Development of safety for marine transportation in the Maratua Island

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Abstract. Safety is a major issue in sea transportation. Improving safety is an important thing that should be conducted. It is to support the achievement of objectives in the fields of transportation, industry, business and so on. In this paper, the research area is Maratua Island. This island is one of the tourist islands in Indonesia. Safety of marine traffic should be developed in this island. It will support the development of the island as an area of marine tourism. The safety of sea transportation also very important to support the development of marine tourism on this island. This paper has established the FMEA methodology for getting RPN number on risk evaluation. Hazard identification is carried out in this study as a first step to determine the level of safety. Furthermore, risk analysis is carried out to determine the level of risk and useful for making decisions for improving safety.

1. Introduction
Indonesia is an archipelago consisting of 17,504 islands. 3,000 islands are classified as inhabited islands and 17,475 are categorized as small islands with an area of less than 2,000 km\textsuperscript{2}. The main problems in the small islands are transportation, safety of sea transportation, education and so on. The small islands in the territory of Indonesia have natural resources. It is the main capital of marine tourism. Maratua Island is one of small islands in Indonesia. Small island development in Indonesia should be conducted. Development of small islands is a challenge for the government and the community. Maratua Island is located in East Kalimantan Province and belongs to Frontier, Outer, and Left behind area. Figure 1 shows the Maratua Island. This 4,118.80 km\textsuperscript{2} island which is located at 2° 16.279' NL and 118° 34.573' EL has big potential of tourism [1].

Maratua Island is one of the small islands of the Derawan-Maratua complex islands, situated in Berau Regency, of the East Kalimantan Provence. The island is one of the carbonate islands and karst islands in Indonesia [2,3]. Maratua Island has great potential of natural beauty for tourism development. Presently, tourism in Maratua Island has also been growing and attracted a more significant number of both domestic and foreign tourists. This development in tourism is also responded by investment and infrastructure development as well. A carpet of a white-sand beach and, karst caves, reef, and a saltwater lake constitute the attraction of tourism in Maratua Island [4].
Marine safety in the Maratua Island should be established. In this case, several motorboats and speedboats used for transportation. They have several route and schedule [4]. Sea transportation safety will be able to support the transportation from the departing area to the destination [5].

In this paper, the safety analysis uses the FMEA method. This method is able to analyze the level of risk. Determination of risk evaluation by determining the RPN value. At this RPN value will consider the value of occurrence, severity and detection. If the RPN value is calculated, the next step is to carry out mitigation steps. Thus, the safety of sea transportation will improve in the Maratua Island area.

2. Study Area

Figure 1 shows Maratua Island as the location of research in this paper. On the island of Maratua, sea transportation using motorboats and speedboats. From Berau, east Kalimantan, motorboat and speedboat sail to the Maratua Island. In Maratua Island, motorboats and speedboats are the main sea transportation to get to the tourist sites, and the main transportation to other areas on the island. The population on Maratua Island is spread over four villages. There are Bohe Silian, Payung-Payung, Harapan Bay, and Alulu Bay. Transportation between the four villages using motorboats and speedboats. Transportation safety is very important to support community life activities and the development of tourist areas.

3. Sea Transportation Safety

Enhancing sea safety transportation is very important [6]. It is in a central position in all aspects of the shipping world. Aspects of shipping safety include the characteristics of attitudes, values, and activities regarding the importance of meeting safety and security requirements relating to transportation in waters and ports [7]. Neglecting shipping safety will increase economic and environmental costs such as reduced production, medical costs, pollution and inefficient energy use. The low safety of shipping can be caused by human resources (education, competence, working conditions, working hours) and management processes, weak management and others.

Safety of Life at Sea (SOLAS) are regulations governing maritime safety with the aim of increasing the guarantee of life safety at sea, starting with a focus on navigation regulations, systems and equipment on ships, ship construction, communication equipment, and other equipment [8,9]. For improving marine transportation safety in Indonesia, the Directorate General of Sea Transportation has issued a policy in the prevention of ship accidents such as making shipping notices for improving safety for
ships, also making notice about weather conditions such as telegram regarding the readiness of bad weather at sea.

Figure 2. Ship navigation system

Figure 2 shows the ship navigation system which is comprised of navigation technology, ship and navigation environment. Safety is the level of freedom from accidents and hazards [10]. Several factors causing ship accidents [11]. There are ship's condition, human error, failure of machinery and electrical system, navigation factors and so on. Based on previous research, human error is a major cause of ship accidents [12].

4. FMEA Method

Failure Mode and Effect Analysis (FMEA) is a structured procedure to identify and prevent as many failure modes as possible. FMEA is used to identify the sources and root causes of a quality problem. A failure mode is anything that is included in the defect / failure in the design, conditions outside the specified specifications, or changes in the product that cause disruption of the function of the product.

FMEA Design will help eliminate design-related failures, such as failures due to improper strength, inappropriate material, and so on. Process FMEA will eliminate failures caused by changes in process variables, for example conditions outside the specified specification limits such as incorrect size, incorrect texture and colour and others. FMEA define the risk priorities of failure modes through the risk priority number \( RPN \), which is the product of the occurrence \( (O) \), severity \( (S) \), and detection \( (D) \) of a failure [13]. The formula is below,

\[
RPN = O \times S \times D
\]  

The occurrence is defined as the possibility of an accident on the ship in the specified route area. Severity is an assessment of the effects of potential failure modes on subsequent components, subsystems, or customers. Detection is an assessment of the ability of the current design control to detect potential causes or mechanisms. These three factors use the FMEA standard scale consisting of 1 to 10 based on mutually agreed evaluation criteria described in Tables 1-3. Because \( RPN \) is a measure of the risk of each failure, \( RPN \) can be used to rank failures and prioritize actions. Failure modes with a higher \( RPN \) are considered more important and will be given a higher priority for correction [13].

There are 9 basic steps in the FMEA process:

- Process Review
• Brainstorming various forms of possible process errors / failures
• Make a list of the effects of each error
• Assess the level of impact (severity) error
• Assess the level of the occurrence of errors
• Assess the likelihood of detection of each error and its effects
• Calculate the risk priority level (RPN) of each error and its impact
• Determine the priority of errors
• Safety measures

Table 1. Crisp rating for occurrence of a failure

| Rating | Probability of occurrence | Failure probability |
|--------|---------------------------|---------------------|
| 9–10   | Very High: failure is almost inevitable | > 1 in 2 |
|        |                            | 1 in 3             |
| 7–8    | High: repeated failures    | 1 in 8             |
|        |                            | 1 in 20            |
|        |                            | 1 in 80            |
| 4–6    | Moderate: occasional failure | 1 in 400 |
|        |                            | 1 in 2000          |
| 2–3    | Low: relatively few failures | 1 in 15,000 |
|        |                            | 1 in 150,000       |
| 1      | Remote: failure is unlikely | < 1 in 1,500,000   |

Table 2. Severity of a failure

| Rating | Effect | Severity of effect |
|--------|--------|--------------------|
| 9–10   | Very High | very serious effect of accident |
| 7–8    | High    | serious effect of accident     |
| 4–6    | Moderate | moderately serious effect of accident |
| 2–3    | Low     | little serious effect of accident |
| 1      | Remote  | no serious effect of accident |

Table 3. Detection of a failure

| Rating | Detection | Likelihood of detection |
|--------|-----------|-------------------------|
| 9–10   | Remote    | Remote chance to detect potential cause failure mode |
| 7–8    | Low       | Low chance to detect potential cause failure mode |
| 5–6    | Moderate  | Moderate chance to detect potential cause failure mode |
| 3–4    | High      | High to detect potential failure mode |
| 1–2    | Very High | Very high to detect potential failure mode |

5. Results and Discussions
The safety of sea transportation on the Maratua Island should be improved. There are many factors that affect the safety of sea transportation on this island. In this paper, 7 scenarios were built to analyze and
The RPN value is the standard output of the FMEA method. These 7 scenarios are based on interviews conducted with motorboat and speedboat operators, communities and stakeholders on Maratua Island. The RPN value is shown in Table 4. There are 4 villages in the Maratua Island: Bohe Silian, Payung-Payung, Harapan Bay, and Alulu Bay. Transportation between the four villages using motorboats and speedboats. Transportation safety is very important to support community life activities and the development of tourist areas.

Table 4. Risk level based on FMEA

| Scenario | Process                     | Occurrence | Severity | Detection | RPN  | Rank |
|----------|-----------------------------|------------|----------|-----------|------|------|
| 1        | Bad weather                 | 4          | 7        | 3         | 84   | 4    |
| 2        | Ship condition              | 5          | 6        | 3         | 90   | 5    |
| 3        | Human Error                 | 6          | 8        | 4         | 192  | 1    |
| 4        | Failure of Machinery        | 3          | 6        | 3         | 54   | 7    |
| 5        | Head on                     | 3          | 5        | 4         | 60   | 6    |
| 6        | Crossing                    | 5          | 6        | 4         | 120  | 2    |
| 7        | Overtaking                  | 4          | 5        | 5         | 100  | 3    |

Table 4 shows that human error is at the highest risk level with RPN 192. In the area of sea transportation, human error is still the highest problem that causes ship accidents. Then the risk mitigation steps are needed to reduce human error problems, such as improving skills, increasing experience, improving communication between ships, not overworked and so on.

Crossing is at level 2 for the RPN value with a number of 120. The crossing situation requires more careful actions in sailing. The navigator's visibility must be good and the distance between ships needs to be adjusted properly. Crossing situations need to regulate the speed of the ship so that no collisions occur. Figure 3 shows the crossing position based on COLREG. In Table 4 we have seen several other levels of risk that require mitigation so that ship accidents can be avoided and ship safety can be improved.

Overtaking is at the third risk level with total RPN 100. The occurrence value is 4, severity is 5 and detection = 5. Encounter ship of overtaking could be shown in Figure 3. Bad weather is the fourth risk level with an RPN of 84. Bad weather is still a problem for ship operators in the Maratua Island. To improve safety, operators should be carefully and see information before sailing. When the weather is bad, marine tourism activities should be stop for a while until the weather returns to normal.

In Indonesia, weather conditions as one of the important factors that need to be a concern in shipping activities. Therefore, the Directorate General of Sea Transportation of the Ministry of Transportation issues a Shipping Notice that is issued routinely. This notice contains an appeal to the ranks of the Directorate General of Sea Transportation and ship crews to be aware regarding extreme weather and high waves in Indonesian sea.

The ship condition has an occurrence value 5, severity is 6 and detection is 3. The total RPN value is 90. The proper ship condition will be able to improve the safety of the ship and has a low risk value. Ship conditions are classified as ship age, ship performance, distance between ships and the ship's operating system. Damaged ships are recommended for repairs. The ships that are not suitable for use are expected to be renewed with new ones. Thus, the safety of sea transportation in the Maratua Island will increase to support other activities.
Rank 6 is the head on position. It is presented in Table 4. Head on has an occurrence value = 3, severity = 5 and detection is 4. Total RPN value is 60. The position of head on is dangerous if not careful in navigating the ship. Figure 3 presents the position of head on, crossing and overtaking according to the COLREG 1972. Then, rank 7 is failure of machinery. Failure of machinery has an occurrence value = 3, severity = 6 and detection is 3. Total the RPN is 54. In the Maratua Island, failure of machinery on ship is rare. Engine maintenance is very necessary to keep the engine operating properly.

![Figure 3. Encounter types according COLREG](image)

6. Conclusions
FMEA is very good to be used to evaluate the risks of sea transportation on the island of Maratua. There are 4 villages in the Maratua Island: Bohe Silian, Payung-Payung, Harapan Bay, and Alulu Bay. Sea transportation between the four villages using motorboats and speedboats. Transportation safety is very important to support community life activities and the development of tourist areas. Marine traffic safety in the Maratua Island should be developed. It could support economic activities, education, and other activities. The result of risk priority number explored that human error was leading, followed by crossing, overtaking, ship condition, bad weather, head on and failure of machinery. Human error is still the highest problem that causes ship accidents. The risk mitigation steps are needed to reduce human error problems, such as improving skills, increasing experience, improving communication between ships, not overworked and so on.

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