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Article

Defect Analysis to Improve Quality in Traditional Shipbuilding Processes

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Abstract: As one of the livelihoods of the Indonesian people, the sea has many benefits, such as fish, marine plant cultivation, and others. Most Indonesian live in the coastal area and work as fishermen. Its existence and role are very important in coastal development, especially fisheries. This study aims to investigate logic tree analysis to solve defects in traditional shipbuilding. It is envisaged that such implementation shall improve the quality of ships produced. Traditional ships are currently experiencing a significant demand proportionally to the increase in the number of fishermen utilizing traditional ships. However, shipbuilders experienced many obstacles during the manufacturing process. Therefore, the quality of the ships produced was different from the ship owners' standards or demands. For solving this problem, initial identification processes should be conducted to determine any potential defects that may affect the quality of the ships. Defects that pose a high risk to the quality of the ship were resolved using a logic tree analysis to obtain recommendations for improvements. The result shows that four risks of damage have been identified that affect the quality of the traditional ships produced: the selection of the quality of raw materials, imperfect wooden joints, easily corroded steel bolts, and poor installation of additional equipment.

Keywords: shipbuilding; defect; reliability-centered maintenance; industrial design.

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1. Introduction

The sea is one of the livelihoods of the Indonesian people because of its many benefits, such as fish, marine plant cultivation, and others. Most Indonesian people in the coastal area work as fishermen whose existence and role are very important in development, especially in the fisheries sector. Indonesia's abundant marine resources. Ideally, the fishing community can also get a quality of life following its strategic role. Along with the coast of Aceh with its waters, of course, it has great potential in the field of fisheries. Along the coast in this area, many residents work in the fisheries sector, including in West Aceh Regency, which has such a wide coastline that many residents work as fishermen.

In general, fishermen in West Aceh District still use traditional ships made of wood, so traditional ship makers experience much demand for ship production. In addition to many requests, craftsmen also experience problems during the manufacturing process, so the ship's quality is sometimes different from the standards or wishes of the ship owner. This condition is a consideration of fishermen because many complained about the condition of their boats, which are quickly damaged. A good ship will impact the safety and comfort of the crew while working, especially during fishing operations.

For solving this problem, initial identification processes were conducted to determine any potential defects that may affect the quality of the ships. In this work, defects that pose a high risk to the quality of the ship were resolved using Logic Tree Analysis (LTA) to obtain recommendations for improvements. The Failure Mode and Effects Analysis (FMEA) approach will be incorporated to identify the potential damage, effects, and impacts on the ship. FMEA is widely used in various engineering fields, particularly in assessing the production systems of manufacturing activities (I Pamungkas & Dirhamsyah, 2019; Rastayesh et al., 2019; Yucesan et al., 2021). LTA has been widely used in various problems, such as minimizing the risk of natural disasters (Bommer & Scherbaum, 2008; Porter et al., 2017; Satake et al., 2007), machine maintenance problem management (Tang et al., 2015; Waghen & Ouali, 2019, 2021), and operational hazard risk (Abdelgawad & Fayek, 2012; Akyuz et al., 2020; Ramzali et al., 2015). In addition, the integration of the FMEA and LTA approaches is part of the Reliability Centered Maintenance (RCM) approach (Alencar & de Almeida, 2015; Gupta et al., 2016; Tang et al., 2017). The results from this work will be able to identify and solve defect problems, hence improving the quality of traditional shipbuilding using the LTA approach.

2. Materials and Methods

This research was conducted at a traditional shipyard in Tanjong Village, Meureubo District, West Aceh Regency, Indonesia. Figure 1 shows a map of the research location.

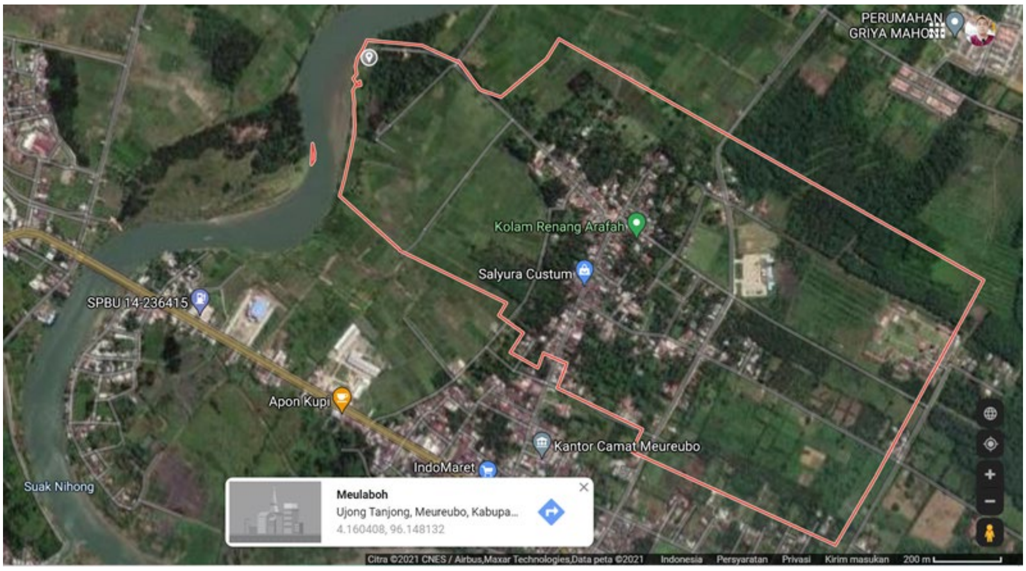

Figure 1. Map of the Research Location

Researchers start the initial stage to identify the research object after searching the topic. Initial identification aims to determine the object of research in general, such as the shipyard's condition and the problems these ship crafters experienced. Figure 2 shows a research flow diagram.

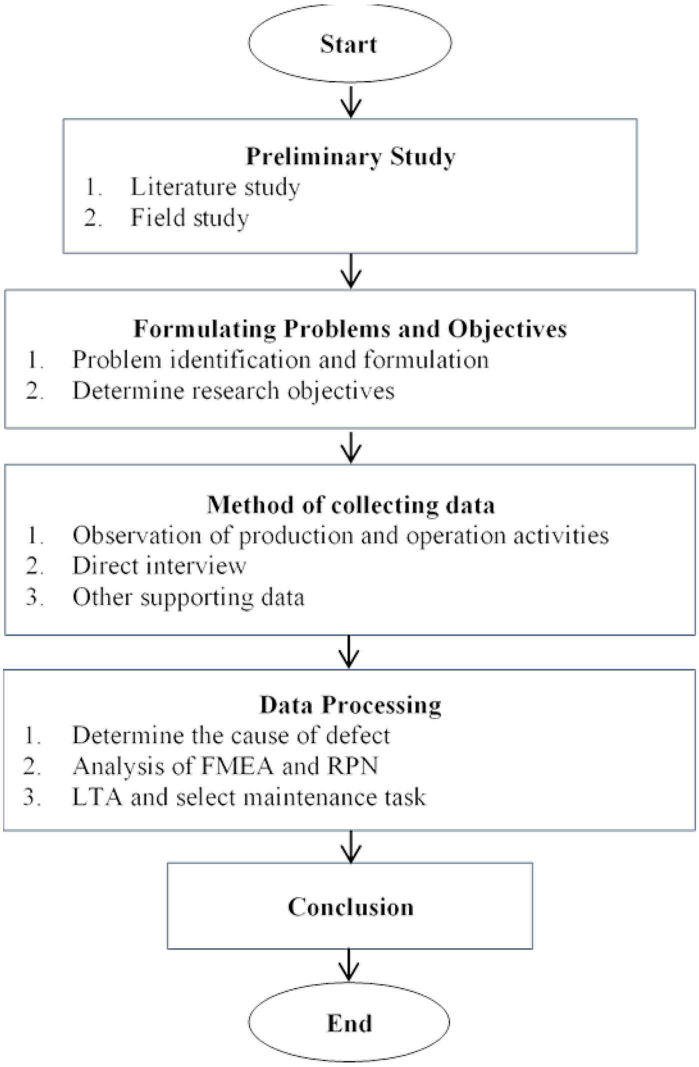

Figure 2. Research Flow Diagram.

The stages of data processing carried out in this study as seen in Figure 2:

- Determine the cause of defects in the traditional shipbuilding process.
- Identify failure modes, effects, and solutions to minimize defects, along with the Risk Priorities Number (RPN) using the Failure Mode and Effects Analysis (FMEA) approach. FMEA is a useful approach for evaluating failures or defects that occur in systems, process designs, or services (Iing Pamungkas et al., 2019). Identifying potential failures is done by providing a score or score for each failure mode based on its occurrence, severity, and detection (Stamatis, 2003). In this research, FMEA will identify functions, failure modes, failure effects and preventive measures of each defect's causes in traditional shipbuilding. Identifications were collected from interviews with the owner and shipbuilders. Each rating has potential, and the scale is rated from 1 to 10 (Arabian-Hoseynabadi et al., 2010). After getting a score for each assessment component, the next step is calculating the risk priority number (RPN). Equation 1 follows to calculate RPN (Kim & Zuo, 2018). RPN = Severity x occurrence x Detection
- Take measures to prevent defects in traditional shipbuilding using logic tree analysis (LTA) (in tabular form). Logic Tree Analysis (LTA) aims to prioritize each damage mode and perform a function and damage review. The priority of the damage mode can be determined by answering the questions that have been provided in this LTA (Waghen & Ouali, 2019). LTA contains information regarding the number and name of damage, amount and mode of damage, criticality analysis and additional information required. The critical analysis places each mode of damage into one of four categories: evidence, safety, extinction and category (Rabinowitz et al., 1998). In this

study, every defect in shipbuilding will be given the appropriate questions to be further analyzed in the maintenance task.

- Select maintenance tasks for each cause of the defect.

3. Result and Discussion

3.1. Determining the Cause of Defects

The causes of defects in traditional shipbuilding are determined based on common occurrences observed on the various ships. As for some of the causes of defects in traditional shipbuilding, namely:

- The wood quality does not meet the requirements, namely when the wood drying process is not perfect and there are wooden knots that can cause gaps during assembly. Figure 3 shows the poor quality of the wood.

Figure 3. Poor Quality Wood.

- Incompatible and carefulness when making parts connections, worker experience and thoroughness are very important in this process. Figure 4 shows mismatched connections.

Figure 4. Mismatched Connections.

- The choice of how to use bolts and nails that rust easily is still not quite right. Figure 5 shows bolts or nails that rust easily.

Figure 5. Bolts or Nails that Rust Easily.

- Install motor drive tubes and rubber pipes where low-quality materials are used. Figure 6 shows the installation of motor drive tubes and rubber pipes.

Figure 6. Installation of Motor Drive Tubes and Rubber Pipe.

3.2. Failure Mode and Effect Analysis (FMEA) Result

FMEA starts by determining the failure mode and identifies each failure mode's impact and the Risk Priority Number (RPN). The FMEA method is based on discovery, regulation, and failure or error reduction and has been used in various industries (Rhee & Ishii, 2003). FMEA uses three risk factors to identify failure modes, namely occurrence (O), detection (D), and severity (S). The risk factor is indicated in the form of RPN. Three input parameters are rated on a 10-point scale (I Pamungkas et al., 2020; Iing Pamungkas & Irawan, 2020). This paper analyses the four causes of defects in traditional shipbuilding using the FMEA approach. Failure modes, effects and damage prevention are measures to be identified in advance. Tables 1 and 2 show the FMEA and RPN for defects in traditional shipbuilding.

Table 1. FMEA for Defects in Traditional Shipbuilding.

Cause of Defect	Function	Failure Mode	Failure Effect	Preventive Measure
Poor quality of wood	prevent spoilage and leakage on the ships	Cracked and broke	The ship failed because it leaked	The selection of wood must be right so that damage does not occur
Mismatched connections	An improper connection to the bow will result in the planned thickness of	Leaking	The ship works sub-optimally, with a wet surface, corrosion	Perform reconnections

	the planks not being fulfilled, thereby reducing the ship's strength to its weakest point.			
Bolts or nails that rust easily	Prevents minor leaks due to improper bolts	Cracked	There are leaks or seepage in a ship, and it cannot hold the existing arrangement of wooden beams	Replacing bolts with hot dipped galvanized bolts
Installation of motor drive tubes and rubber pipes	Affect the ship's performance while operating	Broken connections and leakages	The pipe breaks or leaks, causing water to enter the ship	Protects pipe rods from opening directly

Table 1 and Table 2 show the highest RPN obtained for poor-quality wood (392), Mismatched connections (336), Bolts or nails that rust easily (252), and installation of motor drive tubes and rubber pipes (150). The highest cause of RPN defects is found in poor-quality wood. It reflects that traditional shipbuilding's main ingredients greatly affect the ship's overall quality. This problem can be overcome by choosing the right wood to prevent damage. The next highest RPN is for mismatched connections; it can be fixed by reconnecting. Bolts or nails that rust easily can be prevented by replacing these bolts with hot-dipped galvanized bolts. Errors in the installation of motor drive tubes and rubber pipes can be prevented by protecting the pipe rods from opening directly.

Table 2. RPN for Defect in Traditional Shipbuilding.

No	Cause of Defect	Severity	Occurrence	Detection	RPN
1	Poor quality of wood	8	7	7	392
2	Mismatched connections	7	6	8	336
3	Bolts or nails that rust easily	7	6	6	252
4	Installation of motor drive tubes and rubber pipes	5	5	6	150

3.3. Logic Tree Analysis (LTA) and Selection of Maintenance Tasks

LTA is carried out to make maintenance or repair task decisions using the decision logic tree criteria. The criteria used are based on the failure mode, failure detection method, and equipment failure characteristics (Song et al., 2008). Table 3 and Table 4 of the four causes of damage in the traditional shipbuilding process, several measures can be proposed. The poor quality of the wood causes the ship to crack and break easily, making it easy to rot and leak. It is advisable to replace the damaged components with new ones. An improper connection can reduce the ship's strength and make it prone to leaks. It can be recommended to be reconnected if a leak occurs. Rusty bolts or nails can easily cause fractures and cracks, so they leak easily. It is advisable to replace them with hot-dipped galvanized bolts. Incorrect installation of the motor drive tube and rubber pipe can cause it to break easily and leak at the joint. It is advisable to take corrective action on the joint. Here are some descriptions from Table 4.

a. E is evident, and H is hidden.
b. Risk characteristics, S is severity, CL is the current likelihood, CR is the current risk.
c. A selected task, PL has projected likelihood, PR is a priority risk

Table 3. Precautions based on Logic Tree Analysis (LTA).

Cause of Defect	1	2	3	4	5	6	7
Poor quality of wood	Yes	Yes	Yes	Yes	Yes	No	Yes
Connection mismatched	Yes	Yes	Yes	Yes	Yes	No	Yes
Bolts or nails that rust easily	Yes	Yes	Yes	Yes	Yes	No	Yes
Installation of motor drive tubes and rubber pipes	Yes	Yes	Yes	Yes	Yes	No	Yes

Note: 1. Whether the failure model can be detected by surveillance? 2. Are there other surveillance techniques available? 3. Can failure be predicted with confidence?, 4. Will corrective action or update improve performance like new?, 5. Can a replacement item increase its functionality like new?, 6. What is the hidden failure model? and 7. Does failure lead to safety, or is it an accident?

Table 3 shows the precautions based on LTA, and Table 4 shows the selection of maintenance tasks.

Table 4. Selection of Maintenance Tasks.

Cause of Defect	Failure Mode	Failure Characteristics	H/E
1	Cracked and broke	Weathered and leaking Description: Poor quality of wood	E
2	Reducing the strength of the ship	Leaking Description: Connection mismatched	E
3	Cracked	Minor leak Description: Bolts or nails that rust easily	E
4	Disconnected and leaking	The connection broke and leaked Description: Installation of motor drive tubes and rubber pipes	E

Table 5. Selection of Maintenance Tasks (Cont'd).

Cause of Defect	Failure Mode	Effect		
		Local	Functional Failure	End
1	Cracked and broke	-	Water enters the ship	Drowned
2	Reducing the strength of the ship	-	Wrong ship thickness	Corrosion
3	Cracked	-	Unable to withstand the arrangement of wooden beams	Water is seeping
4	Disconnected and leaking	-	Water enters the ship	Drowned

Table 6. Selection of Maintenance Tasks (Cont'd).

Cause of Defect	Failure Mode	Risk Characteristics		
		S	CL	CR
		Difficulty	Maybe it happened	The risk that occurs
1	Cracked and broke	-	Sometimes	High
2	Reducing the strength of the ship	-	Sometimes	High
3	Cracked	-	Sometimes	High
4	Disconnected and leaking	-	Sometimes	High

Table 7. Selection of Maintenance Tasks (Cont'd).

Cause of Defect	Failure Mode	Selected Tasks		
		Proposed Action	PL Estimated odds	PR Estimation of risk
1	Cracked and broke	Replacement of damaged components	Far from being planned	Moderate
2	Reducing the strength of the ship	Reconnection	Far from being planned	Moderate
3	Cracked	Hot dipped galvanized bolt replacement	Far from being planned	Moderate
4	Disconnected and leaking	Repair, connection	Far from being planned	Moderate

Table 8. Selection of Maintenance Tasks (Cont'd).

Cause of Defect	Failure Mode	Disposition
1	Cracked and broke	Required for all part orders
2	Reducing the strength of the ship	Repair
3	Cracked	Bold Replacement
4	Disconnected and leaking	Repair

Table 4 displays four risks of damage that affect the quality of the traditional ships produced, namely, the selection of the quality of raw materials that have an impact on ship cracks and rupture, incorrect connections that can reduce the strength of the ship, bolts or nails that rust easily, which can cause cracks and leaks, and installation of motor drive tubes and rubber pipes that cause the pipes to break easily and leak. Several actions can be used, among others: replacement of damaged components, reconnection, hot dipped galvanized bolt replacement, and repair of the installation of additional equipment. Several inputs can be used to improve the quality of traditional shipbuilding, namely careful and precise planning for the use of the main material (wood) and additional materials (pipes, bolts, nails, etc.), making standard operating procedures (SOPs) in the manual book, conduct training to workers regularly, set standard shipbuilding time per unit, and create a layout for each stage of shipbuilding.

4. Conclusion

Along with the increasing demand for traditional ships, ship quality is one of the most important things that ship manufacturers must pay attention to meet customer satisfaction. Logic tree analysis is used in this research to solve quality problems or defects in traditional shipbuilding. It is hoped that it can improve the quality of the ships produced with the recommendations for improvement obtained. The causes of defects commonly found in the traditional shipbuilding process at the research location will be identified first. The logic tree analysis (LTA) method was applied to traditional shipbuilding for the research work reported in this paper. On the basis of the results, four risks of damage have been identified that affect the quality of the traditional ships produced, namely, the selection of the quality of raw materials, imperfect wooden joints, easily corroded steel bolts, and poor installation of additional equipment. Several actions can be used, among others: replacement of damaged components, reconnection, hot dipped galvanized bolt replacement, and repair of the installation of additional equipment.

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