# Study on Implementation of Risk based Inspection using FMEA-FTA Method on Ro-Ro Ship Bastiong-Sofifi Route

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Abstract: Routine checking is one of the preventions of ship accidents by ensuring that the condition of the ship is feasible to carry out operational activities. The condition checking of the ship can be done in the form of a ship survey or inspection. The survey process that was carried out less effectively resulted in less directed inspection activities on the ships, so that the results of the inspection could not be on target. One method of inspection carried out to obtain inspection results that are right on target is to use a Risk Based Inspection (RBI) method. This method prioritizes the risk assessment of the equipments or parts to direct the inspection activity process. By inspecting 20% of all parts, the risk of failure of the remaining 80% of the share can be mitigated. The application of RBI to Ro-Ro Ships in Bastiong-Sofifi Trip can be carried out from previous inspection data to produce optimum inspection and mitigation procedures. In this study, the RBI was carried out based on the results of the calculation of the risk with the FMEA method. Whereas for inspection and mitigation procedures carried out based on the results of the analysis using the FTA method.

## 1 INTRODUCTION

Cruise lines from Bastiong-Sofifi often experience bad weather. Bastiong Harbor is a port located on Ternate Island, while Sofifi port is a port located on Halmahera Island. This cruise connects Ternate Island and Halmahera Island. But lately BPPD North Maluku reported that often occur in bad weather in the shipping channel, so the potential event of an emergency (BBC, 2018).

Accidents on North Maluku waters occur twice according to emaritim.com in 2017. One of them is the speedboat that goes to Ternate, which fires in January. Then in November 2017 KM Karya Indah, departing from Bacal Bacan Harbor, the destination of Bastiong Harbor, Ternate, crashed into Kasiruta Island in the waters of Tanjung Berek, West Bacan, South Halmahera, North Maluku (Emaritim, 2017). this incident needs to be examined for internal and external causes.

Based on the events that occurred in the north Maluku shipping channel, this ship accident occurred on traditional ships and conventional ships. Although it has adjusted the regulations issued by the government and the classification bureau, vessel accidents can still occur due to conditions that are not predictable. Ship accidents that result in sinking ships and falling casualties are the biggest risks that must be avoided by ship operators.

Periodic condition checking is one of the mitigations of ship accidents by ensuring that the condition of the ship is feasible for operational activities. Checking the condition of the ship can be done in the form of a ship survey or inspection. Inspection is checking the condition of the ship as a whole and in detail on the condition of the ship.

One method of inspection carried out to obtain inspection results that are right on target is to use a Risk Based Inspection (RBI) method. This method puts forward the risk assessment that exists in the equipment or part to direct the inspection activity process. By inspecting 20% of all parts, the risk of failure of the remaining 80% of the part can be mitigated (Drozyner et.al., 2012). Therefore, a study of ro-ro ferry inspection on bastiong-sofifi routes in northern Maluku waters with a risk-based method needs to be carried out.

RBI offers a more focused and targeted approach to inspection rather than constants. Although it requires more effort to achieve this 'focus', the RBI assessment applied to the 'design circle' can first see areas that can be redesigned, thus creating a more reliable unit with fewer checks and interventions during the operational phase. The benefit of the initial effort is that some checks may be done less frequently, reducing downtime and possible shutdowns (Llyod's Register, 2017). RBI can be done by combining the FMEA method (to obtain the



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value and level of risk) with the FTA method (to detect the cause of failure) (Peeters, et.al., 2017).

# 2 RESEARCH DESCRIPTION

The purpose of this paper is to determine the potential for frequent operational failures, risk values, and causes of failure on the Ro-Ro Ferry Ship on the Bastiong-Sofifi route so that the results can later be used as a reference in risk-based inspection and the making of mitigation procedures.

This research was carried out with the following procedures:

## 2.1 Literature Study

Literature study is done to find sources relevant to the topic of Risk Based Inspection on Ships. The RBI in this case study was carried out with an FMEA and FTA approach, so literature is also needed. Literature is obtained from papers, journals, previous research, opinions of experts, the internet and others.

## 2.2 Data Collection and Inspection Data Screening

Data was collected by the inspection data collection ro-ro ships operating in the shipping lanes Bastiong-Sofifi. The inspection data obtained an overall data checks the parts of the ship in each month during the period July 2017-June 2018.

## 2.3 Clustering of Mode of Failure

Clustering of inspection results is done by screening and grouping data. This data grouping is done based on the failure mode that occurs.

## 2.4 Risk Identification and Assessment

This identification and assessment is in accordance with the Failure Modes and Effects Analysis (FMEA) method. Risk identification and assessment is carried out based on the value of the probability, consequences and effectiveness of failure prevention. The probability value is obtained based on the inspection results of the ro-ro ship on the Bastiong-Sofifi shipping line. The assessment of the consequences and effectiveness of prevention is based on expert judgment (IMCA, 2002).

After the assessment, a calculation and creation of a risk values is carried out, whichever mode of failure can be mapped which has the highest risk level.

## 2.5 Identification of Causes of Failure

Identification of causes of failure is done in failure modes that have the highest risk level. This identification uses the FTA method. The results of the identification of the causes of this failure can be used as a reference in carrying out inspections, mitigation, and prevention of subsequent failures.

# 3 RESULTS AND DISCUSSION

The Ro-Ro Ferry Vessels that often sail on the airport-sized routes are between 000 GT to 111 GT. In this study using inspection data from one of the ships with the following main dimensions LOA 45.5 m, LBP 40.21 m, B 12 m, H 3.2 m, T 2.75 m with an average speed of 9 knots.

Inspection data used is inspection data for 1 year on the measured vessel for risk analysts.

## 3.1 Screening Phase

The result of this phase is the initial identification of all inspection data on ships sailing on the Bastiong-Sofifi route.

The purpose of the screening phase is to identify any changes that have occurred and check whether the previous risk assessment basis reflects operational and technical conditions (DNV, 2016).

Stages in the screening phase are:

- Review of previous risk assessments
- Categorize changes that occur
- Perform analysis on changes occurring by identifying how much influence the changes to the operating system, then calculate the level of risk.

From the screening phase, there were several locations that experienced the most changes, namely in the construction section.

## 3.2 Risk Identification and Assessment

Failure identification and risk assessment using the FMEA method. In the previous procedure general identification of all inspection data was carried out. At this stage the FMEA method is carried out through several stages (OpenAIS, 2015):

- Identify the potential and effects of failure on components
- Identify the control process from the owner/ company
- Determine the rank of the occurance, Severity, and Detectability using RPN (Risk Priority Number)

The following is the result of identifying the greatest damage that occurs most often and based on the results of periodic inspections and their impacts based on the assessment of the user / expert judgement.

### 3.2.1 Construction of the Steering Wheel

In the steering room there are plate construction and reinforcement. In this ship, corrosion is often found in the plate and its construction as shown in Figure 1.

Figure 1: Plate and construction on steering room.

Based on data from periodic inspections, in the steering room there is often a puddle from the seepage of the steering shaft. If this corrosion continues to occur it can have an impact on the thinning of the plate and result in a hull in the hull of the steering wheel. Prevention that has been carried out is by draining the steering room if the puddle is high enough.

### 3.2.2 Side Plate and Side Stringer Hull

Corrosion occurs in the reinforcement and outer plates on the side hull. In Fig 2 it can be seen that the ship is experiencing corrosion on the side of the hull and its reinforcement. Corrosion of the hulls (inside) occurs due to seepage of water and air from the outside. This seepage can occur because of a crack on the side hull (Figure 2a).

Figure 2: (a) side hull (b) side stringer hull.

Crack on the side hull can occur due to corrosion that forms naturally due to interaction with the environment (sea water and air). If no countermeasures are taken, there can be a leak on the side hull of the ship.

### 3.2.3 Main Deck Plate

The next part of the vessel that has the potential to fail is the plate and main deck construction as shown in Figure 3. Corrosion in part is due to the lack of care and there are indications there is a crack that sea water and air can seep in until corrosion occurs on the inner stiffener.

Figure 3: Main deck plate.

Corrosion in this section results in the thinness of the main deck plate so that there is a possibility of a break due to the inability of the structure to withstand load loads.

### 3.2.4 Plates and Hinges on Rampdoor

Rampdoor is a very important part of the ferry ro-ro vessel because the rampdoor is an access for loading and unloading vehicles. Shows that corrosion also occurs in the construction part of the rampdoor and its hinges.

Figure 2: Plate and hinges on rampdoor.

Unmanageable corrosion can result in thinning of plates on the rampdoor, and also the reduced strength of the support on the rampdoor. This will disrupt the operation because the hinges are broken and the rampdoor can be separated from the original position, so that it can disrupt the process of loading and unloading the vehicle.

## 3.3 Risk Rating Determination

Determination of risk levels is done by calculating event probability, impact score, and detectability score (IMCA, 2002; OpenAIS, 2015). The probability of occurrence is obtained from the input data every month for one year. Then the impact and detectability scores were obtained from the results of the questionnaire and interview user expert (expert judgment).

In this paper the risk assessment uses the FMEA method FMEA is a simple method that is easy to implement, can be used to improve the quality of products and processes. This method focuses on additional consequences and protection to reduce the impact of failure.

The assessment in the FMEA method uses a RPN (Risk Priority Number) where this RPN is a multiplication of the probability of occurrence, the value of the impact / consequence, and the value of the detection carried out.

$$RPN = (S) \times (D) \times (O) \qquad (1)$$

Occurance (O) is an estimate of the probability or chance that a cause will occur and produce a failure mode that causes certain consequences.

Severity (S) is a subjective estimate or estimation of how bad the end user will feel the consequences of that failure.

Detectibility (D) is a subjective estimate of how effectiveness and prevention or detection methods are.

The RPN value of each potential problem can then be used to compare the causes identified during the analysis. In general, the RPN is between the specified limits, corrective actions can be proposed or done to reduce risk. When using a risk assessment technique, it is very important to remember that the RPN level is relative to a particular analysis (carried out with a set of general rating scales and team analysts that attempt to rank consistently for all causes of problems identified during the analysis). In this paper the rating uses the standard from IMCA (The International Marine Contractors Association – Guidance on FMEAs).

For that reason, an RPN in an analysis can be compared to other RPNs in the same analysis, but can be incomparable to the RPN in one analysis.

Table 1: Calculation of RPN.

| No. | Failure Modes | O | S | D | RPN |
|---|---|---|---|---|---|
| 1 | Side plate hull | 6 | 8 | 7 | 336 |
| 2 | Side plate hull construction | 6 | 8 | 7 | 336 |
| 3 | Plate of steering room | 8 | 8 | 6 | 384 |
| 4 | Constructions of the plate of steering room | 8 | 8 | 6 | 384 |
| 5 | Main deck plate | 6 | 7 | 4 | 168 |
| 6 | Plate and hinges of rampdoor | 7 | 7 | 5 | 245 |
| 7 | Rampdoor construction | 7 | 7 | 5 | 245 |

Table 1 shows that the highest RPN occurred in the Plates and Toners failure modes in the steering room with a total RPN 384. The steering wheel and the enforcement of the steering room are located in the same location (Figure 1) so that each other affects each other. A high enough score for the occurrence of events. This score is obtained from inspection data that has been scaled according to IMCA standard. Detectability has a lower score because there is enough maintenance in this location by way of draining stagnant water. Severity gets a high score because the impact of this failure mode is considered to be large enough that it can threaten passenger safety in the event of a leak.

Other parts that have a large RPN are on the reinforcement and side hull plates. In this section the probability of moderate occurrence is based on the results of the inspection. But for severity is quite high because the failure mode on the side plate of the hull can be fatal, namely a leak that can threaten passenger safety. Preventive measures in the form of checking have often been done but are less effective.

## 3.4 Identification of Causes of Failure

Identify the causes of this failure using the FTA method. Fault Tree Analysis is an analytical tool that graphically translates combinations of errors that cause system failure. This technique is useful for describing and assessing events in the system (Haasl, et.al., 1981). This Fault Tree Analysis method is effective in finding the core of the problem by ensuring that an undesired event or loss caused does not originate at one point of failure. Fault Tree Analysis identifies the relationship between causal factors and is displayed in the form of an error tree involving a simple logic gate.

Identification of the causes of failure was carried out in the two modes of failure with the highest RPN in the Plates and steering wheel constructions as well as on the plates and the side of the hull.

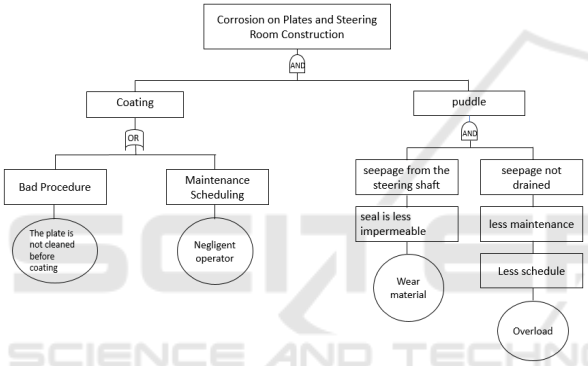


Figure 5: FTA of corrotion of the steering room construction

Figure 5 shows that the cause of the corrosion of the plate and construction in the steering room is the presence of stagnant water and problems with the coating. Stagnant water comes from seepage of water from the steering shaft which is not immediately drained. This water seepage occurs due to the seal of the rudder stock which is less impermeable due to the wear of the material.

Coating problems occur due to bad procedures or there are problems with maintenance scheduling. The bad procedure is that when the plates are being coated, sometimes the operators have not cleaned the remaining dirt on the plate first. While the problem in maintenance scheduling can occur due to negligence of officers who do not do the coating according to the coating schedule.

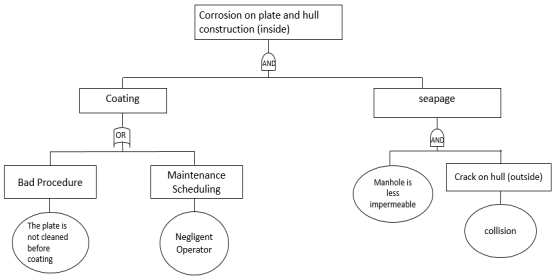


Figure 6: FTA of corrotion of the hull construction

The cause of corrosion in ship side hull construction is water seepage and coating problems (Figure 6). Seepage of water comes from manholes that are not impermeable and crack side hulls. The Crack can occur due to collisions when docked at the port.

# 4 CONCLUSIONS

- Based on FMEA analysis, potential operational failures that often occur on Ro-Ro ferry vessels, especially on Bastiong-Sofifi shipping lines, are corrosion on plates and reinforcement in the steering and side hulls which can have an impact on vessel leakage which can threaten passenger safety. This potential failure is classified as high risk according to the standards of IMCA (The International Marine Contractors Association) in the assessment of the risk.

- Based on FTA analysis, the cause of the potential failure is the presence of water seepage and problems in coatings, as well as problems with maintenance scheduling.
  From these conclusions can be used as a reference for further risk-based inspection, as well as the making of mitigation procedures.

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