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RESEARCH ARTICLE

Analysis of Formal Safety Assessment (FSA) for Ship Accident Risk Assessment: A Case Study of Work Accident MV Mandarin Ocean at Tanjung Priok Main Port

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Abstract: Tanjung Priok Port is one of the busiest loading and unloading ports in Indonesia which serves both export and import activities, causing a risk of accidents that can occur. In order to anticipate these problems, an effort is required to identify and reduce the risk of accidents. This study aims to analyze the MV ship accident case of MV. Mandarin Ocean at the Main Port of Tanjung Priok. Through the implementation of the Formal Safety Assessment (FSA), it is expected that an accurate and scientific analysis will be obtained regarding the hazards that will occur, costs in risk control, and recommendations for overcoming them in the loading and unloading process at Tanjung Priok Port. This study used the Fault Tree Analysis method to find the root causes of accidents to reduce/eliminate the risk of accidents. Based on the research results, it is known that the Implementation of Safety Management System PT. Prima Bandar Samudera is not optimal. Likewise with the Monitoring Supervision of the Implementation of Safety Management carried out by PT. Tanjung Priok Port is also not optimal. Therefore, based on the priority scale on the FSA results, immediate implementation is necessary as a corrective measure to reduce and even prevent various accident cases that occur at the Tanjung Priok Port. This is to achieve the main goal of ship safety management, which is to realize "Zero Accident".

Keywords: Formal Safety Assessment, FSA, Work Accident

1. Introduction

As the largest archipelagic country in the world, Indonesia has more than 17.000 island with 95.181 km long coastline. 2/3 of the country area is marine area (Nata Kusuma et al., 2019). Maritime transportation is a vital element in the life of the nation, fostering the unity and practical of the Indonesian nation as an archipelagic country. Besides, role of marine transportation naturally means as the main inrealizing interconnectivity island in Indonesia (Kim & Kim, 2020; Novikova et al., 2022).

In carrying out a voyage, there is a ship operational procedure that refers to SOLAS-1974, Regulation International about Regulation Prevention Collisions at Sea (P2IL), Standard for Training Certification and Watch Keeping for Seafarer's (STCW), Marine Pollution (Marpol), International Safety Management-Code (ISM-Code) and others that provide guidance and instructions to the crew ship in the operation of the ship for safety, environmental protection,



security and comfort crewman boat, goods, as well as boat to be guaranteed. However, in the implementation of voyages, accidents often occur during sailing. Recorded in data accident from Committee National Safety Transportation (NTSC), which is in an Extraordinary Event (PLH), maritime accidents experience fluctuations of both decrease and increase in each year. Incident that can be categorized as extraordinary incidents are maritime accidents that result in casualties or injury (Nata Kusuma et al., 2019).

With increasing serious attention to ship safety around the world, The International Maritime Organization (IMO) is constantly dealing with safety issue. Improving safety at sea is strongly emphasized, especially in terms of operations, management, surveys, ship registrations, and regulations. International safety related regulations at sea are learned from a serious accident that has already occurred. Then, these rules regulations made to prevent accident that possible happens. As an example, the capsizing of Herald of Free Enterprise in 1987 had a significant impact on the development of regulations by the IMO. The accident raised serious questions about operational requirement and the role of management. Eventually, the International Safety Management (ISM) Code emerged, which addresses the role of management after discussions at the IMO (Purba et al., 2019).

After the publication of the investigation report on the capsizing of the Herald of Free Enterprise in 1992, the UK Maritime and Coastguard Agency (formerly known as the Marine Safety Agency or MSA) quickly responded and proposed to the IMO in 1993 that Formal Safety Assessment (FSA) should be applied to ships. This aims to ensure safety strategies and efforts to prevent potential pollution. UK MCAs also proposed to IMO to explore FSA concepts and implement it in operation and design boat. Since at that time, large jobs (including applications on fast ferries catamarans and bulk carriers) has held by UK MCAs. Generally, in a recent year, final FSA application has growing significantly (Browne et al., 2021; Iswadi et al., 2022; Nata Kusuma et al., 2019).

Utilization of the FSA application in assessing the risk of ship accidents is also carried out for the assessment of ship accidents that occurred in the port area. Harbor according to Government Regulation of the Republic of Indonesia Number 69 of 2001 concerning port is a place that consists of land and waters in surrounding area with certain boundaries as a place for government activities and activity economy used as place boat lean, anchored, passengers embarkation and/or cargo handling equipped with maritime safety facilities and port supporting activities, as well as serving as a transfer point for intra and inter-modal transportation (Aryarajendra Suprpto & Fauziah, 2020; Lee et al., 2001).

The loading and unloading process at container ports is carried out using lifting equipment, namely *cranes*. According to Regulation Minister of Manpower and Transmigration of the Republic of Indonesia No.Per.05/MEN/1985 concerning lifting and transporting equipment, which refers to devices specifically designed or constructed for raising and lowering cargo. Auxiliary equipment, such as rubber-tyred gantry cranes (RTG), container cranes, and trucks are used to expedite the work (Lilian Enggal Ekasari, 2017).

Accidents often occur in ports during ship loading and unloading activities. According to a study on accidents in 95 countries occurring at ports, 56,6% are caused by cargo transportation and 14,9% are attributed to port loading and unloading operations. Additionally, according to the International Maritime Organization (IMO), the percentage of accidents caused by human error is 43.06%, natural factors account for 33.57%, and technical factors with 23,35% of all marine accidents.

Main Port of Tanjung Priok is the biggest ports in Indonesia which serves as a barometer of the national economy with 50% of the flow of goods, and 30% of national non-oil and gas cargo flows through this port in each year. Currently, the Main Port of Tanjung Priok is one of the ports that own level density and the highest cross boat in Indonesia. The desired condition for maritime safety is to achieve zero accidents, but in reality, this has not been fully realized at the Port of Tanjung Priok. The number of work accidents that occurred from 2017 to 2021 will be explained below (Hu et al., 2007; Puisa et al., 2021):

One of the accident cases during loading and unloading activities ships at the Main Port of Tanjung Priok recently occurred on 9 January, 2022 in Terminate Multipurpose on moment loading *Phywood* on MV Mandarin Ocean. When carrying out the loading of *Phywood*, wiresling that was on the MV Mandarin Ocean V boat broke and hit the two workers and cause casualties.

With this incident, of course the shipping safety efforts are carried out with the motto *zero accident* becomes disruptive and needs to be done immediately analysis of Formal Safety Assessment (FSA). Through the FSA method, it can give solution which expected to minimize accident as small as possible and even lost. By conducting Formal safety Assessment (FSA), a precise and in-depth analysis of potential danger, the cost of risk control, and recommendation for management of the Main Port of Tanjung Priok will be obtained to address them (Trucco et al., 2008; Zhang et al., 2013).

2. Literature Review

2.1. Risk Concept

Risk in the context of engineering is generally defined as something that produces consequence and opportunity of an incident. Consequences are simply changed in the form of quantity and can also be very subjective. In general, the risk is a measure of the opportunities of various consequence variation (Svein Kristiansen, 2005).

The risks resulting from accidents can lead to death and disability. The risk of death from accidents can affect individuals or groups, resulting in fatal incidents with multiple fatalities. The risk of disability is also divided into two categories: permanent disability and temporary disability caused by accidents (Lee et al., 2001; Zaman et al., 2015).

Similar approaches can be used for environmental risks associated with damage to assets. There are many alternative measures provided for consequences. In reality, there are many actors involved in safety efforts, which can be used as different statistical measures. For example, safety managers generally rely on safety experience levels, and during risk analysis, there is a significant concern about estimating/predicting risks and safety (Artaba, 2007).

2.2. Risk Management

Risk management is an activity carried out to identify, analyze, and control potential risks in an activity or project to achieve higher effectiveness and efficiency (Drmawi, 2022). In construction projects, it is very difficult to avoid risk, which is why risk management is necessary, as it significantly influences project activities. When risk management in a project is well-handled, the activities will proceed smoothly without obstructions caused by risk ("Polit. Manag. Publics," 2020).

The stages of risk management must be carried out comprehensively and are integrated part of the process management.

2.3. Formal Safety Assessment

Formal Safety Assessment (FSA) is a methodology or process that rational, structured and systematic way to assess the risks associated with activity in the field of maritime (cruise), as well as for evaluating cost and benefits of several risk control options using risk analysis and cost benefits assessment (International maritime Organization, 2004). FSA aims to reduce risk and improve shipping safety (marine safety includes protection to life, health, marine environment, and property rights (IMO, 2015).

With the Formal Safety Assessment (FSA) method, a precise and in-depth analysis of potential risks, the cost of risk control, and recommendations to address them in accordance with IMO regulations can be obtained. The FSA process begins with problem definition, followed by five process steps, and concludes with the presentation of the process results (Lee et al., 2001; Trucco et al., 2008)

The purpose of problem definition is to accurately describe the issue based on analyses related to the regulations under review or development. Problem definition should align with operational experience and applicable requirements, considering all relevant aspects (Agus Selamat Prabowo et al., 2022; Zaman et al., 2015).

Aspects that can be considered relevant for the review of a ship are as follows:

- a. Vessel category (for example, type, GT length or range, new or old, type payload);
- b. System or function boat (for example, layout, subdivision, propulsion type);
- c. Boat operation (for example operation in harbor and/or during voyages);
- d. External influence on boat (for example, system traffic boat, weather, report, routes);
- e. Categories of accidents (for example crash, explosion, fire); and
- f. Risk connected with consequence (such as injuries/losses and/or fatalities on passenger and crew, environmental impact, damage on boat or facility harbor, or impact on trade).

Meanwhile, FSA consists of five steps that must be carried out sequentially:

a) Danger Identification (hazard identification)

Hazard identification is a list of all relevant accident scenarios with potential causes and consequences, in response to the question 'what errors might occur?' The purpose of step 1 is to identify a list of hazards and a set of scenarios, prioritized based on the level of risk related to the issue being addressed. This objective can be achieved by using standard techniques to identify hazards that contribute to accidents, filtering these hazards through a combination of available data and opinions, and reviewing the general model established during the problem definition.

b) Risk Assessment

Risk assessment form evaluation to factors risk, as answer from question "how severe and how likely is it to happen?".

Objective from risk analysis in step 2 is to:

- a. Investigate in detail the causes and consequences of scenario that has identified in step 1; as well as
- b. Identify and evaluate factors influencing the level risk.

c) Risk Control Options (RCOs)

Risk Control Options (RCOs) refers to devising regulatory measures to control and reduce identified risk, in response to the question "can the occurring errors be revised?"

The aim of step 3 is to propose effective and practice RCOs through four principles steps as follows:

- a. Focus on risk that require control, to filter the outputs from the step 2, thereby narrowing down to areas that most require risk management;
- b. Identify actions to control potential risks (risk control measures = RCMs);
- c. Evaluate the effectiveness of RCMs in reducing risk by re-evaluate step 2;
- d. Grouping RCMs into practical options.

d) Cost Benefit Assessment

Involves determining the economic usefulness (cost-effectiveness) of each risk control option in response to the question 'what losses will be incurred, and how much cost is required to address them?'

The purpose of step 4 is to identify and compare benefit and cost from implementation each RCOs identified in step 3.

e) Decision-Making Recommendations

Consists of providing information about hazards, risk implications, and the cost-effectiveness of alternative risk control options as an answer to the question 'what actions should be taken?'

The objective of step 5 is to define recommendations to decision-makers in an auditable and traceable manner. Recommendations are based on:

- a. Comparing and ranking the levels of all hazards and their causes;
- b. Comparing and ranking the levels of risk control options as a function of cost-benefit combinations; and
- c. Identifying risk control options that keep risks as low as reasonably practicable to implement.

Recommendations should be presented in a format understandable by all parties, regardless of their experience. Delivering recommendations as a result of the FSA process should be timely and have access to relevant supporting documents, with a mechanism for including comments.

3. Research Method and Materials

The analytical study was carried out using the Formal Safety Assessment (FSA) as a methodology systematic adopted by IMO (International maritime organization) in identify, analyze, control risk, count cost, and benefit to establish the steps.

4. Results and Discussion

Initial Data

Ship Name	: MV Mandarin Ocean V (Berbeberda Singapura)
PBM Name	: PT. Prima Bandar Samudera
Name Terminate Operator	: PT. Pelabuhan Tanjung Priok
Name of Victims	: Ahmad Fitry, Manager operational PBM, Anang Joni, PBM Ship Foreman
Amount of Workers	: 2 Gangs/24 people
Amount of PBM Officer	: 8 persons consists of: 4 persons of Foreman Boat 2 persons of Foreman Kade 1 person of Equipment Division 1 person of Man operational

Estimation of Weight Load transported on incident: 6 box Plywood @ 0,9 tons (Total 5,4 tons)

4.1. Hazard identification

Hazard identification is the process used to identify all possible situations in which a person may be injured, sick or disease, type danger that possible occur and how method to organize/manage that danger.

Identification was done by the methods of inspection, observation, interviews and document evaluation as follows:

- a. The MV Mandarin Ocean ship was inspected by the Port State Control
- b. PT Prima Bandar Samudera as a loading and unloading company and PT Tanjung Priok conducted interview to management and related personnel, as well as research on data and documents related and research were conducted on data and documents related to the loading activities of MV Mandarin Ocean, equipment used, documentation, and documents related to the safety management system in place.

The results of hazard identification are explained in Table 1 below as follows:

Table 1. Screening Result of the Identified Hazards

NO	ID	Levels	HAZARDS (<i>UNSAFE ACT & UNSAFE CONDITION</i>)
1	1.1.1	7	The ship does not implement good International Safety Management (ISM) code
2	1.1.2	5	Supervision to amount and qualification of TKBM and PBM worked has not optimal
3	2.1.1	6	Not yet optimal patrol safety conducted by terminal operator
4	2.1.2	4	Lack of <i>Briefing/Safety Induction</i> before work execution by PBM personnel
5	3.1.1	8	PBM uses <i>wire slings</i> that do not have a <i>Safe document Working Load (SWL)</i>
6	3.1.2	8	<i>The Unsafe Act</i> performed by PBM personnel by standing under the lifted cargo
7	4.1.1	5	PBM did not report detailed quantify/qualification and related personnel of PBM
8	4.1.2	8	Non-mechanical equipment maintenance by PBM is not optimal (noprovable)
9	4.1.3	5	PBM did not report details of non-mechanical equipment used
10	4.1.4	7	No periodic inspection of non-mechanical equipment conditions during activities
11	5.1.1	8	Crane operator's competence cannot be proven

Source: *Data Investigation and Analysis Incident 2021*

To facilitate the categorization of risks, all identified risks are ranked. In the risk matrix table, risks at levels 8-10 are classified as Intolerable, requiring serious attention; levels 5-7 are categorized as ALARP (As Low As Reasonably Possible), still within acceptable tolerance; and levels 2-4 fall under the Negligible category, which can be disregarded. Based on the data processing during the risk identification stage, the following results are obtained:

- 4 risks are at level 8 with IDs 3.1.1, 3.1.2, 4.1.2, and 5.1.1, classified as Intolerable, requiring serious attention.
- 2 risks are at level 7 with IDs 1.1.1, 5.1.1, and 4.1.4, categorized as ALARP or within acceptable tolerance.
- 1 risk is at level 6 with ID 12.1.1, classified as ALARP.
- 2 risks are at level 5 with IDs 1.1.2 and 4.1.1, categorized as ALARP.
- 1 risk is at level 4 with ID 2.1.2, considered Negligible or can be disregarded.

4.2. Risk Analysis

The purpose of risk analysis in the second stage of FSA is to provide detailed or clarified causes and consequences of the hazard scenarios identified in stage 1 (Identification of hazards). This can be achieved by applying appropriate methods or techniques to model the risk itself, allowing a focus on areas with high risks to identify and evaluate factors influencing the level of risk.

Risk assessment is a combination of the likelihood of events related to severe injuries ($R = L \times S$), as explained in the table of likelihood and impact of risks below:

Table 2. Possibility and Impact Risk

LIKELIHOOD/ POS SIBLE	LEVELS	RISK EXPOSURE	SEVERITY/ IMP ACT	LEVELS	EXPOSURE RISK
	5	ALMOST CERTAIN		5	CATHROSTOPIC
	4	VERY FREQUENT		4	BIG
	3	FREQUENT		3	MODERATE
	2	OCCASIONAL		2	SMALL
1	RARE	1	INSIGNIFICANT		
RISK		POSSIBILITY	IMPACT	RISK VALUE	
WORK ACCIDENT		5	5	25	

4.3. Risk Control Options

The purpose of the third stage of the FSA is to consider controls risk from a hazard that has been identified with several options. Control risks associated with human interaction with the same approach method, such as steps development to control other risks.

To propose Risk Control Measures (RCM) which is effective and practical identified from the information generated by the risk assessment, then obtained risk control hierarchy in the case of the MV Mandarin Ocean incident as following:



Figure 3. Hierarchies Control Risk

The data on Risk Control Measures (RCM) for the incident involving MV Mandarin Ocean at the Main Port of Tanjung Priok are explained in Table 3 as follows:

Table 3. Possibility and Risk Impact

No	Type Control	Description Control (Risk Control Measures)	Guarantee Answer
1	Substitution	Replacement of non-mechanical equipment that is not fit for use	PT. Prima Bandar Samudera
2	Engineering Control	Use of technology-based non-mechanical equipment Optimization of non-mechanical equipment maintenance	PT. Prima Bandar Samudera PT. Prima Bandar Samudera
3	Administrative Control	Optimization safety Patrol Improvement of SOP/Business Process Issuance of Operational Work Plan related to better supervision of TKBM and non-mechanical equipment used Audits of MV. MANDARIN OCEAN ISM Boat Audit of Safety Management System PT. PRIMA BANDAR SAMUDERA Safety training for employees Development of Safety Check List (before, during, and after cargo operation) Evaluation/Optimization implementation CSMS	PT. Pelabuhan Tanjung Priok, O.P., KSU PT. Pelabuhan Tanjung Priok, OP., KSU Owner Boat of classes, flags state PT. Prima Bandar Samudera, PT. Pelabuhan Tanjung Priok, O.P.,KSU PT. Prima Bandar Samudera, TKBM PT. Pelabuhan Tanjung Priok, O.P.,KSU PT. Pelabuhan Tanjung Priok

Source: FSA Analysis

4.4. Cost Benefit Analysis

This stage is intended to identify the benefits of risk reduction and costs based on the implementation of each risk control option for comparison. To conduct *cost-benefits assessment*, a set of base cases is required so that it can be used.

As for data score cost and benefit are presented on Table 4 and Table 5 as follows:

Table 4. Descriptive Score cost and Benefits

No	Cost Predictions	Score
1	Very High	1
2	High	2
3	Intermediate	3
4	Low	4
5	Very Low	5

No	Benefits	Score
1	Great	5
2	Big	4
3	Intermediate	3
4	Small	2
5	Very Small	1

Table 5. Cost and Benefits Assessment

No	Solution	Cost Predictions	Benefits
1	Replacement of non-mechanical equipment that is not fit for use	Low (4)	Big (4)
2	Utilization of technology-based non-mechanical equipment	High (2)	Intermediate (3)
3	Optimization of non-mechanical equipment	Low (4)	Big (4)
4	Optimization of Safety Patrol	Low (4)	Big (4)
5	Improvement of SOP/PORSES business processes for issuing operational work plans related to better supervision of TKBM and non-mechanical equipment used	Intermediate (3)	Big (4)
6	Audits of MV. Mandarin Ocean ISM Boat	Intermediate (3)	Big (4)
7	Audits safety Management System of PT. Prima Bandar Samudera	Intermediate (3)	Big (4)
8	Training safety for employees	Intermediate (3)	Big (4)
9	Preparation of safety Check List (before, during, and after cargo operations)	Low (4)	Big (4)
10	Evaluation and optimization of CSMS implementation	Intermediate (3)	Big (4)

4.5. Recommendations for Decision Making

This step leads to decision-making and provides recommendations for safety improvement. The information generated can be used to assist in making cost-effective choices and selecting the best options in risk control. The results of this stage are:

- 1) An objective comparison of alternative options based on potential risk reduction and cost-effectiveness, in accordance with existing laws or regulations under review or development.
- 2) Feedback information for reviewing the results provided in the steps step previously.

The recommendations for decision-making involve prioritizing the recommended risk control measures by combining cost-effectiveness and benefits in risk reduction.

Based on the steps taken, the Recommendations for Decision Making regarding the incident involving MV Mandarin Ocean at the Main Port of Tanjung Priok are explained in Table 6 below:

Table 6. Recommendations for Decision Making

No	Solution	Cost(C)	Benefits(B)	C X B	Priority
1	Replacement of non-mechanical equipment that is not feasible to use. mechanical ones No worthy use	4	4	16	VeryHigh
2	Development of Safety Check List (before, during, and after cargo operation)	4	4	16	VeryHigh
3	Optimization of non-mechanical equipment maintenance	4	4	16	VeryHigh
4	Optimization of Safety Patrol	4	4	16	VeryHigh
5	Improvement of SOP/Business processes for issuing operational work plans related to better supervision of TKBM and non-mechanical equipment used	3	4	12	High
6	Audit of ISM for MV Mandarin Ocean	3	4	12	High
7	Audit of Safety Management System for PT. Prima Bandar Samudera	3	4	12	High
8	Safety training for employees	3	4	12	High
9	Evaluation and optimization of CSMS implementation	3	4	12	High
10	Utilization of technology-based non-mechanical equipment	2	3	6	Intermediate

Source: Analysis FSA

5. Conclusion

Based on the Formal Safety Assessment (FSA) analysis conducted on the incident of the MV Mandarin Ocean at the Main Port of Tanjung Priok, the following conclusions can be drawn regarding the work accident of the MV Mandarin Ocean that the implementation and the monitoring and supervision of the Safety Management System by PT. Prima Bandar Samudera are not optimal.

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