BACHELOR THESIS – ME 141502

ROOT CAUSE ANALYSIS OF KMP RAFELIA 2 ACCIDENT

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DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
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SURABAYA
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APPROVAL FORM

ROOT CAUSE ANALYSIS OF KMP RAFELIA 2 ACCIDENT

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Submitted to Fulfill One of the Requirement to Obtain a Bachelor Engineering Degree on Reliability, Availability and Management (RAMS) Laboratory

S-1 Double Degree Program of Marine Engineering Departement Faculty of Marine Technology Institute of Technology Sepuluh Nopember

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Department:	Double Degree Program in Marine Engineering

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ROOT CAUSE ANALYSIS OF KMP RAFELIA 2 ACCIDENT

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ABSTRACT

Ships are transportation used to connect among island and also used as an international trading transportation. Hence, ships are full of regulations. From manufacturing until it will be operated, ship filled with rules to be obeyed and always under the supervision of various stakeholders. Not only the ships, crews also need to complies with several standards and regulations. It aims to compliance with safety regulation in sailing or anchored.

Ship accident is a nightmare for either seafarer or ship company/ owner of the ship. Because it can cause harm for the company. Therefore, every company put the safety first to avoid the accident. But, sometimes, accidents can not be avoided. Accident can caused by many factors. Human error, bad weather, overload capacity, technical factors and heavy traffic are some factors of marine accidents.

In this thesis, will explain factors that causing the sinking of KMP Rafelia 2 in Selat Bali. The aim of this thesis is knowing the causes of the accident, factors that affect the accident and analyze the stability of the ship while the accident happened. The methodology to analyze the cause of this case is using Apollo root cause analysis method utilizes a process called RealityCharting which encompasses all known causes as well as their relationships with each other. This thesis also using Maxsurf for calculate the ship stability. The result will shows if stability is affecting on this accident and will be compared with the stability calculation by NTSC. From calculation, the stability of this ship decreased and does not comply with IMO Resolution A.749 (18). Other than that, the result is to find out the causes of the sinking of KMP Rafelia 2. This accident caused by human error and technical factors. Several factors makes the stability of this ship decreased and causing sinking.

Keywords **–Ship Accident, Ship Sinking, Root Cause Analysis, Apollo Root Cause Analysis Method, Ship Stability**

ANALISIS PENYEBAB KECELAKAAN KMP RAFELIA 2

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ABSTRAK

Kapal digunakan sebagai transportasi yang menghubungkan antar pulau dan juga digunakan sebagai alat transportasi perdagangan internasional. Oleh karena itu, kapal dipenuhi dengan banyak peraturan. Mulai dari pembuatan pembangunan kapal sampai kapa dioperasikan, kapal dipenuhi dengan banyak peraturan yang harus dipatuhi dan dibawah pengawasan pihak berwajib. Tidak hanya kapalnya saja, akan tetapi krew yang bekerja dikapal juga harus mematuhi standard an regulasi yang berlaku. Hal ini bertujuan untuk memenuhi peraturan keselamatan baik saat berlayar maupun saat kapal berlabuh.

Kecelakaan pada kapal menjadi hal buruk bagi pelayar maupun perusahaan pelayaran/ pemilik kapal. Hal tersebut akan merugikan perusahaan. Oleh karena itu, setiap perusahaan mengutamakan keselamatan untuk mencegah kecelakaan. Tetapi, terkadang kecelakaan tidak dapat dihindari. Kecelakaan kapal dapat disebabkan oleh beberapa faktor. Kesalahan manusia, cuaca buruk, faktor teknis, ataupun kelebihan muatan dapat menjadi penyebab dari kecelakaan.

Pada tugas akhir ini akan menjelaskan faktor- faktor penyebab tenggelamnya KMP Rafelia 2 di Selat Bali. Tujuan dari tugas akhir ini adalah untuk mengetahui penyebab kecelakaan dan menganalisa stabilitas kapal pada saat terjadi kecelakaan. Metodologi yang digunakan untuk menganalisa adalah metode Apollo root cause analysis dengan bantuan software RealityCharting. Tugas akhir ini juga menggunakan software maxsurf untuk menghitung stabilitas kapal guna mengetahui apakah stabilitas mempengaruhi kecelakaan ini kemudian akan dibandingan dengan perhitungan stabilitas oleh KNKT. Dari perhitungan yang didapat, stabilitas kapal Rafelia 2 menurun dan tidak memenuhi criteria IMO Res. A.749 (18). Selain dikarenakan stabilitas yang menurun, tenggelamnya KMP Rafelia 2 juga disebabkan oleh kesalahan teknis dan kesalahan manusia.

Kata Kunci **–Kecelakaan Kapal, Kapal Tenggelam, Analisis Akar Penyebab Kejadian, Metode Apollo Root Cause Analysis, Stabilitas Kapal**

PREFACE

First of all, I would like to thank to Allah SWT for the grace and bless so the writer could finish the Final Project successfully. The title of Final Project is:

"Root Cause Analysis of KMP Rafelia 2 Accident"

As the requirement to obtain a bachelor engineering degree on Department of Marine Engineering Faculty of Marine Technology Institute Technology Sepuluh Nopember. Therefore, I would like to thank those who have helped in completing my final project, among others:

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CHAPTER 1
INTRODUCTION

1.1 Background

Ships are transportation used to connect among island and also used as an international trading transportation. Hence, ships are full of regulations. From manufacturing until it will be operated, ship filled with rules to be obeyed and always under the supervision of various stakeholders. Not only the ships, crews also need to complies with several standards and regulations. It aims to compliance with safety regulation in sailing or anchored.

Although regulations have been implemented, the numbers of ship accidents still shows large quantities. And also number of casualties of the ship accidents shows the large amount. The accident can cause many losses. Not only owner, but also many stakeholders were take responsibility of losses of the accident.

Figure 1.1 below shows the data related to the ship accident has been investigated by National Transportation Safety Committee (NTSC) from 2010- 2016.From the data known that the most causes of accidents causing by fire or explode then followed by accident causing by sink.

No	Year	Number of Accidents	Type of Accident					Fatalities	
			Sink	Fire/Explode	Collision	Aground	Others	Died/Missing	Wounds
1	2010	5	1	1	3	0	0	15	85
2	2011	6	1	3	2	0	0	86	346
3	2012	4	0	2	2	0	0	13	10
4	2013	6	2	2	2	0	0	65	9
5	2014	7	2	3	2	0	0	22	4
6	2015	11	3	4	2	1	0	85	2
7	2016	15	4	4	3	2	2	51	18
Total		54	13	19	17	3	2	337	474

Figure 1.1 Data of Ship Accident Investigated by NTSC from 2010- 2016

In this research, will be appointed issues about the sinking of KMP. Rafelia 2 in Bali on March 2016 which causes reduced stability of the ship.

Figure 1.2 KMP Rafelia 2 Sinking

In figure 1.2 shows the sinking of KMP Rafelia 2. This accident happened by many factors. This research will analyze root causes of water ingress into car deck that leads to decrease stability and sinking of the ship. The method used in this study is Apollo root cause method, this method is an iterative interrogative technique used to explore the cause-and-effect relationships underlying a particular problem. It is recommended for event/incident-based items of complex and higher significance. Apollo Root Cause Analysis method utilizes a process called RealityCharting which encompasses all known causes as well as their relationships with each other [1].RealityCharting is becoming the standard for all event analysis because it is the only process that understands and follows the cause-and-effect principles, thus it is the only process that allows all stakeholders to create a clear and common reality to promote effective solutions every time[2].

1.2 Problems

Based on the description above, the statement problems of this thesis about:

1. What are factors causing sinking to KMP Rafelia 2?
2. What are recommendations needed to avoid similar accident?

1.3 Limitations

The limitation of this research is:

1. The analysis only to the sinking of KMP Rafelia 2.

1.4 Objectives

The objectives of this research are:

1. Determine exact factors that causing sinking in KMP Rafelia 2.

1.5 Benefits

Benefits of this research are:

1. To help owner, crews and related parties to know the exact cause the sinking of the ship.
2. To help crews if facing the same situation.

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CHAPTER 2
LITERATURE STUDY

2.1 Overview

2.1.1 Types of Emergency Situation

Ship is a floating building that moves with thrust at various speeds across different regions of voyage within a certain time, will have various problems which can be caused by various factors such as the weather, the state of shipping routes, humans, ships and others who can not be suspected by the ability of humans and eventually cause a disruption of the voyage ship.

Voyage disturbance basically can be disturbances that can directly overcome, even need to get direct assistance from a particular party, or disruption resulting captain and all the crew must be involved both to cope with the disorder or to have to leave ships.

The state of the voyage disturbance according to the situation can be classified into emergency based on the type of incident itself, so that emergency can be grouped by circumstance as follows:

- Collision
- Fire/ Explosion
- Ship Aground
- Leakage/ Sinking
- Man Over Board
- Pollution

Case of emergency can cause harm to all parties, so it is necessary to understand the conditions in order to have the basic ability to identify the signs state that the situation is able to be overcome by the captain and his crews as well as cooperation with the relevant parties.

1. Collision
   Case of emergency due to ships collisions with ships or ships to dock or with a particular object will probably be situations of damage to the ships, human casualties, the oil spill into the sea (tanker), pollution and fires. Other situation is panic or fear officer on a ship that actually slow down the action, security, rescue and prevention of such emergencies.

2. Fire/ Explosion

   Fire on board may occur at various locations prone to fires, for example in the engine room, cargo space, equipment storage vessels, electrical installations and places of accommodation captain and crew.

   While the explosion may occur due to fire or otherwise the fire occurred because of the explosion, which certainly both can lead to an emergency situation and need to be overcome.

   Case of emergency on the situation of fire and explosion is certainly very different from the emergency because of the collision, because in this situation there are conditions of heat and space is limited and sometimes panic or unpreparedness officers to act on the situation as well as the equipment used is not feasible or where storage has changed.

3. Ship Aground

   Ship aground generally preceded by signs rotation of propeller feels heavy, black smoke in the funnel, the hull vibrate and the ship's speed changes, then a sudden stop.

   When ships aground is not moving, the ship's position will depend on the sea floor or river and the situation in the ship would depend also on the circumstances the ship.

   On the ships aground there is a possibility ships was leaking and causing pollution or danger of drowning if water entered the ship can not be overcome, while the danger of fire will certainly be able to occur if fuel or oil conditioned with damage power supply network causing flames and undetectable so cause a fire.

   Possible human accidents due to ship aground may occur due to unexpected situations or fall when there are changes position of the ship.

   Ship aground can be permanent and also can be temporary depending on the position of the bottom surface of the sea or river, or how to handle it so that emergencies like this would make the environmental situation in the ships will occur complicated.

4. Leakage/ Sinking

   Leaks in the vessel can occur because the ship aground, but can also occur due to the collision and fire as well as the ship plate damage due to corrosion, so if that not solved immediately the ship was sinking.

   Water entering quickly while limited ability to leakage, even ships become skewed makes the situation difficult to overcome. Case of emergency will be complicated if the decision-making and implementation is not fully supported by the entire crew, as it attempts to deal with the situation is not based on the principles of safety and solidarity.

5. Man Over Board
   People fall into the sea is one form of accident that makes the situation becomes an emergency in an effort to rescue.
   Relief provided is not easily done because it will largely depend on the current weather situation and capabilities that will bring relief, or the available of facilities.

6. Pollution
   Marine pollution can occur because of the disposal and oil spills when bunkering, ships cargo tank sewage, waste disposal engine room that exceeded 15 ppm and for cargo tanker spilled due to the collision or leaks.
   Efforts to overcome the pollution that occurs is a difficult thing because to cope with pollution that occurred requires equipment, trained manpower and the possible risks that must be borne by the party which violates the provisions on the prevention of pollution.[3]

Marine-Accident Factors[4]

The emergency case that causing harm has many factors.

1. Human Error
   Human error remains the most important factor in marine accidents. Many accidents caused by this factor. Crews must have knowledge, understanding, proficiency and skills. Its needed to anticipate the risk of accidents and to minimize human error, as a factor of marine accident. [5]

2. Bad Weather
   While the casualty toll of modern-day commercial shipping as a result of result weather may not be as alarming as it was in the day of sail ships, weather conditions still account for numerous shipping accidents every year. Bad weather is a problem often regarded as a main problem of main accidents. The problems that usually happens are high waves, storms, haze that causing limited visibility can cause severe problems for commercial shipping, pushing the ships into shallower waters where the possibility of grounding is significantly increased.[6]

3. Overload Capacity
   Most of accidents caused by number of passengers or cargoes exceeding the payload capacity of the ship. This certainly will reduce stability of ship. Beside it caused by negligence of captain, it also caused by negligence of port's officers when the ship will be depart and underestimate the existing standardization.

4. Traffic Management
   Traffic management in marine transportation, both ship that will be depart or leave the port, used to manage the flow of traffic at port went really well. Lack of information and coordinating can cause some disadvantages, such as delay on arrival and departure of the ship, increasing number of queues, thus enabling the occurrence of accidents.
5. Technical Factor
   Another factor that causing marine accidents is technical factor. Some factors might be the technical factors, include ship's design not comply with the regulation. Unscheduled maintenance can make higher temperature and causing damage these vessels to be caught on fire and explode.

2.1.2 Stability of Ship

Stability of ship is a study of ability of a vessel to return its original position after influenced by external forces. If the ship can not maintain the stability or can not return to the upright position, slowly the ship would sink. That is the importance to maintain the stability. Factors that can be decrease the stability are wind, sea condition or waves, leakage caused by collision or aground. The stability of ship can be divided by three types, stable equilibrium, neutral equilibrium and unstable equilibrium. [7]

a. Neutral equilibrium is a condition which ship is not experiencing the slope due to the force exerted and this condition is not change to the original position or to the slope. In this condition, gravitation (G) coincide with transverse metacenter (M) in one point (zero GM).
b. Stable equilibrium is a condition in which is ship able to return to its original position after rocking due to disturbance forces. This condition occurs when gravitation (G) lower than position of transverse metacenter (M).

c. Unstable equilibrium is a condition which ship is not able to return to its original position due to disturbance forces and will continue to move in the direction of the slope. This condition occurs because gravitation (G) is higher than position of transverse metacenter (M). [8]

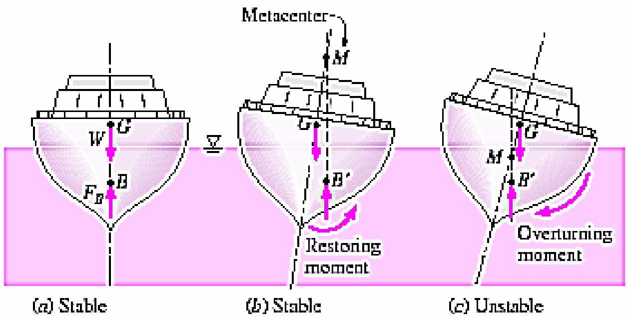

Figure 2.1 Types of Stability[21]

Stability of ship divided into two types by its characteristic, static stability and dynamic stability. Static stability is intended for ships which is stable and consist of transverse stability and longitudinal stability. Transverse stability is the ability of the ship back to the upright position after a slope in the transverse direction caused due to external influences exerted on it. Longitudinal stability is the ability of the ship back to the upright position after a slope in the longitudinal direction caused due to external influences worked on it. Dynamic stability is intended for ship which is being roll, nod or tilt. [9]

In general, things that affect the stability of ship can be grouped into two groups, namely:

- Internal factors are the layout of goods or cargo, shape and size of the ship, leak caused by aground and collision.
- External factors are wind, waves, storm

Crucial point of stability of ship are:

- The center of Buoyancy (B) is a theoretical point though which the buoyant forces acting on the wetted surface of the hull act through.
- The center of Gravity (G) is a theoretical point through which the summation of all the weights act through.
- The Metacenter (M) is a theoretical point through which the buoyant forces act and small angles of list.

The forces acting on gravity center and buoyancy center creating what is called a righting moment. The righting moment is usually taken about the center of gravity point. It is the product of the forces of buoyancy times the distance GZ that separates the line of action of the buoyancy force from the center of gravity as shown. The distance GZ is called the "righting arm". Since the force of buoyancy must equal the weight of the ship, the restoring moment is simply equal to the ship's displacement in tons times the length of the righting arm in feet. The result will be in foot-tons.As seen from Figure 2.2 that GM is an

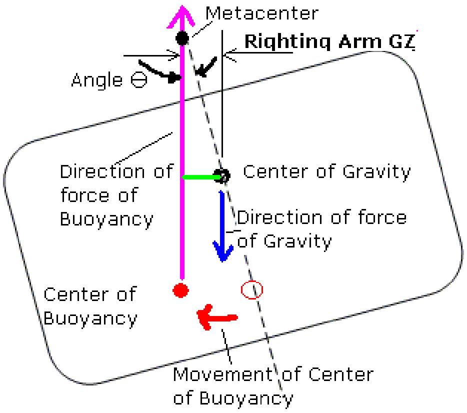

Figure 2.2 Righting Arm

indicator of the ship's initial stability. If M is above G, as shown in the figure above, the metacentric height is positive and the moment which develops when the ship is inclined will be a righting moment tending to bring the vessel back to an even keel. The ship is stable. But if M falls below G, then the metacentric height is negative, and the moment that develops is an upsetting moment. In this case, the ship is unstable and will want to capsize. As shown in Figure 2.3. [10]

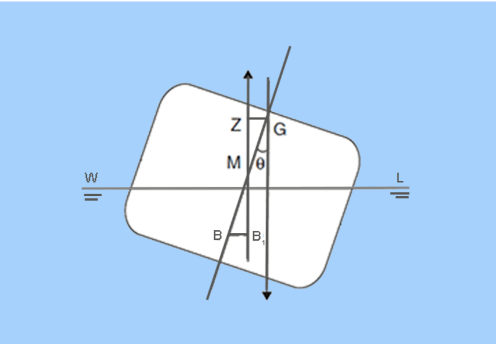

Figure 2.3 Negative Stability[10]

For majority of ship hull forms, the curve of the righting arm(GZ) as a function of angle of heel(Ɵ) departs from an initial straight line with some increasing heel for angles beyond about 10 degrees. As the ship heels further, its wetted area increases and the value of BM, the metacentric radius, also increases. This causes a greater increase in GZ, which produces a greater righting moment as a consequence. Eventually, a point is reached where the value of maximum GZ. The point where that occurs is called the "the angle of maximum stability" and produces the greatest righting moment acting on the ship to bring it back onto an even keel. Beyond that point, the righting arm decreases and reaches zero at what is called the "angle of vanishing stability".

Theoretically, it is the point beyond which the ship will capsize. In reality, capsizing will occur at a somewhat smaller angle than that. An example curve of GZ as a function of heeling angle is shown in Figure 2.4.

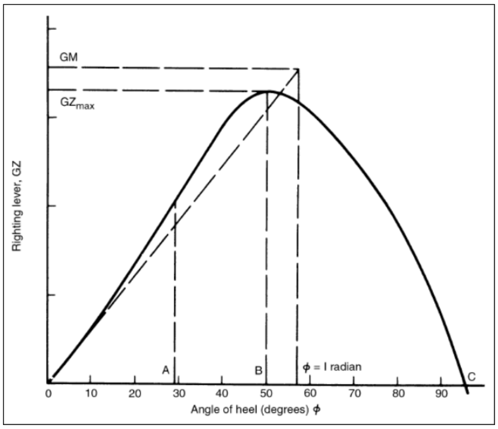

Figure 2.4 GZ Curve[22]

2.2 KMP Rafelia 2

KMP Rafelia 2 is a Ro-Ro (roll on-roll off) passenger ship owned by PT Darma Bahari Utama. Route of this ship is from Gilimanuk, Bali to Ketapang, Banyuwangi, Jawa Timur. Ship start serving the ferriage from Ketapang to Gilimanuk in the beginning of February 2016. In March 4th 2016, KMP Rafelia 2 got an accident, this ship drowning due to decreased the stability of ship. At the time of accident, ship carried 80 passengers, 33 vehicles and 20 crews. [11][12]

Figure 2.5 KMP Rafelia 2[12]

Figure 2.5 shows KMP Rafelia 2 and here the principal data of the ship:

LOA	: 65.8 m
LPP	: 61.15 m
B	: 14 m
T	: 3 m
H	:3.89 m
Speed	: 6 knot
Gross Tonnage	: 1108 t
IMO No	: 9079690
Flag	: Indonesia
Type	: Ro-Ro

KMP Rafelia 2 sinks caused by the water was entering into car deck because the bow ramp door is not properly closed causing the ship can not maintain its stability and can not return into the upright position. Stability of the ship is decreased and ship increasingly moving towards the slope. Approximately 1 NM from the nearest coast, KMP Rafelia 2 completely drowned. This accident killed 6 victims, 4 passenger (3 adults and 1 toddler) and 2 crews (master and chief officer). [12]

NTSC said that the sinking of Rafelia 2 due to the overload of the capacity and the ship itself was not complied the standard requirement of stability of the ship. Not only that, the ship which made in Japan 1993, has been modified at the ramp door from 5 meters to 13.5 meters. Therefore the bow ramp door always opened because if it is closed properly, it will block the viewpoint from bridge. Lack of control from port authority is also one of the causes of this accident. [13]

2.35-Whys Method

5- Whys analysis is an iterative interrogative technique used to explore the cause-and-effect relationships underlying a particular problem. The primary goal of the technique is to determine the root cause of a defect or problem by repeating the question "Why?" Each answer forms the basis of the next question. The "5" in the name derives from an anecdotal observation on the number of iterations needed to resolve the problem.

Benefits of 5-whys analysis are:

- Help to identify the root cause of problem. Question that raised go directly to the performance occurred. Simple cases will be solved without using excessive resources.
- Determine the relationship between different root causes of a problem.
- Easy to learn and apply. The practice of this theory is very simple, simply asking "why" then continued by asking back "why", until there is no answer after that. Last answer is the core of the real problem.

The 5-Why method helps to determine the cause-effect relationships in a problem or a failure event. It can be used whenever the real cause of a problem or situation is not clear. Using the 5-Whys is a simple way to try solving a stated problem without a large detailed investigation requiring many resources. When problems involve human factors this method is the least stressful on participants. It is one of the simplest investigation tools easily completed without statistical analysis. Also known as a Why Tree, it is supposedly a simple form of root cause analysis.

The 5-Whys method uses a Why Table to sequential list the questions and their answers. Figure 2.6 is an example of a completed 5 Why Table for a late delivery that lost a company an important Client. It is vital that each Why question uses the previous answer because that creates a clear and irrefutable link between them. Only if questions and answers are linked is there certainty that an effect was due to the stated cause and thus the failure path from the event to its root is sure. The approach to take with a 5-Whys root cause analysis is to start the

5 Why Question Table			
Team Members:		**Date:**	
Problem Statement: On your way home from work your car stopped in the middle of the road.			
Estimated Total Business-Wide Cost: Taxi fare x 2 = $50, Lost 2 hours pay = $100, Order was late to Customer because Storemen did not get to work in time to despatch delivery and Customer imposed contract penalty of $25,000, Lost Customer and all future income from them, estimated to be $2Million in the next 10 years.			
Recommended Solution: Carry a credit card to access money when needed.			
Latent Issues: Putting all the money into gambling shows lack of personal control and responsibility over money.			
Why Questions	**3W2H Answers** (with what, when, where, how, how much)	**Evidence**	**Solution**
1. Why did the car stop?	Because it ran out of gas in a back street on the way home	Car stopped at side of road	
2. Why did gas run?	Because I didn't put any gas into the car on my way to work this morning.	Fuel gauge showed empty	Contact work and get someone to pick you up
3. Why didn't you buy gas this morning?	Because I didn't have any money on me to buy petrol.	Wallet was empty of money	Keep a credit card in the wallet
4. Why didn't you have any money?	Because last night I lost it in a poker game I played with friends at my buddy's house.	Poker game is held every Tuesday night	Stop going to the game
5. Why did you lose your money in last night's poker game?	Because I am not good at 'bluffing' when I don't have a good poker hand and the other players jack-up the bets.	Has lost money in many other poker games	Go to poker School and become better at 'bluffing'
6. Why			

Figure 2.6 5-Whys Question Table[14]

Why Tree with the top failure event and identify all first level causes. Use the evidence and logic to prove which one(s) brought about the incident. Once the first level cause(s) are confirmed followed by level two causes and confirm which of them produced the level one effects, and so on as seen on Figure 2.7.

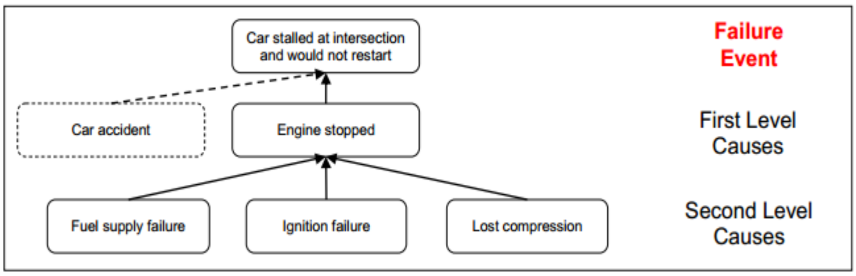

Figure 2.7Starting Right Question [14]

To start analyzing with this method, select the top event not too low down the Why Tree may not find the true root cause. It is vital to start high up the Why Tree when you ask the first Why question. It is better to start well up the Why Tree and ask a few unnecessary questions that are easily answered, than start too far down and totally miss the real cause and effect path of the incident.[14]

Cause-and-Effect Principles[2]

The cause-and-effect principium includes four principles:

1. Cause and effect are the same thing
   Cause and effect are the same things. The difference of those two only by how we perceive them in time. When start with an effect and asking why it occurred, we find a cause. But if we ask again, what was just now a cause becomes an effect.

2. Each effect has at least two causes in the form of action and condition
   Each effect has at least two or causes and the causes come in the form of conditions and actions as shown in Figure 2.8. The fundamental element of all that happens is a single causal relationship made up of an effect that is caused by at least one conditional cause, and at least one action cause. Action is an interaction to a condition that causing an effect.
   Condition is a situation that would be an effect if triggered by an action.

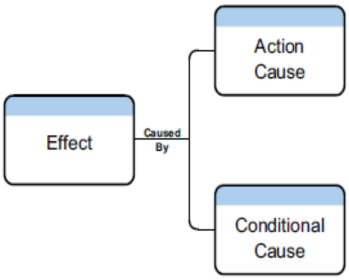

Figure 2.8 Casual Set[2]

3. Causes and effects are part of an infinite continuum of causes
   As shown in Figure 2.9, effects and causes is an infinite continuum of causes. In picture above, still can be search further causes as why the steal has broken and so on, or asking about the effect after injury.

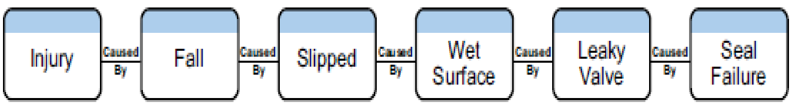

Figure 2.9 A Continuum of Causes[2]

However, the problem is how to determine the top event and the final cause. The reason of determination whether the top event is the main focus from a continuum of causes to be eliminated or minimized. The limit of the final cause is whether the limitation, limit of knowledge, available time and favorite solution.

4. An effect exists only if its causes exist in the same space and time frame
   Cause-and-effect relationships exist with or without the human mind, but we perceive them relative to time and space. For example, there is no fire if there is no oxygen and lighter at the same time.

2.4 RealityCharting (Apollo)

Apollo root cause analysis is an iterative process that looks at the entire system of causes and effects. This method was invented by Dean L Gano and it is recommended for event/incident-based items of complex and higher significance. Apollo Root Cause Analysis method utilizes a process called RealityCharting which encompasses all known causes as well as their relationships with each other [1].RealityCharting is becoming the standard for all event analysis because it is the only process that understands and follows the cause-and-effect principles, thus it is the only process that allows all stakeholders to create a clear and common reality to promote effective solutions every time[2].

CHAPTER 3
METHODOLOGY

The methodology used by author in this thesis is analyze the causes of reduction stability of KMP Rafelia 2 which causing the ship's sinking. Author make this thesis with structured process. It aims to make the process of this thesis easier and more structural. The phases of process are as follows and the flow chart diagram at Figure 3.1.

1. Determining Problems
   Determining problem is the first stage to start this thesis. The existing problem should be solved. This thesis will discuss the problem that causing the sinking of KMP Rafelia 2.
2. Literature Study
   Literature study performed by collecting various references to support this bachelor thesis. The media that will be use are from books, journals and papers. This primary concern in this literature is safety of ship and root cause methods.
3. Collecting Data
   In this stage, data will be collecting to get the information about KMP Rafelia 2 that will be use to complete this thesis. Data that collected for this thesis is ship's data, ship's document, accident's report.
4. Identification Data
   This stage data that has been collected will be identified. Data will be identified, will use to explain the problem that should be solved. Then, the identify data will be analyzed.
5. Data Analysis
   In this stage, data that has been identified and data from literature will be analyzed to know the causes of sinking of the ship using Apollo root cause analysis. If data that has been analyzed show that stability is one of the root cause, the stability should be calculated.
6. Result
   The result of this thesis is knowing factors that causing sinking of KMP Rafelia 2 and the stability analysis of this ship.
7. Conclusion
   At the end of the stage, we will make conclusion about the whole process that has done. The conclusion should solve the existing

problem. The recommendation is given based on the result of analysis.

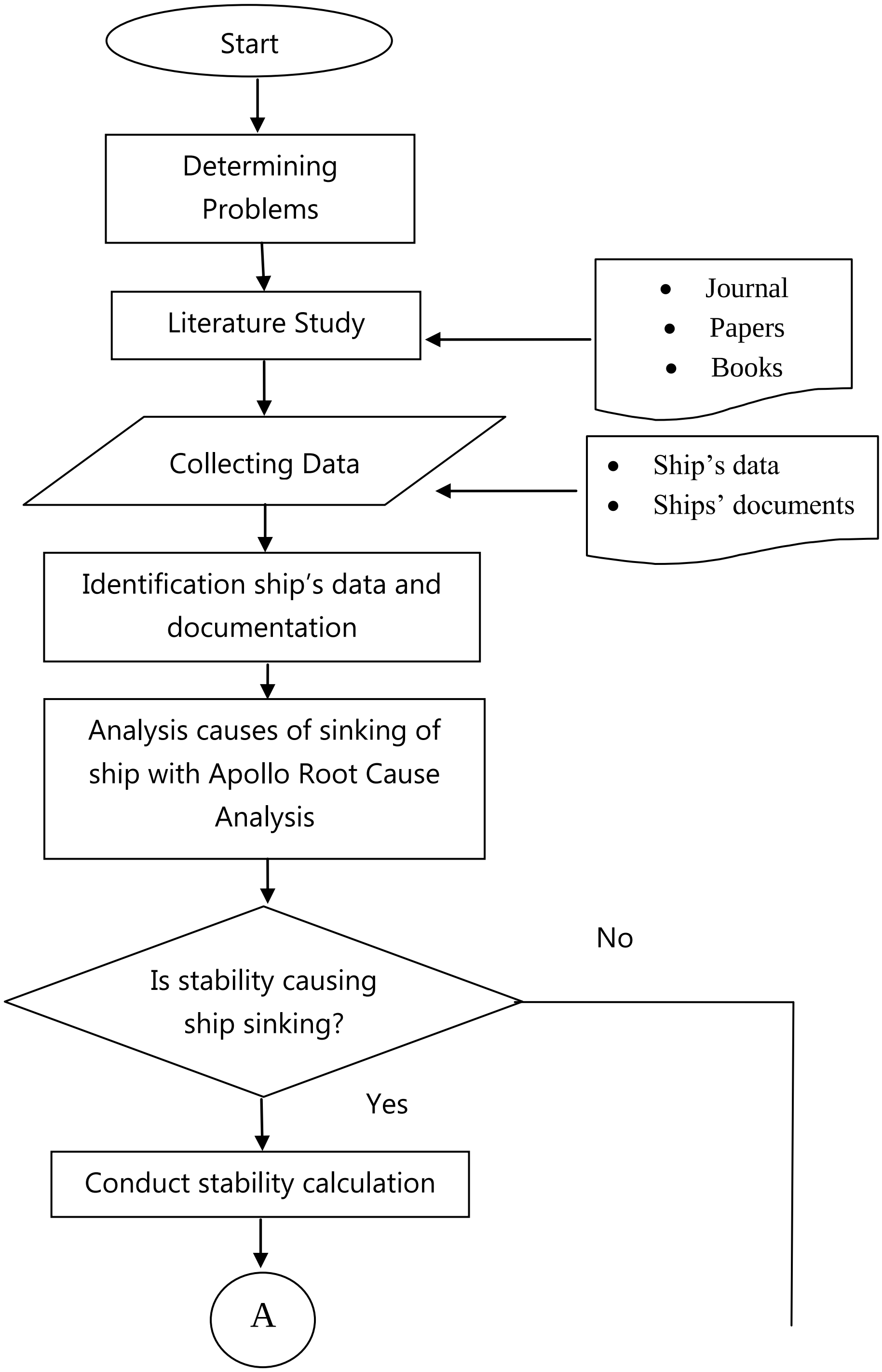

Figure 3.1 Flow Chart Diagram

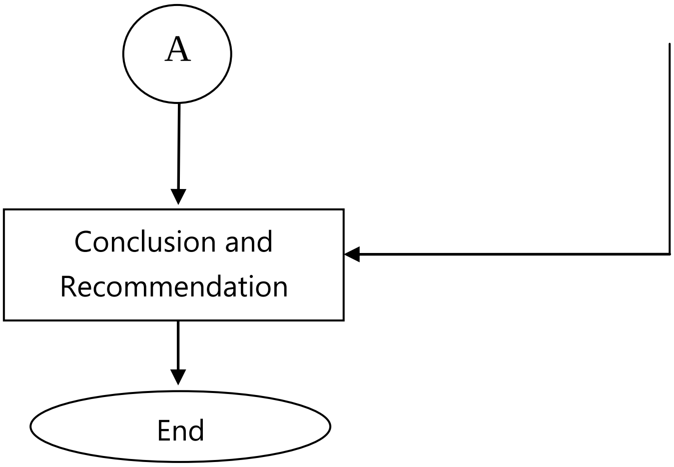

Figure 3.2 Flow Chart Diagram

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CHAPTER 4
DATA ANALYSIS

4.1 Overview

Ship accident can be caused by many factors from construction, crews, owner or port authorities. This chapter will discuss the causes of the sinking of KMP Rafelia 2 by analyze data using 5 whys(using Apollo root cause analysis) method. Data that is required are documents of the ship, ship accident's report, letter of permit to sail and others.

First, data will be identify to determine fault related to the sinking of KMP Rafelia 2. Next, documents will be identify using RealityCharting to know the root cause of the accident. After getting the cause of accident, afterwards is identify possible solution to prevent similar conditions and minimize the accident.

4.2 Data Analysis

4.2.1 Data Identification

This chapter will analysis data using Apollo root cause analysis. In this case, data that will be identified and analyzed are:

1. Accident's Report
2. General Arrangement
3. Certificates and Documents of Ship
4. Letter of Permit to Sail
5. Stability Analysis

4.2.1.1 General Arrangement

General arrangement is to determine the rooms on board to all activities and equipment required based on the layout and way to reach out the room. General arrangement can be determine as a determination of all the rooms that be required, it means as loading space, engine room and superstructure. General arrangement also design some other systems and equipments.

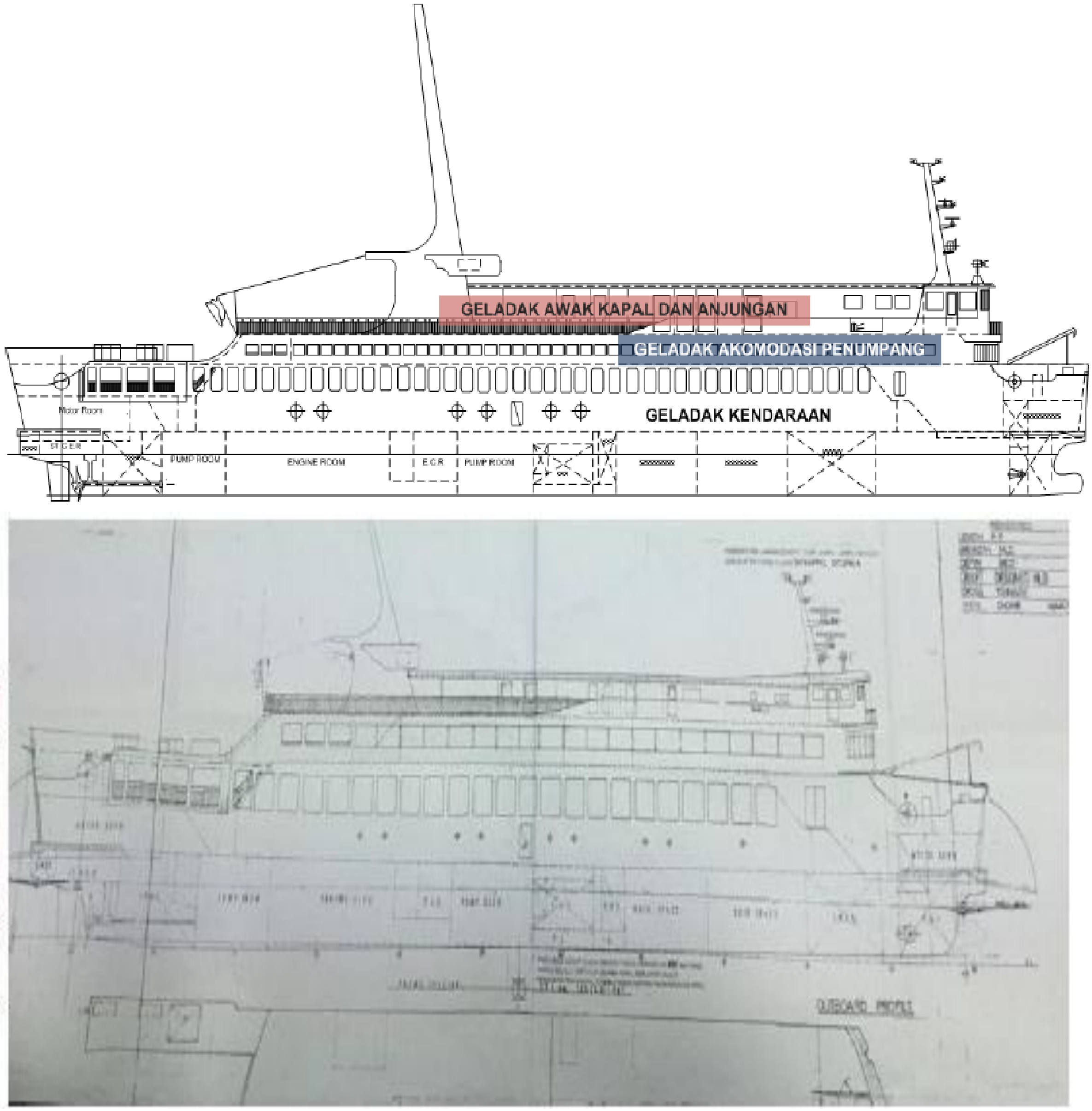

Figure 4.1 General Arrangement of KMP Rafelia 2[12]

Figure 4.1 shows the General Arrangement of KMP Rafelia 2. The above figure is general arrangement of KMP Rafelia 2 which was different from the actual condition. The below one is design of general arrangement made at 2012 based on actual condition. The difference between those two designs shows that KMP Rafelia 2 has added the bulbous bow from its original design.

4.2.1.2 Accident's Report

Reports on the incidents is a report about an event or an accident which was written by authority in order to provide a detailed explanation in the form of a letter or writing, accompanied by evidence that already exist.

4.2.1.3 Certificates and Documents of Ship

Certificates and documents are letters or documentation that owned by a ship which shows that the ship was seaworthy and ready to sail. These letters also to shows that the ship in good condition in accordance with the rules of classification.

4.2.1.4 Permit to Sail

Letter of permit to sail is letter issued by the port state as evidence that the ship was allowed to sail. If the ship did not have letter of permit to sail, ship can not be operated.

4.2.1.5Stability Analysis

Stability analysis is analysis of the ability of the ship to be back in upright to its original position after getting forces from outside. It aims to determine factors that affect the stability of the ship. This thesis will be analyzed the stability when the ship in condition initial heeling at 5 degrees.

4.2.2Root Cause Analysis

Since documents that requires has been obtained, next step is analyze the document to understand the causes of KMP Rafelia 2 accident. This thesis using Apollo root cause method.

RealityCharting is a process that utilized by Apollo root cause method which can becoming the standard for all event analysis because it is the only process that understands and follows the cause-and-effect principles.

The first step is to determine the top event. Based on the instructor, the top even is adjusted to the accident that had happened. So, the sinking of KMP Rafelia 2 was chosen as the top even.

In working on root cause analysis using RealityCharting which encompasses all known causes as well as their relationships with each other, each event should be determined by action and condition. Ship accident, as the top event, caused by many factors. The factors of this accident are technical cause and human error. Human error is the major cause in most of maritime accident. Therefore, technical cause is the condition and human error is an action. As seen on Figure 4.2

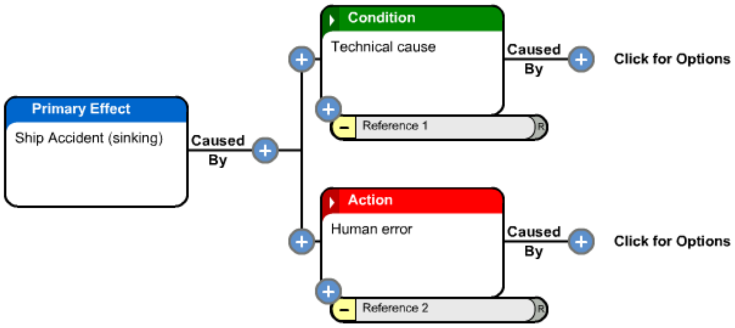

Figure 4.2 Factors that causing KMP Rafelia 2 sinking

Furthermore, determine the technical cause and human error. First, define the technical cause of this accident. In KMP Rafelia 2 accident, ship was sinking caused by decrease of ship stability and water that flooded the car deck as seen on figure 4.3 below.

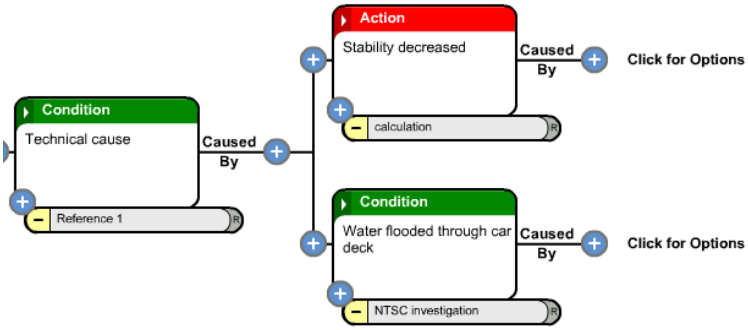

Figure 4.3 Technical factors

Reasons of decreasing stability are ship stability in departure condition were not in good condition, overload and cargo shifting. According from data, lines plan and general arrangement as supporting data for stability booklet, evidently was not accordance with the actual condition of the ship.[1]Hence, the stability was not comply with IMO regulation because the calculation of stability not based on the actual ship condition.

Second, cargo loads exceeds the loads that can be carried. It would decrease the ship stability. Overload can caused by lack of control on cargo load weight. Therefore, the loads that carried was over because there might be the lack of control from port state. As mentioned in Regulation of Minister of Transportation of Republic Indonesia PM no. 27 2016 chapter 3 about supervision of loading vehicles. Ship crews just adjust the loads and not observe the weight of loads. So, in this case, lack of supervision from port state and ship crews leads to overload of cargo.

Moreover, cargo that will be carried by the ship, must be lashed to prevent cargo shifting while the ship was rolling or trim. Cargo shifting may decrease ship stability. Because when ship rolling, if crew not lash the cargo, it will move to one side of the ship and may causing ship sinking when the ship could not maintain stability and back to its original position. In KMP Rafelia 2's case, cargo were not lashed and not arranged properly. In Regulation of Minister of Transportation of Republic Indonesia PM no. 30 2016, already mentioned that every vehicles must be lashing during sailing and it also regulate about procedure to arrange the vehicles.

Another technical factor of this accident is water flooded through car deck. When the chief officer noticed that clinometers showed that the ship heel to starboard, chief officer asked stower to checked the condition in car deck and water already flooded through car deck. The reasons of flooded are ramp door was not closed properly. In ABS part 3 chapter 2 section 9.5 rules for building and classing steel vessel 90 M and above mentioned that doors or ramps may be approved on condition that the shipboard personnel close them before the voyage commences and kept closed during navigation. But, in this case, ramp door was not closed properly because the length of it has been modified from 8 meters to 13 meters. The modification of ramp door is to complied the requirement to be operated as ferry from Ketapang to Gilimanuk. Owner does not report the modification of ramp door to classification.

The modification of ramp door, as seen on figure 4.4, also causing blocking navigation because it longer than it design. In ABS part 3 chapter 6 section 1 about visibility mentioned that the view of sea surface from conning position not to be obscured by more than $2L_{OA}$ or 500 m. By modifying the ramp door, the view of sea surface from conning position will be disturbed and blocking the navigation. Figure 4.4 shows the modified of ramp door if it close properly.

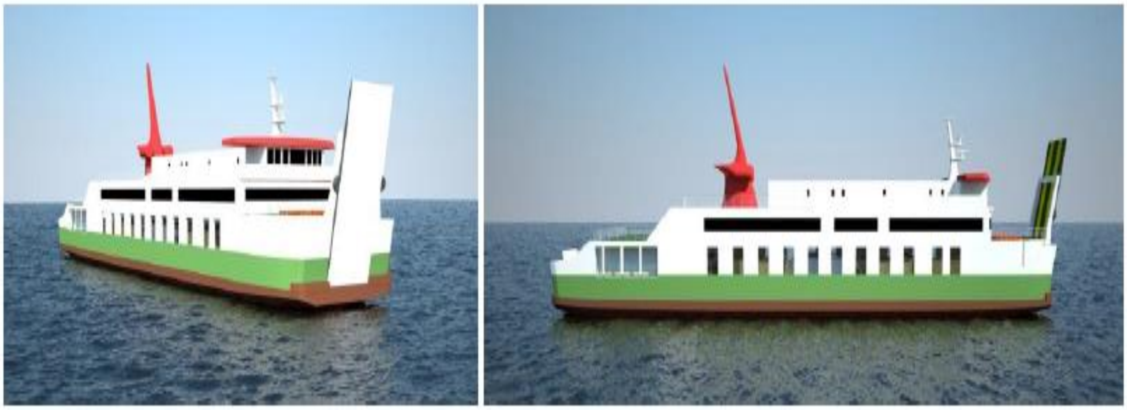

Figure 4.4 Modification of ramp door[12]

The condition of ramp door that was not closed properly, water that could not be discharged quickly also causing the flood in car deck. Even scupper are design to discharge water as many as possible, but when water starts flooding in car deck, scupper could not discharge the water quickly. Water that flooded in car deck makes KMP Rafelia 2 lost its stability and heel to starboard.

Another cause that causing the sinking of KMP Rafelia 2 is human error. Human error is the most common reason of marine accident. Based on USCG data, for all accidents over the reporting period 1999 to 2001, approximately 80 to 85% of the accidents analyzed involved human errors[15][2]. In this case, human error also become one of the factor the ship sinking. Human error in KMP Rafelia 2 are manifest that does not equal with the actual condition and ship crews is less responsible when water starts flooding the car deck.

Lack of supervision from port state to crews causing manifest of loads not matched with the actual condition and also the cargo load weight. In Regulation of Ministry Transportation of Republic Indonesia no. 25 2016 determined the procedure of passenger list and the vehicles list. When the accident happened, number of victims were not match with the manifest. This was not accordance with the regulation.

Another human error factor is crew that not responsible at the beginning of flood in car deck. In this case, more info needed why crew did not responsible at the beginning flood water in car deck.

4.2.3 Stability Analysis

Stability analysis is analysis of the ability of the ship to be back in upright to its original position after getting forces from outside. Here are the principal data of KMP Rafelia2 :

LOA	: 65.8 m
LPP	: 61.15 m
B	: 14 m
T	: 3 m
H	: 3.89 m
Speed	: 6 knot

Stability of ships are regulated based on IMO Resolution A.749 (18). IMO Resolution A.749 (18) is an international code on intact stability. The purpose of this code is to present the mandatory and recommendatory stability criteria and other measure for ensuring the safe operation of ships, to minimize the risk to such ships, to the personnel on board and to the environment. It also determine the special criteria for certain types of ships. The following is the criteria based on IMO Resolution A.749 (18) that used to passenger ship about the righting arm[16]:

1. Chapter 3.1.2.1:
   The area under righting lever curve (GZ Curve) shall not be less than o.o55 m radian up to θ= 30 degree angle of heel and not less than 0.09 m radian up to θ= 40 degree. The area under righting lever curve (GZ Curve) between angle 30- 40 degree, shall not be less than 0.03 m radian.
2. Chapter 3.1.2.3:
   The maximum righting arm should occur at an angle of heel preferably exceeding 30 degree but not less than 25 degree.
3. Chapter 3.1.2.4:
   The initial metacentric height GM_0 shall not be less than 0.15 m.

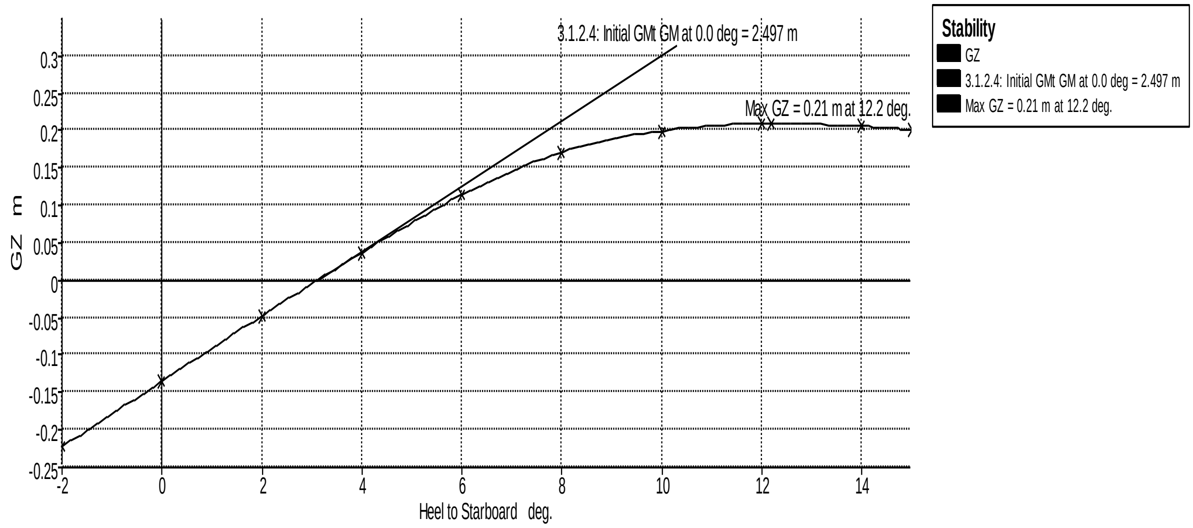

Figure 4.5 GZ Curve

Figure 4.7 shows the GZ curve of initial heeling at 5 degree. The ship heeling to starboard. Based on calculation, maximum righting arm is 0.21 m at an angle of heel 12.2 degree. The area under righting lever curve in this condition is less than 0.055 m radian at less than 30 degree. According to criteria based on IMO Res. A.749 (18), the maximum righting arm should occur at an angle of heel not less than 25 degree and area under righting lever (GZ) shall not less than 0.055 m radian at 30 degree. This condition means that stability of this ships does not comply with IMO requirement.

This calculation will be compared with the stability data from NTSC report. Figure 4.8 shows the stability condition of KMP Rafelia 2 at departure condition from the report. In this condition, KMP Rafelia already inclined at angle of heel 1.5 degree.

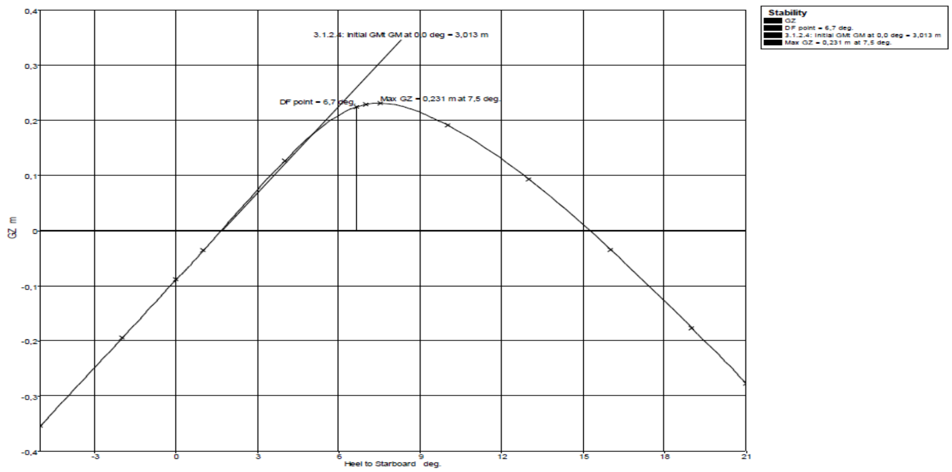

Figure 4.6 GZ Curve at departure condition[12]

Figure above informed that the maximum righting arm at departure condition is 0.231 m with the righting moment at 7.5 degree. According to the requirement, IMO A.749 (18), GM condition is in acceptable range, but the righting arm condition was unacceptable. This condition can cause the risk of its stability.

On the other hand, the risk could be increasing because of sea condition. Displacement of KMP Rafelia 2 is 1478 tons while from the main particular, displacement of this ship is 1219 tons. It shows that KMP Rafelia 2 is overload about 259 tons. This condition could be decreasing the stability.

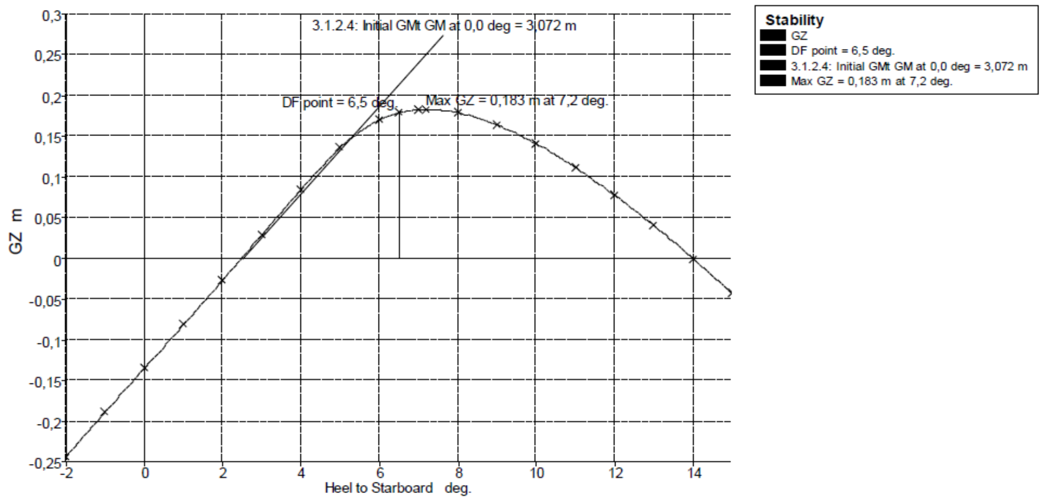

Figure 4.7 GZ Curve at initial heeling 5 degree[12]

Figure 4.9 shows the condition of KMP Rafelia 2 at initial heeling 5 degree. It calculated by NTSC. Maximum GZ in this curve is 0.183 m while the righting moment is at 7.2 degree. The initial GM at 0.0 degree is 3.072 m. Comparing with the previous calculation at the same condition, we will see difference amount of maximum righting arm and different number of righting moment. But, both of calculation, none of them are comply with the requirement.

This curve shows that maximum GZ was decreased from 0.213 m at angle of heel 7.5 degree to 0.183 m at 7.2 degree. Decreasing of GZ caused by displacement that increased. Estimation water that flooded through car deck around 10 tons to make ship inclined to 5 degrees. Furthermore, the cargo loads (vehicles) were not lashed. So, when the ship was inclined, the cargo shifted. Weight shifting will makes the centre of gravity (G) moves to the same direction as a weight shifting. This conditions makes the ship’s stability decreased.

CHAPTER 5
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on data analysis and result which has been done in the previous section, root cause of KMP Rafelia 2 are:

1. Displacement of KMP Rafelia 2 was not matched with the main particular. Displacement from main principal is 1219 tons during the accident, displacement of the ship is 1478 tons.
2. The stability of ship was not comply with IMO requirement from the departure condition and it decreased continuously. Ship can not maintain the stability.
3. The sinking of KMP Rafelia 2 might be caused by lack of supervision from port state and crews does not responsible in the beginning of flooding in car deck.
4. The root cause of this accident are lack of control on cargo load. Cargo loads (vehicles) are not lashed. It does not arranged properly. This ship also overload. Lack of control on load weight.
5. Extension of ramp door cause ramp door can not be close properly that leads to contribute to this accident.
6. From data that has been identified, class certificate of this ship is suspended. But ship still permitted to sail.

5.2 Recommendation

As recommendation that can be deliver in correlate with this bachelor thesis are:

1. Port state should re-check the ship's documents before giving permission for ship to sail.
2. Cargo load should be check before departure. The arrangement of cargo loads should be calculated based on center of gravity and observe the weight of cargo loads.
3. If any changes in ship, owner should give report to classification bureau immediately.
4. Ship stability should be calculated based on actual condition before ship start sailing.

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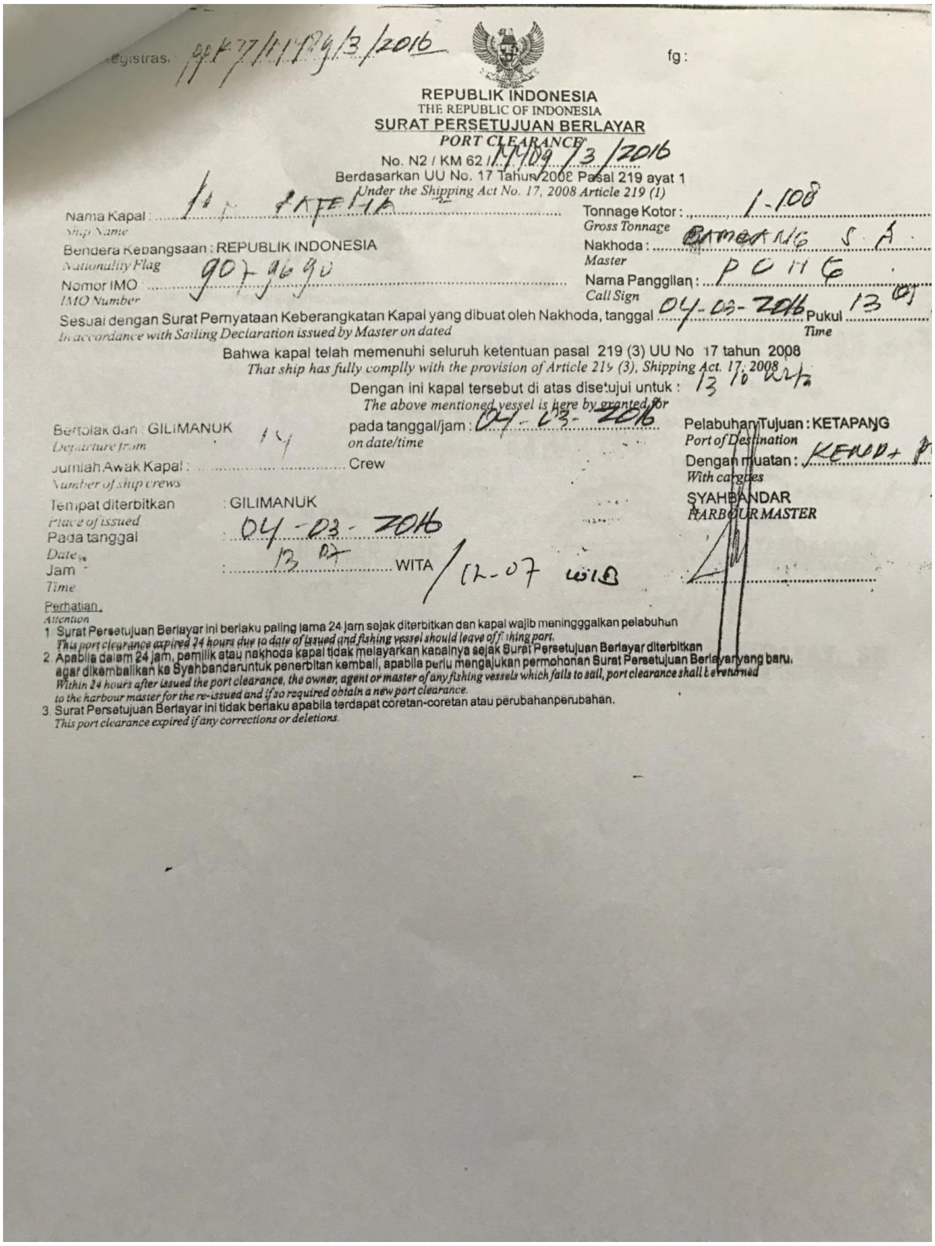
ATTACHMENT



Registrasi: PK77/11/189/3/2016 fg:

REPUBLIK INDONESIA
THE REPUBLIC OF INDONESIA
SURAT PERSETUJUAN BERLAYAR
PORT CLEARANCE
No. N2 / KM 62 / 11/109 / 3 /2016
Berdasarkan UU No. 17 Tahun 2008 Pasal 219 ayat 1
Under the Shipping Act No. 17, 2008 Article 219 (1)

Nama Kapal / *Ship Name*: KM. FATEMA
Tonnage Kotor / *Gross Tonnage*: 1-108
Bendera Kebangsaan / *Nationality Flag*: REPUBLIK INDONESIA
Nakhoda / *Master*: BAMBANG S. A.
Nomor IMO / *IMO Number*: 9079690
Nama Panggilan / *Call Sign*: POHG
Sesuai dengan Surat Pernyataan Keberangkatan Kapal yang dibuat oleh Nakhoda, tanggal 04-03-2016 Pukul 13.07
In accordance with Sailing Declaration issued by Master on dated / *Time*

Bahwa kapal telah memenuhi seluruh ketentuan pasal 219 (3) UU No 17 tahun 2008
That ship has fully complly with the provision of Article 219 (3), Shipping Act. 17, 2008
Dengan ini kapal tersebut di atas disetujui untuk: 13.10 WITA
The above mentioned vessel is here by granted for

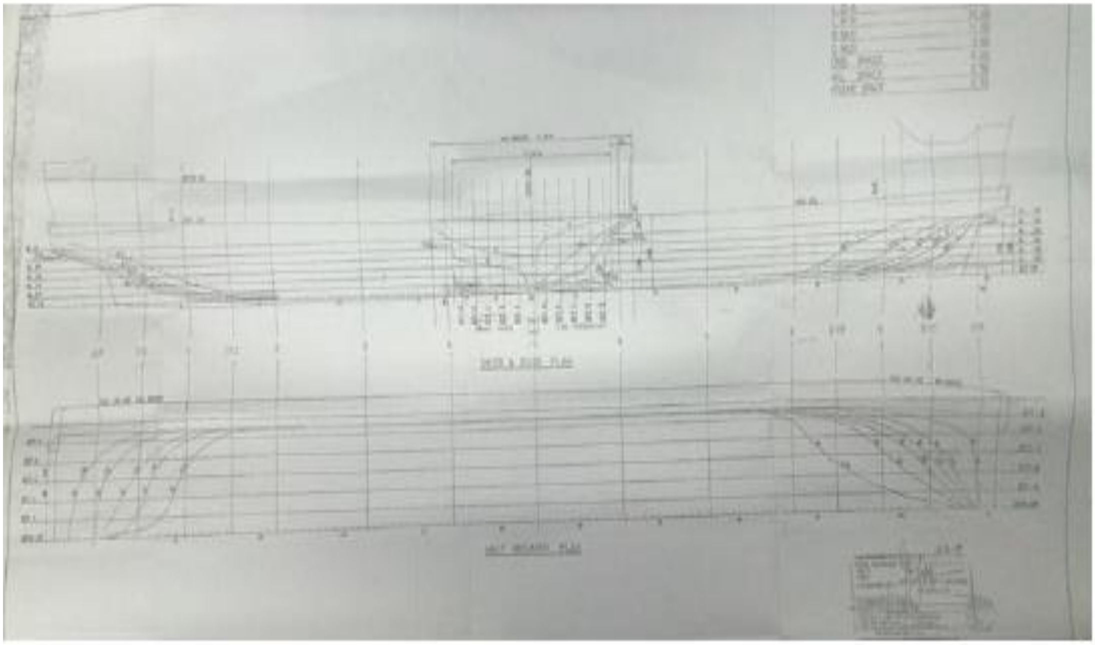
Bertolak dari / *Departure from*: GILIMANUK
pada tanggal/jam / *on date/time*: 04-03-2016
Pelabuhan Tujuan / *Port of Destination*: KETAPANG
Jumlah Awak Kapal / *Number of ship crews*: 14 Crew
Dengan muatan / *With cargoes*: KEND+P

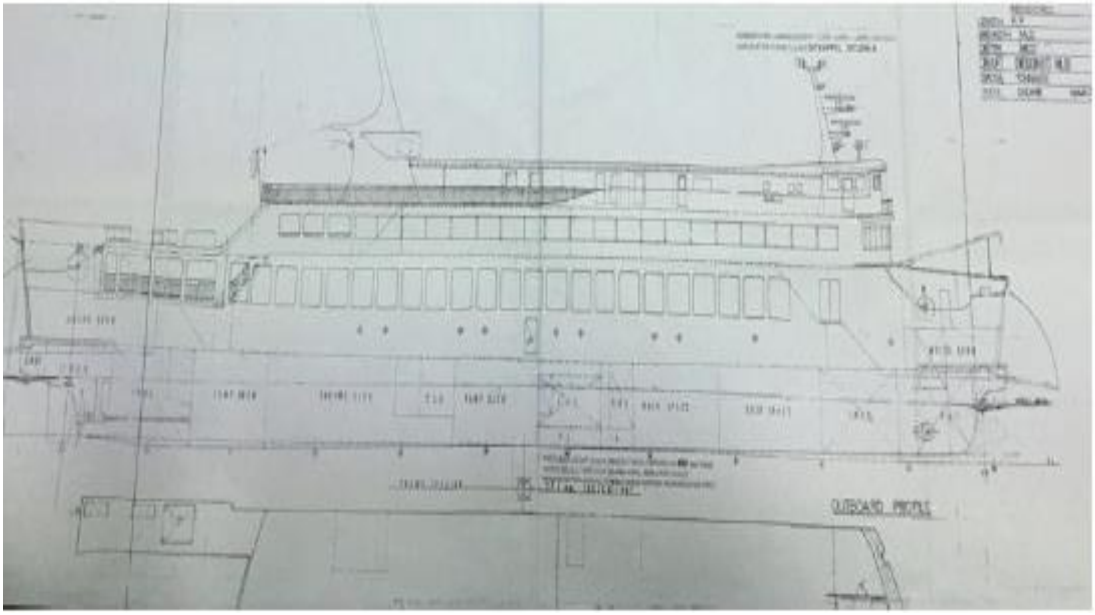
Tempat diterbitkan / *Place of issued*: GILIMANUK
Pada tanggal / *Date*: 04-03-2016
Jam / *Time*: 13.07 WITA / 12-07 WIB

SYAHBANDAR
HARBOUR MASTER

Perhatian / *Attention*
1. Surat Persetujuan Berlayar ini berlaku paling lama 24 jam sejak diterbitkan dan kapal wajib meninggalkan pelabuhan
This port clearance expired 24 hours due to date of issued and fishing vessel should leave of fishing port.
2. Apabila dalam 24 jam, pemilik atau nakhoda kapal tidak melayarkan kapalnya sejak Surat Persetujuan Berlayar diterbitkan agar dikembalikan ke Syahbandaruntuk penerbitan kembali, apabila perlu mengajukan permohonan Surat Persetujuan Berlayar yang baru.
Within 24 hours after issued the port clearance, the owner, agent or master of any fishing vessels which fails to sail, port clearance shall be returned to the harbour master for the re-issued and if so required obtain a new port clearance.
3. Surat Persetujuan Berlayar ini tidak berlaku apabila terdapat coretan-coretan atau perubahanperubahan.
This port clearance expired if any corrections or deletions.

Attachment 1 Letter of Permit to Sail





Attachment 2 Lines plan and General arrangement

tanggal 4 Maret 2015 data GT pada Sertifikat Klasifikasi Lambung dan pada Sertifikat Garis Muat tidak sama.

8. Pemberitahuan BKI kepada otoritas terkait perihal perubahan lambung timbul dari 1212 mm menjadi 912 mm kurang diperhatikan sehingga pada Sertifikat Keselamatan Kapal Penumpang yang dikeluarkan oleh Kesyahbandaran Utama Tg Priok dan KSOP Benoa masih mencantumkan lambung timbul 1212 mm.

9. KMP. Rafelia 2 tidak menjalani Survey Tahunan paling lambat pada tanggal jatuh tempo Survey Tahunan pada tanggal 5 Nopember 2015 sehingga sejak tanggal 06 November 2015 sampai dengan KMP Rafelia 2 tenggelam pada tanggal 4 Maret 2016, kelas kapal ditangguhkan (suspended).

10. Sebagian otoritas terkait baik di Ditjen Hubla maupun Ditjen Hubdat yang berhubungan dengan kapal penyeberangan belum/ kurang mememahami waktu jatuh tempo survey tahunan dan jendela waktu (time window) pelaksanaan survey serta data yang tercantum baik dihalaman depan maupun halaman belakang (visa) pada sertifikat klasifikasi lambung dan sertifikat garis muat yang dikeluarkan oleh BKI, sehingga setelah kelas kapal ditangguhkan sejak tanggal 6 Nopember 2015, masih ada pemeriksaan yang dilaksanakan dan dokumen yang dikeluarkan oleh instansi terkait.
    a. KMP. Rafelia 2 diperiksa oleh Tim Teknis Ditjen Hubdat – Subdit Angkutan SDP pada tanggal 25 Nopember 2015.

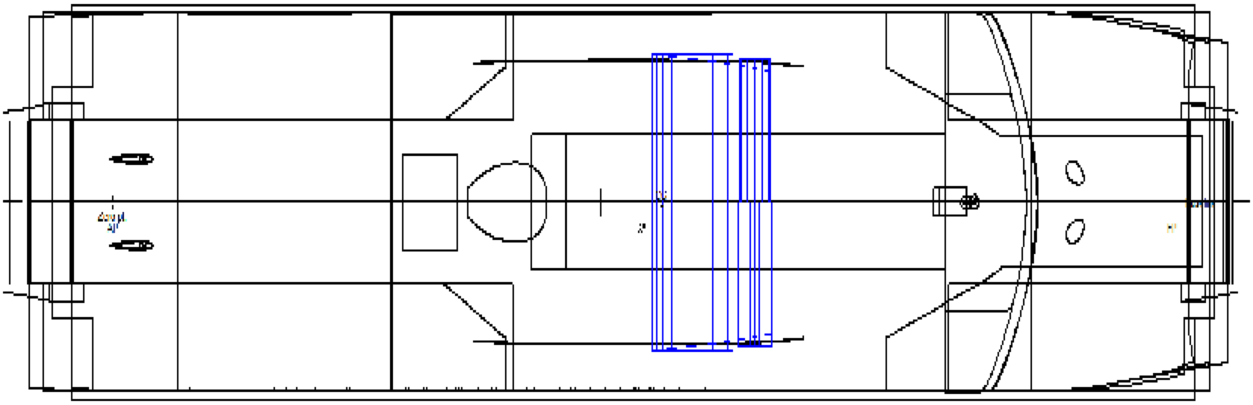
       Dikeluarkan Berita Acara Uji Coba KMP. Rafelia 2 dengan beberapa rekomendasi, salah satunya:

       ✓ Apabila KMP. Rafelia 2 akan dioperasikan di Dermaga Beaching LCM Ketapang maupun Gilimanuk, maka rampdoor agar diubah dan diperpanjang kurang lebih 13 meter, mengingat draft haluan 1,8 meter
    b. Surat Direktur LLASDP No.AP.005/20/11/DJPD/2015 tanggal 17 Desember 2015 tentang Persetujuan Pengoperasian KMP. Rafelia 2 pada Lintas Penyeberangan Ketapang-Gilimanuk.
    c. Keputusan Dirjen Hubdat No. SK.8019/AP.005/DRJD/2015 tanggal 17 Desembar 2015 tentang Persetujuan Pengoperasian Kapal Angkutan Penyeberangan.
    d. Keputusan Dirjen Hubdat No. SK.213/LLASDP/XII/2015 tgl. 17 Desember 2015 tentang Pemenuhan Standar Minimal Angkutan Penyeberangan.

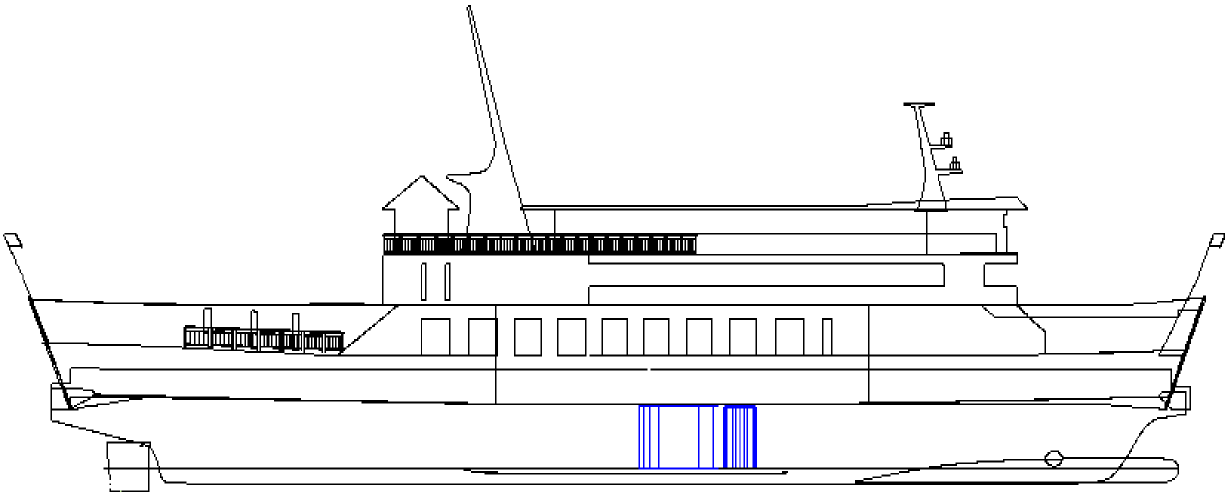
e. Sertifikat Keselamatan Kapal Penumpang No. PK.001/89/13/KSOP BNA-2015 tanggal 22 Desember 2015, yang berlaku s/d 22 Maret 2016, dikeluarkan oleh Kepala Kantor Kesyahbandaran dan Otoritas Pelabuhan Benoa.

f. Berita Acara Uji Coba Rampdoor KMP. Rafelia II di Lintasan Ketapang-Gilimanuk tanggal 23 Januari 2016.

g. Surat Kasi Operasi Kantor Otoritas Penyeberangan Gilimanuk No. AP.007/13/14/OPP-GM/2016 tanggal 4 Maret 2016 tentang Persetujuan Masuk Lintasan.



Attachment 3 Top View of Tank Position



Attachment 4 Side View of Tank Position

Stability Calculation - Rafelia2 edited 3

Stability 20.00.06.0, build: 0

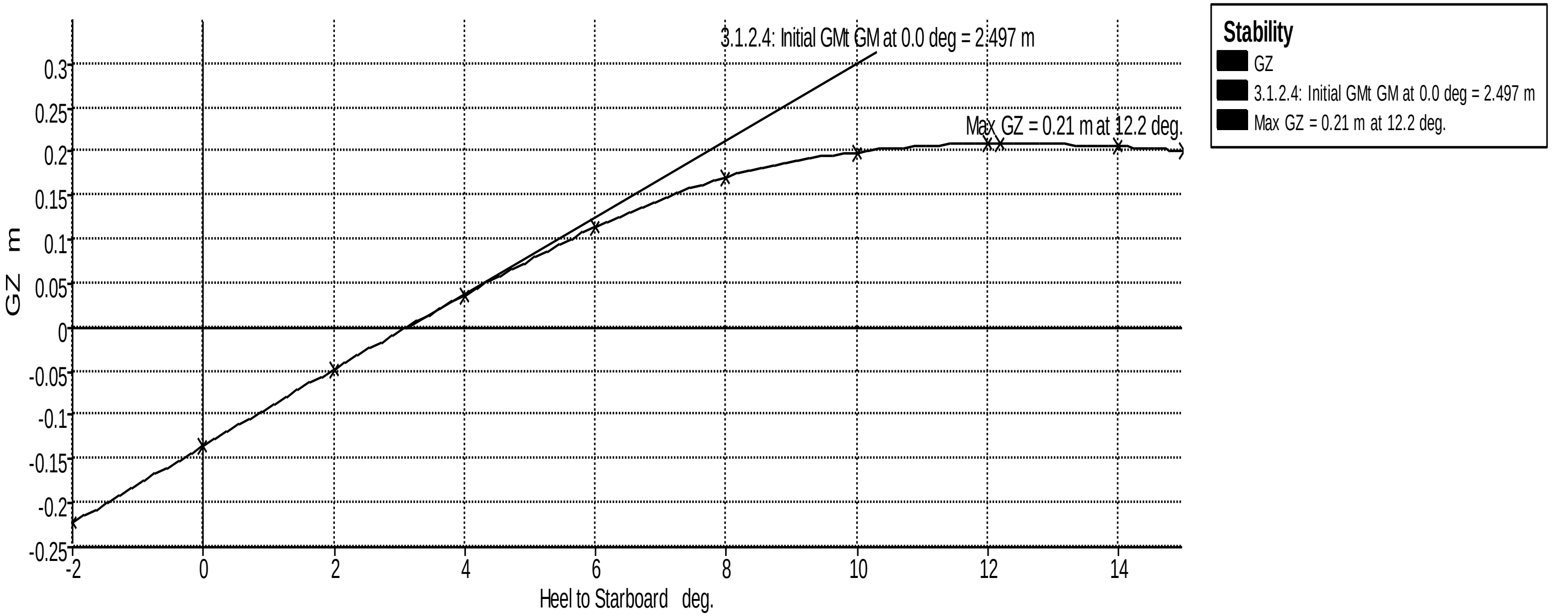
Model file: D:\Titip\KMP Rafelia 2\Rafelia2 edited 3 (Medium precision, 119 sections, Trimming on, Skin thickness not applied). Long. datum: User def.; Vert. datum: User def.. Analysis tolerance - ideal(worst case): Disp.%: 0.01000(0.100); Trim%(LCG-TCG): 0.01000(0.100); Heel%(LCG-TCG): 0.01000(0.100)

Loadcase - Initial Heeling 5 deg
Damage Case - Intact
Free to Trim
Specific gravity = 1.025; (Density = 1.025 tonne/m^3)
Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	633.720	633.720			31.830	0.000	5.846	0.000	User Specified
FPT (P)	0	35.085	0.000			57.569	-0.001	0.319	0.000	User Specified
FPT (S)	0	35.085	0.000			57.569	0.001	0.319	0.000	User Specified
SWBT NO. 1 (P)	0	72.263	0.000			49.528	-0.307	0.177	0.000	User Specified
SWBT NO. 1 (S)	0	72.263	0.000			49.528	0.307	0.177	0.000	User Specified
FWT (P)	30.17%	28.652	8.644	28.652	8.644	36.567	-2.558	1.319	21.835	Actual
FWT (S)	21.24%	28.681	6.092	28.681	6.092	36.567	2.533	1.167	21.569	Actual
Tank004	5%	73.540	3.677	77.877	3.894	32.963	-2.653	0.884	55.135	Actual
Tank005	5%	73.540	3.677	77.877	3.894	32.963	2.653	0.884	55.135	Actual
SWBT NO. 2 (P)	0	49.011	0.000			6.129	-0.116	0.000	0.000	User Specified
SWBT NO. 2 (S)	0	49.011	0.000			6.129	0.116	0.000	0.000	User Specified
Ramp	1	16.000	16.000			69.650	0.000	5.000	0.000	User Specified
Beban Oleng	1	10.000	10.000			28.764	7.000	3.900	0.000	User Specified
Penumpang	60	0.075	4.500			28.764	0.000	10.000	0.000	User Specified
Crew	22	0.075	1.650			28.764	0.000	5.000	0.000	User Specified

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
TRONTON 6 BAN	1	15.000	15.000			3.831	-3.274	5.300	0.000	User Specified
TRONTON 10 BAN	1	25.000	25.000			3.831	0.000	5.500	0.000	User Specified
TRONTON 10 BAN	1	40.000	40.000			3.831	3.274	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			14.077	-5.589	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			14.077	-2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			14.077	2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			16.223	5.589	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			23.838	-5.589	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			23.838	-2.032	5.500	0.000	User Specified

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
DUMP TRUK 10 BAN	1	40.000	40.000			23.838	2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			25.707	5.589	5.500	0.000	User Specified
TRUK ENGKEL 6 BAN	1	15.000	15.000			31.869	-5.589	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			33.323	-2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			33.323	2.032	5.500	0.000	User Specified
TRUK ENGKEL 6 BAN	1	15.000	15.000			33.738	5.589	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			41.907	-5.589	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			42.807	-2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			42.807	2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			42.807	5.589	5.500	0.000	User Specified
L300	1	4.000	4.000			50.215	-5.589	4.900	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			51.876	-2.032	5.500	0.000	User Specified
DUMP TRUK 10 BAN	1	40.000	40.000			51.876	2.032	5.500	0.000	User Specified
L300	1	4.000	4.000			56.307	-4.629	4.900	0.000	User Specified
TRUK ENGKEL 6 BAN	1	15.000	15.000			57.706	4.798	5.300	0.000	User Specified
L300	1	4.000	4.000			61.718	-2.823	4.900	0.000	User Specified
L300	1	4.000	4.000			59.978	0.000	4.900	0.000	User Specified
TRUK ENGKEL 6 BAN	1	15.000	15.000			63.061	2.371	5.300	0.000	User Specified
Tank011	0	25.768	0.000			29.818	0.000	3.900	0.000	User Specified
Total Loadcase			1483.960	213.088	22.524	31.269	0.135	5.567	153.675	
FS correction								0.104		
VCG fluid								5.671		


3.1.2.4: Initial GMt GM at 0.0 deg = 2.497 m
Max GZ = 0.21 m at 12.2 deg.
GZ m
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-2
0
2
4
6
8
10
12
14
Heel to Starboard deg.
Stability
GZ
3.1.2.4: Initial GMt GM at 0.0 deg = 2.497 m
Max GZ = 0.21 m at 12.2 deg.

Heel to Starboard deg	-2.0	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	15.0
GZ m	-0.222	-0.135	-0.048	0.037	0.114	0.171	0.200	0.210	0.206	0.201
Area under GZ curve from zero heel m.rad	0.0060	-0.0008	0.0031	-0.00327	-0.0006	0.0042	0.0106	0.0176	0.0247	0.0282
Displacement t	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Draft at FP m	3.511	3.519	3.511	3.490	3.457	3.434	3.431	3.440	3.457	3.467
Draft at AP m	3.020	3.025	3.020	3.002	2.977	2.944	2.905	2.870	2.836	2.821
WL Length m	65.259	65.277	65.259	65.410	65.561	66.146	66.147	66.197	66.198	66.198
Beam max extents on WL m	13.053	13.018	13.054	12.864	12.914	12.923	12.978	13.057	13.155	13.212
Wetted Area m^2	988.421	990.657	988.439	979.641	983.676	1036.737	1084.035	1131.288	1176.594	1196.786
Waterpl. Area m^2	711.481	713.766	711.496	701.178	688.395	641.104	597.759	560.849	529.331	516.862
Prismatic coeff. (Cp)	0.613	0.612	0.613	0.612	0.611	0.608	0.612	0.616	0.622	0.625
Block coeff. (Cb)	0.492	0.493	0.492	0.481	0.462	0.442	0.424	0.405	0.387	0.378
LCB from zero pt. (+ve fwd) m	31.300	31.300	31.300	31.300	31.299	31.300	31.303	31.305	31.308	31.309
LCF from zero pt. (+ve fwd) m	31.642	31.778	31.642	31.247	30.857	30.068	29.403	29.173	29.130	29.143
Max deck inclination deg	2.0536	0.4691	2.0536	4.0265	6.0170	8.0132	10.0120	12.0115	14.0115	15.0114
Trim angle (+ve by stern) deg	-0.4665	-0.4691	-0.4666	-0.4628	-0.4559	-0.4651	-0.4998	-0.5413	-0.5899	-0.6139

Code	Criteria	Value	Units	Actual	Status	Margin %
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ	25.0	deg	12.2	Fail	-51.22
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt	0.150	m	2.497	Pass	+1564.67

Stability Calculation by NTSC

STABILITY CALCULATION – RAFELIA 2

Departure condition

Stability 20.00.02.31, build: 31

Model file: E:\maxsurf\rafelia_2c (Highest precision, 509 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0,01000(0,100); Trim%(LCG-TCG): 0,01000(0,100); Heel%(LCG-TCG): 0,01000(0,100)

Loadcase - FULL LOAD – departure condition

Damage Case - Intact

Free to Trim

Specific gravity = 1,025; (Density = 1,025 tonne/m^3)

Fluid analysis method: Use corrected VCG

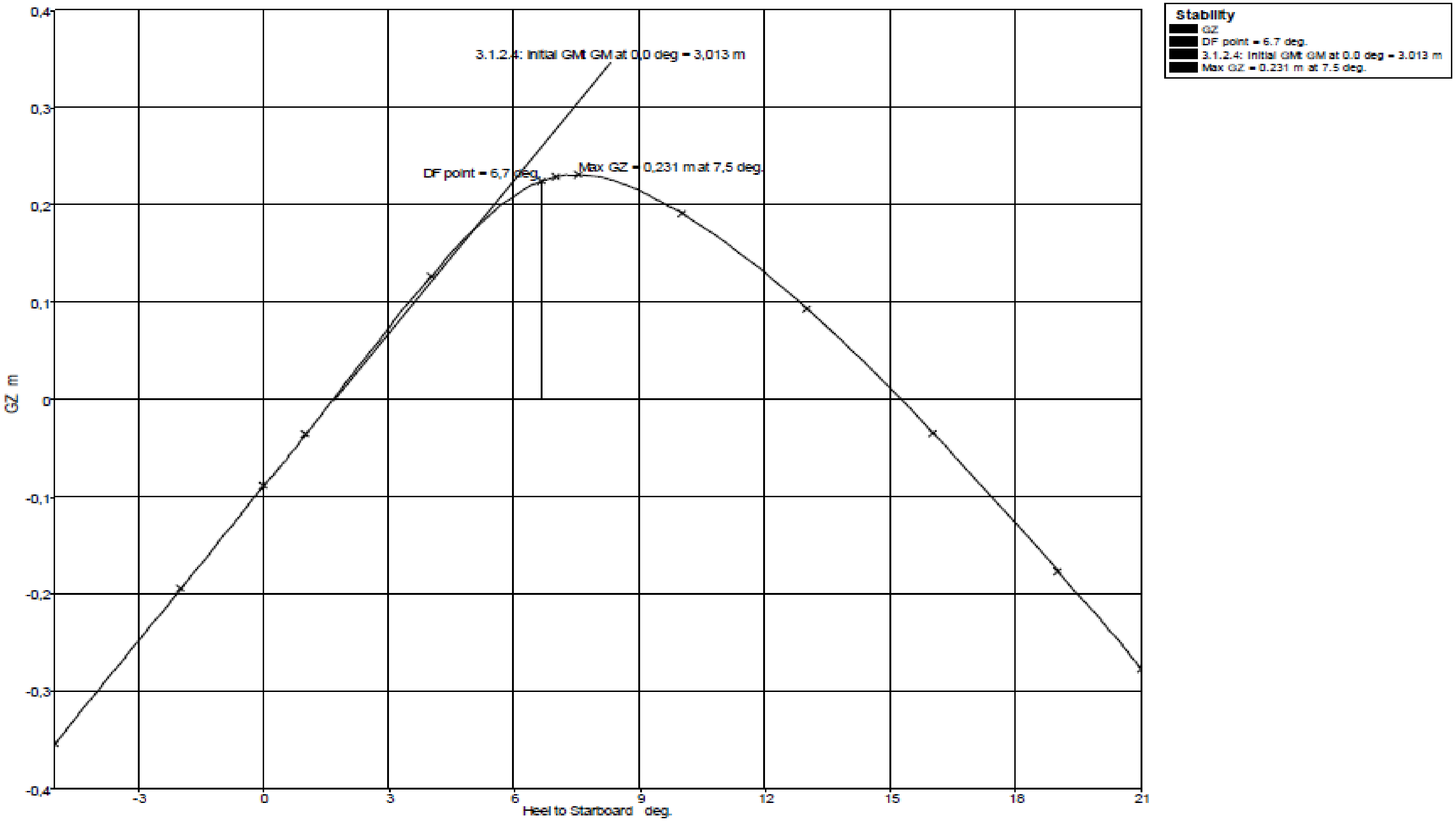
Tabel 0-1: Load Case

Item Name	Specific gravity	Fluid type	Quantity	Sounding m	Unit Mass tonne	Total Mass tonne	Long. Arm m	Aft. Limit m	Fwd. Limit m	Trans. Arm m	Vert. Arm m	Unit FSM tonne.m	Total FSM tonne.m	FSM Type
Lightship			1		633,720	633,720	31,830	31,830	31,830	0,000	5,846	0,000	0,000	User Specified
FPT (P)	Tank default (1,0250)	Sea Water	0%	0,000	35,085	0,000	57,569			-0,001	0,319	n/a	0,000	Actual
FPT (S)	Tank default (1,0250)	Sea Water	0%	0,000	35,085	0,000	57,569			0,001	0,319	n/a	0,000	Actual
SWBT NO. 1 (P)	Tank default (1,0250)	Sea Water	0%	0,000	73,263	0,000	49,528			-0,307	0,177	n/a	0,000	Actual
SWBT NO. 1 (S)	Tank default (1,0250)	Sea Water	0%	0,000	73,263	0,000	49,528			0,307	0,177	n/a	0,000	Actual
FWT (P)	Tank default (1,0000)	Fresh Water	30,17%	1,000	28,975	8,743	36,572			-2,650	1,303	n/a	21,236	Actual
FWT (S)	Tank default (1,0000)	Fresh Water	21,24%	0,707	28,975	6,154	36,571			2,639	1,155	n/a	20,875	Actual
FOT (P)	Tank default	Fuel Oil	5%	0,163	73,983	3,699	32,989			-2,728	0,882	n/a	56,549	Actual

Item Name	Specific gravity	Fluid type	Quantity	Sounding m	Unit Mass tonne	Total Mass tonne	Long. Arm m	Aft. Limit m	Fwd. Limit m	Trans. Arm m	Vert. Arm m	Unit FSM tonne.m	Total FSM tonne.m	FSM Type
	(0,9443)													
FOT(S)	Tank default (0,9443)	Fuel Oil	5%	0,163	73,983	3,699	32,989			2,728	0,882	n/a	56,549	Actual
SWBT NO. 2 (P)	Tank default (1,0250)	Sea Water	0%	0,000	49,011	0,000	6,129			-0,116	0,000	n/a	0,000	Actual
SWBT NO. 2 (S)	Tank default (1,0250)	Sea Water	0%	0,000	49,011	0,000	6,129			0,116	0,000	n/a	0,000	Actual
Ramp			1		16,000	16,000	69,650	69,650	69,650	0,000	5,000	0,000	0,000	User Specified
Beban oleng			0		10,000	0,000	28,764	28,764	28,764	7,000	3,900	0,000	0,000	User Specified
PENUMPANG			60		0,075	4,500	28,764	0,000	0,000	0,000	10,000	0,000	0,000	User Specified
CREW			22		0,075	1,650	28,764	28,764	28,764	0,000	5,000	0,000	0,000	User Specified
TRONTON 6 BAN			1		15,000	15,000	3,831	3,831	3,831	-3,274	5,300	0,000	0,000	User Specified
TRONTON 10 BAN			1		25,000	25,000	3,831	3,831	3,831	0,000	5,500	0,000	0,000	User Specified
TRONTON 10 BAN			1		40,000	40,000	3,831	3,831	3,831	3,274	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	14,077	14,077	14,077	-5,589	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	14,077	14,077	14,077	-2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	14,077	14,077	14,077	2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	16,223	16,223	16,223	5,589	5,500	0,000	0,000	User Specified

Item Name	Specific gravity	Fluid type	Quantity	Sounding m	Unit Mass tonne	Total Mass tonne	Long. Arm m	Aft. Limit m	Fwd. Limit m	Trans. Arm m	Vert. Arm m	Unit FSM tonne.m	Total FSM tonne.m	FSM Type
DUMP TRUK 10 BAN			1		40,000	40,000	23,838	23,838	23,838	-5,589	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	23,838	23,838	23,838	-2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	23,838	23,838	23,838	2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	25,707	25,707	25,707	5,589	5,500	0,000	0,000	User Specified
TRUK ENGKEL 6 BAN			1		15,000	15,000	31,869	31,869	31,869	-5,589	5,300	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	33,323	33,323	33,323	-2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	33,323	33,323	33,323	2,032	5,500	0,000	0,000	User Specified
TRUK ENGKEL 6 BAN			1		15,000	15,000	33,738	33,738	33,738	5,589	5,300	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	41,907	41,907	41,907	-5,589	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	42,807	42,807	42,807	-2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	42,807	42,807	42,807	2,032	5,500	0,000	0,000	User Specified
DUMP TRUK 10 BAN			1		40,000	40,000	42,807	42,807	42,807	5,589	5,500	0,000	0,000	User Specified
L300			1		4,000	4,000	50,215	50,215	50,215	-5,589	4,900	0,000	0,000	User Specified
DUMP TRUK 10			1		40,000	40,000	51,876	51,876	51,876	-2,032	5,500	0,000	0,000	User

Item Name	Specific gravity	Fluid type	Quantity	Sounding m	Unit Mass tonne	Total Mass tonne	Long. Arm m	Aft. Limit m	Fwd. Limit m	Trans. Arm m	Vert. Arm m	Unit FSM tonne.m	Total FSM tonne.m	FSM Type
BAN														Specified
DUMP TRUK 10 BAN			1		40,000	40,000	51,876	51,876	51,876	2,032	5,500	0,000	0,000	User Specified
L300			1		4,000	4,000	56,307	56,307	56,307	-4,629	4,900	0,000	0,000	User Specified
TRUK ENGKEL 6 BAN			1		15,000	15,000	57,706	57,706	57,706	4,798	5,300	0,000	0,000	User Specified
L300			1		4,000	4,000	61,718	61,718	61,718	-2,823	4,900	0,000	0,000	User Specified
L300			1		4,000	4,000	59,978	59,978	59,978	0,000	4,900	0,000	0,000	User Specified
TRUK ENGKEL 6 BAN			1		15,000	15,000	63,061	63,061	63,061	2,371	5,300	0,000	0,000	User Specified
Tank011	Tank default (1,0250)	Sea Water	0%	0,000	25,768	0,000	29,818			0,000	3,900	n/a	0,000	Actual
Total Loadcase						1474,165	31,287			0,088	5,574		155,209	
FS correction											0,105			
VCG fluid											5,679			


3.1.2.4: Initial GMt GM at 0,0 deg = 3,013 m
DF point = 6,7 deg.
Max GZ = 0,231 m at 7,5 deg.
0,4
0,3
0,2
0,1
0
-0,1
-0,2
-0,3
-0,4
GZ m
-3
0
3
6
9
12
15
18
21
Heel to Starboard deg.
Stability
GZ
DF point = 6.7 deg.
3.1.2.4: Initial GMt GM at 0.0 deg = 3.013 m
Max GZ = 0.231 m at 7.5 deg.

Heel to Starboard deg	-5,0	-2,0	0,0	1,0	4,0	7,0	10,0	13,0	16,0	19,0	21,0
GZ m	-0,354	-0,194	-0,088	-0,036	0,127	0,229	0,192	0,093	-0,034	-0,176	-0,277
Area under GZ curve from zero heel m.deg	1,1047	0,2823	-0,0179	-0,0626	0,0789	0,6442	1,3018	1,7381	1,8333	1,5209	1,0684
Displacement t	1474	1474	1474	1474	1474	1474	1474	1474	1474	1474	1474
Draft at FP m	3,336	3,379	3,387	3,385	3,353	3,312	3,317	3,358	3,425	3,514	3,583
Draft at AP m	3,255	3,293	3,301	3,299	3,273	3,227	3,220	3,237	3,271	3,320	3,359
WL Length m	65,364	65,240	64,841	64,815	65,345	65,373	65,410	65,468	65,473	65,476	65,477
Beam max extents on WL m	12,550	12,518	12,480	12,489	12,530	10,818	9,293	8,383	7,777	7,351	7,135
Wetted Area m^2	978,153	987,164	980,853	981,688	985,981	1051,909	1131,387	1179,561	1212,309	1236,370	1249,230
Waterpl. Area m^2	769,900	784,322	777,763	778,660	782,562	649,761	526,073	450,802	399,624	362,478	342,928
Prismatic coeff. (Cp)	0,612	0,611	0,610	0,610	0,612	0,616	0,621	0,627	0,632	0,638	0,641
Block coeff. (Cb)	0,494	0,494	0,494	0,494	0,497	0,556	0,613	0,640	0,649	0,648	0,642
LCB from zero pt. (+ve fwd) m	31,293	31,293	31,287	31,288	31,292	31,292	31,293	31,294	31,296	31,298	31,300
LCF from zero pt. (+ve fwd) m	29,083	28,570	28,385	28,400	28,870	29,620	29,895	30,089	30,230	30,339	30,401
Max deck inclination deg	5,0006	2,0017	0,0825	1,0034	4,0007	7,0005	10,0004	13,0005	16,0006	19,0008	21,0009
Trim angle (+ve by stern) deg	-0,0775	-0,0826	-0,0825	-0,0825	-0,0764	-0,0812	-0,0932	-0,1161	-0,1473	-0,1854	-0,2145

Key point	Type	Immersion angle deg	Emergence angle deg
Margin Line (immersion pos = -3,304 m)		0	n/a
Deck Edge (immersion pos = -3,304 m)		0	n/a
DF point	Downflooding point	17,6	0
DF point	Downflooding point	17,5	0
DF point	Downflooding point	17,4	0
DF point	Downflooding point	17,2	0

Key point	Type	Immersion angle deg	Emergence angle deg
DF point	Downflooding point	17,1	0
DF point	Downflooding point	17	0
DF point	Downflooding point	16,8	0
DF point	Downflooding point	16,7	0
DF point	Downflooding point	16,6	0
DF point	Downflooding point	16,5	0
DF point	Downflooding point	16,4	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	6,7	0

Tabel 0-3: Stability result

Code	Criteria	Value	Units	Actual	Status	Margin %
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ	25,0	deg	7,5	Fail	-69,86
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt	0,150	m	3,013	Pass	+1908,67

Initial heeling 5 degrees

Stability 20.00.04.9, build: 9

Model file: G:\Rafelia\rafelia_2c (Highest precision, 509 sections, Trimming on, Skin thickness not applied). Long. datum: AP; Vert. datum: Baseline. Analysis tolerance - ideal(worst case): Disp.%: 0,01000(0,100); Trim%(LCG-TCG): 0,01000(0,100); Heel%(LCG-TCG): 0,01000(0,100)

Loadcase - FULL LOAD 40 – initial heeling

Damage Case - Intact

Free to Trim

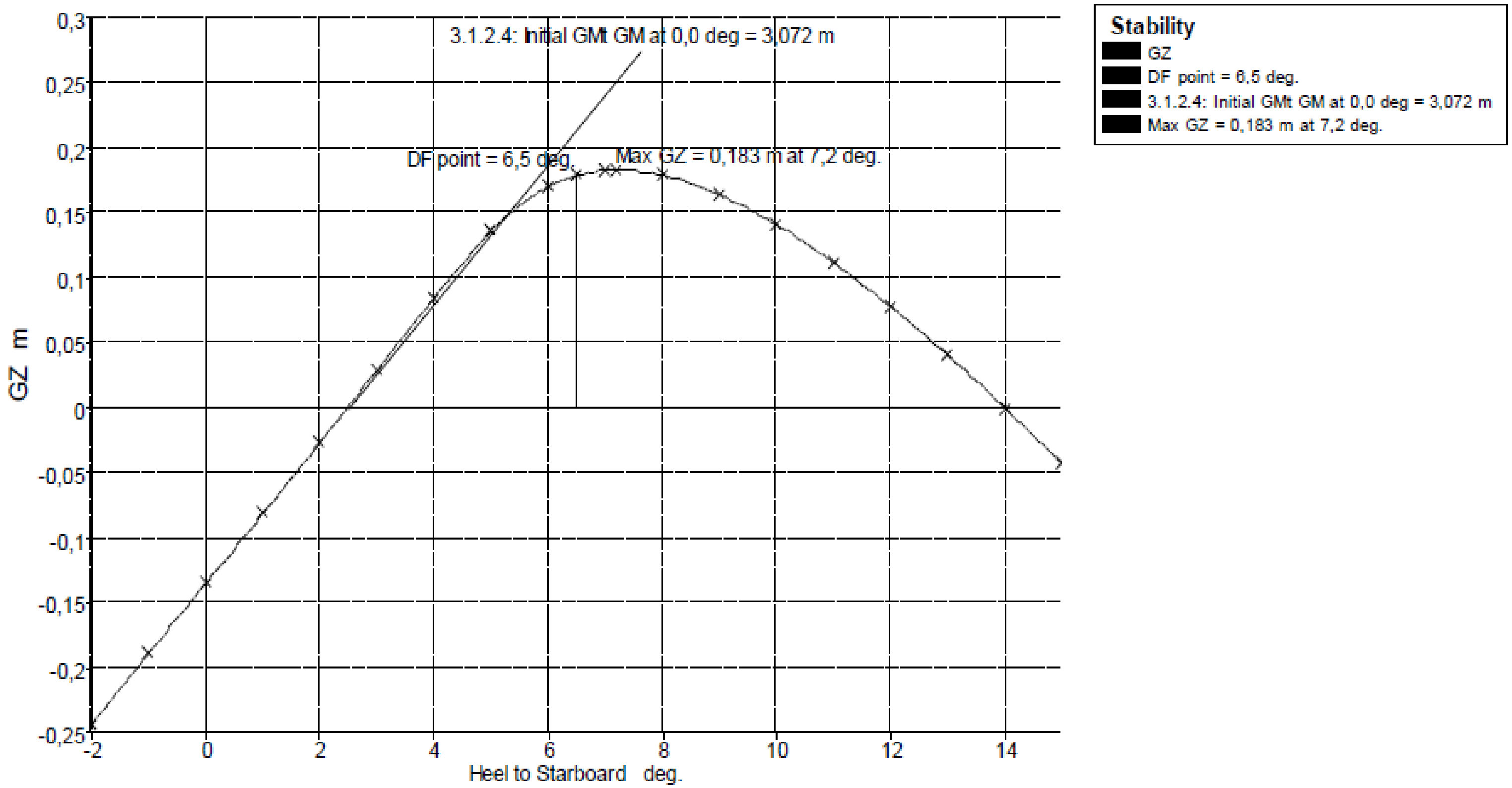
Specific gravity = 1,025; (Density = 1,025 tonne/m^3)

Fluid analysis method: Use corrected VCG

Item Name	Quantity	Unit Mass tonne	Total Mass tonne	Unit Volume m^3	Total Volume m^3	Long. Arm m	Trans. Arm m	Vert. Arm m	Total FSM tonne.m	FSM Type
Lightship	1	633,720	633,720			31,830	0,000	5,846	0,000	User Specified
FPT (P)	0%	35,085	0,000	34,229	0,000	57,569	-0,001	0,319	0,000	Actual
FPT (S)	0%	35,085	0,000	34,229	0,000	57,569	0,001	0,319	0,000	Actual
SWBT NO. 1 (P)	0%	73,263	0,000	71,476	0,000	49,528	-0,307	0,177	0,000	Actual
SWBT NO. 1 (S)	0%	73,263	0,000	71,476	0,000	49,528	0,307	0,177	0,000	Actual
FWT (P)	30,17%	28,975	8,743	28,975	8,743	36,572	-2,650	1,303	21,236	Actual
FWT (S)	21,24%	28,975	6,154	28,975	6,154	36,571	2,639	1,155	20,875	Actual
FOT (P)	5%	73,983	3,699	78,347	3,917	32,989	-2,728	0,882	56,549	Actual
FOT(S)	5%	73,983	3,699	78,347	3,917	32,989	2,728	0,882	56,549	Actual
SWBT NO. 2 (P)	0%	49,011	0,000	47,816	0,000	6,129	-0,116	0,000	0,000	Actual
SWBT NO. 2 (S)	0%	49,011	0,000	47,816	0,000	6,129	0,116	0,000	0,000	Actual
Ramp	1	16,000	16,000			69,650	0,000	5,000	0,000	User Specified
Beban oleng	1	10,000	10,000			28,764	7,000	3,900	0,000	User Specified
PENUMPANG	60	0,075	4,500			28,764	0,000	10,000	0,000	User Specified

CREW	22	0,075	1,650			28,764	0,000	5,000	0,000	User Specified
TRONTON 6 BAN	1	15,000	15,000			3,831	-3,274	5,300	0,000	User Specified
TRONTON 10 BAN	1	25,000	25,000			3,831	0,000	5,500	0,000	User Specified
TRONTON 10 BAN	1	40,000	40,000			3,831	3,274	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			14,077	-5,589	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			14,077	-2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			14,077	2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			16,223	5,589	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			23,838	-5,589	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			23,838	-2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			23,838	2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			25,707	5,589	5,500	0,000	User Specified
TRUK ENGKEL 6 BAN	1	15,000	15,000			31,869	-5,589	5,300	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			33,323	-2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			33,323	2,032	5,500	0,000	User Specified
TRUK ENGKEL 6 BAN	1	15,000	15,000			33,738	5,589	5,300	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			41,907	-5,589	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			42,807	-2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			42,807	2,032	5,500	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			42,807	5,589	5,500	0,000	User Specified
L300	1	4,000	4,000			50,215	-5,589	4,900	0,000	User Specified
DUMP TRUK 10 BAN	1	40,000	40,000			51,876	-2,032	5,500	0,000	User Specified

DUMP TRUK 10 BAN	1	40,000	40,000			51,876	2,032	5,500	0,000	User Specified
L300	1	4,000	4,000			56,307	-4,629	4,900	0,000	User Specified
TRUK ENGKEL 6 BAN	1	15,000	15,000			57,706	4,798	5,300	0,000	User Specified
L300	1	4,000	4,000			61,718	-2,823	4,900	0,000	User Specified
L300	1	4,000	4,000			59,978	0,000	4,900	0,000	User Specified
TRUK ENGKEL 6 BAN	1	15,000	15,000			63,061	2,371	5,300	0,000	User Specified
Tank011	0%	25,768	0,000	25,139	0,000	29,818	0,000	3,900	0,000	Actual
Total Loadcase			1484,165	546,827	22,731	31,270	0,135	5,562	155,209	
FS correction								0,105		
VCG fluid								5,667		


3.1.2.4: Initial GMt GM at 0,0 deg = 3,072 m
DF point = 6,5 deg.
Max GZ = 0,183 m at 7,2 deg.
0,3
0,25
0,2
0,15
0,1
0,05
0
-0,05
-0,1
-0,15
-0,2
-0,25
GZ m
-2
0
2
4
6
8
10
12
14
Heel to Starboard deg.
Stability
GZ
DF point = 6,5 deg.
3.1.2.4: Initial GMt GM at 0,0 deg = 3,072 m
Max GZ = 0,183 m at 7,2 deg.

Heel to Starboard deg	-2,0	-1,0	0,0	1,0	2,0	3,0	4,0	5,0	6,0	7,0	8,0	9,0	10,0	11,0	12,0	13,0	14,0	15,0
GZ m	-0,243	-0,189	-0,135	-0,081	-0,027	0,029	0,085	0,136	0,170	0,183	0,179	0,164	0,141	0,112	0,078	0,041	0,000	-0,043
Area under GZ curve from zero heel m.rad	0,0066	0,0028	-0,0004	-0,0019	-0,0028	-0,0028	-0,0018	0,0001	0,0028	0,0060	0,0091	0,0121	0,0148	0,0170	0,0187	0,0197	0,0201	0,0197
Displacement t	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484	1484
Draft at FP m	3,392	3,399	3,401	3,399	3,392	3,380	3,365	3,348	3,335	3,326	3,323	3,327	3,334	3,345	3,360	3,377	3,398	3,421
Draft at AP m	3,305	3,310	3,312	3,310	3,306	3,298	3,285	3,268	3,253	3,244	3,240	3,239	3,241	3,246	3,253	3,262	3,273	3,286
WL Length m	65,259	65,002	65,029	65,003	65,259	65,322	65,351	65,369	65,368	65,377	65,386	65,396	65,417	65,445	65,466	65,468	65,469	65,470
Beam max extents on WL m	12,568	12,541	12,531	12,541	12,569	12,614	12,531	12,504	11,466	10,694	10,086	9,594	9,184	8,838	8,541	8,283	8,058	7,860
Wetted Area m^2	992,722	986,272	985,220	986,292	992,734	995,995	989,835	984,325	1024,372	1062,549	1094,077	1119,653	1141,034	1159,217	1174,861	1188,484	1200,493	1211,157
Waterpl. Area m^2	789,480	782,858	781,739	782,875	789,490	793,034	785,445	769,184	703,445	643,847	594,813	554,649	521,095	492,521	467,883	446,385	427,457	410,637
Prismatic coeff. (Cp)	0,615	0,617	0,617	0,617	0,615	0,615	0,615	0,616	0,617	0,619	0,620	0,622	0,624	0,625	0,627	0,628	0,630	0,632
Block coeff. (Cb)	0,496	0,498	0,498	0,498	0,496	0,495	0,500	0,499	0,536	0,565	0,589	0,608	0,623	0,634	0,643	0,650	0,654	0,657
LCB from zero pt. (+ve fwd) m	31,276	31,276	31,274	31,276	31,275	31,275	31,275	31,274	31,275	31,275	31,271	31,276	31,276	31,276	31,277	31,277	31,278	31,278
LCF from zero pt. (+ve fwd) m	28,656	28,452	28,428	28,452	28,656	28,684	28,870	29,043	29,417	29,621	29,728	29,813	29,895	29,965	30,028	30,085	30,137	30,183
Max deck inclination deg	2,0017	1,0036	0,0847	1,0036	2,0017	3,0010	4,0007	5,0006	6,0005	7,0004	8,0004	9,0004	10,0004	11,0004	12,0004	13,0004	14,0005	15,0005
Trim angle (+ve by stem) deg	-0,0828	-0,0847	-0,0847	-0,0847	-0,0827	-0,0788	-0,0762	-0,0763	-0,0787	-0,0788	-0,0790	-0,0844	-0,0891	-0,0951	-0,1022	-0,1102	-0,1192	-0,1290

Key point	Type	Immersion angle deg	Emergence angle deg
Margin Line (immersion pos = -3,304 m)		0	n/a
Deck Edge (immersion pos = -3,304 m)		0	n/a
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	Not immersed in positive range	0
DF point	Downflooding point	6,5	0

Code	Criteria	Value	Units	Actual	Status	Margin %
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.3: Angle of maximum GZ				Fail	
	shall not be less than (>=)	25,0	deg	7,2	Fail	-71,27
A.749(18) Ch3 - Design criteria applicable to all ships	3.1.2.4: Initial GMt				Pass	
	spec. heel angle	0,0	deg			
	shall not be less than (>=)	0,150	m	3,072	Pass	+1948,00

AUTHOR PROFILE

Author's name is Gishela Rahayu Suciati was born in Jakarta, 30th January 1995. Author has completed formal education in Al- Azhar 12 Elementary School Cikarang, SMPN 1 Cikarang Utara, SMAN 1 Tambun Selatan and continue to get Bachelor Degree in Double Degree Marine Engineering (DDME) program in Institut Teknologi Sepuluh Nopember and Hochschule Wismar. Author joined Marine Reliability Availability and Management System (RAMS) Laboratory. During in University, author was active in Student Executive Board Faculty of Marine Engineering ITS as Head of Mapping Division in Human Resource Department in 2016. The author have done on the job training in PT. Dok Perkapalan Kodja Bahari 1 Jakarta and PT. Biro Klasifikasi Indonesia Jakarta.