is arranged in a 5 x 5 matrix as follow:

Level risk	**Severity (Impact)**				
Occurance(Probabilities)	1	2 – 3	4 – 5	6 – 8	9 – 10
1					
2 – 3			A11		
4 – 5		A12	A9, A10	A7, A8	
6 – 8				A1, A2, A3, A4, A5, A6,	
9 – 10					

Figure 6. Mapping Severity dan Occurance on Replating

Figure 6. shows that based on the values of Occurrence (likelihood of failure) and Severity (level of work impact), there are 8 high risk categories. As follows:

A1 Taking turns due to limited cutting machines
A2 Incomplete number of cutting machines
A3 Inappropriate and incomplete work equipment
A4 Schedule changes due to additional work
A5 The replating position is difficult to work on
A6 List of work is not well conveyed
A7 Laborers lacking expertise in carrying out their work
A8 Delayed delivery of materials from owner

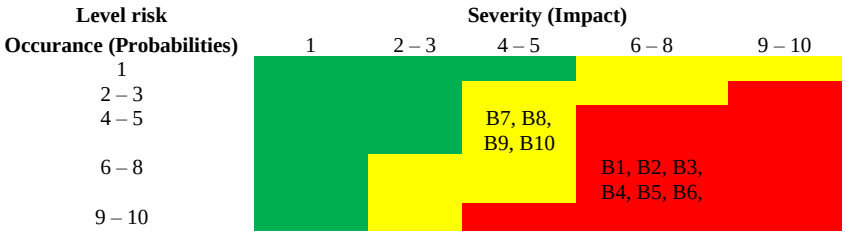

Figure 7. Mapping Severity and Occurance on Painting

Figure 7. shows that based on the values of Occurrence (likelihood of failure) and Severity (level of work impact), there are 6 high risk categories. As follows:

B1 Taking turns due to limited equipment
B2 The presence of other work processes in the vicinity
B3 There are other work processes in the vicinity
B4 Welding fumes affect painting quality
B5 Plate cleaning is not maximized during sandblasting process
B6 Delayed delivery of materials from owner

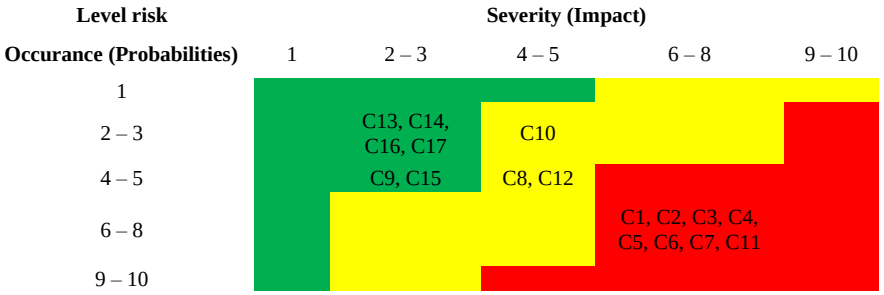

Figure 8. Mapping Severity and Occurance on Piping

Figure 8. shows that based on the values of Occurrence (likelihood of failure) and Severity (level of work impact), there are 8 high risk categories. As follows:

C1 Alternate use of lifting equipment
C2 Limited equipment quantity
C3 Alternate use of machines in the workshop
C4 Incomplete technician equipment and tools
C5 Schedule changes due to additional work
C6 Absence of component care and maintenance
C7 Determination of old work list
C11 Coming materials re-machined to fit requirement

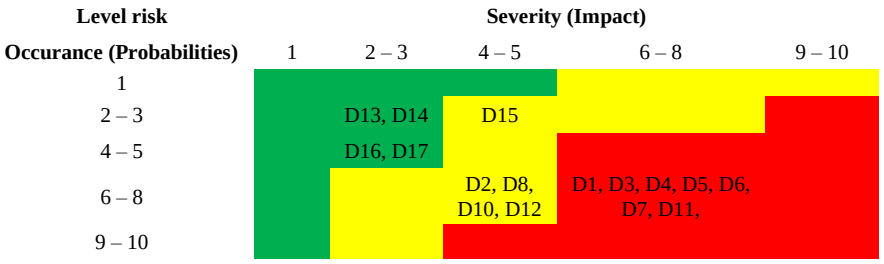

Figure 9. Mapping Severity and Occurance on Engine Room

Figure 9. shows that based on the values of occurrence (likelihood of failure) and Severity (level of work impact), there are 8 high risk categories. As follows:

D1 Alternate use of lifting equipment
D3 Use of machines in the workshop alternately
D4 Incomplete technician equipment and tools
D5 Schedule changes due to additional work
D6 Absence of component care and maintenance
D7 Determination of old work list
D11 Materials need to be imported from abroad.

After obtaining data on the average Severity (S), Occurrence (O), and Detection (D) values for each of the factors causing delays in replating, painting, piping, and machinery room work. And do risk mapping. Next, the Risk Priority Number calculation is carried out based on the value of each factor causing the delay. Based on the RPN value, it is then arranged based on priority and a suiTable solution is found as a handling step.

The formula for calculating the Risk Priority Number value is: RPN = (S) x (O) x (D) ……..(4)

TABLE 11.
RISK PRIORITY NUMBER(RPN) VALUE ON REPLATING WORK

No.	Risk Criteria	Risk Event	Code	Risk Agent	RPN
1.	Machine support tools	Limited and incomplete work equipment	A1	Work is done alternately due to limited cutting machines	270.17
			A2	The number of cutting machines is incomplete	309.83
2.	Working method	Plate cutting process is not on schedule	A3	Inappropriate and incomplete work equipment	183.02
			A4	Schedule changes due to additional work	236.54
			A5	The replating position is difficult to work on	260.51
		There is additional work	A6	List of work is not well conveyed	164.45
			A7	Workers lack the expertise to carry out their work	159.73
3.	Material	Material delivery not as agreed	A8	Late delivery of materials from the owner	131.10
			A9	Lack of coordination between the owner and the shipyard regarding the material to be used	90.87
4.	Technical workforce	Uncoordinated communication	A10	List of work is not understood by workers	56.62
		Non-skilled labor	A11	List of work is not well conveyed	48.58
			A12	Workers lack the expertise to carry out their work	47.78

It is the Risk Priority Number (RPN) value in replating work obtained results with the highest value at the risk of supporting tools due to the incomplete number of cutting machines with an RPN value = 309.83, while the lowest value in labor is less skilled in carrying out its work with an RPN value = 47.78.

TABLE 12.
RISK PRIORITY NUMBER(RPN) VALUE ON PAINTING WORK

No.	Risk Criteria	Risk Event	Code	Risk Agent	RPN
1.	Machine support tools	Limited and incomplete work equipment	B1	Work is done alternately due to limited equipment	229.02
			B2	Existence of other work processes in the vicinity	267.08
2.	Working method	Paint does not stick well	B3	There are still other work processes in the vicinity	255.59
			B4	Welding fumes affect the quality of painting	179.37
			B5	Plate cleaning is not maximized during the sandblasting process	220.08
3.	Materials	Material delivery not as agreed	B6	Late delivery of materials from the owner	208.21
			B7	Lack coordination between owner and shipyard regarding the material be used	150.51
4.	Technical workforce	Uncoordinated	B8	List of work is not understood by workers	58.31
		Non-skilled labor	B9	List of work is not well conveyed	78.34
			B10	Workers lack the expertise to carry out their work	179.37

Is the value of Risk Priority Number (RPN) in the Painting workman ship obtained results with the highest value at the risk of other work processes in the vicinity with a value of RPN = 267.08, while the lowest value on the list of work is less understood by workers with a value of RPN = 58.3

TABLE 13.
RISK PRIORITY NUMBER(RPN) VALUE ON PIPING WORK

No	Criteria Risk	Risk Event	Code	Risk Agent	RPN
1.	Machine support tools	Limited and incomplete work equipment	C1	Alternate use of lifting equipment	285.11
			C2	Limited amount of equipment	277.29
			C3	Alternate use of machines in the workshop	285.36
2.	Working method	Pipe unloading and cutting Not on schedule	C4	Incomplete technician equipment and tools	231.76
			C5	Schedule changes due to additional work	228.85
			C6	Absence of component care and maintenance	206.67
		Work planning not running Smoothly	C7	Determination of old job list	212.41
			C8	Work order is difficult to understand	122.00
			C9	Late delivery of materials from the owner	43.38
			C10	Owner's decision on materials needed long time	44.53
3.	Material	Material delivery not as agreed	C11	Arriving materials are remachined to fit the requirements	335.06
			C12	Lack of coordination between the owner and the shipyard regarding the material to be use	117.86
4.	Technical workforce	Uncoordinated communication	C13	List of work is not understood by workers	24.80
			C14	Subcontractor less communicative with owner and project leader	16.66
			C15	Inexperienced subcontractor	19.67
		Non-skilled labor	C16	Labor lacks initiative in doing work	7.56
			C17	Insufficient human resources required	10.94

Is the Risk Priority Number (RPN) value in piping work obtained results with the highest value at the risk of materials that come re-machining to suit the needs with an RPN value = 335.06, while the lowest value in labor lacks initiative in doing work with an RPN value = 7.5.

TABLE 14.
RISK PRIORITY NUMBER(RPN) VALUE ON ENGINE ROOM

No	Criteria Risk	Risk Event	Code	Risk Agent	RPN
1.	Machine support tools	Limited and incomplete work equipment	D1	Alternate use of lifting equipment	245.65
			D2	Limited amount of equipment	245.73
			D3	Alternate use of machines in the workshop	247.55
2.	Working method	Pipe unloading and cutting not on schedule	D4	Incomplete technician equipment and tools	294.16
			D5	Schedule changes due to additional work	256.61
			D6	Absence of component care and maintenance	186.44
		Work planning not running smoothly	D7	Determination of old job List	216.07
			D8	Work order is difficult to understand	206.98
3.	Material	Material delivery not as agreed	D9	Late delivery of materials from the owner	152.07
			D10	Owner's decision on materials needed long time	158.73
			D11	Arriving materials are remachined to fit the requirements	172.93
			D12	Lack coordination between owner and shipyard regarding the material used	128.24
4.	Technical workforce	Uncoordinated communication	D13	List of work is not understood by workers	9.76
			D14	Subcontractor less communicative with owner and project leader	19.06
		Non-skilled worker	D15	Inexperienced subcontractor	27.17
			D16	Labor lacks initiative in doing work	43.61
			D17	Insufficient human resources required	51.44

The Risk Priority Number (RPN) value in the Engine room work is obtained with the highest value at the risk of incomplete equipment and technician tools with an RPN value = 294.16, while the lowest value on the work list is less understood by workers with an RPN value = 9.76.

TABLE 15.
THE HIGHEST (RPN) VALUE ON REPLATING, PAINTING, PIPING AND ENGINE ROOM

No	Criteria Risk	Risk Event	Code	Risk Agent	RPN
1	Machine support tools	Incomplete work equipment	A2	Limited number of cutting machines	309.83
			Painting		
2	Machine support tools	Limited and incomplete work equipment	B2	Existence of other work processes in the vicinity	267.08
			Piping		
3	Material	Material delivery not as agreed	C11	Arriving materials are remachined to fit the requirements	335.06
			Engine Room		
4	Working method	Demolition and plate cutting not on schedule	D4	Incomplete technician equipment and tools	294.16

The results of risk mapping that has been identified and obtained the Risk Priority Number (RPN) value and risk mapping based on the severity (impact) and occurance (probability) values. Then the next step is to develop a mitigation strategy to prevent the risk from recurring. The results of the mitigation strategy are presented in the table below.

TABLE 16.
RESULTS OF MITIGATION STRATEGIES OF WORKSHOP

Code	Risk Agent	Mitigation Measures
		Replating
A2	Limited number of cutting machines	1. Prepare the number of work tools before the work is carried out, 2. Periodic supervision to avoid delaying the refurbishment project. 3. Provide sufficient cutting machine parts.
		Painting
B2	Existence of other work processes in the vicinity	1. Sequence the work activities by adjusting the schedule. 2. Accelerate work by adding workers.
		Piping
C11	Arriving materials are re-machined to fit the requirements	1. Send a list of appropriate requirements so that machining is processed faster. 2. Piping that needs special specifications and requires more time to order is recommended for the next refurbishment process.
		Engine Room
D4	Incomplete technician equipment and tools	1. Adding equipment and tools before the activity. 2. The implementation of the work is supervised periodically. 3. Provide additional backup tools.

IV. CONCLUSION

The results of research on the risk evaluation of ship repair delays with the MV Berlin Nakroma case study using the Failure Mode and Effect Analysis (FMEA), research method resulted in factors that have the highest influence on each replating, painting, piping and engine room activity as follows:

- In the replating process, the number of cutting machine is incomplete with RPN value 309.83
- In the painting process, existence of other work procecesses in the vicinity with RPN value 267.08
- In the piping, arriving materials are remachine to fit the requirements with RPN value 335.06
- In the engine room work, incomplete technician equipment and tools with RPN value 294.16

Proposed mitigation carried out on repair work on the MV. Berlin Nakroma on replating, painting, piping and engine room activities as follows:

- Prepare amount of work tools before the work is carried out, and anticipate the buildup during the work process by providing additional tools.
- Sort the main level of work by adjusting the schedule and then accelerating the work by adding workers.
- Send a list of appropriate requirements then piping that needs special specifications and requires more time to order is recommended for the next repair work process.

ACKNOWLEDGMENTS

The authors would like to thank PT Yasa Wahana Tirta Samudera and PT PAL Marine Service, as well as the campus of Hang Tuah University Surabaya.

REFERENCE

[1] Alijoyo, A., Wijaya, Q. B., & Jacob, I. (2020). *Failure Mode Effect Analysis Analisis Modus Kegagalan dan Dampak RISK EVALUATION RISK ANALYSIS: Consequences Probability Level of Risk*. www.lspmks.co.id

[2] Ariany, Z., Pitana, T., & Vanany, I. (2023). Risk Assessment Of New Ferry Ship Construction In Indonesia Using The Failure Mode Effect And Analysis (FMEA) METHOD. *Journal of Applied Engineering Science*, 1–12. https://doi.org/10.5937/jaes0-43711

[3] Baroroh, I., Ariana, I. M., & Dinariyana, A. A. B. (2022). Risk Analysis of Engine Room Module Installation with Integration of Bayesian Network and System Dynamics. *International Review of Mechanical Engineering*, *16*(6), 299–308. https://doi.org/10.15866/ireme.v16i6.22456

[4] Baroroh, I., Setiawan, G. V., Azhar, A., Hardianto, D., & Widodo, A. B. (2023.). Risk Analysis of Delay in Ship Repair KM Binaiya with Bayesian Network Method. In *International Journal of Marine Engineering Innovation and Research* (Vol. 8, Issue 3).

[5] Gazali, G. S., & Baroroh, I. (2022). Risk Analysis of the Causes of Delay in Ship Construction (Case Study of KM CL 9E Ship Construction). *BERKALA SAINSTEK*, *10*(4), 235. https://doi.org/10.19184/bst.v10i4.32674

[6] Gray, C. F., Larson, E. W., & Prabantini, D. (2007). *Project management: the managerial process Indeks* (3rd ed.). Andi.

[7] Kerzner, Harold., & Saladis, F. P. (2009). *Project management workbook and PMP/CAPM exam study*

[8] Munir, M., Jajja, M. S. S., Chatha, K. A., & Farooq, S. (2020). Supply chain risk management and operational performance: The enabling role of supply chain integration. *International Journal of Production Economics*, *227*. https://doi.org/10.1016/j.ijpe.2020.107667

[9] Omdahl, T. P. (1988). *Reliability, Availability, and Maintainability (RAM) Dictionary* (T. P. Omdahl, Ed.). ASQC Quality Press.

[10] Padaga, L. K., Teknik, D., Fakultas, K., & Kelautan, T. (2018). *PENJADWALAN BERDASARKAN ANALISIS FAKTOR-FAKTOR PENYEBAB KETERLAMBATAN PROYEK REPARASI KAPAL: STUDI KASUS MV. BLOSSOM*.

[11] Project Management Institute. (2017). *A guide to the project management body of knowledge (PMBOK guide)*.