CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

"Shipping is perhaps the most international of the world's great industries and one of the most dangerous" (International Maritime Organization/IMO, 2002). Globally, statistics reflect the same fiscal importance of this industry for instance there are around 50,000 merchant ships trading internationally, transporting a range of cargoes. The world shipping fleet is registered in over 150 nations, and manned by over one million seafarers (BIMCO, et al., 2004). The shipping industry has a fairly good safety record, however, maritime incidents have a high potential for catastrophes. Merchant shipping is known to be an occupation with a high rate of fatal injuries caused by organizational accidents and maritime disasters (Hansen, et al., 2002). Common incidents such as collision, allisions, and groundings specifically have decreased and that is attributed to enhanced technology in aids to navigation. The UK Marine Accident Investigation Branch (MAIB) states that "one factor still dominates the majority of maritime accidents is human error" (MAIB, 2000). The most common human factors causes were error of judgment and improper lookout or watch keeping, followed by failure to comply with regulations. The "human element" as it is often termed in the shipping literature (O'Neil, 2003) has frequently been cited as a cause of those costly incidents. A United States Cost Guard (USCG) report states that between 75-96% of marine casualties are caused at least in part by some form of human error (Rothblum, 2000).

The maritime transportation affects most of goods and passengers movement among islands in an archipelago country, Indonesia. As the result, the reliability of maritime transportation to link among islands will impact the development of the country especially in the frame of economic sector. The maritime transportation could be divided into two categories which are sea transportation and crossing transportation. The crossing transportation bridges between places as the continuation of road or railway by crossing the straits. The ship operation system contains complex interrelation among technical factor, environment factor as well as human factor that control the ship handling process. One important idea for careful consideration is ship handling.

Ship handling is defined as the practice of guiding a ship which controls ship movement through ship controllability means, visual monitoring means and instrumental monitoring. Therefore, ship navigation operation and ship maneuvering are the integrated part of the ship handling. Successful ship handling will reduce accident from happening. In other word, if there is a problem with ship handling process such as the difficulty of controlling ship behaviour, it might lead to accident. It could be generalized that ship handling difficulty is potentially directed toward ship accident (Inoue, 1998).

2.2 SHIP ACCIDENTS IN INDONESIA

Indonesia is the maritime area that has a unique-features in terms of its transport system, especially the technical and economic aspects, that should be examined more deeply because the age of the current fleet are mostly old. This can cause damage that is not entirely unexpected and it may also affect safety of other ships.

From the report of Trend Analysis of Sea Accident by PT . Trans Asia Konsultan in year 2009 , it states that the vessel must meet the requirements of the materials, the construction of buildings, machinery, and the electrification, governance, stability and structure of radio equipment/ship's electronics, accredited by a certificate, that is obviously required after inspection and testing.Vessels whose condition is excellent, and in accordance with the legal provisions, and declared fit to sail, would be safe to take people and goods, otherwise the ship which is questionable in the condition is likely to find resistance from maritime transport authority. If the ship is damaged during the trip, it will require additional costs, such as the costs due todelay. This is certainly not an easything to maintain. The state of the vessel which complies with the requirements and safety, the prevention of pollution, control of cargo, the health and well-being of the crew, all of these require additional capital. In addition, companies in business of cruise ships also require full cooperation and assistance of the shipyards, while the current conditions of the shipyards are mired with lethargy. Therefore, the Government has a rule to play in devising desirable policy, particularly on the aspects of capital and the creation of a favourable business climate, so that transport and shipbuilding company implement rehabilitation, replacement and expansion of the current fleet.

Accidents occurring in sea, rivers, lakes, and crossing that reached Marine Court in 2003-2010 was mostly due to human error which was 65%,and only a few accidents in the waters are caused by natural factors (Danny and Shariman, 201). Given the reasons mentioned above, all accidents can be minimized if prevention efforts are seriously performed by all parties so as not to stumble on the same stone. Water transport accidents occur mainly due to overcrowding and navigation system, which is characterized by a large number of passengers and goods compared to the draft Commission. For passengers who do not have the expertise and skills in emergency situations, it is important to note that users of the waterway belong in the category of vulnerable population groups. Efforts to ensure the safety of passengers and crew must be considered as a serious issue, including trivial security equipment such as buoys. Current conditions, many ships that do not have safety equipment where they should be able to buoy passengers and crew when the vessel having accident. Most of the accidents occur due to the low awareness on the aspects of security and safety of the crew. Figures differ from the manifest of passengers and number of passengers on the ground become common place. Transportation is the lifeblood of society and the economy in Indonesia. Transportation development activities in Indonesia are out of various dimensions (marine transport and others) and keep on increasing. This is the impact of economic and socio-cultural activities and community. In addition, the process of regulatory reform in the field of national transportation deregulation has also triggered an increase in transport activity. To understand fully that human consciousness towards the preservation of the environment is increasingly high, the sea transportation accidents which can cause damage to the environment (pollution) should be a significant considered. In order to further integrate transport infrastructure and facilities that meet the requirements of security and safety of transport, it is necessary to make a standardization of regulation system and procedures, as well as human resource professionals to realize the service organization of the transport and works in order to hold everything intact. Then it is also necessary to have a system of good governance, where Governments have function in the transportation services which include coaching in the aspects of setting up, monitoring and controlling the system (PT. Trans Asia Konsultan, 2009).

2.3 CHARACTERISTIC OF SEA TRANSPORTATION ACCIDENT

The ship is major means of sea transport, where many people rely on it for their sustenance. Each time the safety of human lifestaes is threatened, both the sailors and the people on board are affected. From the facts and the data obtained, the sea had swallowed many accident victims and property which were not small in size. Ship accidents can happen to anyone at anytime and anywhere. For that reason, the crew and passengers need to know about ways to escape if there is an accident happening including on board first aid and fire safety responsibilities. There is urgent need for training of the crew, especially in the areas of safety as well as rescue techniques, as required by the Convention of the International Maritime Organization (IMO) and the State Governments concerned. Many of the accidents victim at sea are caused by a lack of basic security knowledge and protection of the environment. According to the IMO, numerous deaths occurred at sea were caused by the human factor.

Table 2.1 indicates the characteristic of sea transportation accident. In general, characteristics of accidents are:

a) an accident as a rare occurrence;

b) an event that accidents that we do not know when to expect;

c) accidents as those events Multiple Factors.

Table 2.1: Characteristic Sea Transportation Accident

	Accident Typical	Object
WHAT	Accident Type and Safety Indicator: Accident type: sink, collision, grounded, fired	Ship, Tug Boat, Tanker, Barge
WHY	Cause of accident: - Human factor: • Carelessness in the conduct of the vessel. • Inability of the crew in mastering a variety of problems that may arise in the operation of ships' • Consciously loading ships in excess	Captain, Crew Port Inspection Officer, Passenger
	- Technical factor: o Lack of carefulness in ship design o Neglect of care resulting in damage to the ship or ship parts which can cause an accident or a burning ship	Ship Owner, Marine Inspector, Dockyard, Supplier
	- Natural Factor: Bad weather factors, the storm, the high waves height affected by the storm, the current season resulting in the fog that limits visibility.	Cruise Lines, Ports, BMKG Information
WHO	The Crash and crash victim: a. Ships involved accidents b. Gender (male, female) c. Age	Captain, Crew, Passenger
WHERE	Accident location	Cruise Lines, Ports, Harbour
WHEN	Accident Time: a. Hours of accident b. Date of accident	Ship, Captain, Passenger
HOW	Chronological Events: a. Ship movements b. Ship condition	Ship

Source: PT. Trans Asia Konsultan (2009)

2.3.1 Regulation and Law about Ship Accident

Principles of safety transport has become attention to the Government for long time, such as the policy, established in 1999 Presidential Decree number 105 in year of 1999 on the establishment of the Komite Nasional Keselamatan Transportasi (KNKT) or National Transportation Safety Committee (NTSC).

Government Regulation No. 1 year of 1998 concerning the examination of the ship accident are split into five examination categories, namely:

1) Sinking ship;
2) Ship fired;
3) Ship collision;
4) Ship accidents which cause the loss of human lives, wildlife and property;
5) Ship was run a ground or crashed out.

Examination of the ship accident consists of a preliminary examination by Syahbandar (Harbour Master) and advanced examination by The Marine Court (Mahkamah Pelayaran). Whereas the Legislation of the Republic of Indonesia number 17 year of 2008 about the shipping/ cruise Article 245 states that: Accidents aboard the events experienced by the vessel that may threaten the safety of the ship and/or the human spirit in the form of:

1) Sinking ship;
2) Ship fired;
3) Ship collision;
4) Ship was run aground or crashed out.

Later, in the Article 256 about the investigation of the ship accident is stated that:

1) The Accident Investigation Board conducted by the National Transportation Safety Committee is to search for facts in order to prevent the occurrence of the ship accident with the same causes;
2) Investigation as referred to subsection (1) is made against each ship accident;
3) Investigations conducted by the National Transportation Safety Committee referred to subsection (1) is not to determine which errors or omissions on the occurrence of the ship accident.

To minimize the occurrence of sea accidents, top priority is to rescue the soul in order to satisfy all the rules by the standards and even more to ensure the safety at sea, which requires a support from around the world. There are three organizations that govern the safety of the ship, International Maritime Organization (IMO), International Labour Organization (ILO) and International Telecommunication Union (ITU). Indonesia is one of the three members of the organization and has ratified the convention. To ensure safety at sea, it is required for a standard (the rules) which applies nationally and internationally, which are:

a) National Standard includes:

1) The Legislation of the Republic of Indonesia Act No. 17 year of 2008 about a shipping/cruise that is spelled out in the regulation of the Government and the Minister's decision and the regulation;

2) The Legislation of the Republic of Indonesia Act No. 3 year of 1989 replacement Act No. 5year of 1964 about the Telecommunications that comes with PP No. 10 of 1974 on Public Telecommunications;

3) Government Regulation No. 7 year of 2000 about seamanship that arranges regulation about competence, expertise and skills qualifications for crew and the captain/Master on all ships except sail ship, sail boat with motor, motor boat with a size less than GT 35, private yacht that was used to trade and specialized ships.

b) International Standard includes:

1) Safety of Life at Sea (SOLAS)1974 and the amendment;

2) Marine Pollution (MARPOL) 1973/1978 and the protocols;

3) Load Line Convention 1966;

4) Collision Regulations (COLREGs) 1972;

5) Tonnage Measurement 1966;

6) Standards of Training Certificate and Watch keeping (STCW) 1978 Amendment 1995;

7) International Labour Organization (ILO) No. 147 Year of 1976 about the Minimum Working Standards for Crew Commerce;

8) International Labour Organization (ILO) Convention No. 185 year of 2008 about Seafarers Identification Document (SID) which has been ratified by The Legislation of the Republic of Indonesia law No. 1 year of 2009;

9) Search and Rescue (SAR) Convention;

10) Global Maritime Distress Safety System (GMDSS);

11) International Safety Management (ISM)Code;

12) International Ship and Ports Security (ISPS) Code.

In addition to the conventions mentioned above there is one rule that could not be ommited from the safety of the voyage which set about Radio Communication close relation to the Radio Regulations (RR), Telegraph and Telephone Regulation under the Convention of the International Telecommunication Union (ITU).

2.3.2Causes of Ship Accident

There are many causes of common sea accidents, from PT Trans Asia Konsultan, 2009 :

1) Bad weather;
2) Fires including malicious payload;
3) Ship stability including shift of the cargo;
4) No reserve buoyancy due to excessive charge of cargo;
5) Grounding (stranding);
6) Collision;
7) Imperfect design and the structure;
8) Human negligence;
9) Blow out (offshore oil platform).

Something that has happened in the field of sea transport pertaining to the ship accidents and security threats in the sea/maritime, indicates the existence of weakness to the four devices involved in the world of transport in general, namely hardware, software, a device life (life ware) and devices organization (organization ware). Hence, in order to learnabout why this thing happen, thereare several relevant theoriesneed tobe reviewed.

Van der Schaff (1992) explained that the dangerous situation that lead to accident was the result of the combination of technical, human, and organizational failures. Creating a system of defence, such as automatic safety systems, safety procedures, will prevent these situations from leading to the onset of the incident and make the system return to its normal state. A simple model that describes these can be seen in Figure 2.1:

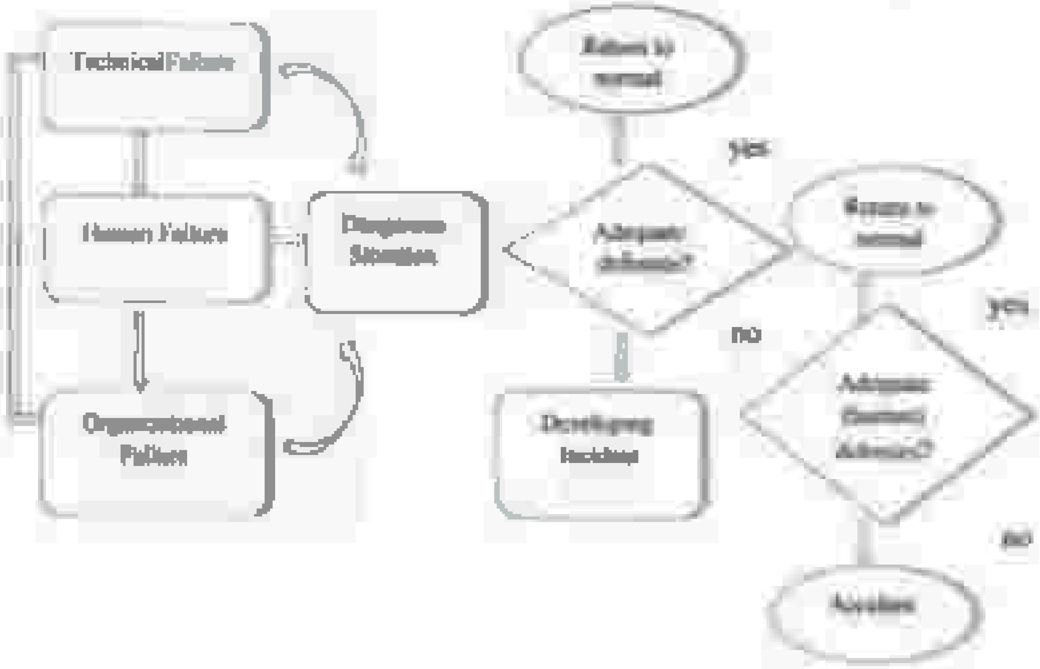

Figure 2.1: A simple Model of Cause of Accident

Source: Van der Schaff (1992)

A simple model of accident causes as formulated above can be differentiated into three categories namely (Figure 2.1):

1) Technical Failure: failure-related or the performance less than optimal on the technical equipment used for the occurrence of the incident, or failure to connect with the physical state where incident occurs;
2) Human Failure: associated with mistakes made as a last defence of the human defence system, as a trigger for the onset of directly related incidents;
3) Organizational Failure: related mistakes were made early defence of the Organization as a system of defences, not directly related to the occurrence of the incident directly but is a trigger that brings other failure leading to the incident.

From year to year, ship accident on Indonesia never decreases. In fact, the cause of the sea accident like repeating the same mistakes of the past, that is never far from the accident caused by bad weather, overloaded, or ships that do not meet the eligibility standards. At least, there are two important reasons of the sea accident in Indonesia. The first, is the condition of the fleet where, the ships transporting coastal is made without the use of certain standards in safety. In addition, many ships in Indonesia were purchased from other countries former fleets. Treatment of these ships is also substandard. Many ships used in Indonesia are usually so old that they are unseaworthy. Furthermore, in its home country, the ships concerned may not actually be used as modes of transportation. The second reason is the operational fleet including, both aspects of the ship and of the charge. This problem occurs because lack of standards supervision procedure. Ship which eventually leads to safety problems or dangerous are charge with excess baggage which is not reported. Bad weather and natural conditions are not the main reason. The Meteorology, Climatology and Geophysics Department always announces the weather conditions forecast. It is the important role of the Harbour Master who has to strictly select which ships are permitted to sail and which ships are to wait for the weather to subside. Those that may be withheld by Harbour Master are specialized ships such as the High Speed Craft/HSC (PT. Trans Asia Konsultan, 2009).

2.4 SAFETY OF THE SHIP

2.4.1 Formal Safety Assessment (FSA) of the Ship

Current models of formal Safety Assessment (FSA) is widely used to analyze accidents at sea where the safety assessment is based on the risk model. FSA was developed by the UK Marine Safety Agency (1992). The FSA concept was adopted by International Maritime Organization (IMO) in the form Guidelines to Formal Safety Assessment (FSA) through memorandum MSC/Circ. 1023-MEPC/Circ. 392 (IMO, 2002) and updated in 2006 which include an evaluation of the FSA Guidelines risk criteria. The FSA basically puts risk factors in which the process systematically uses scientific approach.

IMO and Maritime Safety Committee (MSC) in 1995 decided to adopt the whole concept of FSA. This was done in the hope of improving the IMO rule-making process, and thus further enhancing the safety of shipping. As stated by Wang (2001), it is considered that "Marine safety may be significantly improved by introducing a formal 'goal-setting' safety assessment approach so that the challenge of new technologies and their application to ship design and operation may be dealt with properly". For a more specific discussion on the expected benefits of the FSA as a regulatory tool, and its potential framework for safety assurance in shipping companies, the reader is referred to MSA (1993), Wang (2001) and Peachey (2002). Following the development and introduction of the FSA method, interim guidelines for FSA application were issued by IMO (1997a) to describe and explain the new method and to support its application and further development in practice. Since that time, several FSA trial applications and case studies have been carried out in various IMO member states around the world. Some of the studies have been issued in direct support for the formulation of new IMO safety regulations e.g. DNV (Det Norske Veritas), 1997a; IMO, 1997b, 2000a,b, while in some other studies the objective has been to provide the justification for rule amendments or provisions allowing deviation/exemptions from a particular rule (DNV, 1997b). Other studies have been performed at the national level, for example, in order to support risk decision making of the national maritime authorities in specific local applications (Rosqvist et al., 2001), or to support the implementation of specific safety measures locally (Nyman et al., 2002).

Formal Safety Assessment (FSA) is a rational and systematic process for the proactive management of safety based on principles of hazard identification, risk analysis and cost-effectiveness evaluation of the efforts in controlling the risks. FSA can be used as a tool to help in the development of new safety regulations or in analysing an existing set of regulations, and thus achieve a balance between various technical and operational issues, including human element and costs.

The essential aspects of FSA lie in the proactive control of risks. The 'Interim Guidelines for the Application of Formal Safety Assessment (FSA) to the IMO Rule-Making Process' was adopted at the 68th Session of MSC held in May 1997 and was circulated as MSC/Circ.829 (MEPC/Circ.335) in December 1997. These guidelines were intended to facilitate trial applications of the FSA process. The trial applications covered a wide area of interests e.g. High Speed Crafts, Helicopter Landing Facilities on Large Passenger Ships, Hazard Identification of Ballast Water Exchange, Safety of Lifeboat Launching Devices and most importantly the FSA Studies on Bulk Carrier Safety by various Administrations and International Association of Classification Society (IACS). The Interim Guidelines were revised by IMO during MSC 74, 2001, and released as the revised IMO FSA Guidelines MSC/Circ.1023-MEPC/Circ/392 published in 2002. It is likely that many more applications of FSA will now be carried out and submitted to the regulatory authorities for acceptance.

The characterization of hazards and risks should be both qualitative and quantitative, consistent with the available data, and should be broad enough to include range of options for reduction of risks. A typical FSA exercise in a ship type according to the IMO Guideline would proceed as follows:

Problem definition:

The problem under analysis and its boundaries should be carefully defined. While defining the problem, the following parameters may be considered relevant:

1)Ship category (type, length or gross tonnage, new or existing)

2)Ship systems(type layout, subdivision, propulsion.)

3) Ship operation (in ports and/or during navigation)

4) Accident category (collision, explosion, fire)

5) Risk category (injuries and/or fatalities to passengers and crew, environmental impact, damage to ship or port).

By considering the characteristic of the ship, a formal safety assessment of the ship is described in detail in this chapter regarding by IMO. FSA is a structured and systematic methodology, aimed at enhancing maritime safety, including protection of life, health, the marine environment and property, by using risk analysis and cost benefit assessment. FSA can be used as a tool to help in the evaluation of new regulations for maritime safety and protection of the marine environment or in making a comparison between existing and possibly improved regulations, with a view to achieving a balance between the various technical and operational issues, including the human element, and between maritime safety or protection of the marine environment and costs.

FSA consists of five steps:

1) Identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes);
2) Assessment of risks (evaluation of risk factors);
3) Risk control options (devising regulatory measures to control and reduce the identified risks);
4) Cost benefit assessment (determining cost effectiveness of each risk control option);and
5) Recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options, is provided).

In simple terms, these steps can be reduced to:

1) What might go wrong? = identification of hazards (a list of all relevant accident scenarios with potential causes and outcomes)
2) How bad and how likely? = assessment of risks (evaluation of risk factors);
3) Can matters be improved? = risk control options (devising regulatory measures to control and reduce the identified risks)
4) What would it cost and how much better would it be? = cost benefit assessment (determining cost effectiveness of each risk control option);
5) What actions should be taken? =recommendations for decision-making (information about the hazards, their associated risks and the cost effectiveness of alternative risk control options, is provided).

2.4.2 Hazard Identification (HAZID)

The term 'hazard' is defined as "an undesirable outcome in the process of meeting an objective, performing a task or engaging in an activity"(Kuo, 1998). The objective of this step is to derive a list of all relevent accident scenarios, together with their potential causes and outcomes. To achieve this, many typical techniques are employed to identify the hazards, which might contribute to the occurrence or escalation of each accident scenario. These technique include (Kuo, 1998):

1) Brainstorming;
2) Hazard and Operability Studies (HAZOP);
3) Failure Mode and Effects Analysis (FMEA).

Potential hazard identification are described in Table 2.2 with regard to ship operation. Once the hazards are identified, with respect to each of the categories as shown in Table 2.2, it is essential to carry out a "Probability Assignment" (Passenger Vessel Association, 1997) in order to rate the likelihood or frequency of that hazard occurring. After the examination of the frequency each hazard occurring, it is also essential to carry out a "Consequence Assignment" (Passenger Vessel Association, 1997) in order to rate the impact of that hazard occurring. Five scales are used for the "Probability and Consequence Assignments" and shown in Table 2.3 and 2.4. Table 2.3, rating 1 represents "remote", which means that the hazard might occur once in a lifetime of the ships; rating 2 represents "occasional", which means that the hazard might occur every 5 years; and rating 3 represents "likely", which means that the hazard might occur every season. Rating 4 and 5 represent "probable" and "frequent", which mean that the hazard might occur monthly and weekly or daily, respectively.

Table 2.2: Potential Hazard Identified

Casualties	Description
Personnel	Crew injury Man overboard Medical emergency Passenger injury Passenger Violence Slip and falls while underway
Material-ship	Galley fire Fire/explosion on board Collision/ grounding due to human error Engine room/ machinery space fire Flooding and/or sinking due to hull failure
Material-shore	Fire in terminal Explosion in terminal Structural damage to terminal
Environmental impacts	Exhaust emission Noise Oil pollution due to vessel accident Pollution due to oil discharge

Source: Lois, et al., (1997)

Table 2.3: Frequency Assignment

Assign a rating of	If the frequency is
1	Unlikely : might occur once in a life time
2	Remote : might occur in every five years
3	Occasional : might occur every season
4	Moderate : might occur monthly
5	High frequent : might occur weekly or daily

Source: Lois, et al., (1997)

Table 2.4: Consequence Assignment

Assign a rating of	If the impact could be
1	Negligible : injury not requiring first aid, no cosmetic vessel damage, no environments impact, no missed voyage
2	Minor : injury requiring first aid, cosmetic vessel damage, no environmental impact, no missed voyage
3	Significant : injury requiring more than first aid, vessel damage, some environmental damage, a few missed voyage or financial loss
4	Critical : severe injury, major vessel damage, major environmental damage, missed voyage
5	Catastrophic : loss of life, lost of vessel, extreme environmental impact

Source: Lois, et al., (1997)

2.4.3Risk Assessment

The objective of the second step is to evaluate the factors contributing to the risk associated with each hazard on the prioritized list. This step includes consideration of the various factors (such as training, design, communication and maintenance), which influence the level of risk.

Following to the study of the escalation of the basic or initiating events to accidents and their final outcomes, it is necessary for an influence diagram to be constructed, in order to study how the regulatory commercial, technical and political/social environments influence each accident category and eventually quantify these influences with regard to human and hardware failure as well as external events (Wang et.al.,1999). Again the various operational phases of the ship have to be taken into consideration and generic data or expert judgments to be used. A list of ship's systems/compartments and operational phases is shown in Table 2.5.

Table 2.5: Vessel Compartments and Operational Phases

Ship's Systems & Compartments	Ship's Operational Phases
Navigation Bridge	Design-Construction-Commissioning
Cargo Spaces	Entering and Leaving Port
Engine Room	Berthing-Un berthing
Void Spaces	Cargo Operations
Crew Accommodation	Coastal Navigation
Passenger's Accommodation (if applicable)	Open Sea Navigation
Galley	Dry-docking
Bonded Stores & Provision Storage Area	Decommissioning Maintenance onboard/in port

Source: Wang and Foinikis (2001)

2.4.4 Risk Control Options

The purpose of this step is to derive regulatory measures to control and reduce the risks estimated in step 2. Attention is focused initially on the highest risk areas (Spouse, 1977). Another aim at this stage is to propose effective and practical 'Risk Control Measures' (RCMs) to high-risk areas identified from the information produced by the risk assessment in the previous step (Wang, et al., 1999). At this stage the implementation costs and potential benefits of risk control measures are not of concern. In general, there are three main characteristics according to which RCMs are evaluated and which can be summarized as follow:

1) Those relating to the fundamental type of risk reduction like the preventative measures forming 'safety barriers' not allowing an incident to progress.
2) Those relating to the type of action required (i.e. engineering or procedural).
3) Those relating to the confidence that can be placed in the measure (single or redundant, active or passive).

Reducing the likelihood of occurrence and/or the severity of the consequences of hazards can achieve certain amount of risk reduction. There are three main methods used for risk reduction, namely the management, engineering and operational ones.

3.2.6 Cost-benefit Assessment

Selected RCMs must also be cost-effective (attractive) so that the benefit gained will be greater than the financial loss incurred as a result of the adoption (Wang, 1999). Therefore this step is aiming at identifying the benefits from the reduced risks and the associated costs for each RCM. Attention is necessary to be drawn to the fact that the evaluation of costs and benefits should initially be carried out for the overall situation and then for the various parties concerned and affected by the problem in concern. The parties affected are commonly referred to as 'Stakeholders'. There are limitations in carrying out cost-benefit analysis. The limitations come from imperfect data and uncertainty. It must also be pointed out that cost-benefit analysis as suggested for use by FSA is not a precise science, but it is only a way of evaluation. Thus, it cannot be used mechanistically, but only as a consulting instrument in decision making process.

2.4.5 Decision Making

The final step of FSA is 'decision making' which aims at giving recommendations and making decisions for safety improvement taking into consideration the findings during the whole process. Thus, the pieces of information generated in all four previous steps are used in selecting the risk control option which best combines cost effectiveness and an acceptable risk reduction according to the set risk criteria set by the regulators.

It is equally admitted, however, that the application of absolute numerical risk criteria may not always be appropriate as the whole process of risk assessment also involves uncertainties. Furthermore, opinions on acceptable numerical risk criteria may differentiate between individuals and societies with different cultures, experience and mentalities.

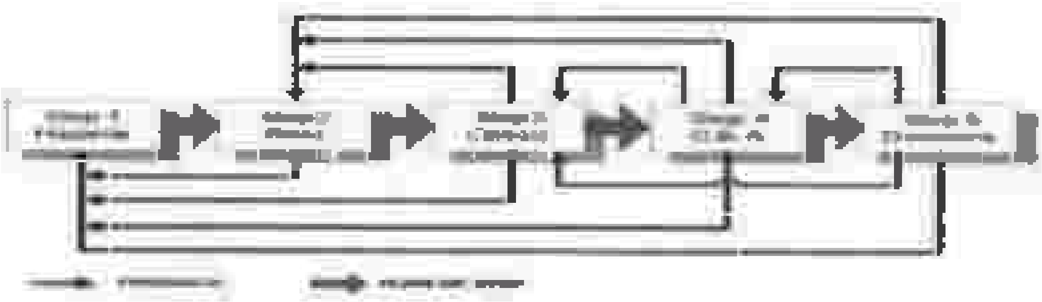

Figure 2.2: Information Flow in FSA Process

Source: Dasgupta, J (2003)

Prior to application of the FSA steps, additional information would be required to be compiled on the following:

1) Identification of existing design concepts and review of existing rules/regulations

2) Identification of existing operational procedures/concepts

3) Compilation of materials under consideration and their properties.

4) Identification of involved parties responsible/liable for safety.

FSA is a rational and systematic process for assessing risks and for evaluating the costs and benefits of different options for reducing those risks (Peachy, 1999). The benefits of adopting FSA as a regulatory tool were very accurately pointed out by UK MSA and can be summarized in the following UK MSA(1993):

1) A consistent regulatory regime which addresses all aspects of safety in an integrated way;

2) Cost effectiveness, whereby safety investment is targeted where it will achieve the greatest benefit;

3) A proactive approach, enabling hazards that have not yet given rise to accidents to be properly considered;

4) Confidence that regulatory requirements are in proportion to the severity of the risks and;

5) A rational basis for addressing new risks posed by the ever changing technology.

2.5 FMEA (Failure Mode and Effect Analysis)

FMEA initialy were used by the U.S military after World War II as a process tool, and gradually spread into industry. It became widely known within the quality community as a total quality management tool in the 1980s and as a Six Sigma tool in the 1990s. A team should apply FMEA to perform risk assessment to see what the customer will experience if a key process input (X) were to fail. The team should then take action to minimize risk and document processes and improvement activities. FMEA is a living document that should be reviewed and updated whenever the process is changed (Jugger, 2002). FMEA is one of the most efficient low-risk tools for prevention of problems and for identification of more efficacious solutions, in cost terms, in order to prevent such problems.

To develop the FMEA, a survey on the functions of each component, as well as on its failure modes and effects, was initialy done. The system of textual description contained in the technical operation instructions, the fault registers in the abnormality cards (service orders for maintenance) of the plant, the maintenance plans currently used and the instrumentation descriptions of the equipment and components were used as support for the analysis. It were also performed a brainstorming session joined by the plant operators, so that it was possible to get more details about the description of the possible failures of each component. The documentation of analysis FMEA was developed according to standardized components shown in the Table 2.6.

Table 2.6: Standardized Components for FMEA Analysis

SYSTEM IDENTIFICATION					
FUNCTION			DESCRIPTION OF SYSTEM FUNCTION		
COMPONENT	COMPONENT FUNCTION	FRACTIONAL FAILURE	FAILURE MODE	FAILURE CAUSE	FAILURE EFFECT

Source: Souza, et al., (2008)

Below are the explanation of each column of the presented form:

- Function: Action which the user desires that the item or system executes in a specified performance standard.
- Component: Identification of each component that belongs tdsystem.
- Component function: Succinct and accurate description of the task that the component must execute.
- Functional failure: Description of all the possible failures pertinent to each component.
- Failure Mode: Description of the form as the failure is observed by the operation team.
- Performance of one determined type of alarm, or performance of a relay signaling failure.
- Failure cause: Simple and concise description of the occurrences (causes) that they can origin to the considered type of failure.
- Failure effect: Consequence of the occurrence of the failure, perceived or not for the final user. It can be local (it does not affect the other components) or global (it can affect other functions or components).

2.6. DIESEL ENGINES

Diesel fuel is the result of a petroleum fraction boiling between 175° C to 370° C and used as fuel in diesel engines. The diesel engine was invented and patented by Rudolph Diesel in 1892. Diesel engine works with the maximum speed is lower compared with gasoline engines that often havespeed of over 4000 revolutions per minute. Most diesel engines work at speeds between 50 to 2,500 rotations per minute. Diesel engine that works with thespeed of less than 500 rotations per minute is called low speed diesel engine, over 1,200 rotations per minute is called high speed diesel engine, while between the two is called medium speed diesel engine. Low speed diesel engine is used as a stationer and machine on large ships. The medium speed is being used on small ships and locomotives, while a high speed used for tractors, buses, trucks and cars. Indonesia currently has two types of diesel fuel, diesel fuel used as motor fuel diesel with high rotation speed and diesel oil for low rotation speed (Diane, et al., 2001). Diesel engines are widely used as generators and prime movers in industry and the military for their durability and efficient performance and they are often used in applications where reliability is a crucial operating requirement. Large and medium size diesel engines can be found in electrical power plants as the prime movers of large oceanic vessels. Meanwhile smaller, high-speed engines have been found in tractors, trucks, cars and small marine vessels. Diesel engines are also used for a wide variety of military applications.

Diesel engines are comparable to Spark Ignited (SI) engines in many respects, with the exception that they use the heat produced from the compression stroke for ignition rather than spark plugs. Diesel fuel is injected at high pressure into the cylinder after the air has been compressed to such a point where auto-ignition occurs.

The compression ratio of diesel engines can be greater than twice of that from SI engines, which translates into greater efficiency. The combustion process of the diesel engine is highly dependent upon the precise injection of atomized fuel into the cylinder or swirl chamber. The fuel injection system controls the injection pressure (necessary for atomization and mixture) and dispenses a metered amount of fuel for specified speed and load conditions, and has effects upon emissions and overall engine noise. The reliable operation of the fuel injection/delivery system is thus a paramount concern for both engine manufacturers and maintenance personnel. The development of the distributor-type injection pump with automatic timing (introduced in the early 1960's) and Electronic Diesel Control (developed during the 1970's) have contributed greatly to the increased power output and lower emissions of modern engines (Perakis and Bahadir, 1990).

Research efforts related to the development of diesel engine diagnostic systems have typically been guided by a thorough knowledge of component failure modes. A reliability-based engineering method that is commonly employed as an evaluation tool is Failure Mode and Effects Analysis (FMEA). FMEA charts describe the function of a component, potential failure modes, possible causes of failure, and the effects such failures would have upon the system's operation. Other versions of how to capture this information are employed in RCM II analysis and FMECA (Failure Modes Effects and Criticality Analysis).

The FMEA chart shown in Table 2.7 is for large, medium-speed marine diesel engines typically employed in large commercial vessels.

Table 2.7: FMEA Chart of Fuel Oil Supply Systems

Component	Function	Failure Mode	Possible Cause of Failure	Effects on System
Fuel Oil Injection Pumps	Provide engine with fuel in quantities corresponding to power required and timed correctly	Broken delivery valve springs		Poor atomization fooling Misfiring of cylinders
		Checked fuel valves	Contaminated fuel	Loss power
		Cavitations	Local pressure fuel below saturated Vapour pressure of fuel	Pump erosions
Fuel Oil Injectors	Atomize fuel in combustion chamber and to ensure that It mixes with sufficient air For complete combustion In cycle time available	Incorrect atomization	Checked atomizer due to contaminated fuel debris and hot gas from cylinder forming carbon	Incorrect combustion
		Cavitations	Low pressure caused by pressure Waves that move between injector And fuel pump at the end of fuel Injection; delivery valve breakage Also aggregate cavitations	Injector erosion
High pressure fuel lines		Cavitations	Same as item 2 (Fuel Oil Injectors)	Erosion in high-pressure lines, ultimately resulting in rupture of main fuel line

Source: Perakis and Bahadir (1990)

In accordance with it operation, diesel engine installed on a ship is supported by fuel oil system, lubricating oil system, water cooling system and starting air system. All of these systems have a function as well as a very important role for the main engine operations. This is because in the event of damage to one of the supported system a main engine carrier must be having problems and the possible main engine cannot operate properly. For example, if the fuel oil system encountered a problem which has yet to satisfy the temperature of combustion, and compression to be low, the flash point of the fuel will not finally be achieved.

The same thing happens to the water cooling system as well as lubricating oil system. If the water cooling system is having problems, the engine will quickly become hot. In addition, if the lubricating oil system that serves as lubricating oil on the engine that needs to be lubricated is having problems, the less lubricated engine will quickly wear out. Therefore, the motor carrier will not be able to withstand the heat generated by the motor of the parent work. And the lastly, when starting air system problems occur the starting system on the carrier motor will fail to operate.

FMEA technique is applied to analyze the possible failures, in order to raise the safety factor and consequently costumer satisfaction. One of the main differences between FMEA and other quality methods is that FMEA is an active method, while other methods are passive (are based on reaction): when failures occur, other methods define some reactions; but reactions have lots of costs and resources. FMEA tries to estimate the potential problems and their risks and then decide upon actions leading to reduction or elimination of risk. This kind of preventive act is an action against failure that possibly could happen in the future. It is obvious that doing preventive actions, which happens in early phases of development, lower cost and time compared to reactions approach (Palady, 1995).

2.7 SUMMARY OF CHAPTER

This chapter discusses at first the situation of ship accidents in Indonesia. As Indonesia is an archipelago, the maritime transportation affects most of goods and passenger movements among the islands. The ship handling difficulty will transmit signal to ship officer in charge to take action properly to current ship handling situation which depends on technical issues, organizational and human issues.

The chapter also described on characteristic of seaaccident causing ship accidents to happen. Then it continued by explaining the theory of Formal Safety Assessment (FSA) regarding with International Maritime Organization (IMO) Regulation. In this FSA there is Hazard Identification. One of the technique commonly used is FMEA. FMEA is an effective technique for identifying and eliminating possible failures. The last part is about the diesel engines. The literature review described about the theoretical aspects of the problem regarding ship accident issues especially in engine room (diesel engine) and informed us about the technique for eliminating possible failure using FMEA.