Istraživanja i projektovanja za privredu
ISSN 1451-4117
DOI:10.5937/jaes0-43711
www.engineeringscience.rs

Journal of Applied Engineering Science
Vol. 21, No. 3, 2023
Original Scientific Paper
Paper number: 21(2023)3, 1129, 872-883

RISK ASSESSMENT OF NEW FERRY SHIP CONSTRUCTION IN INDONESIA USING THE FAILURE MODE EFFECT AND ANALYSIS (FMEA) METHOD

Zulfaidah Ariany[1,3], Trika Pitana[1]*, Iwan Vanany[2]

[1]Departement of Marine Engineering, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya, Indonesia
[2]Department of System Engineering,and Industry, Institut Teknologi Sepuluh Nopember, Kampus ITS Sukolilo, Surabaya, Indonesia
[3]Department of Industry, Sekolah Vokasi, Universitas Diponegoro, Jl. Prof,Soedarto S,H, Tembalang, Semarang, Indonesia
* trika@its.ac.id

This study aims to identify, calculate the impact rating, and mitigate the effects on new ferry construction in Indonesian shipyards. The Risk Matrix method and Failure Mode and Effect Analysis (FMEA) are employed to analyze risk levels. Data were collected through field observations and interviews regarding risks and potential delays in ship components. The results reveal 23 potential hazard sources, with two risks having the highest Risk Priority Number (RPN) values. Assessment based on the quality control section that causes delays in the arrival of ME/AE/pumps and other mechanical equipment 366.18. Assessment of the Project Leader process Delay in the assembly/fabrication/erect process 519.49. Part of production leadership Delay in assembly/fabrication/erecting processes 317.37. Based on the assessment of the three sections, high-risk potential occurs in ship hull work, Delays in assembly/fabrication/erect processes, and machining work Delays in the Arrival of ME/AE/Pumps and Machine Equipment. The risk matrix indicates high-risk ratings for component delays in ship hull work, medium risk for machining work, and the low risk for electrical work and other components. The next step is to assess the potential of domestic components and design a component availability model for new shipbuilding, including imported components. This research offers valuable insights for RoRo ferry shipping stakeholders, helping them understand the mechanisms causing delays in new ship construction and guiding efforts to reduce the risk of failure.

Key Words: failure mode and effect analysis, risk matrix, ferry, RPN, new ship

1 INTRODUCTION

Ferry is an essential means of transportation for the Indonesian state. An archipelagic country that makes sea transportation the lifeblood of society. The construction of government-owned ferries is a routine annual agenda, but the construction is only sometimes timely. In papers [1]– [8], several causes and research has been attempted to anticipate delays in shipbuilding, including in Indonesia. From the several papers read, it turns out that delays do not only occur in Indonesia. Several other countries have also experienced them, including [4], [6], [9]– [11]

Risk management is an effort to minimize risk events that can occur [12]. The purpose of establishing risk management in a production activity is to increase the likelihood of positive events and the consequences of positive events and minimize negative things that can occur. The shipbuilding and shipbuilding industry is an Engineering to Order (ETO) production. Product procurement system by producing products with product specifications per consumer orders.[13][14]

Data from the Ministry of Transportation, Directorate General of Land Transportation, and the Facilities and Infrastructure section shows the continuity of ships' construction, ferries, water buses, and other types. The data is displayed in the following fig.1 graph:

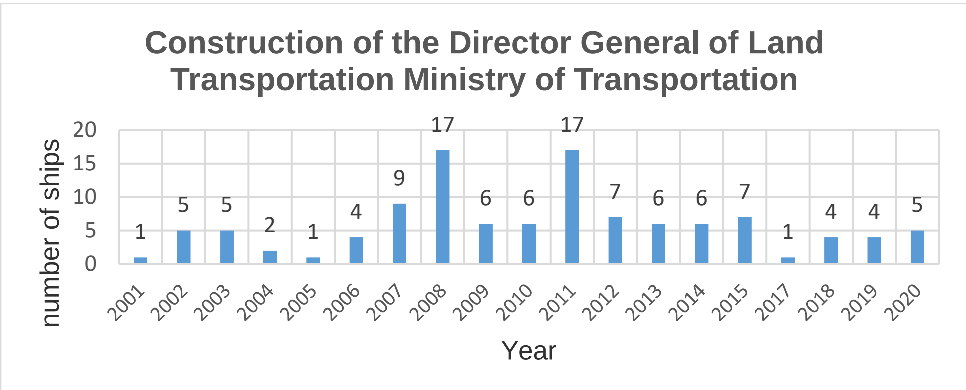

Fig. 1. Graph of continuity of construction of new ships director general of land transportation ministry of transportation

Building a new ship goes through a long series of production stages. In this long production process, of course, there are always obstacles that occur, whether they are the result of technical or non-technical aspects, which result in the productivity of a project so that it experiences deviations from the schedule that has been made [15], [16]. The hope is that the company does not want the project being worked on to fail. In an organizational structure of the quality assurance and standardization department, the departments related to the quality of ships produced and responsible for roles and tasks related to the production process are the Head of Production, Project Leader, Quality Assurance Engineering, and Quality Control departments.

The risk matrix is a method in the risk assessment process to determine the priority level of risk as a product of the risk likelihood or severity category. The Standards Australia/New Zealand (AS/NZS 4360:1999) explains that risk is the possibility of unwanted events that affect an activity or object. Risk is measured in consequences (consequences) and likelihood/probability [17]. It was also explained that risk is exposure to the possibility of something, such as financial loss or gain, physical damage, accident, or delay, resulting from an activity [18], [19]. Various studies and publications discussing the shipbuilding process are still limited to focusing on national shipyard management risk assessment. It is deemed necessary to carry out a risk assessment on ship components considering that the shipbuilding industry is an industry that has a high risk, and the implementation of risk management in the shipbuilding industry is still inadequate.[20].

There are several reasons why the shipbuilding industry must be developed, including the economic value of the shipbuilding industry. The development of this industry will also develop other industries, which will provide a significant multiplier effect on the industrialization process in a country.[21] Deviations from the schedule in the ferry construction can be anticipated by conducting a risk assessment of the ship components installed during construction, starting from identification, assessment, and evaluation to the mitigation that needs to be done. It is stated in the book published by BPPT that domestic ship production policies need to be followed by efforts to develop the local ship component industry—risk assessment of the components of the equipment installed in the construction of government-owned ferries. The continuity of the development of sea, river, land, and port transportation facilities is the government's commitment to continue improving water transportation and people's welfare by preventing delays in the handover of ships according to the construction contracts carried out.

There are not many publications in the field of maritime and shipbuilding using the FMEA method with the latest conditions, including: [1], [22]–[25]. In the article [26], using the risk rating on the risk matrix, hull outfitting (production), machinery outfitting (materials), and hull construction (production) activities are in the high category.

Continuing the previous research publication [27], it is necessary to carry out a risk assessment of the procurement of component materials for the construction of a new ship, the 600GT ferry, as a representative of the government, which is built at national and private shipyards.

2 METHODOLOGY

Failure Mode and Effect Analysis is a risk assessment technique that combines technology and experience from people to identify causes of product or process failure. Besides that, there are also other meanings of FMEA. FMEA is a design methodology for identifying potential failures in the manufacturing process of a product, taking into account the risks associated with these failure variables [28]. Following are some steps that can be taken in the analysis process using FMEA in the construction of a 600 GT ferry:

a) Identifying ship systems and sub-systems to be analysed, plate materials, guard railing hull equipment, ventilation hull equipment, deckhouse door hull fittings, round window hull equipment, box hull equipment, work on deck machinery and equipment, work on deck houses, Assembly/fabrication/erecting process, the arrival of ME/AE/pumps and other machine tools, installation of ME/AE/other machine tools, propellers and propeller shafts, piping work, tank work, panel, and cable material arrival, electrical equipment arrival and lights, Electrical Works, the arrival of Fire Equipment, the arrival of Safety Equipment (Safety of Life at Sea - SOLAS standard), the arrival of Food & Drink Equipment, the appearance of Attack Equipment, the arrival of Communication & Navigation Equipment (Global Maritime Distress and Safety System - GMDSS A2), the arrival of Machine Work Tools. Every critical system and sub-system affecting the safety, comfort, and performance of the ship must be analysed.

b) Establish a cross-functional team involving representatives from different departments for each identified system and sub-system. Each cross-functional team will analyse potential failures and their impact on the systems and sub-systems they have worked.

c) Identify potential failures that may occur in selected systems and sub-systems. Potential failures must be reviewed from all possible aspects, such as hardware failures, software failures, environmental failures, human errors, and others.

d) Evaluate the impact of potential failures on systems and sub-systems. Impacts can be damage, loss of function, or even threats to human safety.

e) Assign scores or priority values of severity, frequency, and detection of potential failures using a scale of 1-10, where 10 indicates the highest severity, frequency, or detection level.

FMEA is an action that can be said to be a preventive effort to reduce or even eliminate failure from a cause that has resulted. Actions to prevent failures from recurring in the future. There are three steps described by [29] in conducting FMEA:

a. Identify Failures: identify errors in a process.
b. Prioritize Failures: Look for the highest risk using the RPN (Risk Priority Number) value.
c. Reduce risk: efforts in various ways to reduce the value of risk

Risk priority determination can also be done by using the probability impact matrix. The probability impact matrix is a risk detection method that aims to determine priority areas of risk, which later need to be discussed about risk responses [5]. The FMEA method determines the priority of risk by calculating the RPN, which uses three main criteria: severity, occurrence, and detection. The basis for calculating the probability impact matrix differs from calculating the RPN value in the FMEA method. In the probability impact matrix method, only two main criteria are used to determine risk priority: severity (impact) and occurrence (probability) values.

Data for calculating the average severity and occurrence values are obtained from the results of the questionnaire I, rounding up to a decimal for values greater than 0.5 (≥ 0.5) and rounding down for values less than 0.5 (< 0.5). Decimal value is necessary because the assessment of the level of risk in the probability impact matrix method refers to integers.

In FMEA, the risk priority number (RPN) is calculated by determining three factors: occurrence (O), severity (S), and detection (D). These factors are discussed below:

a. Occurrence (O): the periodicity of risk occurrence is known as the probability of occurrence.
b. Severity (S): nothing but the level of risk or the impact of risk on the process.
c. Detection (D): detection is the ability of inspection or testing to detect defects or failure modes in time.

A high detection rate indicates a high probability that the failure will escape detection. Otherwise, the probability of detection is low for low detection numbers.

Table 1. Levels of risk assessment [30]

Score	Occurrence	Severity	Detection
1	Very unlikely to occur	Very low will not affect the process	Certain-fault will be caught on test
2/3	Unlikely to occur	Low may affect the process	High
4/5	It may occur about half of the time	Medium-slightly affect the process	Moderate
6/7/8	Likely to occur	High-mostly affect the process	Low
9/10	Very likely to occur	Very high definitely affect the process	The fault will be passed to the customer undetected

In Table 1 above, there are five levels: deficient, low, medium, high, and very high. Each level has a range for each risk's severity and occurrence values after rounding up each risk event's average severity and occurrence.

The results of identifying the hazard/risk sources above are that the hazard will be calculated from the level of severity, likelihood, and opportunity and then evaluated in the consequence/effect assessment and likelihood assessment; the event data obtained for this research is to take data from the shipyard environment that builds ships ferry by conducting direct observation and conducting a question and answer session, the assessment must determine the type of consequence of the incident, the rating scale is obtained from Severity (S), which means the severity of the failure that occurred. The severity rating is based on the severity of the failure consequences. The severity rating is based on a scale of 1 to 10. A rating of "10" means the effect is very severe, leading to harm without warning. Conversely, a severity rating of "1" means the severity is very low.

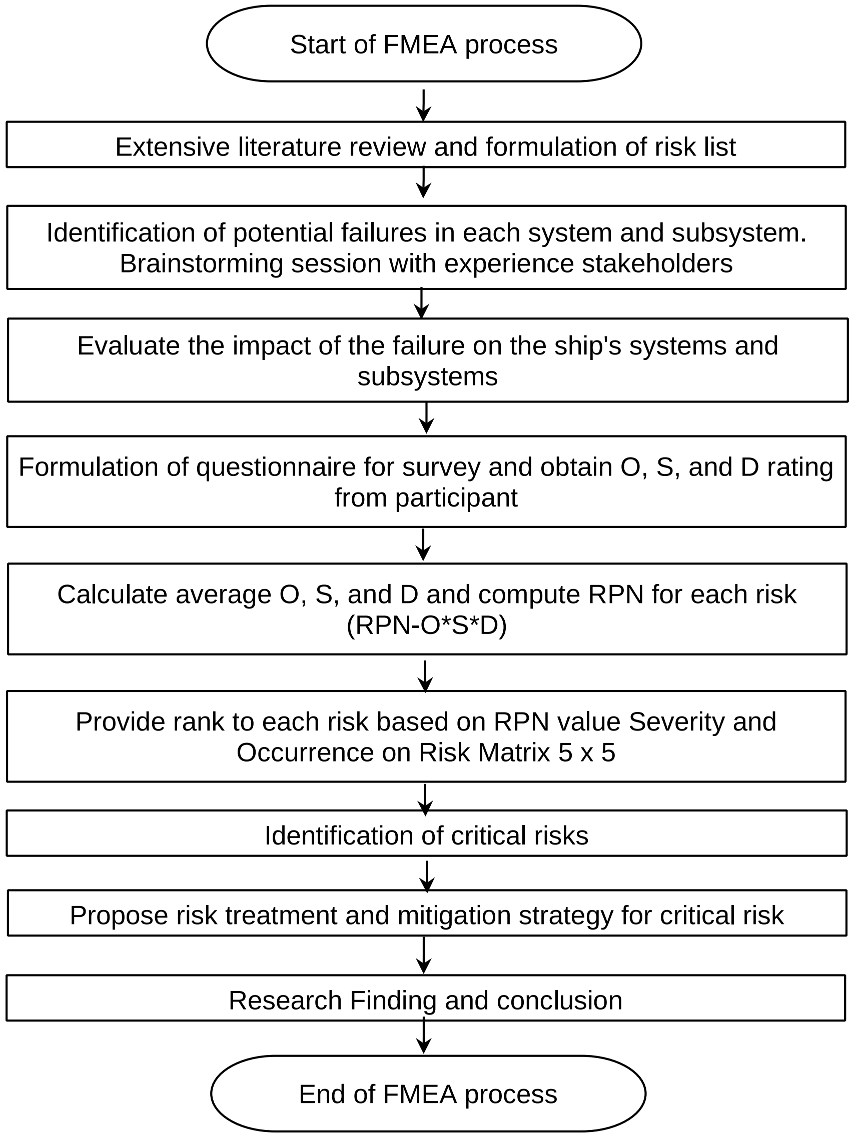

Fig. 2. Research methodology

Occurrence (O) is the probability of a failure occurring. The Event Rating is based on how often the cause of the failure is likely to occur. It is necessary to know the potential causes to rank events because, like severity ratings are effect-driven, event ratings are a function of cause. The event rating is based on the likelihood, or frequency, that the cause (or failure mechanism) will occur. If we know the cause, we can better identify how often a particular failure mode will occur. Like the severity rating, the occurrence rating scale is on a relative scale from 1 to 10. An occurrence rating of "10" means the occurrence of very high failure modes; it happens all the time. On the other hand, "1" means a remote probability of occurrence.

Moreover, Detection (D) means the value of the process to measure the system that makes the failure known. To assign a detection rating, consider the existing design or product-related controls for each failure mode and then assign a detection rating for each control. Think of detection ratings as an evaluation of the ability of design controls to prevent or detect failure mechanisms. A detection rating of "1" means that the probability of detecting a failure is almost inevitable. Conversely, "10" means failure detection or failure mechanism is entirely uncertain. Detection controls detect causes, failure mechanisms, or failure modes after a failure occurs but before the product is released from the design stage.

After everything is determined, then do the calculation of the risk priority number obtained from the multiplication of Severity (S), Occurrence (O), and Detection (D).

$$\begin{aligned} RPN &= \text{Severity x Occurrence x Detection} \\ &= S \; x \; O \; x \; D \end{aligned} \tag{1}$$

This calculation aims to determine the priority level of all risk events.

FMEA, or Failure Mode and Effects Analysis, is a systematic risk analysis method used in product or process development. FMEA aims to identify and analyze potential failures and their impact on the system so that preventive or corrective actions can be taken. Decisions about improving an operation are based on RPN in FMEA. This efficient and valuable method is often adopted for risk assessment. The average incidence (O), severity (S), and detection

(D) will be calculated. In FMEA, the RPN is used to guide risk assessment. No standard describes the number of RPNs eligible to be added to the risk management process and which are not [20]. Calculation of the Risk Priority Number (RPN) for each risk event. The RPN value by multiplying O, S, and D the higher the RPN for a specific factor, the greater the risk of process failure due to that factor. However, FMEA is used extensively for risk analysis. Based on the RPN rating that can be assigned. FMEA is used to identify urgent risks that require an immediate response. The RPN score can evaluate it. Identified risk factors were assessed using a ten-point scale.

This model also can be used as a consideration in designing mitigation efforts. Mitigation efforts that have been designed can then be simulated again to see the impact of mitigation efforts on changes in the probability of delay. The new shipbuilding project is a high-value project. Delays that occur in the project will also result in a significant penalty. Mitigation of the results of this FMEA method can be used to predict the value of delays so that stakeholders can use it to assess the feasibility of a project or as a tool to improve the production process.

3 CASE STUDY

The Roro Ferry ship is a means of inter-island crossing transportation that loads passengers and vehicles. Besides being used for truck transportation, the Roro ship also transports passenger cars, motorcycles, and pedestrians. Roro ships generally have two doors, namely in the bow and stern positions, which are used for entering and leaving vehicles.

Identification of risks in ferry construction projects in Indonesia was obtained by conducting interviews and brainstorming with Managers, Section Heads, and Supervisors/staff who have experience in each section in several shipyards in Indonesia. From the interviews and brainstorming results, 23 risk sources were obtained for the four sections studied. The Hull Work Section has nine sources of risk, the Ship Engineering Work Division has five sources of risk, the Electrical work Section has three sources of risk, and the Miscellaneous work section has six sources of risk. These risk sources can be grouped into four risk events in each section which refers to several works of literature, namely: [1][4][6][7].

Figure.3 shows the 600GT ferry, one of the research data objects. Ship produced by the national shipyard X in Cirebon, West Java, left image after the ferry launching and right image While still in the building block, preparations for launching.

Fig.3. RoRo Ferry MH After - Before Launched (Source: private picture, 2019)

Based on the risk identification list, Questionnaire was prepared to determine the severity, occurrence, and detection values for each risk event in the four sections studied: hull construction work; ship machinery work; ship electrical work; and other equipment. Determination of severity, occurrence, and detection values using the criteria in Table 2 below adopted from those adapted to the conditions of the shipbuilding project.

Table 2. Severity, occurrence and detection value criteria [8]

Value Score	Severity		Occurrence		Detection	
	Criteria	Description	Criteria	Description	Criteria	Description
10 - 9	Very high	High impact and > 20% impact on the project schedule	Very likely to occur	An event may occur in almost any condition	Almost impossible to detect	Work plans or proceduresmake it almost impossible to detect risk
8 – 7	High	Has a significant impact and a 10% -20% impact on the project schedule	Likely will occur	An event that will occur under several conditions	Low probability of detecting	Work plans or procedures have a small possibility of detecting risk

Value Score	Severity		Occurrence		Detection	
	Criteria	Description	Criteria	Description	Criteria	Description
6 – 5	Medium	On Impact 5%-10% against project schedule	Equal chance of occurring or not	An event that may or may not occur under certain conditions	Moderate probability of detection	A work plan or procedure has a moderate likelihood of being detected detect risk
4 – 3	Low	Impact < 5% on the project schedule	Likely will not occur	An event may occur under certain conditions but is unlikely	Occurrence High probability of detecting	Work plans or procedures have a high likelihood of detecting risk
2 – 1	Very low	Insignificant impact	Highly unlikely to occur	An event that is unlikely to occur in some condition	Highly likely to detect	Work plan or procedure highly likely to detect risk

4 RESULTS AND DISCUSSIONS

4.1 Calculation of Risk Priority

The Risk Priority Number (RPN) is calculated by multiplying the average value for each risk source and then calculating the RPN value for each risk event. The results of calculating the average RPN for each Risk Event based on the views of the Quality Control, Project Leader, and Head of Production can be seen in Table 3 dan 4 below:

Table 3. Average of occurrence (O), severity (S) and detection (D) risk assessment

Risk Code	Risk Description	Quality Control			Project Leader			Production Head		
H1	Plate material delays	6,08	5,88	5,80	5,19	4,44	2,32	4,95	5,24	4,56
H2	Delay in hull equipment guard railing	4,93	4,20	3,88	6,93	6,66	3,16	5,91	5,29	3,09
H3	Gastric Ventilation Equipment Delay	6,58	2,83	1,56	7,63	7,42	2,58	5,81	5,67	2,10
H4	Hull Equipment Delays Deckhouse hermetic doors	5,84	2,94	2,41	7,13	6,38	3,22	6,06	4,41	3,38
H5	Round Window Hull Fittings Delay	5,44	2,34	2,19	6,69	5,94	3,28	5,41	4,84	2,66
H6	Window Box Hull Fixture Delay	6,19	2,38	2,31	5,06	4,85	3,65	4,75	4,27	2,88
H7	Delays in the work of deck machinery and equipment.	5,55	4,32	3,79	4,23	3,95	4,34	4,32	4,13	3,48
H8	Delays in Work on Deckhouses	5,68	2,51	2,36	5,79	5,19	3,67	6,38	5,69	2,86
H9	Delays in assembly/fabrication/erect processes	7,09	4,16	4,45	8,25	8,13	7,75	6,55	7,66	6,32
M1	Delay in Arrival of ME/AE/Pumps and other machinery equipment	6,75	6,24	5,82	5,83	6,22	6,22	6,38	5,90	4,70
M2	Delay in Installing ME/AE/other Machine Equipment	6,64	6,14	5,36	6,27	6,95	6,27	6,07	5,93	4,55
M3	Propeller and Axle delays	7,69	7,16	6,66	7,53	7,31	6,66	7,03	6,81	5,94
M4	Piping Work Delays	6,64	5,93	5,50	6,21	6,05	6,05	5,88	5,80	4,80
M5	Delay in Tank Work	6,02	6,00	4,96	4,79	4,73	5,71	4,80	5,34	3,86
L1	Delay in the arrival of panel materials and cables	5,95	5,61	5,27	4,88	4,88	4,97	4,93	4,30	3,91
L2	Delay in the arrival of electrical appliances and lights	6,70	5,17	4,88	5,92	5,92	4,56	5,91	4,97	3,91
L3	Electrical Work Delay	6,30	5,63	4,93	5,70	5,70	6,98	5,65	5,73	4,00
P1	Delay in the arrival of firefighting equipment	6,31	4,70	4,41	6,25	6,25	3,75	5,51	5,16	3,17
P2	Late arrival of Safety Equipment	6,40	5,41	5,16	6,27	6,27	3,61	5,08	5,45	3,65
P3	Late arrival of Food & Beverage Equipment	3,14	1,65	1,43	2,83	2,83	2,23	1,77	1,77	2,06

Risk Code	Risk Description	Quality Control			Project Leader			Production Head		
P4	Delayed arrival of the Serang Equipment	6,40	2,41	2,51	3,60	3,60	2,48	2,13	2,11	1,99
P5	Delayed the arrival of Communication & Navigation Equipment	6,75	2,03	2,44	4,13	4,13	2,47	5,33	5,33	3,80
P6	Delay in the arrival of Machine Work Tools	6,45	2,11	2,35	3,56	3,56	2,36	2,35	2,10	2,06

S = Severity O = Occurrence D= Detection

Table 4. Calculation of the Risk Priority Number (RPN) for shipbuilding in Shipyards

Risk Code	Risk Description	QC RPN	PL RPN	PH RPN
H1	Plate material delays	207,00	53,49	118,27
H2	Delay in hull equipment guard railing	80,15	145,91	96,52
H3	Gastric Ventilation Equipment Delay	29,14	146,09	69,31
H4	Hull Equipment Delays Deckhouse hermetic doors	41,31	146,20	90,16
H5	Round Window Hull Fittings Delay	27,88	130,29	69,56
H6	Window Box Hull Fixture Delay	33,98	89,59	58,32
H7	Delays in the work of deck machinery and equipment.	90,85	72,47	62,07
H8	Delays in Work on Deckhouses	33,72	110,31	103,86
H9	Delays in assembly/fabrication/erect processes	131,15	519,49	317,37
M1	Delay in Arrival of ME/AE/Pumps and other machinery equipment	245,01	225,24	176,88
M2	Delay in Installing ME/AE/other Machine Equipment	218,60	272,90	163,91
M3	Propeller and Axle delays	366,18	366,57	284,41
M4	Piping Work Delays	216,60	227,73	163,78
M5	Delay in Tank Work	179,25	129,41	98,93
L1	Delay in the arrival of panel materials and cables	176,25	118,02	82,81
L2	Delay in the arrival of electrical appliances and lights	168,99	159,72	114,71
L3	Electrical Work Delay	174,53	226,62	129,39
P1	Delay in the arrival of firefighting equipment	130,82	146,48	90,15
P2	Late arrival of Safety Equipment	178,53	142,19	101,07
P3	Late arrival of Food & Beverage Equipment	7,40	17,83	6,46
P4	Delayed arrival of the Serang Equipment	38,71	32,15	8,93
P5	Delayed the arrival of Communication & Navigation Equipment	33,55	41,96	107,81
P6	Delay in the arrival of Machine Work Tools	32,09	29,90	10,17

QC RPN = Risk Priority Number by Quality Control
PL RPN = Risk Priority Number by Production Leader
PH RPN = Risk Priority Number by Production Head

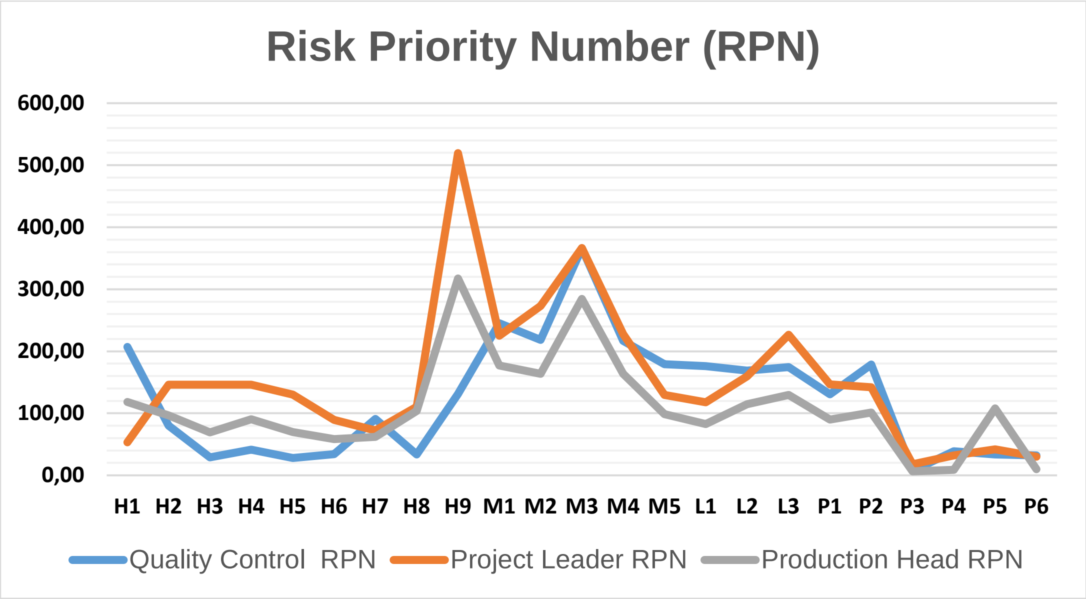

Fig. 4. Risks priority number [RPN] calculation chart

Figure 4 shows the RPN as a chart table, the calculation results of the three-part assessment at the shipbuilding yard.

The Probability Impact Matrix provides an illustration related to assessing existing risk events. In this case, the risk events are grouped into three levels: Low Risk, Moderate Risk, and High Risk. Mild risk is depicted in green, where the risk should be on the lower left diagonal of the matrix in ideal conditions. High risk is depicted in red, where the highest risk must be avoided in the upper correct diagonal. The yellow area indicates moderate risk, between high and low risks.

The results of the risk priority assessment obtained by the Probability Impact Matrix method are the same as the risk priority levels obtained by calculating the Risks Priority Number (RPN) using the FMEA method

The relationship between the RPN in the FMEA method and the 5x5 Risk Matrix is that the RPN can be used to determine the risk level of a failure, and this risk can be plotted on the 5x5 risk matrix. In the risk matrix, the RPN value can be used to determine risk assessment (for example, as a factor that considers the level of likelihood or severity). The probability impact matrix method only uses two main criteria to determine risk priority: severity (impact) and occurrence (probability) values. To relate the RPN value to the 5x5 risk matrix, we can consider only the RPN's severity (S) and occurrence (O) factors to determine the risk position in the matrix. However, remember that this will not include the detection factor (D) present in the RPN calculation, so not all information from the FMEA analysis will be represented in the 5x5 risk matrix. To reduce the risk and failure rate in ship-building projects is necessary to mitigate the risk of these four risk events. Based on the data on the average severity and occurrence of each risk event, a probability impact matrix can be compiled. Probability impact matrix based on assessment from Quality Control, as presented in Figure 5 below:

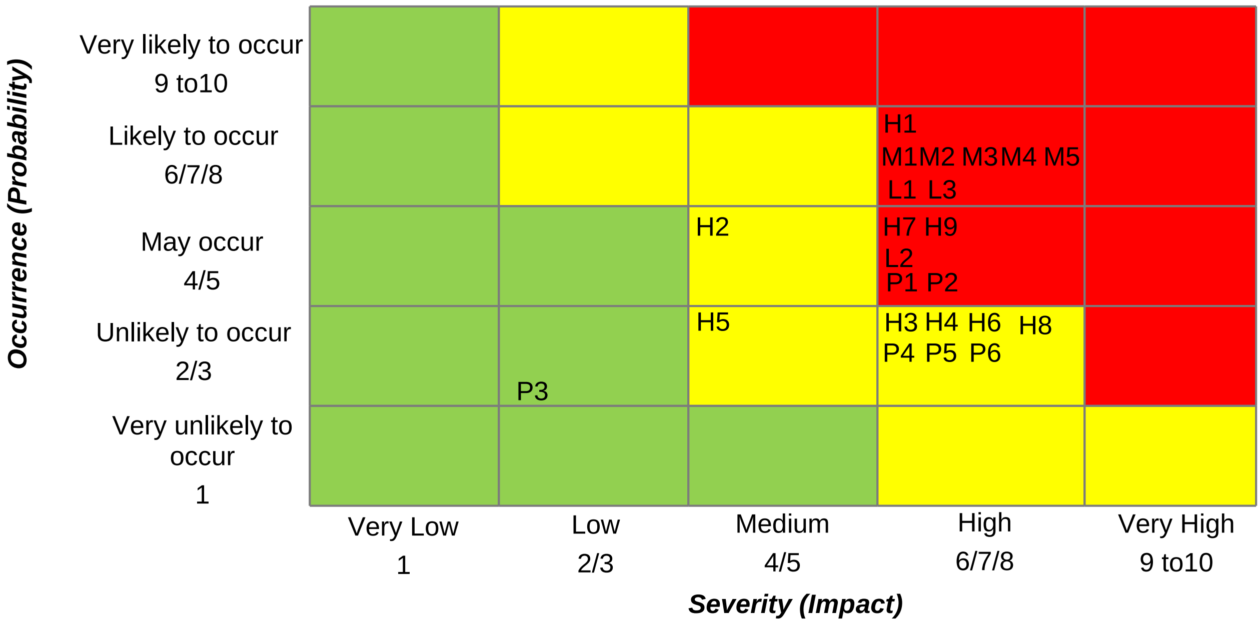

Fig. 5. Probability impact matrix based on data assessment from Quality Control

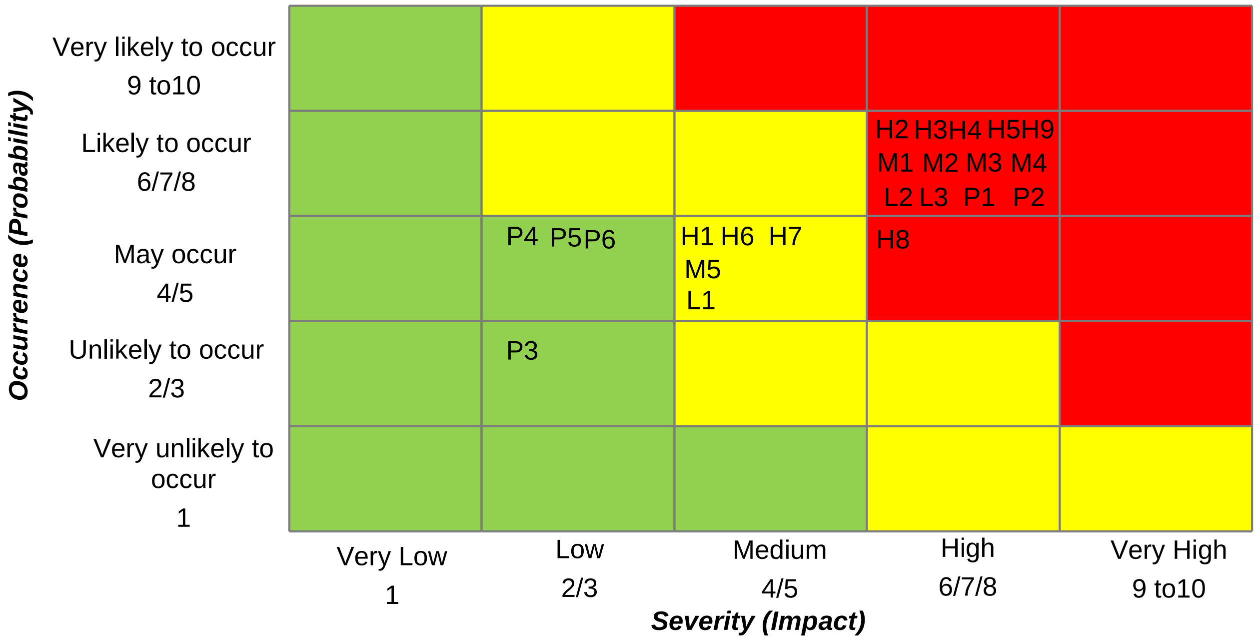

Fig. 6. Probability impact matrix based on data assessment from Project Leader

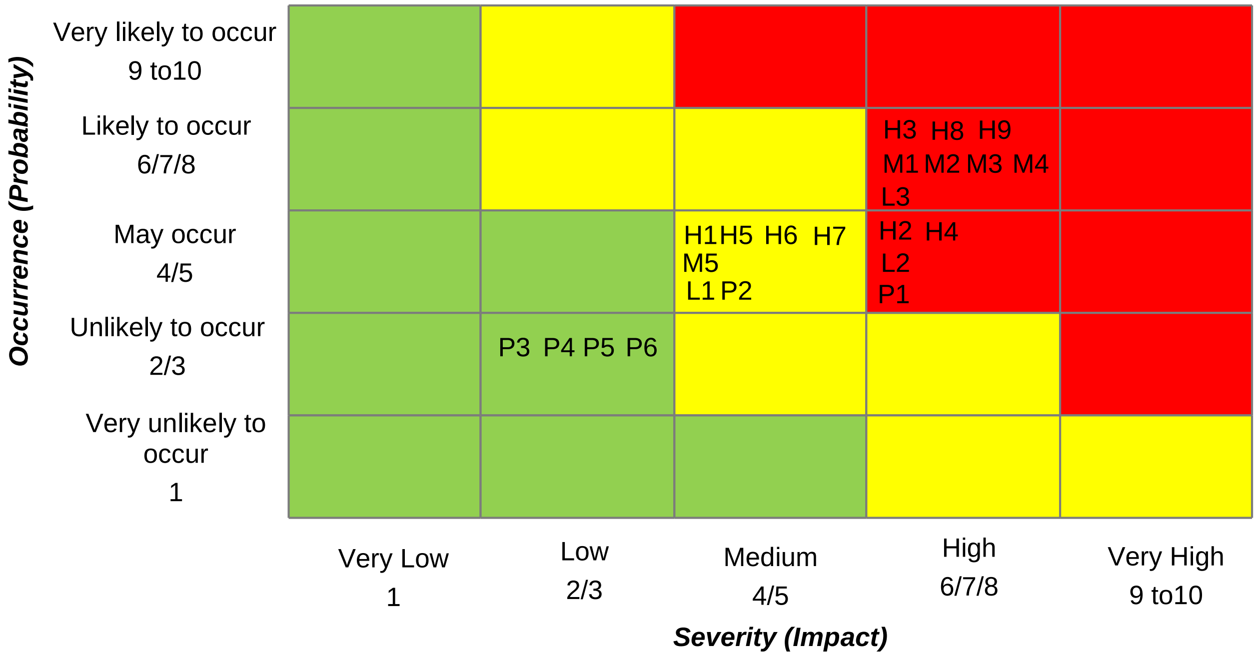

Fig. 7. Probability impact matrix based on data assessment from Production Head

Explain the arrival of materials, machining work, and delays in electrical materials that may occur. Based on the mapping results on the 5x5 risk matrix, Figure 5 describes the results of risk research from quality control. Likewise, figure 6 is by the project leader, and figure 7 is by the production head.

Assessment of the probability impact matrix in Figures 5, 6, and 7 can be obtained from risk events that have a level of risk classified as critical in the red matrix and must be mitigated.

4.2 Mitigation

Following are some examples of mitigation that can be done if there is a delay in each of the 600 GT ferry construction factors:

a) Hull construction work:
b) Hire more workers to increase construction speed. It ensures sufficient supplies of materials and equipment to ensure timely delivery due to a lack of resources. Carry out strict monitoring and supervision at each stage of construction to identify problems and minimize the risk of delays.
c) Ship machining work:
d) Ensure that all required equipment and materials are available before starting work. Employ a skilled and experienced workforce in the machinery field to increase work efficiency. Perform periodic maintenance on equipment to prevent damage and extend the life of the equipment.

e) Ship Electrical Work:
f) Employ a workforce that is skilled and experienced in the field of ship electricity. They use high-quality materials and equipment to avoid problems and delays due to equipment damage. Perform periodic tests and inspections on electrical systems to ensure they function correctly.
g) Other equipment:
h) Employ a skilled and experienced workforce in other equipment fields to increase efficiency. They ensure inventory of all equipment and components needed before starting work. Carry out strict supervision and monitoring at every installation stage to identify problems and prevent delays.

5 CONCLUSION

The results of research on the construction of the 600 GT ferry can be concluded that the risk identification process in the 600 GT Ferry development section produces 23 types of risks including: Potential Delay in plate material, Potential Delay in Guard Railing Hull Equipment, Potential Delay in Gastric Ventilation Equipment, Potential Delay in Gastric Equipment Deckhouse watertight doors, Potential Delays for Round Window Hull Equipment, Potential Delay for Square Hull Equipment, Potential Delays in the work of deck machinery and equipment, Potential Delays in Work on the Deckhouse, Potential Delays in the assembly/fabrication/erect process, Potential Delays in Arrival of ME/ AE/Pumps and other engine equipment, Potential Delays in Installing ME/AE/other Machinery Equipment, Potential Delays for propellers and Propeller Axles, Potential Delays in Piping Works, Potential Delays in Tanks Work, Potential Delays in arrival of panel and cable materials, potential delays in arrival of electrical equipment and lights, potential delays in electrical work, potential delays in arrival of fire equipment, potential delays in arrival of safety equipment (SOLAS standard), potential delays in arrival of food & drink equipment, potential delay in arrival of attack equipment, Potential Delays in Arrival of Communication & Navigation Equipment (GMDSS A2), Potential Delays in Arrival of Machine Work Tools.

Quality Control (QC) Assessment. Through the FMEA method, the QC team can prioritize repairs and controls based on the RPN value, enabling efficient resource allocation to reduce risks. Based on data processing results, the highest RPN value was in the hull section. The delay in plate material was 207. RPN value in the engine section, Delay in Arrival of ME/AE/Pumps and other engine equipment, was 366.18. Electrical division Delay in arrival of panel and cable materials 176. Completion of delay in the arrival of safety equipment (SOLAS standard) 179. Risk matrices resulting from quality control assessment data entering high risk are delays in plate material, delays in work on deck machinery and equipment, and Delays in assembly/fabrication/erect processes (H1/H7/H9), overall machine work (M1/M2/M3/M4/M5), electrical work (L1/L2/L3), and other equipment (P1/P2).

Project Leader Assessment, FMEA helps Project Leader manage project risk in a systematic and structured manner. This method allows project managers to identify potential failures and risks at each project stage, so they can plan mitigation measures and reduce negative impacts on the project. The results of the risk matrix in the assessment of project managers who are considered high risk are hull work (H2/H3/H4/H5/H8/H9), mechanical work (M1/M2/M3/M4), electrical work (L2/L3), and ship equipment. Based on data processing, the average RPN value is high in each section—hull section Delay in assembly/fabrication/erecting process 519.49. The average engine part RPN value for propeller delay and propeller shaft is 366.57. In the electrical section, the average RPN value for Delay in Electrical Work is 226.62. Equipment division Delay in arrival of firefighting equipment 146.48. (P1/P2).

FMEA provides Production Head with insight into the risks present in the production process and how to manage them. By identifying potential failures and the associated risks, production head can increase the efficiency and reliability of production processes and reduce downtime and costs associated with failures. Based on data processing, the highest RPN average value is in each section. Hull work department delay in assembly/fabrication/erecting process 317.37. Machine work delays in propellers and Propeller Axles 284.41. Electrical work delay in electrical work 129.39. Other equipment Delay in arrival of Communication & Navigation Equipment (GMDSS A2) 107.81. The results of the risk matrix in the assessment of production leaders who enter high-risk are hull works (H3/H8/H9/H2/H4). M1/M2/M3/M4 engine work. L2/L3 electrical work. Other accessories delay the arrival of Fire Fighting equipment (P1).

Hull Section Mitigation is to Improve coordination with suppliers to ensure the availability and timely delivery of plate material. Monitor the material purchasing process to ensure compliance with the project schedule. Increase the efficiency of assembly, fabrication, and erection processes through training and better use of technology. Determine a realistic project schedule considering the time required for each production stage. Machinery Parts Mitigation Improve coordination with main engines, auxiliary engines, pumps, and other mechanical equipment suppliers to ensure timely delivery. Monitor the process of order and delivery of machine tools to avoid delays. Ensure proper scheduling of machine installation and testing. Have a contingency plan in case of delays in the arrival or installation of related machinery and equipment. Mitigation of the Electrical Section Improves coordination with panel and cable suppliers to ensure on-time delivery. Set a realistic work schedule.

6 ACKNOWLEDGMENTS

Thanks to the ministry of transportation, especially the director general of land transportation. National and private shipyards are very helpful in data collection - department of marine systems engineering, ITS-Surabaya, Indonesia, and colleagues for their support and assistance.

7 REFERENCES

[1] K. Cicek, H. H. Turan, Y. I. Topcu, and M. N. Searslan. (2010). Risk-based preventive maintenance planning using Failure Mode and Effect Analysis (FMEA) for marine engine systems. 2010 *second International Conference Engineering System Management and Its Applications (ICESMA), https://ieeexplore.ieee.org/document/5542687.*

[2] L. Brun, S. Frederick, and J. Lee. (2017). Korea and the Shipbuilding Global Value Chain [Chapter 4], [Online]. Available: https://gvcc.duke.edu/wpcontent/uploads/Duke_KIET_Korea_and_the_Electronics_ GVC_CH_3.pdf

[3] Direktur Jenderal Perhubungan darat. (2019). Perhubungan Darat Dalam Angka 2018. Kementrian Perhubungan, Jakarta.

[4] J. Crispim, J. Fernandes, and N. Rego. (2020). Customized risk assessment in military shipbuilding. *Reliability Engineering System Safety*, vol. 197, no. 106809 January. https://doi.org/10.1016/j.ress.2020.106809

[5] C. P. P, M. Basuki, and E. Pranatal. (2018). Analisa Risiko Operasional Proses Bangunan Kapal Baru (Studi Kasus Pembangunan Kapal Lpd 124 M di PT . PAL Indonesia (Persero). *Seminar Nasional Sains dan Teknologi Terapan IV 2018 ITATS*, vol. IV. http://ejurnal.itats.ac.id/sntekpan/article/view/367

[6] E. Lee, Y. Park, and J. Gye. (2009). Large engineering project risk management using a Bayesian belief network. *Expert System with Application 36 5880–5887 Contents*, vol. 36, pp. 5880–5887, DOI: 10.1016/j.eswa.2008.07.057.

[7] A. A. Pratiwi, I. K. Gunarta, and B. Wirjodirdjo. (2016). Modeling Shipbuilding Industrial Cluster of East Java ' S Competitive Advantage Using System Dynamic. *International Journal Industrial Electronic and Electrical Engineering*, no. 9, pp. 123–127.

[8] M. Prihandono and B. Syairudin. (2017). Shipbuilding Risks Analysis (Case Study of New Build Pertamina Tanker 3.500 DWT on PT . Dumas Tanjung Perak Shipyards). *International Seminar of Contemporary Research in Business and Management (ISCRBM). Surabaya, Indonesia*. https://www.researchgate.net/publication/325319674

[9] F. de A. L. Ferreira, L. F. Scavarda, P. S. Ceryno, and A. Leiras. (2018). Supply chain risk analysis: a shipbuilding industry case. *International Journal of Logistics Research and Applications*, vol. 21, no. 5, 542–556, DOI: 10.1080/13675567.2018.1472748.

[10] Surhan Cam, Serap Palaz. (2016). Challenges and Opportunities of Globalisation for an Independent Small Manufacturer: A Case Study in Turkey's Shipyard. *Journal of Organizational Ethnography*, vol. 5, no. 3, pp. 15–22, DOI: 10.1108/JOE-10-2015-0024

[11] Yuri Kochetkov and B. Aliev. (2016). Risks In The Shipbuilding And Ship Repair Industry In Latvia. *Vadyba Journal of Management*, vol. 28, no. 1, pp. p9-13, https://www.ceeol.com/search/article-detail?id=408945

[12] Sianitawati and A. H. Prasetyo. (2022). Rancangan Manajemen Risiko Korporat Terintegrasi pada Perusahaan Pertambangan Batu Bara Tahun 2023-2024. *JURNALKU*, vol. 2, no. 4, pp. 482–501, DOI: 10.54957/jurnalku.v2i4.302

[13] F. Adrodegari, A. Bacchetti, R. Pinto, F. Pirola, and M. Zanardini. (2015). Engineer-to-order (ETO) production planning and control: An empirical framework for machinery-building companies. *Production Planning and Control*, vol. 26, no. 11, pp. 910–932, DOI: 10.1080/09537287.2014.1001808.

[14] E. B. Santoso, U. F. Kurniawati, and A. N. Dewanti. (2014). Development Factors of Shipping Industry Special Zone to Support Regional Innovation System," *Jurnal Ekonomi Pembangunan: Kajian Masalah Ekonomi dan Pembangunan.* vol. 15, no. 2, p. 141, DOI: 10.23917/jep.v15i2.243.

[15] M. Basuki, D. Manfaat, S. Nugroho, and A. A. B. Dinariyana, (2014), "Probabilistic Risk Assessment at Shipyard Industries. *International Journal of Technology*, vol. 5, no. 1, p. 88, DOI: https//doi.org/10.14716/ijtech.v5i1.157.

[16] O. H. Mahendra and M. Basuki, (2021), "Mitigasi Risiko Keterlambatan Material dan Komponen Impor Menggunakan House of Risk (HOR) pada Proyek Pembangunan Tug Boat 2x1200 HP," in *Seminar Nasional Teknologi Industri Berkelanjutan (SENASTITAN I)*. http://ejurnal.itats.ac.id/senastitan/article/view/1684

[17] Standart Australian International. Ltd. (2006). *Risk Management Guidelines Companion to AS/NZS 4360:2004*, vol. 10, no. 5. 2007. SAI Global, Australia.

[18] D. E. W, Wiediartini, and A. I. J. (2013). Risk Analysis for Ship Converting Project Accoplishment (Case study of KRI KP Converting Project). *Kapal*, vol. 10, no. 3, pp. 116–123, DOI: https://doi.org/10.14710/kpl.v10i3.5595

[19] I. Pascu, D. Paraschiv, and A. Didu. (2020). Research about using the Failure Mode and Effects Analysis method for improving the quality process performance. *IOP Conference Series: Materials Science and Engineering*, vol. 898, no. 1, pp. 8–13, DOI: https://doi.org/10.1088/1757-899X/898/1/012037.

[20] R. Mulcahy. (2010). Risk Management: Tricks of the Trade for Project Managers. ISBN: 1932735321, 9781932735321. *RMC Publications, Minnesota.*

[21] M. Basuki and A. A. Wacana Putra. (2014). Model Probabilistic Risk Assessment Pada Industri Galangan Kapal Sub Klaster Jakarta. Prosiding Seminar Nasional Rekayasa Material, Sistem Manufaktur dan Energi. ISBN: 978-602-71380-0-1. Jurusan Teknik Mesin, Fakultas Teknik, Universitas Hasanuddin, Makassar.

[22] R. R. Iwan and ´kowicz and Wlodzimierz Rosochack. (2014). Clustering Risk Assessment Method for Shipbuilding Industry. *Industrial Management & Data Systems.* vol. Vol. 114 N. Emerald Group Publishing Limited 0263-5577, pp. 1499–1518, doi: DOI 10.1108/IMDS-06-2014-0193.

[23] Y. D. Ghadage, B. E. Narkhede, and R. D. Raut. (2020). Risk Management of Innovative Projects using FMEA; a case study. International Jurnal Business Excellence, vol. 20, no. 1, pp. 70–97, DOI: 10.1504/IJBEX.2019.10017566

[24] M. Ozkok. (2014). Risk Assessment in Ship Hull Structure Production using FMEA. Journal of Marine Science and Technology (Taiwan) vol. 22, no. 2, pp. 173–185, DOI: 10.6119/JMST-013-0222-1.

[25] M. B. Zaman, A. Santoso, Hasanuddin, and W. Busse. (2020). Risk Evaluation of Ferry in the Bali Straits using FMEA Method. IOP Conference Series: Earth and Environmental Science, vol. 557, no. 1, DOI: 10.1088/1755-1315/557/1/012045.

[26] M. Basuki and A. W. Putra. (2013). Penilaian Risiko Pekerjaan Bangunan Baru Pada Galangan Kapal Klaster Jawa Menggunakan Matrik Risiko. Prosiding Seminar Nasional Aplikasi Sains & Teknologi (SNAST) 2014, pp. 1–8.

[27] Z. Ariany, T. Pitana, and I. Vanany. (2022). Review of the Risk Assessment Methods for Shipbuilding in Indonesia. IOP Conference Series: Earth and Environmental Science, vol. 972, no. 1, doi: 10.1088/1755-1315/972/1/012056.

[28] N. Budi Puspitasari, G. Padma Arianie, and P. Adi Wicaksono. (2017). Analisis Identifikasi Masalah dengan Menggunakan Metode Failure Mode and Effect Analysis (FMEA) dan Risk Priority Number (RPN) pada Sub Asembly Line (Studi Kasus : PT. Toyota Motor Manufacturing Indonesia). *J@ti Undip : Jurnal Teknik Industri.*, vol. 12, no. 2, p. 77- 82, DOI: 10.14710/jati.12.2.77-84.

[29] C. S. Carlson, (2012). *Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes Using Failure Mode and Effects Analysis*. ISBN: 978-1-118-00743-3. John Wiley & Sons, Inc.

[30] M. S. Kirkire, S. B. Rane, and J. R. Jadhav. (2015). Risk management in medical product development process using traditional FMEA and fuzzy linguistic approach: A case study. Journal of Industrial Engineering International, vol. 11, no. 4, pp. 595–611, DOI: 10.1007/s40092-015-0113-y.

[31] H. T. Liu and Y. lin Tsai. (2012). A Fuzzy Risk Assessment Approach for Occupational Hazards in The Construction Industry. Safety Science, vol. 50, no. 4, pp. 1067–1078, DOI: 10.1016/j.ssci.2011.11.021.

Paper submitted: 30.03.2023.
Paper accepted: 25.08.2023.