BACHELOR THESIS & COLLOQUIUM – ME 184841

THE ANALYSIS OF HUMAN ERROR AS CAUSE OF SHIP COLLISION ACCIDENT AT PORT OF TANJUNG PERAK SURABAYA BY USING HUMAN FACTOR ANALYSIS AND CLASSIFICATION SYSTEM (HFACS) AND ANALYTICAL HIERARCHY PROCESS (AHP)

DHEO CAKRA SATYA PUTRAMAN
NRP 042115 4100 0007

SUPERVISOR:
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DOUBLE DEGREE PROGRAM
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BACHELOR THESIS

Submitted to Comply One of the Requirements to Obtain the Bachelor of Engineering Degree

On

Reliability, Availability, Management and Safety (RAMS) Laboratory
Study Program Bachelor Double Degree of Marine Engineering Department
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember, Surabaya

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THE ANALYSIS OF HUMAN ERROR AS CAUSE OF SHIP COLLISION ACCIDENT AT PORT OF TANJUNG PERAK SURABAYA BY USING HUMAN FACTOR ANALYSIS AND CLASSIFICATION SYSTEM (HFACS) AND ANALYTICAL HIERARCHY PROCESS (AHP)

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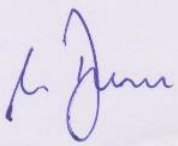

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Bachelor Thesis Title	: The Analysis of Human Error As Cause of Ship Collision Accident at Port of Tanjung Perak Surabaya by Using Human Factor Analysis and Classification System (HFACS) and Analytical Hierarchy Process (AHP)
Study Program	: Double Degree of Marine Engineering Department

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ABSTRACT

Port of Tanjung Perak Surabaya is one of the largest ports in Indonesia. Specifically port of Tanjung Perak Surabaya is the second largest port position after port of Tanjung Priok in Jakarta. Port of Tanjung Perak also holds a very important position in the process of distributing logistics from western Indonesia to eastern Indonesia. Based on the annual report from PT. Pelindo III, the main gate of Tanjung Perak port will go through the main gate in the APBS area with a width of 100 meters and also a length of 25 Nm. In 2017 there are 26901 ship movements and will continue to grow in every year. With a small area and also a very high traffic movement of ships, it can increase the occurrence of ship collision accidents in this area. Based on reports from the *Mahkamah Pelayaran*, the causes of ship accidents are dominated by human factors or human errors. Therefore the Human Factor Analysis and Classification System (HFACS) method will be used in this study to determine what factors can cause of human error. Classification is obtained based on studies of ship collision accident data in previous years. In this method it was found that the highest factor causing human error was 9 pre-condition for unsafe acts or 37%, 6 indicators for unsafe supervision, 5 indicators for unsafe acts or 21% for 4 indicators or 17% for indicators. on the level of organizational influences. While, based on weighting value that using the Analytical Hierarchy Process (AHP) method, it was found that human error was the highest cause of ship collision with a weight value 0.553 or 55%. Human error itself could be happen because factors from the precondition for unsafe acts with weight value 0.345 or 35%, unsafe supervision with weight value 0.290 or 29%, unsafe acts with weight value 0.249 or 25% and also organizational influences with weight value 0.115 or 12%.

Keywords: Ship Collision Accident, Human Error, Human Factor Analysis and Classification System (HFACS), Analytical Hierarchy Process (AHP)

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ANALISIS *HUMAN ERROR* SEBAGAI PENYEBAB KECELAKAAN TUBRUKAN KAPAL DI PELABUHAN AREA PELABUHAN TANJUNG PERAK SURABAYA DENGAN MENGGUNAKAN METODE *USING HUMAN FACTOR ANALYSIS AND CLASSIFICATION SYSTEM (HFACS)* DAN *ANALYTICAL HIERARCHY PROCESS (AHP)*

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ABSTRAK

Pelabuhan Tanjung Perak Surabaya merupakan salah satu pelabuhan terbesar di Indonesia. Dimana pelabuhan Tanjung Perak menduduki posisi pelabuhan terbesar kedua setelah pelabuhan Tanjung Priok di Jakarta. Pelabuhan Tanjung Perak juga memegang posisi yang sangat penting dalam proses penyaluran logistic dari Indonesia bagian barat ke Indonesia bagian timur. Berdasarkan laporan tahunan dari PT. Pelindo III gerbang utama pelabuhan Tanjung Perak akan melalui pintu utama di area APBS dengan lebar 100 meter dan juga panjang sepanjang 25 Nm. Pada tahun 2017 terdapat pergerakan kapal sebanyak 26901 dan akan terus bertambah setiap tahunnya. Dengan area yang sempit dan juga pergerakan kapal yang sangat padat, akan dapat meningkatkan terjadinya kecelakaan tubrukan kapal di area ini. Berdasarkan laporan dari Mahkamah Pelayaran, penyebab kecelakaan kapal di dominasi oleh adanya faktor manusia atau *human error*. Oleh karena itu metode *Human Factor Analysis and Classification System (HFACS)* akan digunakan pada penelitian ini untuk mengetahui faktor-faktor apa saja yang dapat menyebabkan terjadinya *human error.* Klasifikasi didapatkan berdasarkan kajian dari data-data kecelakaan tubrukan kapal pada tahun-tahun sebelumnya. Pada metode ini didapatkan bahwa faktor tertinggi penyebab adanya *human error* terletak pada level *pre-condition for unsafe acts* sebanyak 9 indikator atau 37%, *unsafe supervision* sebanyak 6 indikator atau 25%, *unsafe acts* sebanyak 5 indikator atau 21% dan 4 indikator atau 17% pada level *organizational influences.* Berdasarkan pembobotan dengan menggunakan metode *Analytical Hierarchy Process (AHP),* didapatkan bahwa *human error* merupakan penyebab tertinggi dari kecelakaan tubrukan kapal dengan bobot 0.553 atau 55%. Adanya *human error* dikarenakan faktor dari *precondition for unsafe acts* dengan bobot 0.345 atau 35%, *unsafe supervision* dengan bobot 0.290 atau 29%, *unsafe acts* dengan bobot 0.249 atau 25% dan juga *organizational influences* dengan bobot 0.115 atau 12%.

Kata kunci: Kecelakaan Tubrukan Kapal, *human error, Human Factor Analysis and Classification System (HFACS), Analytical Hierarchy Process (AHP)*

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PREFACE

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Surabaya, July 2019

Author

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CHAPTER I
INTRODUCTION

1.1. Background

Indonesia is the largest archipelago country in the world. There are thousands of islands in 2/3 area of Indonesia. Therefore, as the largest country in the world, this is the right time to increase the productivity and quality in maritime transportation to support the economic record. Maritime transportation is the main transportation mode for economic trade activity. It is estimated that 90% of the goods of world trade is transported by sea (UNCTAD, 2014). While *Tol Laut* Program is the right mission from the President of Republic Indonesia Mr. Joko Widodo to utilizing the Indonesian area as the archipelago country.

Tol Laut Program is a good idea but it will not happen if none of the improvement to increase the safety management to using the transportation itself. Based on the data from *Komite Nasional Keselamatan Transportasi*/National Transportation Safety Committee of Indonesia that shown on the Figure 1.1. below, ship accident is increasing from 2012-2016. The recommendation has given to some parties to increasing safety management. But the ship accident will always happen without self-awareness of each individual about safety management. Cause based on the data the ship accident happened because of human error. It means the increasing of ship accident is a cause of lack of self-awareness of individual as a human being.

No	Year	Total Accident	Type of Accident					Type of Effect to People		Recommendation
			Sinking	Exploding	Collisions	Grounding	Others	Loss Life	Injury	
1	2010	5	1	1	3	0	0	15	85	45
2	2011	6	1	3	2	0	0	86	346	82
3	2012	4	0	2	2	0	0	13	10	28
4	2013	6	2	2	2	0	0	65	9	47
5	2014	7	2	3	2	0	0	22	4	25
6	2015	11	3	4	3	1	0	85	2	11
7	2016	15	4	4	3	2	2	51	18	35
TOTAL		54	13	19	17	3	2	337	474	273

Figure 1.1. Data of Ship Accident
Source: Media Release KNKT 2016

Considering the data from the National Transportation Safety Committee Indonesia (NTSC), there have been 337 seafarers lost their lives and 474 people were injured from 2012-2016. Also due to the data, 6% of ship accident is grounding accident and 31% for collision accident from 2010-2016. Such figures show that grounding accidents endanger maritime shipping (Mazaheri, 2014). Collision accident may result in the loss of human life and damage to the ship and the environment (Karahalios, 2014).

One of the busiest sea areas in Indonesia is around port of Tanjung Perak. Port of Tanjung Perak is the second busiest port after Tanjung Priok in Jakarta, with the average of the ship that sails across Madura straits from 2008 - 2013 is 20,582 per year (Sumarsono, 2017). Because of those conditions, there were several accidents that

occurred in Tanjung Perak which caused by collision, hull leakage, overload, and bad weather condition (Firdaus and Supomo, 2018) in *Alur Pelayaran Barat Surabaya (APBS)*. While, according to the PT. Pelindo Annual Report in April 2013 and as shown as the Figure 1.2. below. The APBS region, which has a width of 100 meters and a length of 25 Nautical Mile, is one of the main gateways of the international port network and is a consolidation, distribution of goods from/to Eastern Indonesia, with the ship movement reached around 23.352 ships in 2016 and 26901 ship movements in 2017 (VTS Report, 2018).

Figure 1.2. Port of Tanjung Perak Surabaya Area
Source: www.maps.google.com

Due to the data from Vessel Traffic System in Port of Tanjung Perak Surabaya, the ship accident is increasing from the 2015-2018 start from 2 accidents until 22 accidents noted on September 2018. From the data, ship collision is the one of the most accident in the port of Tanjung Perak with 7 of ship collision accident until September 2018. While, according to statistical data, there have been 174 collisions in the Madura Strait for 20.5 years, and it can be interpreted that the average accident is 9.8 ships per year. The large number of ship accidents caused by ship collisions in this area can be seen in Figure 1.3.

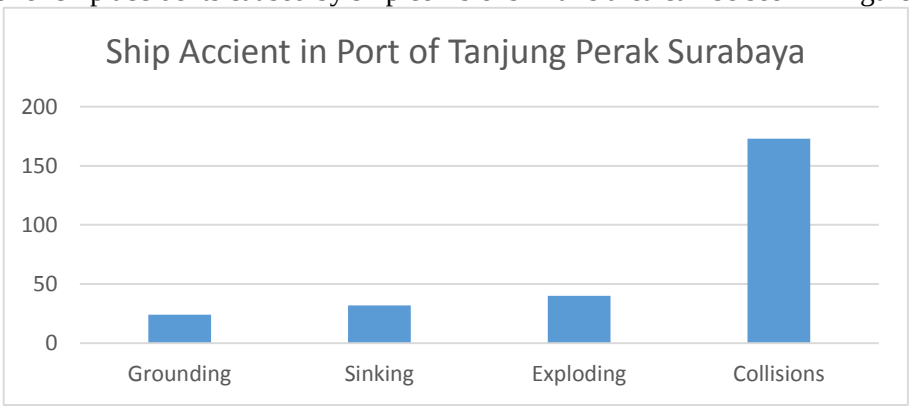


Figure 1.3. Types of Ship Accident in Madura Strait
Source: Annual Report PT. Pelindo Branch Tanjung Perak Surabaya

Statistically, human factor accounts for 75-96% of the marine accident (Ugurlu, 2013; Pennie, 2007). While International Maritime Organization (IMO) have paid considerable efforts to tackle such an issue, marine accidents caused by human error are still continuing and have not been decreased to the desired level (Noroozi, 2014: Gaonkar, 2011). Therefore, understanding the human and organizational factors underlying marine accident is of key importance for main management and policy (Macrae, 2009).

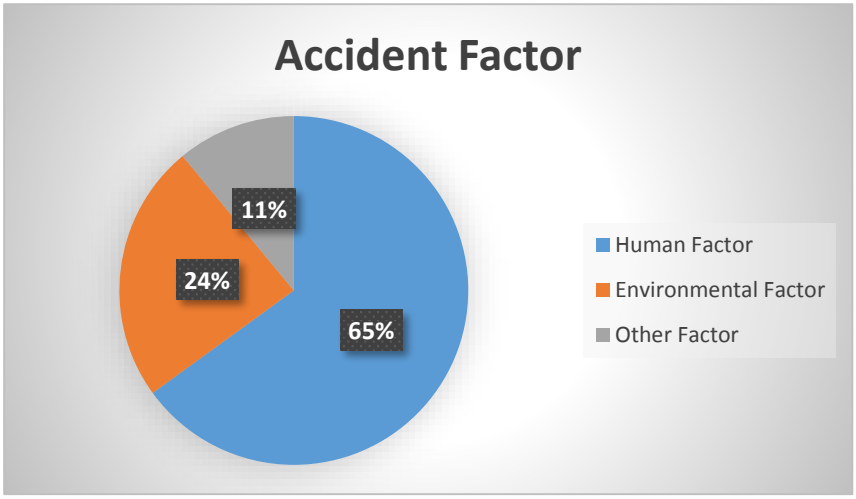


Figure 1.4. Ship Accident Factor
Source: *Putusan Mahkamah Pelayaran*

Due to the data from *Putusan Mahkamah Pelayaran* on Figure 1.4 above, 65% of ship accident is the cause of the human factor. Therefore, in this thesis will provide the analysis of human error with the closest method of Human Factors Analysis and Classification System (HFACS) as one of the most preferred to determining human factors, organizational related and the relationship between both of them. While, Analyical Hierarchy Process (AHP) method will be use to determine the weight value and also the priority of each factors.

1.2. Problem Statement

According to the background of the problem above, therefore the problem statement that will be discussed are:

1. What are the factors of human error in ship collision accident according to HFACS method?
2. What are the factors of ship collisions accident according to AHP method?
3. How much the human error effect to ship collision accident according to AHP method?
4. What is the most factors in human error as ship collision accident?

1.3. Limitation

The limitation that were made in order to specify the focus of this thesis are:

1. The data being used is limited to the result of the questionnaire that will be conducted at Port of Tanjung Perak Surabaya
2. The type of ship accident is about ship collision accident.
3. The analysis of ship collision accident caused by the human factor.

1.4. Objectives

The objectives of this thesis are:

1. To determine what are the factors in human error according to HFACS method as cause of ship collision accident.
2. To discover the factors of ship collision accident according to AHP method.
3. To determine the value of human error as cause of ship collision accident according to AHP method.
4. To determine what is the most factors in human error according to HFACS method as cause of ship collision accident.

1.5. Benefits

Benefits that can be gained from this thesis are:

1. Giving information about what are the factors that cause ship collision accident based on human factors.
2. Giving information to some parties about the variables that affect human productivity as prevention of ship accident by recommendation.
3. The research could be used as the reference to some parties in another research, therefore this thesis could be used as prevention ship collision accident that cause of human factors.

CHAPTER II
LITERATURE STUDY

2.1. Port of Tanjung Perak Surabaya

Indonesia has is an archipelago country, therefore Indonesia should be have a lot of port or terminal as one of ways to distribute the logistics for export or import. Port of Indonesia Corporation is one of the company held by the government to manage port in Indonesia. and one of the busiest port located in Port of Tanjung Perak Surabaya.

Port of Tanjung Perak Surabaya is the second busiest port after Port of Tanjung Priok in Jakarta. As the center of distribution logistic in East Java, Port of Tanjung Perak has high performance that divided into seven terminals, which are:

- Jamrud Terminal
- Nilam Terminal
- Mirah Terminal
- Berlian Terminal
- Teluk Lamong Terminal
- Peti Kemas Terminal
- Kalimas Terminal

The location of each terminal are shown at the Figure 2.1. below.

Figure 2.1. Port of Tanjung Perak Surabaya Layout
Source: www.pelindo.co.id

The data on Figure 2.2. below is about the ship and cargos activity in Port of Tanjung Perak Surabaya from 2013-2017. Due to the data below, there are total 68.805 units and 415.925.796 Gross Tonnages of ships activity from 2013-207. These activity increase in 2016 with 10.4% than a year before. But the activity ever been decrease in 2017 with 18.7%. For the total cargo in 2013-2017, Port of Tanjung Perak Surabaya has total 83.465.201 Tons. These total has increase in every year except in 2017. For container stevedoring in Port of Tanjung Perak, it quite decrease from 2013-2015 and increase in 2016 with total 2.832.087 boxes in 2013-2017. While for passengers in Port of Tanjung Perak has total 3.224.597 persons. It total was decrease from 2013-2016 and quiet stagnant in 2017.

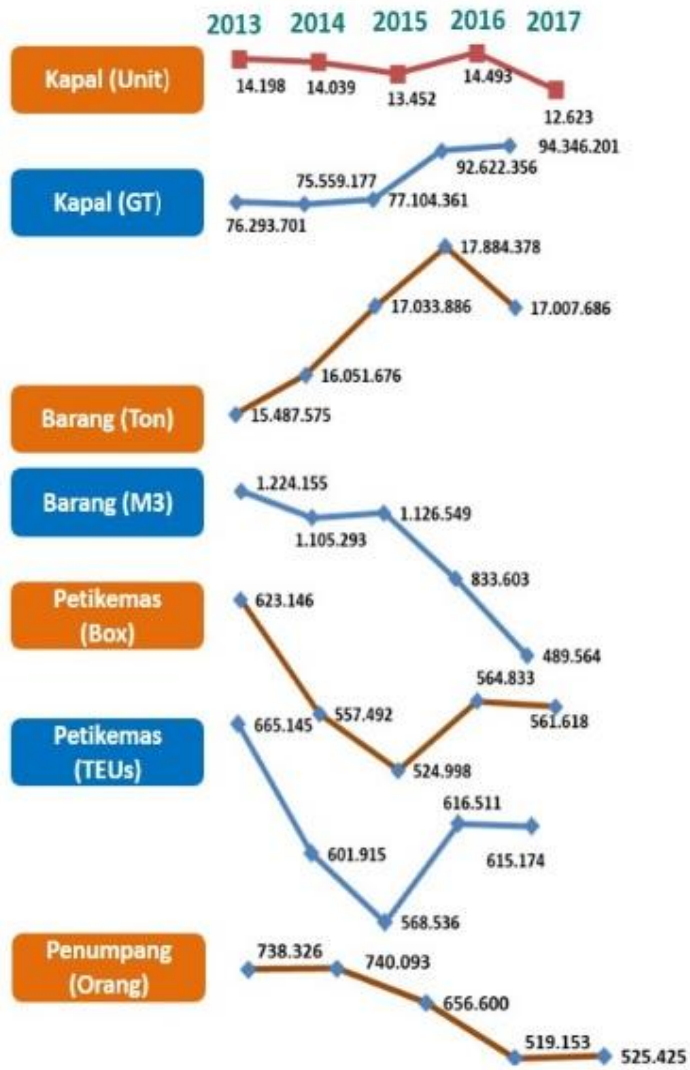


Figure 2.2. Data statistics of Ships and Cargos Activity in Port of Tanjung Perak Surabaya
Source: www.pelindo.co.id

2.2. Shipping Activity and Marine Accident Probability

2.2.1. Marine Safety Theory

Marine activity is one of the most importance thing in the world. It caused 90% of goods is distributed by sea. But, during the activities, there are a lot of accidents in the world that inflict a financial cost by the cargos, ship or even people inside it. It started from ship accident of Titanic that loss of financial and also lot of people was died and injured. Therefore, a lot of regulations as the prevention of marine accident by made of regulations from International Convention by learning from ship accidents that happened around the world. Those regulations have their own function to ensure the safety and security at sea like as the explanation below.

2.2.2. Ship Regulations

Ship regulations have made due to International Convention and have purpose to avoid marine accidents and also increase the security and marine safety during sailing. Every ship accident happened in the world will affect to marine ecosystem around it. Therefore, there are a lot of regulations to prevent the marine accident that difference based on the affects to marine accident. Those regulations consist of:

a) Safety of Life at Sea (SOLAS) 1974

Safety of life at sea started the first version when Titanic accident happened in 1914. From this accident lot of people was died and injured, therefore International Convention made the regulation to make sure the safety of life at sea that called SOLAS 1974. But during the accidents in the world. SOLAS has changed a lot. These change has purpose to make sure the ship has in safety condition to do the operation, there are some requirements that divided into 5 chapters consists of:

- Navigation equipment.
- Ship construction about structure, stability, machinery and electrical installation.
- Ship construction about fire extinguisher, fire detector and etc.
- Safety equipment installation.
- Etc

As the approval that ship has done the regulations above, they will get the certificate from the bureaucracy related. As well as another chapter in SOLAS like ISM (International Safety Management) Code, ISPS (International Ship and Port Facility Security) Code, also IMDG (International Maritime Dangerous) Code that applied since 1st January 2010.

b) Marine Pollution (MARPOL) 1973/1978

Marine Pollution (MARPOL) 1973/1978 is the regulations about the preventing pollution from marine activity to marine ecosystem that included in Annex MARPOL. These pollutions could be divided into several types such as oil pollution, chemical pollution, garbage and also air pollution. Passenger ship as the highest cause of pollution at sea. It cause passenger ship has lot of people inside it, therefore there are several pollution made it by passenger ships like oil from the ships itself and also garbage pollution from the passengers itself that cause lack of self-awareness to keep the environment especially in marine

ecosystem. there are several certificates as approval or implementation of MARPOL 1973/1978 that consist of:

- Certificate that caused by oil pollution.
- Certificate that caused by sewage pollution.
- Certificate that caused of garbage pollution.

c) Standard of Training Certification and Watchkeeping for Seafarers (STCW) 1978

Standard of training certification and watchkeeping for seafarers or STCW is the regulation or certificate that has purpose as the requirements for the crew during the duty at sailing activity. These requirements included the minimum of training or even degree to ensure their activity. This certificate is one of the importance things to ensure the safety and as prevention of marine accidents. When a crew has already required, they will have a good preparation when marine accident happen by considering safety and security at sea due to the rules or certification.

2.2.3. Ship Collision

Ship collision is a collision between two or more vessels when its moving and affect to human safety inside the ship or injuries fatalities, environmental damage, and also lost of cargo that brought by the vessel itself. According to Karahalios, 2014, collisions accidents may result in loss of human life and damage to the ship and the environment. Therefore, when an accident occurs, understanding the reasons behind it is important to be able take effective preventive measures (Hollnagel, 2002). Risk of ship collision can be calculated by the formula below,

$$R = P.C \quad (1)$$

Where,

P = probability of ship collision

C = consequences that occur from ship collision

As mentioned above, there are a lot of consequences that occur from ship collision. Therefore, we could divide the consequences such as:

- Injuries of people or crews and also the cargos inside the ships.
- Damage of ship construction, equipment or even the cargos itself cause of the ship collision itself.
- Potential of environmental pollution can be occurring from ship collision if there is an oil spill, chemical liquid or other liquid that affect or damage to environment.
- The potential of material losses caused of the oil spill, cost recovery, and other cost that divided into IOPC

  According to Fujii Macduff research about the ship collision, the probability of ship collision can be calculating by the formula:

  $$P = Na.Pc(2)$$

  Where, Na is the number of ships that can cause of ship collisions and Pc is the causation probability to avoid the ship collisions that can be causes of human error, equipment failure, or the other external factor like environment.

2.2.4. Close-Quarter Situation

In the COLREG (Collision Regulatio), was explained that there are several types of collisions which are called close quarter situations. The danger of the collision is illustrated that both ships are moving or dynamic condition.

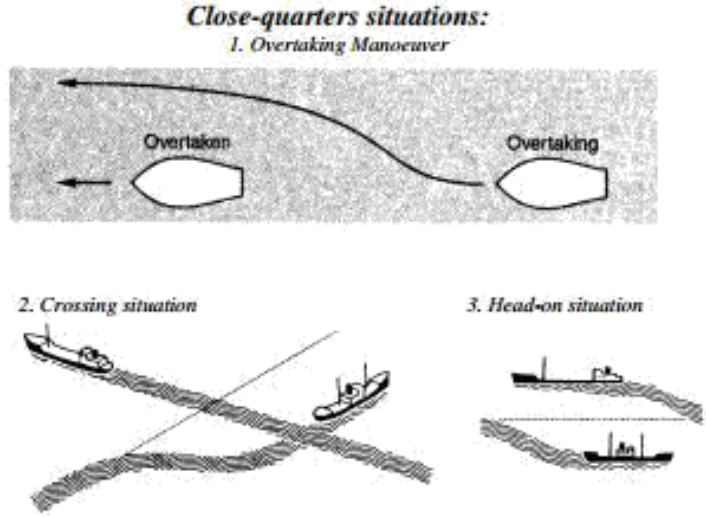


Figure 2.3. Scenario of Ship Collision Damage Close-Quarter Situation
Source: Collision Regulation (COLREGS) Unit 33

According to the Figure 2.3. above, there are three situations occur with their respective conditions such as:

a) Head-on Situation
   This event happens when 2 ships move and collide between the bow of the ship. To avoid this incident, each of them must cross each other between starboards to give each other a way.
b) Crossing Situation
   This event happens when 2 ships move intersect and will collide. Potential collisions can be avoided if one of the ships provides a road and the other ships keep a distance or reduce speed. This event is possible happen if the ship that comes out of the port maneuvers and another ship is in the shipping lane.
c) Overtaking Situation
   This collision accident happens if one of the ships moves from behind another ship to overtake the ship in front of it. To avoid the possibility of collisions from both ships, the ship preceded allows other ships to overtake with a safe distance between the sides of the ship and a higher speed for the ship that precedes. The possibility of such a risk if the ship in the dense shipping lane is not given a safe recommendation so that the possibility of overtaking each other can occur.

In the situation mentioned above, the vessel experiencing the incident must pay attention to its speed and direction to avoid collision in accordance with the rules in COLREG that have been set. The illustration of ship collision accident can be seen on the Figure 2.4. below.

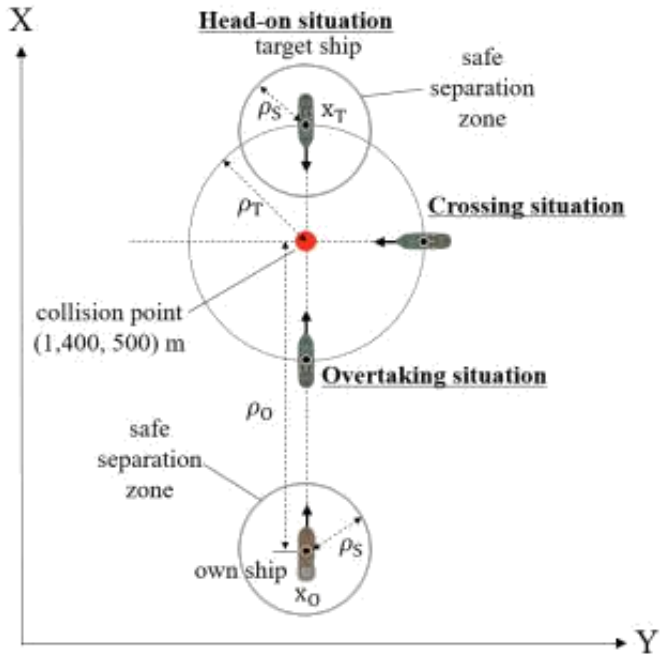


Figure 2.4. Vessel Traffic Simulation by 3 Scenarios
Source: Journal of Probabilistic Quantification of Ship Collision Risk Considering Trajectory Uncertainties, IFAC 2016

2.2.5. Marine Accident in Indonesia

Due to the data from National Transportation Safety Committee of Indonesia (NTSC) on the Table 2.1. below, the ship accident in Indonesia is always increase since 2012-2016. Therefore, we have to give a question mark to some parties such as port authorities, shipping management or even the passenger during the sailing how could the accident is always happened or even increase in every year.

Table 2.1. Ship Accident Report
Source: Media Release KNKT

Year	Total Accident	Types of Accident					Loss Types		Recommendations
		Sinking	Exploding	Collisions	Grounding	Others	Loss Life	Injury	
2012	4	0	2	2	0	0	13	10	28
2013	7	3	2	2	0	0	65	9	47
2014	8	3	3	2	0	0	22	4	41
2015	12	4	4	3	1	0	85	2	45
2016	18	6	4	3	3	2	46	18	70
2017	34	6	14	6	6	2	42	2	18
TOTAl	83	22	29	18	10	4	273	45	249

From the Figure above, we knew there are 107 of ship accidents since 2012-2017 that increase in every year. From those accidents there are 931 seafarers lost their live or lost and 631 people were injured in 5 years period. There are some types of ship accident on 2012-2017 such as, 29 of sink accident, 40 of explode accidents, 24 of collision accidents, 10 of grounding accidents, and other accidents for 4 accidents. Due to the data, we knew Indonesia has a high frequency of ship accidents. Therefore, it has to be the Government's responsibility to make sure the security and also marine safety during the sailing in the national scale.

2.2.6. Marine Accident in Port of Tanjung Perak

According to the stated above, that port of Tanjung Perak is one of bussiest port in Indonesia with high transportation moving. On the other hand, each ships that will enter the port of Tanjung Perak will surely pass through the Madura Strait as the main line in port of Tanjung Perak for domestic or even international vessels. Figure 2.5. shown the Madura Strait as the main area of vessels enter or going to port of Tanjung Perak Surabaya.

Figure 2.5. The area of Madura strait
Source: www.maps.google.com

According to the Port Infrastructure Development Study data in Indonesia; 2011, the width of access to shipping lanes in the Madura Strait is 100 meters and a draught of 9.5 meters LWS. With the characteristics of such narrow and shallow waters, this high

traffic is less able to control accidents. Finally, collisions cannot be avoided. For busy waters, collisions are those that most often cause accidents.

2.3. Literature Review

Because there are lot of ship collision accident happened in Indonesia especially in port of Tanjung Perak Surabaya. Therefore, this is as main background of research to prevent the ship collision accident in the future. While, according to the data statistic, the main factor of ship accident was human error. Therefore, we need some preview research with the same accident or event do implement the research in port of Tanjung Perak Surabaya.

On the research of W Lucky Andoyo, 2015 about the analysis of human error that affect to ship accident according to electrical system in port of Ketapang, Banyuwangi. The research was used analytical hierarchy process that combined with SHELL model to know the main factor of personality's crew to human error as cause of ship accident. Result of this research found that crew's healthy is the highest concern as cause of human error in ship accident according to AHP method. While the approached by using SHELL model is the experience of crew that affect to human error. The recommendation of this research is developing the sub-criteria be more specific to get a specific result about human error. Also, this research give suggestion to develop the prevention or decrease the probability of human error in electrical system as the system operator in vessels.

In their study, Lady Lovely, P. Marliana, and Ani Umyati, 2014, examined the ship accident in port of Banten by using human factor analysis and classification system (HFACS) according to analytical hierarchy process (AHP). In this research, they collecting the data by questionnaire from chief and crew in deck department and engine department as much as 6 people as the representative for each ships. The result of their study found that the factor of ship accident is unsafe acts with 6 causes or 40% with AHP rating as much as 12.24%, preconditions for unsafe acts as 4 causes of ship accident or 27% and 8,51% with rating by AHP method, while unsafe action as much as 2 causes accident or 13% and rating AHP with 8.24%, and the last one is organizational influences with 3 causes of accident or 20% with AHP rating as much as 10.84%.

In the study of Chauvin, et al. 2013, examined 27 ship-to-ship and ship-to-fishing vessel collisions between 1998 and 2012 and they included 39 ships involved in collisions in their coding process. in their study, they used accident report as database prepared by English MAIB eally, in the study which used chi-square test, multiple correspondence analysis and hierarchical clustering methods, it was found out that the main cause of the collision were decision errors. Their study emphasizes the importance of bridge resource management in restricted waters and navigation during pilotage.

While, in research of Yildirim Umut, et al, 2017, the study is about the assessment of grounding and collision by using human factor analysis and classification system (HFACS) and some statistical method like chi-square test and simple correspondence analysis. Result from this research are the highest factor in grounding and collisions accident was unsafe acts and preconditions for unsafe acts. Also, they continue the analysis by using simple correspondence analysis to know the closest relationship between the bridge team and human factor itself. Due the research they also give some recommendation like developing the bridge team member's accident as prevention of

ship accident in the future, ensure the bridge team in a good condition and also developing coordination between bridge team and the other people.

2.4. Human Error

Human error is often stated as the main factor of causing an accident happened. For most of people, the news about transportation accident with human error as a cause is often interpreted as human error by system operators such as drivers, pilots, captains, engineer, and other people inside the ship. This perception is actually the wrong perception because there are a lot of factors and aspects that affect as directly or even indirectly encourage an operator to take the unsafe actions.

Error is generally defined as a failure to shown a correct action and is expected in a situation. And also error is defined as a difference between the desired and actual performance or behavior of a system or object. This definition is the basis of operation for many types in a system, in which error as defined as difference between a set point and the process value. Therefore, as the final result of the error is an event, while there will be an event that can be observed.

Error that caused by human factors are likely caused by repetitive work with possible error of 1%. Therefore, the errors caused by repetitive work must be prevented or at least reduces as much as possible, which purpose to increase the operator's reliability by decreasing the level of errors that occur. Therefore, it is necessary to improve human performance to reduce the error rate. The error rate of 1 in 100 occurs with a probability 1%. If this kind of thing happens, it can be said that the condition is in a good condition.

Whereas, the accident is defined as an event that is not planned, expected or desired and usually produces bad output. Error is also a psychological event caused by psychiatric factors. Therefore, there is possibility that some or all the errors that occur are not identified.

2.4.1. Human Error Classification

Basically there is a classification to identification the causes of human error. Therefore, the classification itself was divided into 3 categories such as:

a) Induced Human Error System
   Induced human error system is a human error that happened because of the system. For an example the management doesn't provide rules of discipline for the employee or crew in ships.
b) Induced Human Error Design
   Induced human error design is a human error that cause of the design in work field that made by designer or managers. According to Murphy's Law state, that if an equipment is designed to be unsuitable with the user (ergonomic aspects) then there will be a possibility that there will be a discrepancy when using the equipment, therefore soon or later human error would occur.
c) Pure Human Error
   Pure human error is a human error that cause of the human itself. Pure human error could cause of lack knowledge, skill or talent to do the operation.

2.4.2. Human Error Causes

According to Atkinson,1998, the causes of human error was divided into 3 (three) categories such as:

a) Premier Causes
   Premier causes in human error was happened in each individual level. Therefore, to avoid the failure in this level, the experts given some suggestion to increasing the training, educational, knowledge and choosing the right operators. More over these suggestions would not prevent the failure that cause of dissimulation.
b) Managerial Causes
   According to Kletz, 1985: ACSNI, 1993: Atkinson,1998, Emphasis on the role of each individual to make a mistakes or failures is an inappropriate thing. We cannot avoid the failure, while training and education have limited effects and dissimulation will always occur. And unfortunately none of technology used to prevent the failure itself. Therefore, the managerial asset is needed. Managerial causes can be defined as the failure is happened because of lack of self-awareness from each individual to do their tasks or their own responsibility. Therefore, this is the function of people in management field to decrease, control and also ensure the employees or crews are responsible with their own tasks and do the right things during their operation.
c) Global Causes
   Global causes can be defined as failure that out of the managerial control that included the pressures from the environment. The pressure itself could be as financial pressure, timing pressure, social pressure and also the organizational culture or organizational environment.

2.5. Human Factor Analysis and Classification System (HFACS)

As mentioned above, there are lot of losses from marine accident. Therefore, we need make some research about prevent marine accident in the future. According to Wiegmann and Shappell, 2003 the Human Factor Analysis and Classification System (HFACS) is one of the most preferred accident analysis systems when determining human factors, organizational factors and the relationsip between them and collecting and analyzing accident/incident information. HFACS was divided into 4 categories level such as external factors, organizational influences, unsafe supervision, precondition for unsafe acts, and the last one is unsafe acts as explain below.

2.5.1. Organizational Influences

The first level of human factor analysis and classification system is organizational influences. Organizational influences can be defined as the decision error by the senior management and direct management applications that affect to the individual or the operators during operation in marine industries. Due to Figure 2.6. below, this level consists of asset management, the issues also related with the organizational environment and the last is organizational process. While the indicators that affect to organizational level can be seen on the Table 2.2.

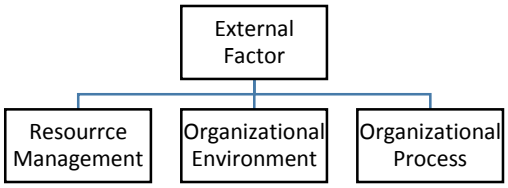


Figure 2.6. Organizational Influences Level

- Resource management defined as the allocation and also management and maintenance of organizational resources such as human resource (that included, from selection, staffing, training and monetary equipment/facilities). To implement its management, organizational decisions usually given based on two targets which are achieving the target timely and safely but also in cost effectiveness. Therefore, management need to excessive cost cutting as the stabilization of cost effectiveness those resources. Excessive cost-cutting could also result in reduced funding for new equipment or may lead to the purchase of equipment that is sub optimal and inadequately designed for the type of operations flown by the company.
- Organizational environment is defined as the work environment including management structure, company policies and also the culture in the work itself. Management structure contains of the chain of command and also the communication and being open to supervision related. Just like in the bridge deck, communication and coordination are vital within an organization. If management and staff within an organization are not communicating, or if no one knows who is in charge, organizational safety clearly suffers and accidents do happen. Company policies include management recruitment, promotion, raises excuse, drugs, alcohol or smoking use in work field.
- Organizational process defined as formal operation (time pressure, operational tempo, incentives, etc), procedures (standards, instructions and documentation) and the organization's surveillance (risk management, safety programs). All of the process could be affect to each individual in work field or safety in the system indirectly.

Table 2.2. Organizational Influences Indicators

Organizational Influences	**Resource Management**	Human Resources
		Selection
		Staffing
		Training
		Budget
		Excessive cost cutting
		Lack of funding
		Equipment/facility resources
		Poor design
		Purchasing of unsuitable equipment
	Organizational Environment	Structure
		Chain of command
		Communication
		Policies
		Hiring and firing
		Promotion
		Drugs and alcohol
		Culture
		Norms and rules
		Values and beliefs
		Organizational justice
	Organizational Process	Operation
		Operational tempo
		Time pressure
		Production quotas
		Incentives
		Measurement/apprasial
		Schedule
		Deficient planning
		Procedures
		Standards
		Clearly defined objectives
		Documentation
		Instruction
		Oversight
		Risk management
		Safety programs

2.5.2. Unsafe Supervision

The third level of human factor analysis and classification system is unsafe supervision. Unsafe supervision defined as lack of supervision or leadership management and also the communication from the supervision itself that affect to accident. This level consists of inadequate supervision, panned inappropriate operations, failure to fix the known problems and also violation of the management that shown on Figure 2.7 and the indicators on Table 2.3 below.

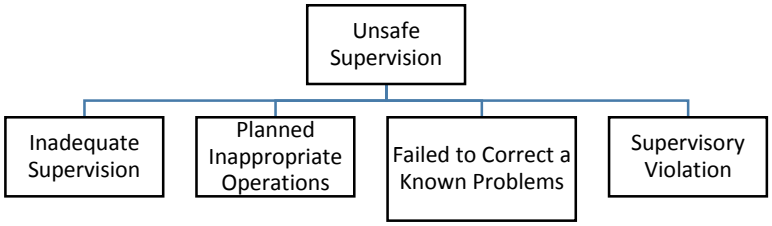


Figure 2.7. Unsafe Supervision Level

- Inadequate supervision could be described as the role of any supervisor is to provide the opportunity to succeed. To do this, the supervisor, no matter at what level of operation, must provide guidance, training opportunities, leadership, and motivation, as well as the proper role model to be emulated. Unfortunately, this is not always the case. For example, it is not difficult to conceive of a situation where adequate crew resource management training was either not provided, or the opportunity to attend such training was not afforded to a particular crew member. Therefore, it could be make more worst situation when the accident happen.
- Planned inappropriate operations can be accepted in emergency situation only, not in the routine o
- perations, therefore, the management should have a good management in assigning or giving extra employee to do the operation. In some case management giving an extra assignment that unrelated duties in officers. Therefore, it just giving an additional problem or bother other officer during the operation.
- Failed to correct a know problem is the condition when the supervisor is already knew about the problem in the field. But, the supervisor did not or haven't make it clear the situation until the accident happen. For example, it is not uncommon for accident investigators to interview the captain's friends, colleagues, and supervisors after a fatal crash only to find out that they "knew it would happen to him some day." If the captain knew that a pilot was incapable of voyage safely, and allowed the voyage anyway, he clearly did the pilot no favors. The failure to correct the behavior, either through remedial training or, if necessary, removal from sailing status, essentially signed the pilot's death warrant not to mention that of others who may have been on operation.

- Supervisory violation can be described as the violation of existing rules, regulations, instructions or standard operating procedures by those in management field. Violation of the management is rare, but if it is happened in the work field, it will affect the entire organization. For instance, there have been occasions when individuals were permitted to operate a vessel without current qualifications or license. Likewise, it can be that the supervisor couldn't obey the rules from the government or the authority related. While rare and possibly difficult to cull out, such practices are a flagrant violation of the rules and invariably set the stage for the tragic sequence of events that predictably follow.

Table 2.3. Unsafe Supervision Indicators

Unsafe Supervision	**Inadequate Supervision**	Failed to provide guidance
		Failed to provide operational doctrine
		Failed to provide training
		Failed to track qualification
		Failed to track performance
	Planned Inappropriate Operations	Failed to provide correct data
		Failed to provide adequate brief time
		Improper manning
		Operation not accordance with rules/regulations
		Provided inadequate opportunity for crew rest
	Failed to Correct a Known Problems	Failed to correct document in error
		Failed to identify a risk of navigational equipment
		Failed to report unsafe tendencies
	Supervisory Violation	Authorized unnecessary hazard
		Failed to enforce rules and regulations
		Authorized unqualified crew of vogaye

2.5.3. Preconditions for Unsafe Acts

Precondition for unsafe acts is the third level of human factor analysis and classification system. As shown as the Figure 2.8. below, this level can be described as the triggered for unsafe acts. This level will be divided into 8 subcategories with 3 headings. These headings consist of environmental factors (included physical environment and also technological environment), condition of individual (included adverse mental states, adverse physiological state and also physical and mental limitation), and the last is personal factors (included communication between VTS and ships, resource management, and readiness for the task). While the indicators that affect on this level can be seen on the Table 2.4.

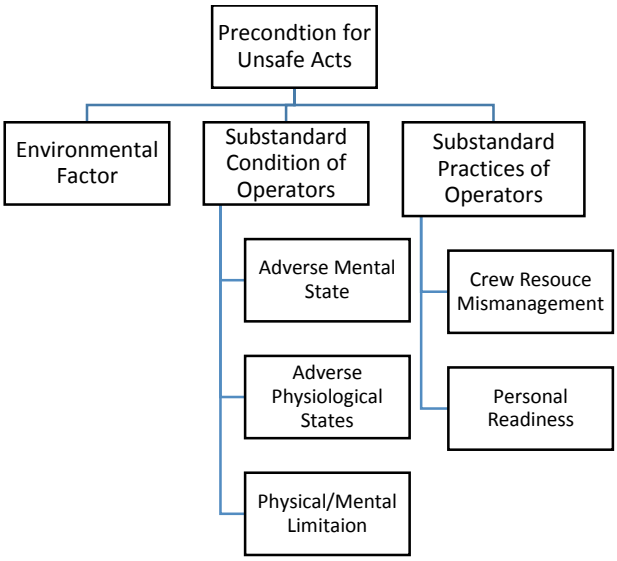


Figure 2.8. Precondition for Unsafe Acts Level

- The environment factors refer to high vibration, high temperature, failure to identify sea condition weather, lack of visibility, failure to use the devises or failure in automation devices. Those factors can affect the accident during the operation. For example, bad weather or unsafely sea condition effect to operator visibility. Therefore, this condition can be affected as the factor of marine accident.
- Substandard condition of operators consists of adverse mental state, adverse physiological state also physical/mental limitation. Adverse mental state is one of the important things that should be in concern. If it is happened to the employees or crew it will affect to crew's or employee's performance to do the operation. Adverse mental state can be defined like loss of situational awareness, mental fatigue, attention deficit, circadian rhythm disorder, apathy or improper motivation. Then, adverse physiological states, refers to those medical or physiological conditions that preclude safe operations. Particularly, the medicene could be have some effect like visual limitation, dizzy or something like that. Therefore, it is important to ensure that the medicine have a good effect for the crew while working condition. While, physical or mental limitation are lack of knowledge, skill, talent or time to perform their job.
- While substandard of practices of operators refer to resource management and personal readiness. One of example of resource management is good communication. As we knew that communication is one of the important things in marine operation. Therefore, keeping the good communication between VTS (Vessel Traffic System) and also ships is important. The communication is considered between ship to ship or ship to VTS communication. Lack of coordination from each parties can affect to marine accident especially collision accident. While, readiness for the task can be defined as the employee is unready to do the task. In aviation, or for that matter in any occupational setting, individuals are expected to show up for work ready to perform at optimal levels.

Table 2.4. Indicators of Precondition for Unsafe Acts

Precondition for Unsafe Acts	**Environmental Factors**	High vibaration
		High temperature
		Lack of visibility
		Failure to identify weather
		Failure to identify sea condition
		Failure in bridge devices
		Failure to use the devices
		Failure in automation devices
	Substandard Condition of Operators	**Adverse Mental State**
		Lost of situational awareness
		Circadian rhythm disorder
		Improper motivation
		Overconfidence
		Adverse Physiological States
		Hypothermia
		Health condition
		Fatigue
		Medical illness
		Physical/Mental Limitation
		Visual Limitation
		Lack of skill
		Lack of talent
		Lack of time
	Substandard Practices of Operators	**Resouce Management**
		Failed to back-up
		Failed to communicati (VTS-Ship)
		Failed to conduct adequate brief
		Failed to use all available resources
		Lack of leadership skill
		Personal Readiness
		Excessive physical training
		Self-medicating
		Violation of crew test reqruitment

2.5.4. Unsafe Acts

The last level of human factor analysis and classification system is unsafe acts. Unsafe actions are the action of operators or individual that including pilot, captain, or even officer that affect to accident directly. According to the Figure 2.9. below, this level has two headings which are errors and violations. Errors classified as decision, skill based and perception. While, violation classified as routine and exceptional. While the indicators that affect on this level can be seen on the Table 2.5.

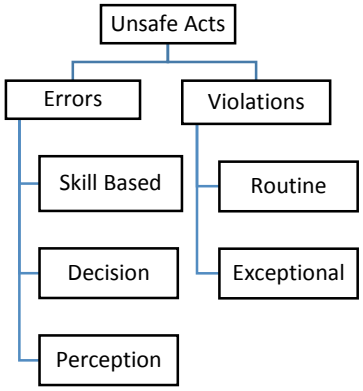


Figure 2.9. Unsafe Acts Level

- Errors divided into decision, skill based and also perception. According to Mazaheri et al, 2015: Patterson and Shappell, 2010, skill based errors happened when attention, memory and technical shortcomings are present. These are errors arising from low or no awareness. They are considered to be related to routine practices, action without thought or mechanical behaviors. Decision error is defined as improper or inadequate planning of designed or ongoing behaviors to reach the goal (Ergal, 2016: IMO, 2010). Decision error divided into 3 subcategories such as rules (procedures), information (selection), and problem solving. Decision error based on rules occur when incorrect diagnosis happened by the crew. While, lack of knowledge could be as the reason of crew doing the wrong selection when the accident happened. More over problem solving decision errors occur when and individual does not fully understand about the problem was happening, therefore they don't know what should they do to solve the problems. According to IMO, 2010, perception errors ate the accident caused by false or wrong perception due to visual auditory, cognitive or attention problems. For the example in ship accident, the grounding accident happened because officers fail to notice the reef in sailing area.
- While, violations are behaviors where rules and regulation are totally ignored by employee or crews that affect to accident. Routine violations which are customary or often tolerated by competent authorities are the causative factor (Wiegman and Shappell, 2003). Exceptional violations defined as not malicious acts but actions performed with the intent to finish the job. Such as violations don't reflect the crew's characters and they are tolerated by the ship management (IMO, 2000, 2010).

Tables 2.5. Unsafe Acts Indicators

Unsafe Acts	Errors	**Skill-based Errors**
		Failed to prioritize attention
		Inadvertent use of navigational controls
		Omitted step in procedure
		Omitted checklist item
		Poor technique
		Decision Errors
		Improper procedure
		Misdiagnosed emergency
		Wrong response to emergency
		Inappropriate manuever
		Poor decision
		Perception Errors
		Misjudged distance of vessel
		Visual illusions
	Violations	**Routine**
		Failed to adhere to brief requirements
		Improper Procedure
		Failed to inspect equipment prior to use
		Not qualified for equipment
		Exeptional
		Voyage or operation an unauthorized approach
		Accepted unnecessary risk
		Violated training rules
		Voyage an overagressive manuever
		Failed to prepare for the voyage safely
		Failed to use the radar

2.6. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a decision support model developed by Thomas L. Saaty. This decision support model will outline multi-factor problems or complex multi criteria into a hierarchy. Hierarchy is defined as a representation of a complex problem in a multi-level structure where the first level is a goal, followed by a level of factors, criteria, sub criteria, and so on down to the last level of alternatives (Saaty, 1993). The example of hierarchy process can be seen on the Figure 2.10 below. With hierarchy, a complex problem can be broken down into groups which are then arranged into a hierarchical form so that the problem will appear more structured and systematic.

AHP is often used as a problem solving method compared with the other methods for the following reasons:

1) A hierarchical structure, as a consequence of the criteria chosen, reaches the deepest sub-criteria.
2) Calculating the validity up to the tolerance limit of inconsistencies in various criteria and alternatives chosen by decision makers.
3) Take into account the durability of the output of the sensitivity analysis of decision making.

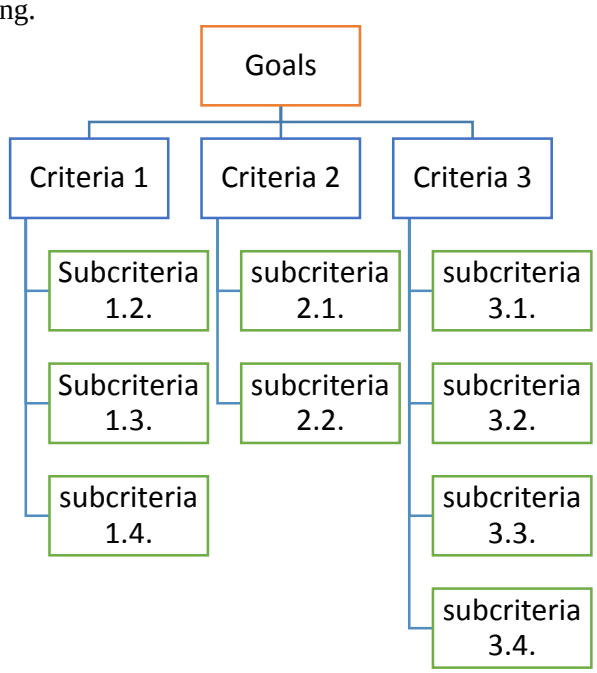


Figure 2.10. The Example of AHP Process

2.5.1. Stages of Making the Hierarchy

The stages to making the analytical hierarchy process will be following as (Kadarsyah Suryadi and Ali Ramdhani, 1998):

1) Defining Problems and Determining Solutions
   In this stage we try to determine the problem that we will solve clearly, in detail and easily understood. From the problem we are trying to determine a solution that might be suitable for the problem. Solutions for problems may amount to more than one. We will develop these solutions further in the next stage.
2) Making a hierarchical structure
   After arranging the main objectives as the top level, a hierarchy level will be arranged below which criteria are suitable for considering or evaluating the alternatives we provide and determine these alternatives. Each criterion has a different intensity. The hierarchy continues with sub-criteria (if needed).
3) Make a Pairwise Comparison Matrix
   The matrix used is simple, has a strong position for a framework of consistency, obtains other information that may be needed with all possible comparisons and

is able to analyze the sensitivity of the overall priority for changing considerations. The approach to the matrix reflects the dual aspects of priorities, which are dominating and dominated. Comparison is based on judgment from decision makers by assessing the importance of an element compared to other elements. To start the pairwise comparison process, a criterion from the top level of the hierarchy is chosen, for example that shown on the Table 2.6. below criteria and then from the level below the elements to be compared are for example SC 3.1, SC 3.2, SC 3.3 and also SC 3.4.

Table 2.6. Comparison Matrix

Criteria	SC 3.1	SC 3.2	SC 3.3	SC 3.4
SC 3.1				
SC 3.2				
SC 3.3				
SC 3.4				

4) Defining Pair Comparison
The results of the comparison of each element will be a number from 1 to 9 which shows a comparison of the importance of an element. If an element in the matrix is compared to itself then the results of the comparison rated 1 - 9 has been proven to be acceptable and can distinguish intensity between elements. The results of the comparison are filled in cells that correspond to the elements compared. The scale of comparative pairings and their meanings introduced by Saaty can be seen on the Table 2.7. below.

Table 2.7. Table of Relatives Score by Saaty

Itensity of Importance	Definitions
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Important
9	Absolutely important
2, 4, 6, 8	intermediate values

5) Calculate Eigen Value and Eigen Vector
If it is not consistent, therefore, the data should be repeated.
6) Repetition of stages 3,4 and 5
Repetition is carried out at all levels of hierarchy

7) Calculating Priority Value
   Calculates the eigenvectors of each paired comparison matrix which is the weight of each element for prioritizing elements at the lowest hierarchy level until they reach the destination. Calculations are done by summing the values of each column of the matrix, dividing each value from the column by the corresponding column to obtain the normalization of the matrix, and adding up the values of each row and dividing by the number of elements to get the eigenvector value.
8) Ensure the Hierarchy Consistency Value
   What is measured in AHP is the consistency ratio by looking at the consistency index. The expected consistency is near perfect so as to produce a decision that is almost valid. Although difficult to achieve perfect, the consistency ratio is expected to be less than or equal to 10% (<0.1).

2.5.2. Pros and Contras of AHP Method

Like an analysis method, AHP also has advantages and disadvantages in its analysis system. The advantages of this analysis are:

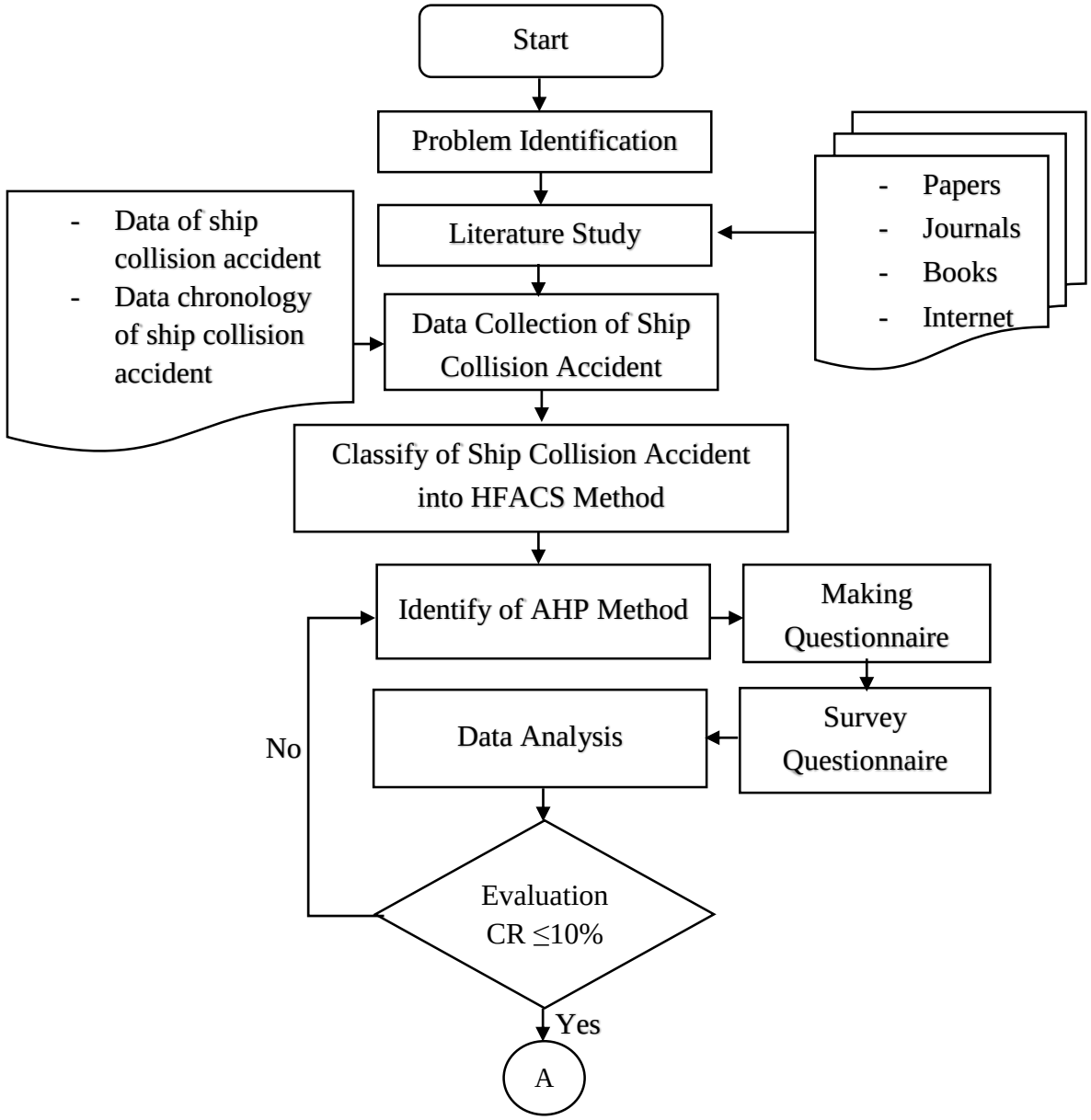
- **Unity**
  AHP makes broad and unstructured problems into a model that is flexible and easy to understand.
- **Complexity**
  AHP solves complex problems through a system approach and deductive integration.
- **Interdependence**
  AHP can be used on system elements that are mutually independent and do not require linear relationships.
- **Hierarchy Structuring**
  AHP represents natural thinking which tends to group system elements into different levels of each level containing similar elements.
- **Measurement**
  AHP provides measurement scales and methods to get priority.
- **Consistency**
  AHP considers logical consistency in the assessment used to determine priorities.
- **Synthesis**
  AHP leads to an overall estimate of how desirable each alternative is.
- **Trade Off**
  AHP considers the relative priority of the factors in the system so that people are able to choose the best alternative based on their goals.
- **Assessment and Consensus**
  AHP does not require the existence of a consensus, but combines different assessment results.
- **Repetition Process**
  AHP is able to make people filter the definition of a problem and develop their assessment and understanding through the repetition process.
  While the weaknesses of the AHP method are as follows:

- Dependence on the AHP model on its main input. The main input is in the form of an expert's perception so that in this case involving the subjectivity of the expert besides that the model becomes meaningless if the expert gives a wrong assessment.
- This AHP method is only a mathematical method without statistical testing so that there is no limit of trust from the truth of the model formed.

CHAPTER III
METHODOLOGY

3.1. Overview

Methodology is a systematics procedure that explain the steps of research in certain order that has to be done sequentially. Therefore, methodology is using to easier the author during the research. These procedures of this thesis are described in the Figure 3.1. below.



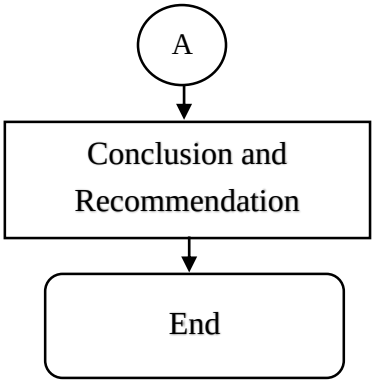


Figure 3.1. Methodology Flowchart

3.2. Problem Identification

Problem identification is a statement for area concern. The problem should be done in order to define the problem and to achieve the purposes of this thesis. According to concern of collision accident in the port of Tanjung Perak Surabaya from 2015-2018, therefore the problem identification in this thesis have five problems such as:

1. What are the factors of human error in ship collision accident according to HFACS method?
2. What are the factors of ship collisions accident according to AHP method?
3. How much the human error effect to ship collision accident according to AHP method?
4. What is the most factors in human error as ship collision accident?

3.3. Literature Study

Literature study is a process of collecting the information that related to the area of study. This process should be described, summarize, evaluate, clarify this literature and give the theoretical base for the research. In this thesis, the literature review sourced from paper, journals, books, and internet that related to shipping accident about ship collision, the methods consists of human factor analysis and classification system (HFACS) and also Analytical Hierarchy Process (AHP).

3.4. Data Collection of Ship Collision Accident

Data collection of marine accident has purpose to know the total and chronology of marine accident in port of Tanjung Perak Surabaya. Therefore, the data needed will follow by:

1. Data ship Collision accident in Port Authority Surabaya to know the frequency of marine accident in port of Tanjung Perak Surabaya
2. Data chronology of ship collision accident to identify cause of ship collision accident to make hierarchy process in AHP.

3.5. Classify of Ship Collision Accident into HFACS Method

After knowing the data of marine accident in port of Tanjung Perak Surabaya, next step is determining and classify of Human Factor Analysis and Classification System (HFACS) categories by checklist all of the ships collision accident and input it into each indicator in HFACS method. This step will identify of Human Error Criteria in AHP Method in next step. Checklist of HFACS category will be shown by the Figure 3.1. below.

Table 3.1. Identify of Marine Accident into HFACS Method

HFACS Level	HFACS Sub-Level	Marine Accidents				Total by Indicators	Total Each Level
		Accident 1	Accident 2	Accident 3	Accident 4		
		Date	Date	Date	Date		
Organizational Influences (Level 1)	Resource Management						
	Organizational Environment						
	Organizational Process						
Unsafe Supervision (Level 2)	Inadequate Supervision						
	Planned Inappropriate Operations						
	Failed to Correct a known						
	Supervisory Violations						
Precondition for Unsafe Acts (Level 3)	Environmental Factor						
	Condition of Operators						
	Practices Factor						
Unsafe Acts (Level 4)	Errors						
	Violations						
Number of Causes in Each Accident							
Number of Level in Each Accident							

3.6. Identify the AHP Method

This stage requires all the things needed in making AHP. Starting from the decomposition of the problem or abuse or problem into several criteria, comparative assessment or making a relative importance assessment that compares two elements at a certain level, prioritizes synthesis or looks for eigenvectors to get local offers from each matrix, and logical consistency or consistency of answers given by respondents in priority elements.

3.7. Making Questionnaire

Making a questionnaire will be done if the stages of AHP preparation and hierarchy have been carried out. Making this questionnaire depends entirely on what has been done at the previous stage, namely determining the problem, determining each factor that affects the problem, and determining the criteria that affect these factors.

3.8. Survey Questionnaire

Data analysis was carried out after the questionnaire survey was carried out. At this stage the survey is aimed at people who are experts in their fields so that the collected data will be valid and can be used as a benchmark in solving problems.

3.9. Data Analysis

The data analysis will be conducted by doing qualitative method to define the ship collisions accident. After that questionnaire will conduct into crews in port of Tanjung Perak Surabaya. Then scoring and calculating to ensure the priority number from the questionnaires. The questionnaire will be accepted if the consistency ratio (CR) <10%. But if CR value more than 10% therefore we need to find the problem by back into data collection. After ensure the value of CR <10%. , then the analysis will be continuing according to the result and also the recommendation when doing the interview with the experts.

3.10. Conclusion and Recommendation

In this step, the writing of conclusion and recommendation will be written from the result of the data analysis. The final of this study is to evaluate the human factors as causing of ship accident. Therefore, in the future, we can improve the quality of services and safety during using sea transportation.

3.11. Schedule

To ensure the research will be done, therefore the schedule has been made as show as the Table 3.2. below.

Table 3.2. Table of Schedule

No	Activity Plan	January				February				March				April				May				June			
		1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	Problem Identification																								
2	Literature Study																								
3	Data Collection of Ship Collision Accident																								
4	Classify of Ship Collision Accident into HFACS Method																								
5	Identify of AHP Method																								
6	Making Questionnaire																								
7	Survey Questionnaire																								
8	Data Analysis																								
9	Conclusion and																								
10	Final Report																								

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CHAPTER IV
ANALYSIS AND DISCUSSION

4.1. General Description

In this thesis, the value of human error and other criteria will be determining through the Analytical Hierarchy Process (AHP). While, the hierarchy itself will be determining through the Human Factor Analysis and Classification System (HFACS) indicators. This chapter will explain about concerning on the data collection related to the ship collision accident that cause of human error in port of Tanjung Perak Surabaya. The data will be processed in order to acquire the recommendation to decreasing the ship collision accident.

The first step that should be obtained is to understand about the causes of ship collision accident around port of Tanjung Perak Surabaya. Therefore, the historical data of ship collision accident would be needed to identifying the causes of these ship accident. The data have got from the port authority in Tanjung Perak Surabaya and also from the report of Mahkamah Pelayaran.

4.2. Data Collectivity

The data collection will be conducted in the port of Tanjung Perak Surabaya area. The process of this data collection will be determined by an interview and questionnaire that would be spread to some stakeholders in order to define the real condition before, and during the sailing process according to stakeholders' experience. The questionnaire and the data collectivity will be based on journals, historical data of ship collision accident and research from previous literatures concerning on the method related.

The questionnaire method will be spread into 2 different target such as expert judgment and also professionals. The expert judgement will conduct by the operator in VTS office which has duty to communicate with the operator in ship to ensure the ship will be sailing in safely condition by the concern of vessel traffic, port authority which has duty to issue the permission letter before doing the operation and also the lecturer that expert in safety management studies. While, the professionals will conduct to the crews' ship which has duty to operating the ship itself.

4.3. HFACS Classify

In chapter III, the research methodology has defined that the first step in this thesis is by determining and classifying of HFACS categories by doing these steps:

1) Determining causes of each ship collision accident at port of Tanjung Perak Surabaya.
2) Classify of each causes ship collision accident into some categories in HFACS level.
3) Classify of each causes ship collision accident into HFACS distribution

4.3.1. Determine of Ship Collision Accident

As the statement before that port of Tanjung Perak is the second biggest port in Indonesia. Therefore, there are a lot of ship accident happened in this territory. Then, the first thing that we have to do is determine some samples from the accident itself.

In this part, to determine the causes of ship collision accident will use the samples of ship collisions accident from 2012-2015 with 4 accidents. The chronology information of ship collision accident has got from the report of *Mahkamah Pelayaran* and also some information from the port authority in port of Tanjung Perak Surabaya area.

a) Accident in 11th December 2012

This accident happened because of 9 main causes did by some parties until the accident happened such as captain gave a command to unqualified crew, lack of communication between crews in deck department, lack of certificate and experience, vessel did an inappropriate maneuver, lack of awareness in risk management, lack of visibility, vessel didn't use the navigational equipment (GPS and Radar), Vessel voyage without permission letter from the authority, and also the management didn't use the tug bout in mandatory area.. These 9 main causes will explain more as shown as the Table in 4.1 below.

Table 4.1. Causes of 1st Accident

No	Causes of Accident	Indicator of HFACS	Sub-Level	Level
1	Captain gave a command to unqualified crew	Authorized unqualified crew of voyage	Supervisory Violation	Unsafe Supervision
2	Lack of communication between crews in deck department with company	Lack of communication between crews and company	Organizational Environment	Organizational Influences
3	Lack of certificate and experience	Failed to correct document in error	Failed to correct a known problem	Unsafe Supervision
4	Vessel did an inappropriate manuever	Inappropriate manuever	Errors	Unsafe Acts
5	Lack of awareness in risk management	Failed to provide operational doctrine	Inadequate Supervision	Unsafe Supervision
6	Lack of visibility	Visual limitarion	Condition of Operators	Precondition for Unsafe Acts
7	vessel didn't use the navigational equipment like GPS and Radar	Failed to use radar	Violations	Unsafe Acts
8	Vessel voyaged without permission letter from Authority	Voyage or operation an unauthorized approached	Violations	Unsafe Acts
9	Management didn't use the tug bout in mandatory area	Failed to enfore rules and regulations	Supervisory Violations	Unsafe Supervision

According to the Table 4.1. above, there are some indicators that happened before and during the accident did by the operator such as authorized unqualified crew of voyage, lack of communication between crews and company, failed to correct document in error, did inappropriate maneuver, failed to provide operational doctrine, lack of visual limitation, failed to use radar, voyage or operation an unauthorized approached, and also failed to enforce rules and regulation. While,

according to sub level and also each level on HFACS method. This accident has 9 parts such as 1 organizational environment in organizational influences level (level 1), 2 supervisory violations, 1 failed to correct a known problem also 1 inadequate supervision in unsafe supervision level (level 2), 1 condition operator in precondition for unsafe acts (level 3), then the last one is 1 error and 2 violations in unsafe acts level (level 4).

b) Accident in 26th March 2013

In this part, the accident happened because of 16 main causes did by some parties until the accident happened as shown as the Table 4.2 below.

Table 4.2. Causes of 2nd Accident

No	Causes of Accident	Indicator of HFACS	Sub-Level	Level
1	The position is not accordance with the Ministry Regulations	Failed to enfore rules and regulations	Supervisory Violation	Unsafe Supervision
2	Lack of supervison from the company about the captain qualification	Lack in human resource selection	Resource Management	Organizational Influences
3	Vessel did an inappropriate manuever	Inappropriate manuever	Errors	Unsafe Acts
4	Operator didn't check the main engine before voyage	Lost of situational awareness	Condition of Operators	Precondition for Unsafe Acts
5	Captain made the worst condition because he was in panic attack in the bad condition	Poor decision	Errors	Unsafe Acts
6	Lack of risk management	Failed to provide operational doctrine	Inadequate Supervision	Unsafe Supervision
7	There wasn't the safety instruction in the ship	Lack of safety instruction document	Failed to correct a known problem	Unsafe Supervision
8	Lack of supervision about safey manegement from the company	Lack of safety program from the company	Organizational Process	Organizational Influences
9	High wave in berthing condition	Failed to identify sea conditions	Environmental Factors	Precondition for Unsafe Acts
10	Lack of knowlegment about the ship characteristic	Failed to provide operational doctrine	Inadequate Supervision	Unsafe Supervision
11	Captain didn't anticipation about the navigational condition after the accident	Failed to identify a risk of navigational equipment	Failed to correct a known problem	Unsafe Supervision
12	Operator didn't use the navigational equipment	Failed to use the devices	Environmental Factors	Precondition for Unsafe Acts
13	No response to other vessels	Failed to communication (ship-ship)	Practices Factors	Precondition for Unsafe Acts
14	Management didn't use the tug bout in mandatory area	Failed to enfore rules and regulations	Supervisory Violations	Unsafe Supervision
15	Made a worst condition by turn off the main engine	Wrong response in emergency situation	Errors	Unsafe Acts
16	Lack of sailing experience	Lack of sailing experience	Condition of Operators	Precondition for Unsafe Acts

These 16 main causes of this accident such as the position is not accordance with the Ministry Regulations of Republic Indonesia, lack of supervision from the company about the captain qualification, vessel did an inappropriate maneuver, operator didn't check the engine before voyage, captain made the worst condition because he was in panic attack, lack of management, there isn't safety instruction in ship, lack of supervision about safety management from the company, high wave in berthing condition, lack of knowledge about ship characteristic, captain didn't anticipation about navigational equipment after the accident before, operator didn't use navigational equipment, not giving a response to another vessels, management didn't use the tug bout in mandatory area, made a worst condition by turn of the main engine and also lack of sailing from the crews itself.

While based on the Table 4.2. above. This accident also has 16 sub level that divided into some level in HFACS method. These sub level are divided into 1 resource management and 1 organizational influences in organizational influences level (level 1), 2 supervisory violations, 2 inadequate supervisions and 2 failed to correct a known problem in unsafe supervision level (level 2), 2 environmental factors, 2 condition of operators, and 1 practices factor in precondition for unsafe acts level (level 3), and also 3 errors in unsafe acts (level 4).

c) Accident in 1st April 2014

In this accident, happened because of 11 main causes did by some parties until the accident happened as shown as the Table 4.3 below.

Table 4.3. Causes of 3rd Accident

No	Causes of Accident	Indicator of HFACS	Sub-Level	Level
1	Lack of communication between vessel and Port Authority	Failed to communication (ship-authority)	Practices Factors	Precondition for Unsafe Acts
2	Lack of communication between vessel and the company	Lack of communication between operator and company	Organizational Environment	Organizational Influences
3	Operator was misscomunication with the company	Lack giving clearly defined objectives	Organizational Process	Organizational Influences
4	Lack of understanding about the standad operational	Lost of situational Awareness	Condition of Operators	Precondition for Unsafe Acts
5	Lack of knowlegment about the ship characteristic	Failed to provide operational doctrine	Inadequate Supervision	Unsafe Supervision
6	Wrong decision to did the voyage operaion in the bad condition	Poor decision	Errors	Unsafe Acts
7	Captain didn't learn about the system in the ship specifily	Lost of situational Awareness	Condition of Operators	Precondition for Unsafe Acts
8	Management didn't use the tugbout in mandatory area	Failed to enfore rules and regulations	Supervisory Violations	Unsafe Supervision
9	Failure in propulsion system	Failure in automation devices	Environmental Factors	Precondition for Unsafe Acts
10	Vessel did inappropriate manuever	Inappropriate manuever	Errors	Unsafe Acts
11	Lack of risk analysis in weather condition	Failure to identify the weather condition	Environmental Factors	Precondition for Unsafe Acts

According to the Table 4.3. above, there 11 main causes of ship collision accident happened such as lack of communication between vessel and port authority, lack of communication between vessel and the company, operator was miscommunication with the company. Lack of understanding about the standard operational, lack of knowledge about ship characteristic, wrong decision during the operation in the bad condition, captain didn't learn about system in the ship specifically, management didn't use the tug bout in mandatory area, failure in propulsion, vessel did inappropriate maneuver, and the last one is lack of risk analysis in weather condition.

While based on the table also, we knew that there are 11 sub level in that divided into HFACS level such as 1 organizational environment, 1 organizational process in organizational influences level (level 1), 1 inadequate supervision and 1 supervisory violation in unsafe supervision level (level 2), 1 practices factors, 2 environmental factor and 2 condition of operators in precondition for unsafe acts level (level 3), and also 2 errors in unsafe acts level (level 4).

d) Accident in 28th June 2015

While in the last sample of the accident happened in 28th June 2015 with 4 causes during the operation. These causes could be shown as the Figure in the table 4.4 below.

Table 4.4. Causes of 4th Accident

No	Causes of Accident	Indicator of HFACS	Sub-Level	Level
1	Vessel did inappropriate manuever	Inappropriate manuever	Errors	Unsafe Acts
2	Lack of anticipate about the ship manuever and ship load	Wrong response to emergency	Errors	Unsafe Acts
3	Did an unsafety manuever	Failed to enfore rules and regulations	Supervisory Violations	Unsafe Supervision
4	Lack of communcation between the vessel and tug boat	Failed to communication (ship-ship)	Practices Factors	Precondition for Unsafe Acts

According to the table above there 4 main causes of ship collision accident happened such as vessel did inappropriate maneuver, lack of anticipate about the ship maneuver and ship load, did an unsafety maneuver and also lack of communication between vessel and tug boat during the operation.

While the accident also contributed to sub level in each level of HFACS method as much as 4 sub levels. These 4 sub levels are divided into 1 unsafe supervision in unsafe supervision level (level 2). 1 practices factors in precondition for unsafe acts level (level 3) and also 2 errors in unsafe acts level (level 4).

4.3.2. Classify of Each Causes into HFACS Indicators

According to the classify and also historical data of ship collision accident in port of Tanjung Perak Surabaya. Therefore, there are several indicators in each level in these accident such as:

a) Organizational Influences

Due to the chapter II, organizational influences is giving lower impact than the other level, but organizational influences is one of the important things to start a work. When the company doesn't implement a good organizational in the company, it will be effect to another part. According to the historical data of ship collision accident happened in port of Tanjung Perak Surabaya, there are 4 indicators that effect to the human error in ship collision accident as shown as the Table 4.5 below.

Table 4.5. Organization Influences Classify

Level	Sub-Level	Indicators	Total Indicators
Organizational Influences (Level 1)	Resource Management	Lack in human resource selection	4
	Organizational Environment	Lack of communication between operator and company	
	Organizational Process	Lack of safety program from the company	
		Lack giving clearly defined informati	

These are 4 indicators that divided into 3 sub level in organizational level such as resource management, organizational environment and also organizational process. Therefore, the indicators in this level consist of lack in human resource selection, lack of communication between operator and company, lack of safety program form the company, and also lack giving clearly defined objective.

b) Unsafe Supervision

Supervision is a person in charge to ensure the team in a good condition. But unfortunately, there still have a bad implementation that doing by the supervision during the duty. According to the HFACS classify and the historical data of ship collision accident, unsafe supervision has 6 indicators that shown as the Table 4.6 below.

Table 4.6. Unsafe Supervision Classify

Level	Sub-Level	Indicators	Total Indicators
Unsafe Supervision (Level 2)	Inadequate Supervision	Failed to provide operational doctrine	6
	Planned Inappropriate Operations	(-)	
	Failed to Correct a known Problem	Failed to correct document in error	
		Lack of safety instruction document	
		Failed to identify a risk of navigational equipment	
	Supervisory Violations	Failed to enfore rules and regulation	
		Authorized unqualified crew of voyage	

Due to the table above, there 3 sub level in unsafe supervision level that effect to human error as cause of ship collision accident at port of Tanjung Perak Surabaya. These 3 sub level such as inadequate supervision, failed to correct a known problem and also supervisory violations. While according to the indicator of each sub level in unsafe supervision level. There are 6 indicators that effect to the human performance itself. These indicators consist of failed to provide operational doctrine, failed to correct a document in error, lack of documentation, failed to identify a risk of navigational equipment, failed to enforce rules and regulation also authorized unqualified crew of voyage.

c) Precondition for Unsafe Acts

In some case precondition for unsafe acts is a level that giving a highest effect to human error in the accident. Therefore, According to the historical data of ship collision accident in port of Tanjung Perak Surabaya. Precondition for unsafe acts have 9 indicators that effect to the human error as following as the table 4.7 below.

Table 4.7. Precondition for Unsafe Acts Classify

Level	Sub-Level	Indicators	Total Indicators
Precondition for Unsafe Acts (Level 3)	Environmental Factors	Failed to identify sea conditions	9
		Failed to use navigational devices	
		Failure in automation devices	
		Failure to identify safe weather condition	
	Condition of Operators	Visual limitation	
		Lost of situational awareness	
		Lack of sailing experience	
	Practices Factors	Failed to communication (ship-ship)	
		Failed to communication (ship-authority)	

Due to the Table 4.7. above, there 3 sub level in precondition for unsafe acts level such as environmental factors, condition of operators and also practices factors. While in this level has 9 indicators that effect to human performance in the accident. These 9 indicators consist of failed to identify sea condition, failed to use the devices, failure in automation devices, failure to identify the weather condition, visual limitation, loss of situational awareness, lack of sailing experience, failed to communication between ship-ship also failed to communication between ship-port authority.

d) Unsafe Acts

Unsafe acts are also quite important but unfortunately, the operator still doesn't have an awareness to implement all the regulations and doing all the safety behavior. Unsafe acts have 6 indicators that effect to the human factor of ship collision accident at port of Tanjung Perak Surabaya as shown in the table 4.8. below.

Table 4.8. Unsafe Acts Classify

Level	Sub-Level	Indicators	Total Indicators in Level 4
Unsafe Acts (Level 4)	Errors	Inappropriate manuever	5
		Poor decision	
		Wrong response to emergency	
	Violations	Failed to use radar	
		Voyage or operation an unauthorized approached	

Due to the Table 4.8. above, there are 2 sub level in unsafe acts level such as errors and also violation. While the indicators in this level consist of 5 indicators that effect to human performance as cause of ship collision accident. These 5 indicators consist of inappropriate maneuver, poor decision, wrong response to emergency, failed to use radar and also voyage or operation an unauthorized approached.

4.3.3. Classify Each Causes of Ship Collision Accident to HFACS Distribution

After classify of each category that effect to human error according to HFACS method. The next step is doing classify these causes or accident into HFACS distribution. This part has purpose to know what is the lower and also the highest level that effect to human performance or human error in ship collision accident. The HFACS distribution will show in table 4.9 below.

Table 4.9. Distribution of HFACS Classify

HFACS Level	HFACS Sub-Level	Marine Accidents				Total by Indicators	Total Each Level
		Accident 1	Accident 2	Accident 3	Accident 4		
		11-Dec-12	26-Mar-13	1-Apr-14	28-Jun-15		
Organizational Influences (Level 1)	Resource Management		v			1	4
	Organizational Environment	v		v		1	
	Organizational Process		v	v		2	
Unsafe Supervision (Level 2)	Inadequate Supervision	v	vv	v		1	6
	Planned Inappropriate Operations					-	
	Failed to Correct a known	v	vv			3	
	Supervisory Violations	vv	vv	v	v	2	
Precondition for Unsafe Acts (Level 3)	Environmental Factor		vv	vv		4	9
	Condition of Operators	v	vv	vv			
	Practices Factor		v	v	v	2	
Unsafe Acts (Level 4)	Errors	v	vvv	vv	vv	3	5
	Violations	vv				2	
Number of Causes in Each Accident		9	16	11	4		
Number of Level in Each Accident		1, 2, 3, 4	1, 2, 3, 4	1, 2, 3, 4	2, 3, 4		

Based on the Table 4.9. above, each level is always giving a contribution as the causes of ship collision accident in port of Tanjung Perak Surabaya. Level 2 (unsafe supervision), level 3 (precondition for unsafe acts) and level 4 (unsafe acts) is always giving contribution as the causes of ship collision accident. While, number level 1 (organizational influences) is not always giving a contribution as cause of ship collision accident.

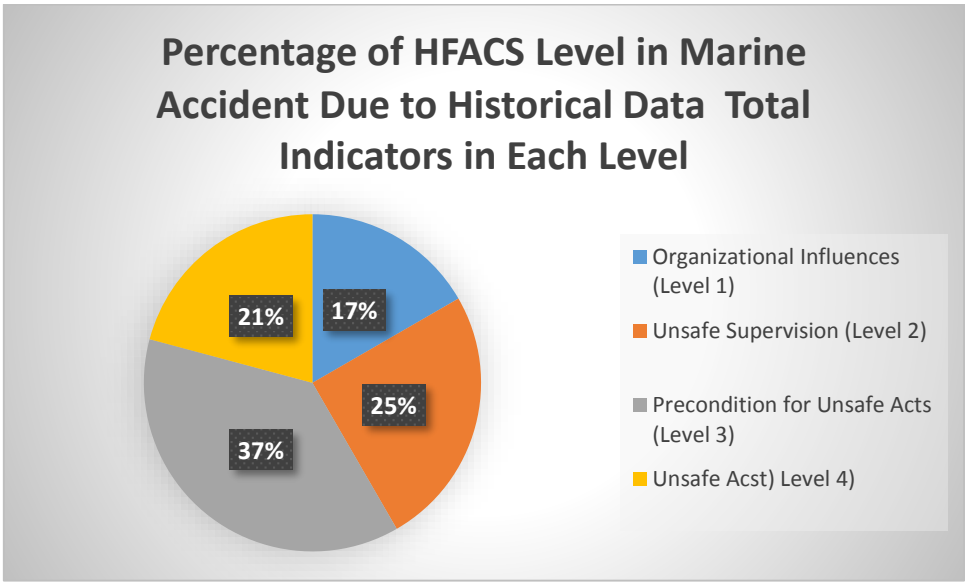


Figure 4.1. Percentage of HFACS Level in Marine Accident

Also, according the Table 4.9. and diagram as shown as the Figure 4.1. above , precondition for unsafe acts is a higher contribution to the ship collision accident with 9 indicators with percentage 37%, following by unsafe supervision on second level with 6 indicators or percentage with 25%, then unsafe acts with 5 indicators or percentage 21%and the last one is organizational influences with 4 indicators with percentage value 17%.

4.4. AHP Method

In this research, AHP method will be used to identify the value of main problem which ship collision accident. While ship collision accident would be happened because of some factors. And the value of each factors will be used as the recommendation and suggestion to increasing safety management to some parties.

4.4.1. Identification of Analytical Hierarchy Process

The first to determining of AHP method is by compile a hierarchy of hazard values from a main problem. In determining the hazard value, it must concern about all

elements that affect the danger level of the vessel itself, therefore the assessment is divided into several criteria. Each criterion has an influence on the level of the ship's effect with different values. From each criterion will be divided more into several sub-criteria. This step is to facilitate the assessment process.

The main purpose of this hierarchy is to find out the value of each criterion that effect to the ship collision accident. From this hazard the criterion was divided into 4 influencing criteria. These criteria are human error factors, sailing route, navigation and information system, and also ship propulsion system as shown as the Figure 4.2 below.

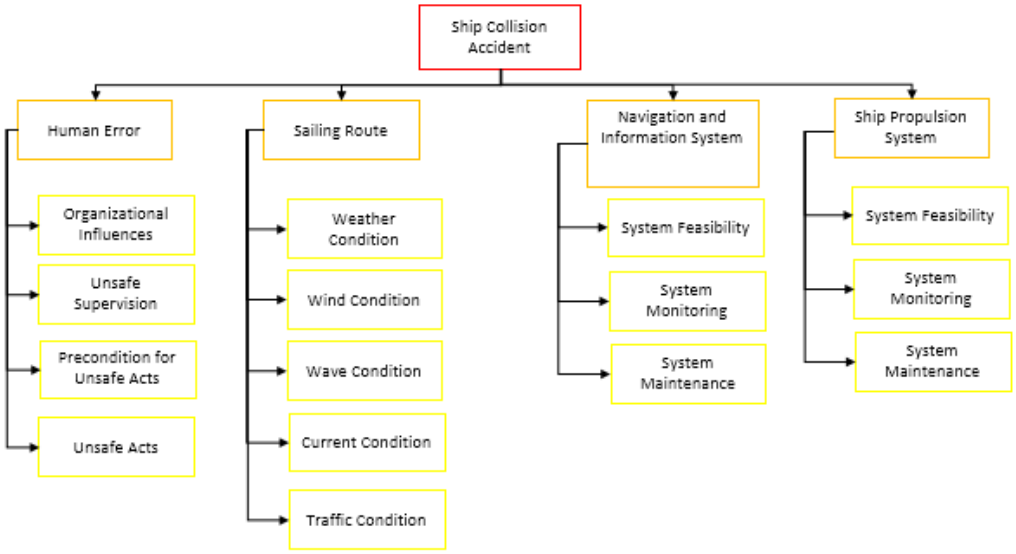


Figure 4.2. Hierarchy Structure of Ship Collision Accident

Human error as cause of ship collision accident will identify by using HFACS level. HFACS level have 4 level such as organizational influences, unsafe supervision, precondition for unsafe acts and also unsafe acts. These levels will be explained as sub-criteria in AHP method that effect to human error values in ship collision accident. While, each levels of HFACS have some indicators that effect to the level itself. The indicators of each category in HFACS method will be shown in the Figure 4.3 below.

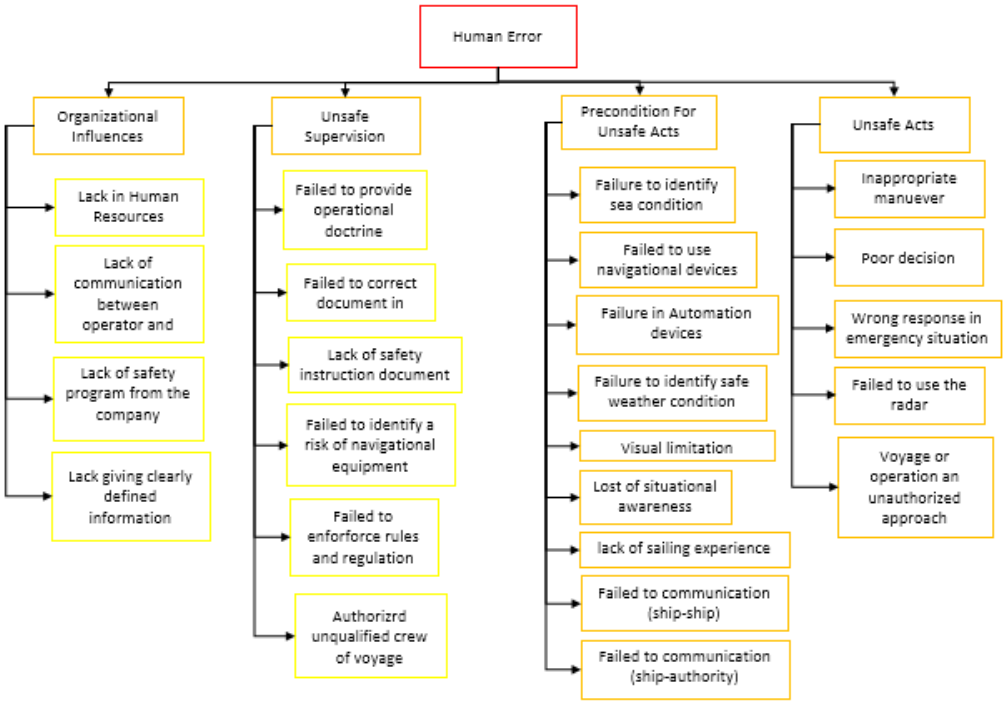
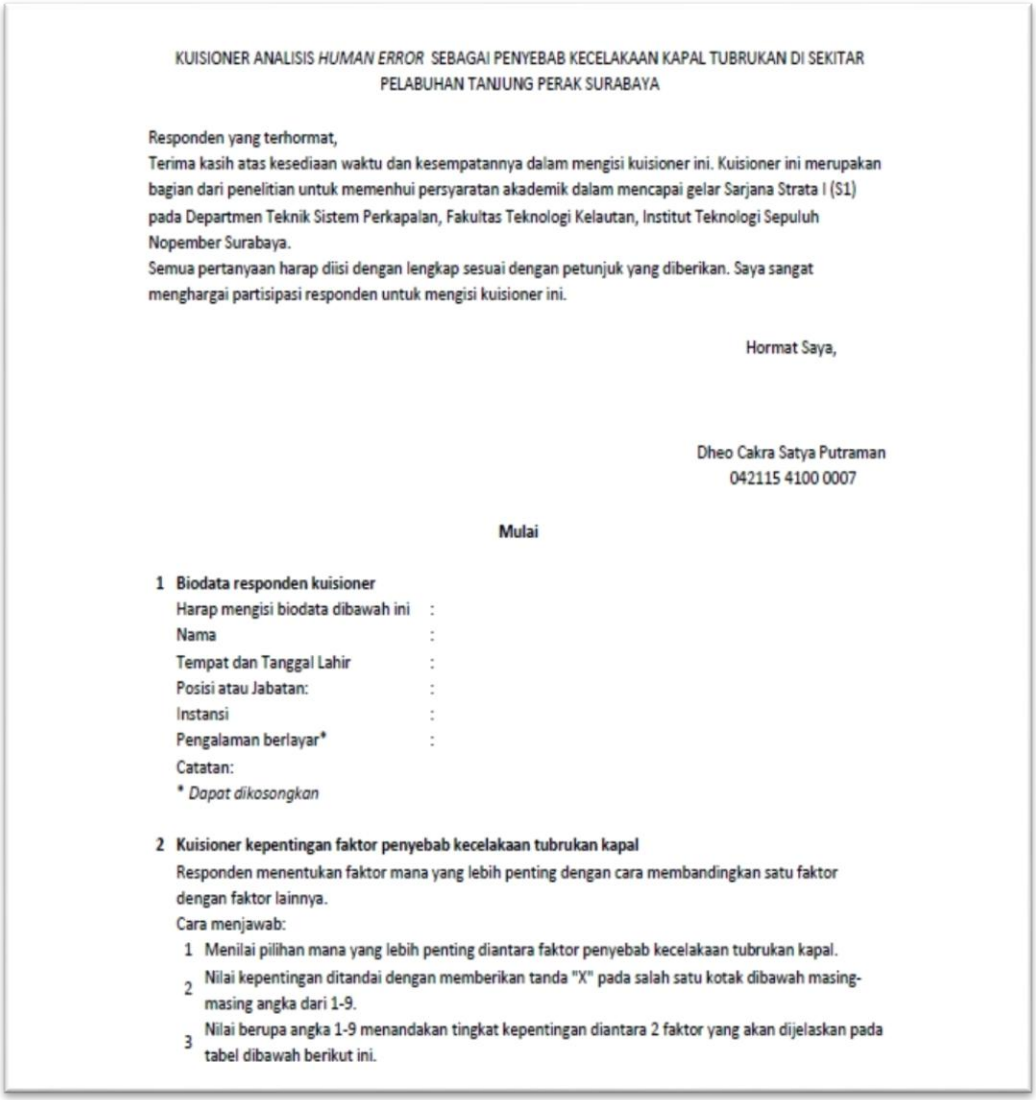


Figure 4.3. Hierarchy Structure of Human Error

4.5. Making Questionnaire

The first step that needs find out the value of each criterion and sub-criteria of the hierarchy that has been prepared is to prepare a questionnaire format that will be distributed to the respondents. The making of questionnaires uses formal language that is easy to understand to the respondent. The information that submitted to respondents must be clear on the questionnaire. The preface can be attached on the questionnaire as the information to respondent, so they know the purposes of filling out the questionnaire.

A questionnaire is a source of data that can be used to find out the opinions or information from a population. Source clarity is an absolute thing, so that the information obtained can be accounted for. So that it can be known whether the selected respondents are in accordance with the theme of the questionnaire or not. This is very important and must be really considered so that the theoretical basis obtained from a questionnaire could be using as the validation or not according to the result of their questionnaire. The questionnaire that using in this thesis will be shown on the Figure 4.4 and Figure 4.5 below.



KUISIONER ANALISIS *HUMAN ERROR* SEBAGAI PENYEBAB KECELAKAAN KAPAL TUBRUKAN DI SEKITAR PELABUHAN TANJUNG PERAK SURABAYA

Responden yang terhormat,
Terima kasih atas kesediaan waktu dan kesempatannya dalam mengisi kuisioner ini. Kuisioner ini merupakan bagian dari penelitian untuk memenhui persyaratan akademik dalam mencapai gelar Sarjana Strata I (S1) pada Departmen Teknik Sistem Perkapalan, Fakultas Teknologi Kelautan, Institut Teknologi Sepuluh Nopember Surabaya.
Semua pertanyaan harap diisi dengan lengkap sesuai dengan petunjuk yang diberikan. Saya sangat menghargai partisipasi responden untuk mengisi kuisioner ini.

Hormat Saya,

Dheo Cakra Satya Putraman
042115 4100 0007

Mulai

1 **Biodata responden kuisioner**
Harap mengisi biodata dibawah ini :
Nama :
Tempat dan Tanggal Lahir :
Posisi atau Jabatan: :
Instansi :
Pengalaman berlayar* :
Catatan:
* *Dapat dikosongkan*

2 **Kuisioner kepentingan faktor penyebab kecelakaan tubrukan kapal**
Responden menentukan faktor mana yang lebih penting dengan cara membandingkan satu faktor dengan faktor lainnya.
Cara menjawab:
1 Menilai pilihan mana yang lebih penting diantara faktor penyebab kecelakaan tubrukan kapal.
2 Nilai kepentingan ditandai dengan memberikan tanda "X" pada salah satu kotak dibawah masing-masing angka dari 1-9.
3 Nilai berupa angka 1-9 menandakan tingkat kepentingan diantara 2 faktor yang akan dijelaskan pada tabel dibawah berikut ini.

Figure 4.4. Questionnaire information

Seen in the Figure 4.4 is a questionnaire infromate that consist of the introductions and questionnaire objectives. The purpose of distributing detailed questionnaires is to convince a respondent to fill out the questionnaire. For the validity of filling out the questionnaire, there is a column of identity of the respondent so that the source can be known from the results of the assessment of the questionnaire.

Penjelasan Angka dalam mengisi kuisioner adalah sebagai berikut:

Angka	Definisi	Penjelasan
1	Sama Pentingnya	Kedua elemen memberikan penilaian yang sama
3	Sedikit lebih penting yang satu atas lainnya	Elemen yang satu cukup penting dari elemen yang lain
5	Lebih penting	Elemen yang satu lebih penting dari elemen yang lain
7	Sangat Penting	Elemen yang satu sangat penting dari elemen yang lain
9	Kepentingan yang mutlak atau pasti	Elemen yang satu mutlak atau pasti penting dari elemen yang
2, 4, 6, 8	Penilaian bila kompromi dibutuhkan	Nilai-nilai tengah diantara 2 pertimbangan nilai lainnya

2.1. Penilaian Bobot Kriteria

Terdapat 6 kotak dalam faktor-faktor berikut yang berhubungan dengan penyebab kecelakaan tubrukan kapal sebagai bobot kriteria.

Petunjuk:

Manakah indikator yang lebih berperan dalam penyebab kecelakaan tubrukan kapal ?

1	Human Error atau kesalahan pada manusia	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Rute pelayaran
2	Human Error atau kesalahan pada manusia	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Kondisi sistem navigasi dan informasi pada kapal
3	Human Error atau kesalahan pada manusia	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Kondisi sistem propulsi pada kapal
4	Rute pelayaran	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Kondisi sistem navigasi dan informasi pada kapal
5	Rute pelayaran	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Kondisi sistem propulsi pada kapal
6	Kondisi sistem navigasi dan informasi pada kapal	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Kondisi sistem propulsi pada kapal

Figure 4.5 Instruction to fill the questionnaire

In Figure 4.5, there are points of assessment that can be given to compare the elements. This step is called comparative judgment, which is giving an assessment of the relative importance of two elements at a certain level in relation to the levels above. Also seen are the columns for filling out the assessment along with examples of how to fill out an assessment, so that the respondent is not wrong in making an assessment. In addition, the consistency of respondents' answers in determining priority elements will determine the validity of the data and the results of decision making.

4.6. Choosing the Respondents Target

Determination of respondents was chosen based on the research theme. In this study the criteria that exist in the assessment score is a material that is understood and experienced by sailors or ship crews. So that the respondents chosen were crew of the ship such as crews from the vessel that operating in port of Tanjung Perak Surabaya. While, according to the historical data of ship collision accident in port of Tanjung Perak Surabaya. The voyage activity will be synergy with other parties, therefore port authority, and person in charge in *Distrik Navigasi Kelas I* Surabaya will be included into the respondent target. And also as explained in part data collection above, lecturer that expert in marine safety management could be included as the respondents. Therby, the total of respondents in this thesis are 20 respondents which divided into 5 lectures, 10 crews, 3 persons from *Distrik Navigasi Kelas I Surabaya* and 2 persons from port Authority office Surabaya. While, to ensure the validity result the respondent could be had sailing experience. Therefore, the respondents of the questionnaire for this research is 94% had sailing experience.

4.7. Calculation Process

There are several steps to do the calculation in this thesis that would be explain below.

4.7.1. Calculation Preparation

Calculation process would be process by using a software to calculate the priority value of each critera and sub-criteria according to the hierarchy process. while in this thesis critera and sub-criteria would be calculate to determine what is the most factor of ship collision accident in port of Tanjung Perak Surabaya.

The goal of this research is ship collision accident. At this point the weight of the decision is 100%. The arrangement below this main objective is all the criteria and sub-criteria that affect the hazard value which is the purpose of this problem. The overall weight of the main problem must be divided into several criteria. Each criterion obtains a weighting value in accordance with the results of the respondent's assessment. There are several methods for including the assessment. However, all methods have the same basis, namely by comparing all the criteria to determine the value or weight of these criterion. The results or outputs is to obtain criteria with priority levels are preferred and the value of consistency ratios that can prove that this weighting value is still consistent enough to be used as explained above.

The first step to starting the calculation is to enter the goal and objectives of the problem, which in this case is a ship ship collision accident. After that each criterion and sub-criteria that have been compiled at the hierarchy should be included in the assessment weight as shown as the Figure 4.6. below.

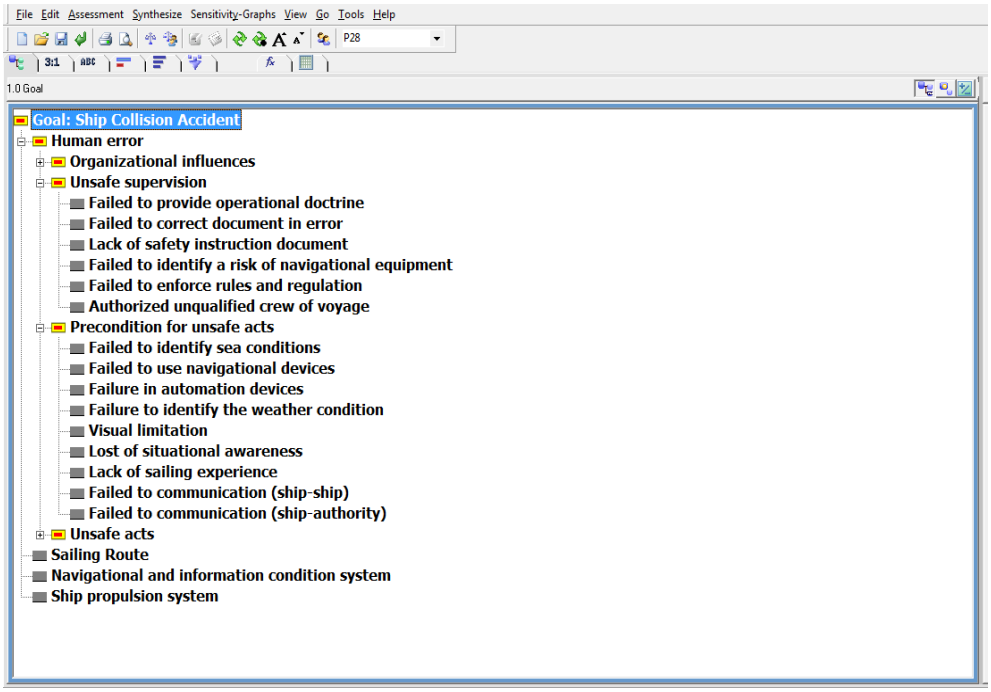


Figure 4.6. Hierarchy Process

After all the objectives, criterias, and subcriteria are entered into the calculation, the next step is to determine how many respondents will be used in this analysis. In this final assignment the author uses 20 respondents who have professions as lecturers, ship crew, person in charge in VTS and port authority. After determining how many respondents will participate in the assessment of the weight of each criterion and subcriteria, then all respondents must also be included in the list of respondents like the Figure 4.7. below.

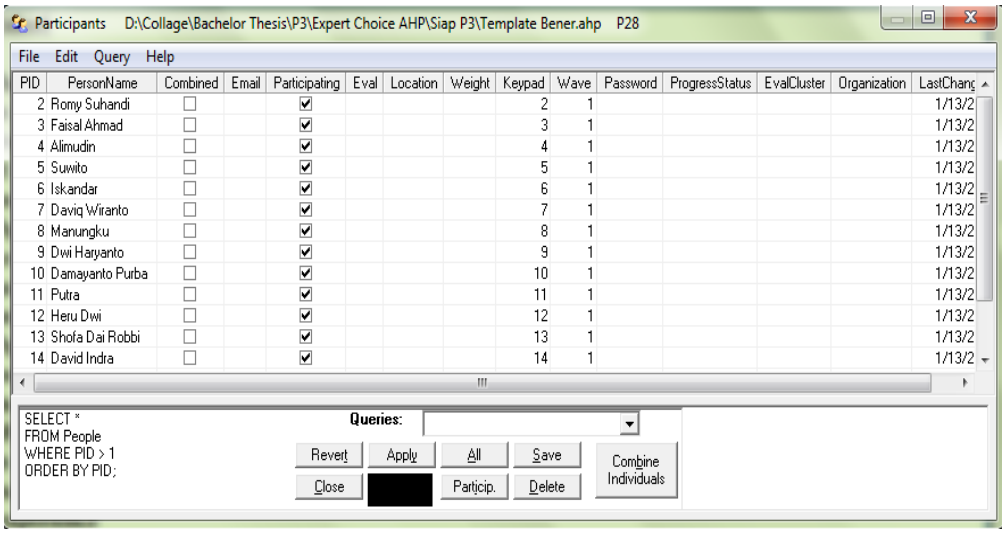


Figure 4.7. Participant Lists

4.7.2. Calculation Process

After the main objective data, criteria, and subcriteria are entered, an assessment of the comparison of each element could be doing as shown as the Figure 4.8. below. The assessment process uses the Pairwise Numerical Comparisons method, which compares two elements using a scale in the form of a number. The scoring used is the same as the rating scale listed on the questionnaire sheet.

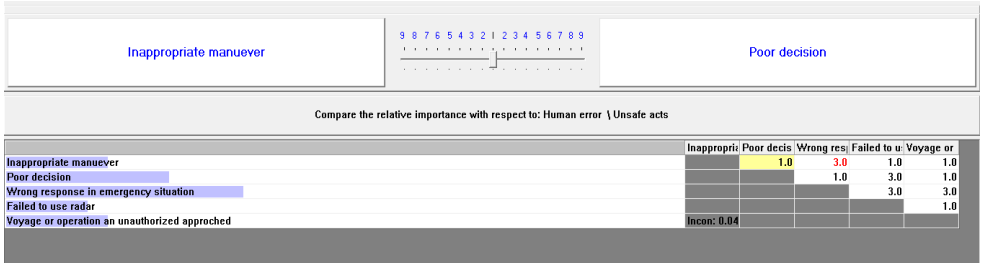


Figure 4.8. Pairwise Numerical Comparisons

After all assessments are entered, there will be inconsistencies in the answers given by the respondents. If the inconsistency value is more than 10% (> 0.1) then the results of the calculation cannot be used, so it is necessary to repeat the data collection with questionnaire as in the previous stage. If the result of the inconsistency value is less than or equal to 10% (> 0.1) then the data can be used. Repeat al the steps to all the respondents result. When all the respondents have

inconsistency ratio less than 10%, therefore the next step in calculating all the value of respondents by using the combination step like the Figure 4.9. below.

Figure 4.9. Combined All the Participants Result

After combined all the participants result. The value would be different because the value included is the geometric average of all assessments based on the results of the questionnaire as shown as the Figure 4.10. and Figure 4.11. below.

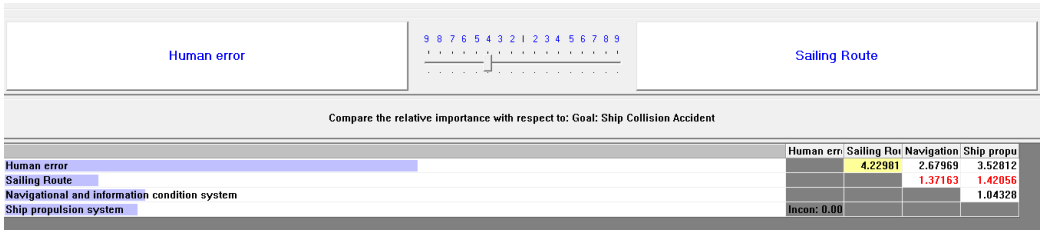


Figure 4.10. Geometric Average Number

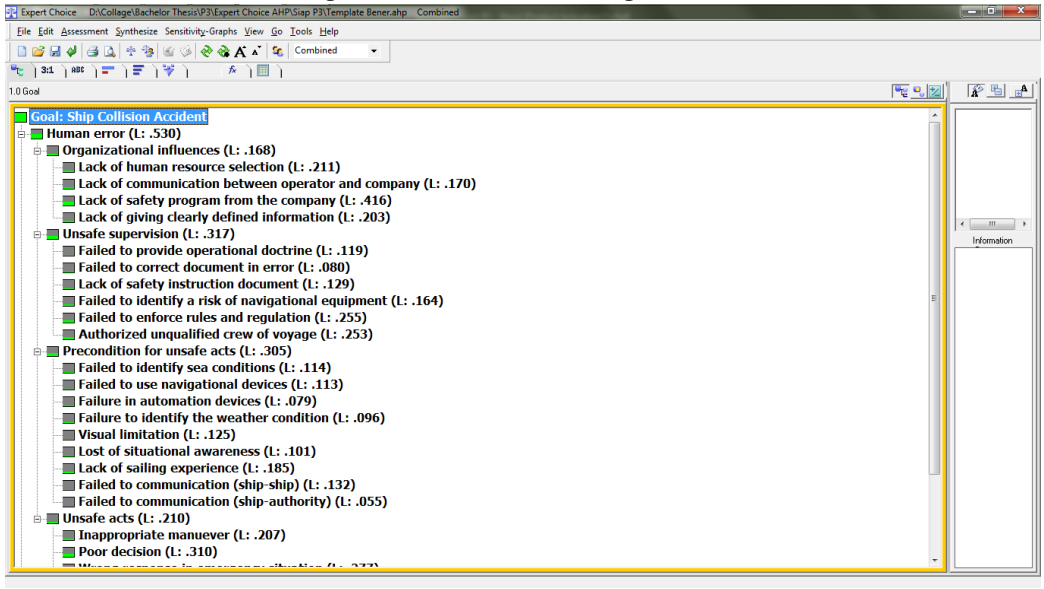


Figure 4.11. Combined Result

4.8. Result Analysis

In this part, result analysis will be explain in 3 analysis according to weight value. These analysis will be included such as weight value of criteria in ship collision accident, weight value of human error and the last one is weight value of human factor analysis and classification system (HFACS) level. As explained above, HFACS will be divided into 4 levels. Therefore, in this part, HFACS will be explain in 4 level condition such as weight value of organizational influences level, weight value of unsafe supervision level, weight value of precondition for unsafe acts level and last one is weight value of unsafe acts level.

4.8.1. Weight Value of Criteria in Ship Collision Accident

As it is known that the analysis with the aim of the ship collision accident is divided into four criterion or factors could be seen in Figure 4.12. These criterion consist of human error, sailing route, navigation and information system condition and the last one is ship propulsion system condition. By comparing all the criteria obtained from twenty respondents who have been determined, using the pairwise number comparisons method. Due to the Table 4.10. below, the results show that the human error have the highest relative weight 0.53 with a percentage reaching 53%, continue with navigational and information condition system with weight value 0.18 or 18%, ship propulsion system with weight value 0.166 or 17% and the last one is sailing route with weight value 0.124 or 12%. While inconsistency ratio in this calculation is 0.00256 ≤ 10%, therefore the result is in consistent condition.

Table 4.10. Weight Value of Criterion

Priority	Criteria	Weight Value	Percentage
1	Human Error	0.53	53%
2	Navigational and information condition system	0.18	18%
3	Ship propulsion system	0.166	17%
4	Sailing route	0.124	12%

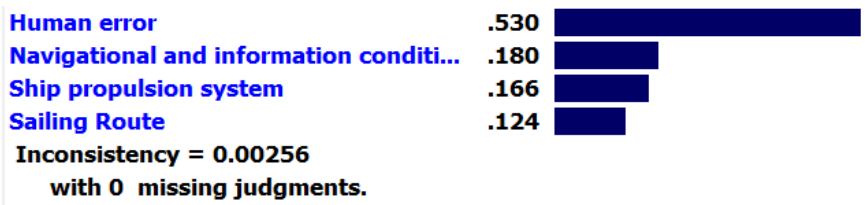


Figure 4.12. Weight Value of Criterion

4.8.2. Weight Value of Human Error in Sub-Criteria

Human error as the sub-criteria would be using the HFACS method that have 4 levels. These levels consists of organizational influences (level 1), unsafe supervision (level 2), precondition for unsafe acts (level 3) and the last one is unsafe acts (level 4). Therefore, the priority of each sub-criterion will be explain as the Figure and table below.

Table 4.11. Priority Value of Human Error

Priority	Sub-indicators	Weight Value	Percentage
1	Unsafe supervision	0.317	32%
2	Precondition for unsafe acts	0.305	31%
3	Unsafe acts	0.21	21%
4	Organizational influences	0.168	17%

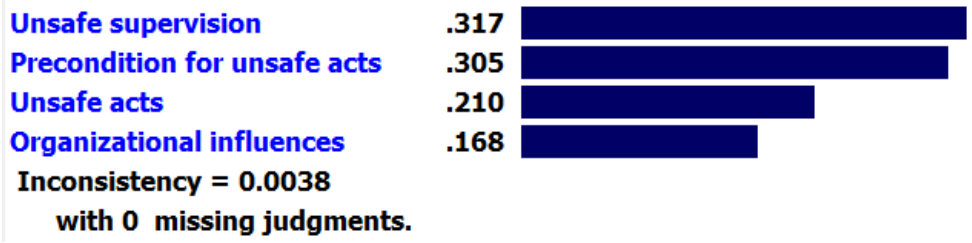


Figure 4.13. Weight Value of Human Error

According to the Figure 4.13. and the Table 4.11. above. Unsafe supervision is the first priority with weight value 0.317 or percentage 32%, continue with precondition for unsafe acts in the second highest priority with weight value 0.305 and percentage 31%, then unsafe acts is the third priority with weight value 0.210 or percentage 21%, and the last one in organizational influences with weight value 0.168 or percentage 17%. Value of consistency ratio in this level is 0.0038 ≤ 10%, therefore the calculation could be used in this analysis.

4.8.3. Weight Value of HFACS

Because the limitation analysis in this research is about human factor as cause of ship collision accident. Therefore, as explained in the previous page, human factor analysis and classification system (HFACS) is consists of 4 level. These level such as organizational influences, unsafe supervision, precondition for unsafe acts, and unsafe acts level. While each level have some indicators inside it that would be calculate by using pairwise number comparison as the same method above from all the participants value. Thereby, the weight value and the result will be explain below.

4.8.3.1. Weight Value of Organizational Influences Level

Organizational influences as the first level in HFACS have 4 indicator that effect to this level such as lack of safety program from the company, lack of human resource selection, lack of giving clearly defined information and lack of communication between operator and company. These incators also could be see in the Figure 4.14 below. Therefore, according to the priority of each level that affect to the level of organizational influences will be explain as the explaination below.

Table 4.12. Priority of Indicators in Organizational Influences Level

Priority	Indicators of organizational influences level	Weight Value	Percentage
1	Lack of safety program from the company	0.416	42%
2	Lack of human resource selection	0.211	21%
3	Lack of giving clearly defined information	0.203	20%
4	Lack of communication between operator and company	0.17	17%

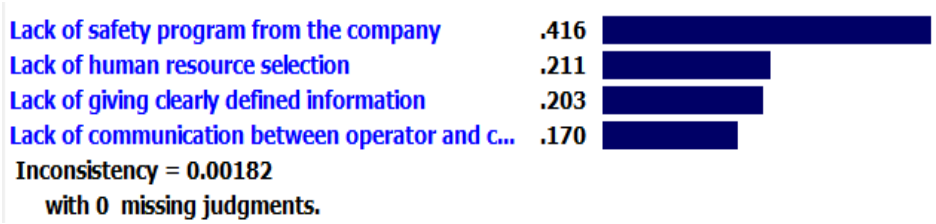


Figure 4.14. Weight Value in Organizational Influences Level

Due to the Table 4.12. ablove, lack of safety program as the highest weight value with 0.416 and percentage 42%, then lack of human resource selection as the second highest with weight value 0.211 or percentage 21%, continue with lack of giving clearly defined information with weight value with 0.203 or percentage 20%,. Thus, lack of communication between operator and company is the lowest indicator that effect to organizational influences level in human error with weight value 0.17 or percentage value 17%. This level has consistency ratio 0.00182 $\leq$ 10%, therefore the calculation could be used in this analysis.

4.8.3.2. Weight Value of Unsafe Supervision Level

Supervision level is the second level in human factor analysis and classification system method. In this level, there are 6 indicators that effect to the level such as failed to enforce rules and regulation, authorized unqualified crew of voyage, failed to identify a risk of navigational equipment, lack of safety program from the company, failed to provide operational doctrine and the last indicator is failed to correct document in error. While, the explaination of the priority in this level will be explain on the explaination below.

Table 4.13. Priority of Unsafe Supervision Level

Priority	Indicators of unsafe supervision level	Weight Value	Percentage
1	Failed to enforce rules and regulation	0.255	26%
2	Authorized unqualified crew of voyage	0.253	25%
3	Failed to identify a risk of navigational equipment	0.164	16%
4	Lack of safety instruction document	0.129	13%
5	Failed to provice operational doctrine	0.119	12%
6	Failed to correct document in error	0.08	8%

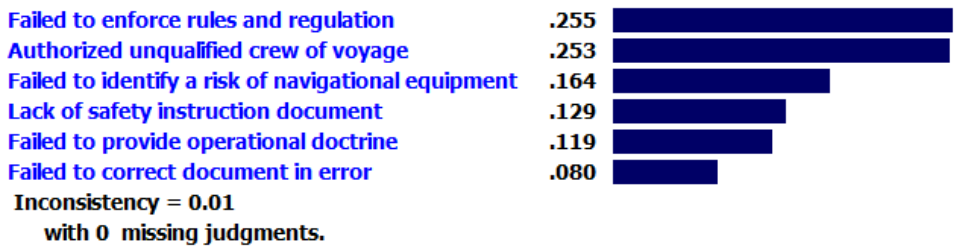


Figure 4.15. Weight Value of Unsafe Supervision Level

According to the Table 4.13. and Figure 4.5. above, failed to enforce rules and regulation is the highest indicator with weight value 0.255 or percentage 26%, then authorized unqualified crew of voyage with weight value 0.253 or percentage 25%. Continue with failed to identify a risk of navigational equipement with weight value 0.164 or percentage 16%. Then the next priority

is lack of safety instruction, this indicator has weight value 0.129 with percentage 13%. Then, failed to provide operational doctrine is on the fifth position with weight value 0.119 or percentage 12%. Thus, failed to provide operational doctrine is on the lowest indicator with weight value 0.008 or percentage 8%. While, the value of consistency ratio in this level is 0.01 ≤ 10%, therefore the calculation could be used in this analysis.

4.8.3.3. Weight Value of Precondition for Unsafe Acts Level

Precondition for unsafe acts level is the third level in human factor analysis and classification system (HFACS) method. While, in this level there are 9 indicators that effect to the level itself. These indicators consist of lack of sailing experience, failed to communication between ship and the other ship, visual limitation, failed to identify sea condition, failed to use navigational devices, lost of siuational awareness, failure to identify the weather condition, failure in automation devices, and the last indicator is lack of communication between the ship operator and pilot from the authority related. While, the priority of each indicators in this level would be explain as the explanation below.

Table 4.14. Priority of Precondition for Unsafe Acts Level

Priority	Indicators of precondtion for unsafe acts level	Weight Value	Percentage
1	Lack of sailing experience	0.185	19%
2	Failed to communication (ship-ship)	0.132	13%
3	Visual limitation	0.125	13%
4	Failed to identify sea condition	0.114	11%
5	Failed to use navigational devices	0.113	11%
6	Lost of situational awareness	0.101	10%
7	Failure to identify the weather condition	0.096	10%
8	Failure in automation devices	0.079	8%
9	Failed to communication (ship-authority)	0.055	6%

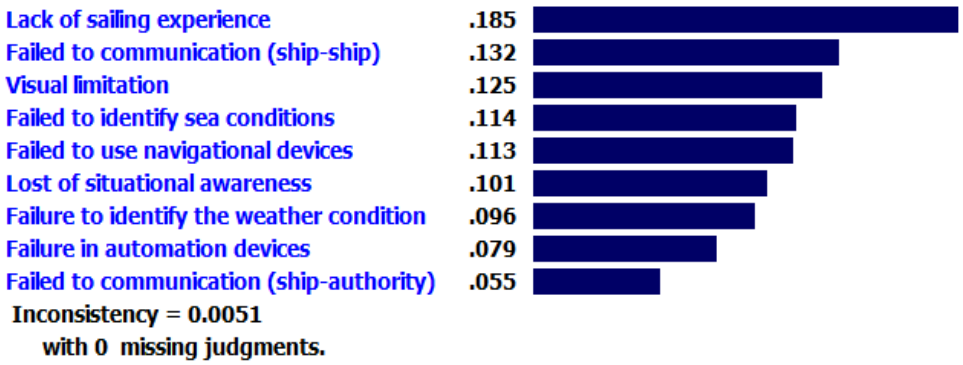


Figure 4.16. Weight Value of Precondition for Unsafe Acts

According to the Table 4.14. and Figure 4.16. above, the highest priority in this level is lack of sailing experience with weight value 0.185 or percentage 19%. Continue with the second indicator is failed to communication between ship and the other ship with weight value 0.132 or percentage 13%. While, visual limitation is on the third priority with weight value 0.125 and this indicator has the same percentage value with the previous indicator which 13%, then failed to identify sea condition with weight value 0.114 or percentage value 11%, failed to use navigational devices with weight value 0.113 and this indicator also has the same percentage value with the previous indicator that has percentage value 11%. The next one is lost of situational awareness with weight value 0.101 or percentage 10%, failure to identify the weather condition with weight value 0.096 and has the same percentage with the previous one which 10%, failure in automation devices with weight value 0.079 or percentage 8%. Then, the lowest priority in this level is failed to communication between ship and pilot from the authority with weight value 0.055 or percentage 6%. While, value of consistency ratio in this level is $0.0051 \leq 10\%$, therefore the respondent is consistent to filled the questionnaire.

4.8.3.4. Weight Value of Unsafe Acts Level

Unsafe acts level is the last level in human factor and classification system (HFACS) level. This level consist of 5 indicators. These indicators consist of poor decision , wrong response in emergency situation, inappropriate maneuver, voyage or operation unauthorized approached and the last indicator is failed to use the radar. While the explanation of the priority in this level would be explain the explaination below.

Table 4.15. Priority of Unsafe Acts Level

Priority	Indicators of unsafe acts level	Weight Value	Percentage
1	Poor decision	0.310	31%
2	Wrong response in emergency situation	0.277	28%
3	Inappropriate manuever	0.207	21%
4	Voyage or operation unauthorized approached	0.105	11%
5	Failed to use radar	0.102	10%

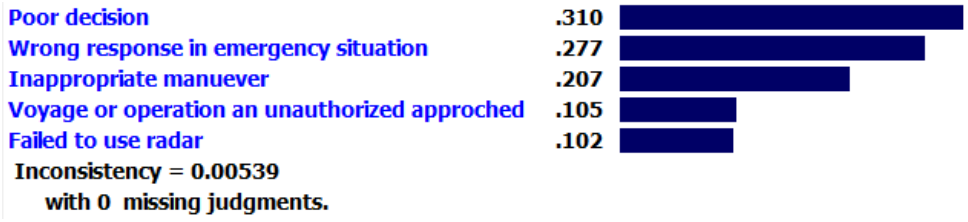


Figure 4.17. Weight Value of Unsafe Acts Level

According to the Table 4.15. and Figure 4.17. above, the highest priority that effect to this level is poor decision with weight value 0.310 or percentage value 31%, continue with the second indicator is wrong response in emergency situation with weight value 0.277 or percentage value 28%, then inappropriate maneuver with weight value 0.207 or percentage value 21%. Voyage or operation an unauthorized approached is the second lowest indicator with weight value 0.105 or percentage value 11%, while the lowest indicator is failed to use radar with weight value 0.102 or percentage 10%. Consistency ratio in this level is 0.00539 ≤ 10%, therefore the result could be use as the analysis.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1. Conclusion

According to the data and the analysis in previous chapter, there are several conclusion in this research which are:

1) Due to HFACS method, there are several factors of human error in ship collision accident such as:
   - In organizational influences level there 4 indicators that affect to human error such as lack in human resource, lack of communication between operator and company, lack of safety program and lack giving clearly defined information
   - In unsafe supervision level there are 6 indicators that affect to human error such as failed to provide operational doctrine, failed to correct document in error, lack of safety instruction document, failed to identify a risk of navigational equipment and authorized unqualified crew of voyage.
   - In precondition for unsafe acts level there are 9 indicators that affect to human error such as failed to identify sea conditions, failed to use devices, failure in automation devices, failure to identify the weather condition, visual limitation. Lost of situational awareness, lack of sailing experience, failed to communication between ship and the other ship and failed to communication between ship and the pilot from the authority.
   - In unsafe acts level there are 5 indicators that affect to human error such as inappropriate maneuver, poor decision, wrong response to emergency, failed to use radar and voyage or operation unauthorized approached.
2) Due to AHP method, ship collision accident could be happen because of human error or human factor, sailing route, navigation and information condition system and also propulsion system.
3) According to weight calculation using AHP method, human error have the highest relative weight with 0.53 or with percentage reaching 53%, continue with navigational and information condition system with weight value 0.18 or 18%, ship propulsion system with weight value 0.166 or 17% and the last one is sailing route with weight value 0.124 or 12%.

4) According to HFACS level and weight value from AHP method. The most factors how human error happen are because:
   - Organizational influences level has weight value as much as 0.168 or percentage 17% than the other level. While, the most indicator that affect to human error is cause lack of safety program from the company with weight value 0.416 or percentage 42% from the other indicators in this level.
   - Unsafe supervision level has weight value as much as 0.317 or percentage 32% than the other level. While, the most indicator that affect to human error is cause of failed to enforce rules and regulation with weight value 0.255 or percentage 26% from the other indicators in this level.
   - Precondition for unsafe acts has weight value as much as 0.305 or percentage 31% than the other level. While, the most indicator that affect to human error is cause lack of sailing experience with weight value 0.185 or percentage 18% from the other indicators in this level.
   - Unsafe acts level has weight value as much as 0.21 or percentage 21% than the other level. While, the most indicator that affect to human error is cause of poor decision with weight value 0.310 or 31% from the other indicators in this level.

5.2. Recommendation

Therefore, from these conlusion we could make the recommendation such as:

1) According to the organizational influences level, lack of safety program from the company being one of the highest priority of cause ship collision accident with priority value 42%. Therefore, recommendation for shipping company is doing some safety program periodically to ensure the crew or person in charge is always ready and aware in any condition.
2) According to unsafe supervision level, failed to enforce rules and regulation is the highest priority in this level that cause of ship collision accident woith priority value as much as 26% with the other indicators. Therefore, the recommendation is to all the supervisor to ensure their team is in good performance and obeying the rules to avoid the accident during the work.

3) According to precondition for unsafe acts level, sailing experience is being one of the important things to ensure the crew is ready to work with priority value as much as 18% with other indicators. Therefore, the recommendation to decrease this action is making the rules, ensure and recheck sailing experience in recruitment process.
4) According to unsafe acts level, poor decision is the higehest priority with the other indicators with priority value as much as 31%. Therefore, recommendation to decreasing this action is giving the education to the crew to ensure every single decision when it needed and also having a good communication with the supervision or the team itself to ensure the decision is the right or the best one.

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Appendages

a) Pairwise Number Comparison Due to Criterion

No	Name	Criteria Values					
		C 1	C 2	C 3	C 4	C 5	C 6
1	Crew 1	6	5	5	3	1	1
2	Crew 2	5	5	5	3	1	1
3	Crew 3	7	1	1	1/3	1/3	1
4	Crew 4	1	1	1	1/3	1/3	1
5	Crew 5	5	1	7	1/5	5	7
6	Crew 6	5	1	3	1	1	1
7	Crew 7	1	1	4	1	1	1
8	Crew 8	3	1	5	1	1	1
9	Crew 9	3	3	3	5	3	1
10	Crew 10	1	5	3	3	1	1
11	Lecturer 1	3	3	3	3	3	1
12	Lecturer 2	6	5	5	3	1	1
13	Lecturer 3	9	3	4	1/5	1/7	1
14	Lecturer 4	7	9	9	1	3	1
15	Lecturer 5	7	5	5	1	1	1
16	Authority 1	5	1	1	1/5	1/5	1
17	Authority 2	4	2	2	1/4	1/4	1

No	Name	Criteria Values					
		C 1	C 2	C 3	C 4	C 5	C 6
18	Distrik Navigasi 1	8	6	3	1/6	1/8	1/3
19	Distrik Navigasi 2	8	8	7	1/5	1/3	1
20	Distrik Navigasi 3	7	5	5	1/5	1/5	1

Note

C 1 : Human error >< Sailing route

C 2 : Human error >< Navigational and information system condition

C 3 : Human error >< Ship propulsion system

C 4 : Sailing route >< Navigational and information system condition

C 5 : Sailing route >< Ship propulsion system

C 6 : Navigational and Information system condition >< Ship propulsion system

b) Pairwise Number comparison Due to Human Error

No	Name	Human Error Value					
		SC 1	SC 2	SC 3	SC 4	SC 5	SC 6
1	Crew 1	1/3	1/3	3	3	5	7
2	Crew 2	1/3	1	5	1	1	3
3	Crew 3	1/3	1/4	3	3	8	6
4	Crew 4	1/7	1	1	5	5	1
5	Crew 5	1/3	1/3	1/7	1/3	1/4	1/5
6	Crew 6	3	3	4	3	3	3
7	Crew 7	1	1	3	1	1	3
8	Crew 8	3	3	3	1/3	1	1
9	Crew 9	1	3	3	4	5	3
10	Crew 10	1	3	4	4	3	4
11	Lecturer 1	1	1/4	1/5	1/5	1/5	1/3
12	Lecturer 2	1/5	1/5	1/3	1	5	1
13	Lecturer 3	3	1/5	1/3	1/3	1/4	1
14	Lecturer 4	1/5	1/4	1	1/3	5	1
15	Lecturer 5	1	1/7	1/7	1/3	1/5	1
16	Authority 1	1/3	1/5	1/3	1	3	3
17	Authority 2	1	1/4	1	1/3	1/2	1
18	Distrik Navigasi 1	1/7	1/3	1/5	5	4	2
19	Distrik Navigasi 2	1/6	1/4	1/5	1	3	3
20	Distrik Navigasi 3	1/7	1/6	1/5	1	3	5

Note

SC 1 : Organizational influences >< Unsafe Supervision

SC 2 : Organizational influences >< Precondition for unsafe acts

SC 3 : Organizational influences >< Unsafe acts

SC 4 : Unsafe supervision >< Precondition for unsafe acts

SC 5 : Unsafe supervision >< Unsafe acts

SC 6 : Precondition for unsafe acts >< Unsafe acts

c) Pairwise Number Comparison Due to Organizational Influences Level

No	Name	Organizational Influences Value					
		OI 1	OI 2	OI 3	OI 4	OI 5	OI 6
1	Crew 1	3	1/3	1	1/3	1/5	3
2	Crew 2	1	5	3	3	1	1
3	Crew 3	1	1/5	1/3	1	1/3	1
4	Crew 4	1/5	1/5	1/5	1	1	3
5	Crew 5	1/3	1/4	1	1	1	1
6	Crew 6	3	6	4	3	1	1/6
7	Crew 7	3	1	1	1/3	1	3
8	Crew 8	3	3	3	1/3	1	1
9	Crew 9	1	1/4	1	1/3	1	5
10	Crew 10	1	1/3	1	1/4	1	3
11	Lecturer 1	1	1/5	1/3	1/3	1/3	5
12	Lecturer 2	7	3	7	1/3	1	7
13	Lecturer 3	7	7	7	1	1	1
14	Lecturer 4	1/3	1/9	1/5	1/3	1	3
15	Lecturer 5	7	7	7	1/3	1	4
16	Authority 1	1/3	1/5	1/3	1/5	1	5
17	Authority 2	1/2	1/3	1/3	1/2	1	3
18	Distrik Navigasi 1	1/3	1/5	1	1/5	3	5
19	Distrik Navigasi 2	5	1	4	1/6	1/4	5
20	Distrik Navigasi 3	1/3	1/7	1/4	1/5	1	1

Note

OI 1 : Lack in human resources >< Lack of communication between operator and company

OI 2 : Lack in human resources >< Lack of safety program from company

OI 3 : Lack in human resources >< Lack of giving clearly defined information

OI 4 : Lack of communication between operator and company >< Lack of safety program from company

OI 5 : Lack of communication between operator and company >< Lack of giving clearly defined information

OI 6 : Lack of giving clearly defined information >< Lack of safety program from company

d) Pairwise Number Comparison Due to Unsafe Supervision Level

No	Name	Unsafe Supervision Value								
		US 1	US 2	US 3	US 4	US 5	US 6	US 7	US 8	US 9
1	Crew 1	5	5	1/3	1/3	1/5	1	1/5	1/3	1/5
2	Crew 2	1/4	1/5	1/4	1/5	3	3	11	2	3
3	Crew 3	3	1	1/3	1/3	3	1/5	1/3	1	1
4	Crew 4	1/5	1/5	1/5	1/5	1/7	1	3	3	1/5
5	Crew 5	1	1/2	1/3	1/5	1/6	1/3	1/5	1/4	1/6
6	Crew 6	3	1/3	1	1	2	1/5	1/3	1/3	1/3
7	Crew 7	5	3	3	1	3	1	1	1/3	1/3
8	Crew 8	3	5	3	1	3	1	3	1/3	1
9	Crew 9	5	4	1	1	1	1	1	1/4	1/3
10	Crew 10	4	1	1	1/4	1/3	1	3	1/5	1/4
11	Lecturer 1	3	3	3	1/7	1/7	1/3	1	1/7	1/7
12	Lecturer 2	5	1/5	1/3	1/3	1/5	1/5	1/7	1/7	1/7
13	Lecturer 3	5	5	3	1/5	1	1	1	1/3	1/3
14	Lecturer 4	1	1	1/3	1/5	5	1/3	1/3	1/5	5
15	Lecturer 5	1	1/3	1/3	1/3	1/5	1/3	1/5	1/4	1/7
16	Authority 1	1	1/5	1/5	1/3	1/7	1/3	1/3	1/5	1/7
17	Authority 2	3	3	1/3	1/6	3	2	1/2	1/5	1
18	Distrik Navigasi 1	3	1/4	1/4	1/5	1/2	1/7	1/3	1/7	1/7
19	Distrik Navigasi 2	5	1/4	1/4	1/5	1/5	1/4	1/5	1/5	1/4
20	Distrik Navigasi 3	1	1	1/3	1	1	1	1/3	3	3

No	Name	Unsafe Supervision Value					
		US 10	US 11	US 12	US 13	US 14	US 15
1	Crew 1	1/4	1/3	1/7	3	1/3	1/5
2	Crew 2	3	3	3	3	3	1/3
3	Crew 3	1/5	1/3	3	4	5	3
4	Crew 4	5	1	1/5	1/3	1/5	1/5
5	Crew 5	1/5	1/3	1/5	1/4	1/4	1/3
6	Crew 6	5	3	1	3	1/2	1
7	Crew 7	3	1/4	1/3	1/5	1/4	1
8	Crew 8	1	1/3	1/5	1/3	1/3	1
9	Crew 9	1/3	1/3	1	1	1/4	1
10	Crew 10	3	1/3	1/4	1/3	1/5	1
11	Lecturer 1	1	1/5	1/7	1/8	1/8	1/5
12	Lecturer 2	1	1/5	1/3	1/3	1/3	1
13	Lecturer 3	1	1/5	1/3	1/3	1/3	1
14	Lecturer 4	1/5	1/3	3	1/3	5	9
15	Lecturer 5	1	1/4	1/7	1	1/7	1/7
16	Authority 1	3	1/3	1/4	1/3	1/7	1/5
17	Authority 2	1/4	1/5	1/2	1/4	3	3
18	Distrik Navigasi 1	1	1	1/2	1/4	1	1
19	Distrik Navigasi 2	1/4	1	1	1	4	1
20	Distrik Navigasi 3	1	3	1	3	3	3

Note

US 1 : Failed to provide operational doctrine >< Failed to correct document in error
US 2 : Failed to provide operational doctrine >< Lack of safety instruction document
US 3 : Failed to provide operational doctrine >< Failed to identify a risk of navigational equipment
US 4 : Failed to provide operational doctrine >< Failed to enforec rules and regulation
US 5 : Failed to provide operational doctrine >< Authorized unqualified crew of voyage
US 6 : Failed to correct document in error >< Lack of safety instruction document
US 7 : Failed to correct document in error >< Failed to identify a risk of navigational equipment
US 8 : Failed to correct document in error >< Failed to enforec rules and regulation
US 9 : Failed to correct document in error >< Authorized unqualified crew of voyage
US 10 : Lack of safety instruction document >< Failed to identify a risk of navigational equipment
US 11 : Lack of safety instruction document >< Failed to enforec rules and regulation
US 12 : Lack of safety instruction document >< Authorized unqualified crew of voyage
US 13 : Failed to identify a risk of navigational equipment >< Failed to enforec rules and regulation
US 14 : Failed to identify a risk of navigational equipment >< Authorized unqualified crew of voyage
US 15 : Failed to enforec rules and regulation >< Authorized unqualified crew of voyage

e) Pairwise Number Comparison Due to Precondition for Unsafe Acts Level

No	Name	Precondition for unsafe acts Value								
		PUA 1	PUA 2	PUA 3	PUA 4	PUA 5	PUA 6	PUA 7	PUA 8	PUA 9
1	Crew 1	1	1	1	7	1	1	7	1	1
2	Crew 2	1	1	1	1	4	1	3	3	1/3
3	Crew 3	1/3	1/3	1/3	1/5	1/3	1/3	1/5	1/5	3
4	Crew 4	1	1/3	3	1	4	1	1	5	1
5	Crew 5	1/4	1/2	3	1/5	1/5	1/5	1/5	1/3	5
6	Crew 6	1	1	1	1	1	1/5	1/3	3	1
7	Crew 7	1	1	1	1	1	1/3	4	3	1
8	Crew 8	3	3	1	1	1	1	4	3	1
9	Crew 9	4	3	1	1	1	1./3	1	3	1
10	Crew 10	3	3	3	1	1/3	1	1	3	1
11	Lecturer 1	5	5	3	5	3	5	5	5	3
12	Lecturer 2	1/5	1/3	1	1	5	1/5	5	1/3	3
13	Lecturer 3	1/5	1/3	1	1	1	1/3	1	1	3
14	Lecturer 4	1	3	1	1	3	1	1	5	3
15	Lecturer 5	1/5	1	1	1	1	1/7	1	1/5	3
16	Authority 1	1/5	1/5	1/3	1/5	1/3	1/7	1/7	5	1
17	Authority 2	3	3	1	4	1	2	2	4	3
18	Distrik Navigasi 1	4	3	3	1	1	1	1/4	5	1
19	Distrik Navigasi 2	1	4	3	1	3	1/3	1/2	5	6
20	Distrik Navigasi 3	3	5	1	3	1	1/3	1/3	3	1

No	Name	Precondition for unsafe acts Value								
		PUA 10	PUA 11	PUA 12	PUA 13	PUA 14	PUA 15	PUA 16	PUA 17	PUA 18
1	Crew 1	1/3	1/3	1/3	1/3	3	1	1/3	1/3	1/3
2	Crew 2	1/3	1	1	1/3	3	1	1/3	1	1
3	Crew 3	1/4	1/5	1/4	1/3	1/5	1/3	1/3	1/4	1/3
4	Crew 4	1	1	3	3	1/3	3	3	5	3
5	Crew 5	3	1	3	1	1	1	3	1/5	1/5
6	Crew 6	1	1	1	1	1	1	1	3	1
7	Crew 7	1	1	1	1/4	1	3	1	1	1
8	Crew 8	1/3	1/3	1/5	1/4	1	4	1/3	1/4	1/3
9	Crew 9	1	1/3	1/3	1/4	1/3	4	1	1/3	1
10	Crew 10	1	1/3	1/4	1/3	1	5	3	1/5	1/3
11	Lecturer 1	1	3	1/3	5	5	5	1/3	1/3	1/3
12	Lecturer 2	3	5	1	5	1	1	1	1	7
13	Lecturer 3	3	3	3	1	1	3	3	1	1
14	Lecturer 4	1	1	1	1/3	1/3	1/3	1/3	1/3	1/3
15	Lecturer 5	7	3	7	1	7	7	3	1	5
16	Authority 1	5	5	3	1	1	5	5	3	5
17	Authority 2	1	5	1	2	1	4	1/4	1	1
18	Distrik Navigasi 1	1/5	1/5	1/5	1/5	1/7	5	1/5	1/7	1
19	Distrik Navigasi 2	4	1/4	5	1/5	1/7	7	1/5	1/5	1
20	Distrik Navigasi 3	1/2	1	1/3	1/5	1/3	2	1/2	1/4	1/3

No	Name	Precondition for unsafe acts Value								
		PUA 19	PUA 20	PUA 21	PUA 22	PUA 23	PUA 24	PUA 25	PUA 26	PUA 27
1	Crew 1	1/3	3	3	1	1	1	3	3	1
2	Crew 2	1/3	1	3	3	5	5	3	3	3
3	Crew 3	1/3	1/4	1/3	1	3	1/4	1/5	1/4	1
4	Crew 4	3	5	3	3	3	3	1/3	3	1
5	Crew 5	1/3	1/5	1	1/4	1/3	1/3	1/3	1/3	5
6	Crew 6	1/4	1	1/3	3	1/3	1/3	1/5	1/3	3
7	Crew 7	1/3	1/3	4	1	1	1/3	1/3	4	1/3
8	Crew 8	1/4	1/3	3	1	1/4	1/5	3	3	1
9	Crew 9	3	1/3	3	1	1/3	1/3	1/3	3	1
10	Crew 10	1/3	1/5	4	1	1/3	1/3	1	4	1
11	Lecturer 1	1/3	5	1	1/3	1	1/5	1	1/3	5
12	Lecturer 2	1	1	3	3	1	1	3	3	3
13	Lecturer 3	1	1	3	3	1	1	3	3	3
14	Lecturer 4	1/5	1/5	1/5	1	1	1	1/4	5	1
15	Lecturer 5	1/7	7	1/7	1/7	1	1/7	1	1/7	7
16	Authority 1	1	1	7	1/3	1	1/7	1/5	3	1
17	Authority 2	1	3	2	3	1/3	1	1	3	1/2
18	Distrik Navigasi 1	1/3	1/3	1	1/6	1	1/3	1/3	5	5
19	Distrik Navigasi 2	1/7	1/9	2	1/4	1/5	1/7	1/7	4	4
20	Distrik Navigasi 3	1/6	1/5	1/3	3	1/5	1/4	1/2	4	1/5

No	Name	Precondition for unsafe acts Value								
		PUA 28	PUA 29	PUA 30	PUA 31	PUA 32	PUA 33	PUA 34	PUA 35	PUA 36
1	Crew 1	1	3	3	1	3	3	3	3	1/4
2	Crew 2	3	1	3	1	1	1	1	1	1
3	Crew 3	1	1/3	1/3	1/4	1/3	1	1/3	1	1
4	Crew 4	1	1/3	3	1/3	1/3	3	1	3	5
5	Crew 5	3	1	3	1/3	1/3	1/3	1	1	3
6	Crew 6	1	1	3	1	1	5	1	6	1
7	Crew 7	1	1	4	1/4	1/3	3	1	5	5
8	Crew 8	1	1	5	1/3	1	4	1	3	1
9	Crew 9	1/3	1	4	1	1	4	1	5	4
10	Crew 10	1	1	4	1	1	5	4	3	1
11	Lecturer 1	1	1	3	3	3	4	1/3	1	3
12	Lecturer 2	1/5	3	1	1/5	1	1/7	6	3	1
13	Lecturer 3	1	3	5	1	3	3	1	3	3
14	Lecturer 4	1	1/3	1	1/3	1/5	1/3	1	1	1/3
15	Lecturer 5	1	7	1	1/7	1	1/7	5	1	1/7
16	Authority 1	1/7	1 1/2	3	1/7	1/5	3	1	7	7
17	Authority 2	1/3	1/3	3	1	1/3	4	1	3	3
18	Distrik Navigasi 1	1	1	5	1/3	1/3	2	1	6	7
19	Distrik Navigasi 2	1	1/2	6	1/6	1/7	5	1	7	9
20	Distrik Navigasi 3	1/5	1/4	1/2	1	1/3	5	5	5	3

Note

PUA 1 : Failure to identify sea condition >< Failed to use navigational devices
PUA 2 : Failure to identify sea condition >< Failure in automation devices
PUA 3 : Failure to identify sea condition >< Failure to identify safe weather condition
PUA 4 : Failure to identify sea condition >< Visual limitation
PUA 5 : Failure to identify sea condition >< Lost of situational awareness
PUA 6 : Failure to identify sea condition >< Lack of sailing experience
PUA 7 : Failure to identify sea condition >< Failed to communication (ship-ship)
PUA 8 : Failure to identify sea condition >< Failed to communication (ship-authority)
PUA 9 : Failed to use navigational devices >< Failure in automation devices
PUA 10 : Failed to use navigational devices >< Failure to identify safe weather condition
PUA 11 : Failed to use navigational devices >< Visual limitation
PUA 12 : Failed to use navigational devices >< Lost of situational awareness
PUA 13 : Failed to use navigational devices >< Lack of sailing experience
PUA 14 : Failed to use navigational devices >< Failed to communication (ship-ship)
PUA 15 : Failed to use navigational devices >< Failed to communication (ship-authority)
PUA 16 : Failure in automation devices >< Failure to identify safe weather condition
PUA 17 : Failure in automation devices >< Visual limitation
PUA 18 : Failure in automation devices >< Lost of situational awareness
PUA19: Failure in automation devices >< Lack of sailing experience
PUA 20 : Failure in automation devices >< Failed to communication (ship-ship)
PUA 21 : Failure in automation devices >< Failed to communication (ship-authority)
PUA 22 : Failure to identify safe weather condition >< Visual limitation
PUA 23 : Failure to identify safe weather condition >< Lost of situational awareness
PUA 24 : Failure to identify safe weather condition >< Lack of sailing experience

PUA 25 : Failure to identify safe weather condition >< Failed to communication (ship-ship)
PUA 26 : Failure to identify safe weather condition >< Failed to communication (ship-authority)
PUA 27 : Visual limitation >< Lost of situational awareness
PUA 28 : Visual limitation >< Lack of sailing experience
PUA 29 : Visual limitation >< Failed to communication (ship-ship)
PUA 30 : Visual limitation >< Failed to communication (ship-authority)
PUA 31 : Lost of situational awareness >< Lack of sailing experience
PUA 32 : Lost of situational awareness >< Failed to communication (ship-ship)
PUA 33 : Lost of situational awareness >< Failed to communication (ship-authority)
PUA 34 : Lack of sailing experience >< Failed to communication (ship-ship)
PUA 35 : Lack of sailing experience >< Failed to communication (ship-authority)
PUA 36 : Failed to communication (ship-ship) >< Failed to communication (ship-authority)

f) Pairwise Number Comparison Due to Unsafe Acts Level

No	Name	Unsafe acts Value									
		UA 1	UA 2	UA 3	UA 4	UA 5	UA 6	UA 7	UA 8	UA 9	UA 10
1	Crew 1	1	1/3	1	1	1	3	1	3	3	1
2	Crew 2	1/3	1/3	3	1	1	3	1	3	1	1/5
3	Crew 3	1/5	1/3	4	1/3	5	5	3	4	1	3
4	Crew 4	1/3	1/3	1/5	1/4	1/3	1/3	1/3	1/3	1/3	1/3
5	Crew 5	1	3	3	7	1	3	5	5	6	3
6	Crew 6	1	4	3	3	4	3	3	3	2	3
7	Crew 7	1/3	3	3	4	3	4	3	4	3	2
8	Crew 8	1/3	1/3	1	3	3	3	3	3	3	4
9	Crew 9	1	4	3	3	4	3	4	3	3	3
10	Crew 10	1	3	6	7	4	5	5	5	5	5
11	Lecturer 1	1	3	5	5	1	5	5	5	5	1/3
12	Lecturer 2	1	1/3	7	5	1	7	7	7	7	1
13	Lecturer 3	1	1	3	3	5	5	5	3	5	3
14	Lecturer 4	1/3	1/5	1/3	3	1/5	1/5	3	1	7	9
15	Lecturer 5	1	1/3	3	5	1/5	4	5	5	7	3
16	Authority 1	3	1	1	1/5	3	1	1/7	1	1/7	1/7
17	Authority 2	3	2	3	3	1/3	2	3	3	4	3
18	Distrik Navigasi 1	1/3	1/6	1	1/2	1/4	6	5	7	4	1/3
19	Distrik Navigasi 2	1/3	1/4	5	1/2	2	5	2	5	4	1/2
20	Distrik Navigasi 3	1/3	1/3	4	3	5	5	5	5	5	1

Note

UA 1 : Inappropriate manuever >< Poor decision

UA 2 : Inappropriate manuever >< Wrong response in emergency situation

UA 3 : Inappropriate manuever >< Failed to use the radar

UA 4 : Inappropriate manuever >< Voyage or operation an unauthorized approached

UA 5 : Poor decision >< Wrong response in emergency situation

UA 6 : Poor decision >< Failed to use the radar

UA 7 : Poor decision >< Voyage or operation an unauthorized approached

UA 8 : Wrong response in emergency situation >< Failed to use the radar

UA 9 : Wrong response in emergency situation >< Voyage or operation an unauthorized approached

UA 10 : Failed to use the radar >< Voyage or operation an unauthorized approached

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BIOGRAPHY OF AUTHOR

Dheo Cakra Satya Putraman was born in Palembang, South Sumatera on 2nd July 1997. He is the second child from Kaman and Suwarti, S.Pd., M.Pd. Author has received formal education from SD Negeri 117 Palembang (2003 – 2009), SMP Islam Terpadu Raudhatul Ulum Kabupaten Ogan Ilir (2009 – 2012) and SMA Negeri 6 Palembang (2012 – 2015). Author recently enrolled in Double Degree Program of Marine Engineering Department, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember with Hochschule Wismar University, Germany. During the study, author active on an external organization called AIESEC *(Association Internationale des étudiants en sciences économiques et commerciales)* from 2016 – 2018. During the organization, author has positioned as Corporate Sales Executive of Business Development Department (2016-2017) and Local Committee Vice President of Business Development and External Relations Department (2017-2018) AIESEC Local Committee Surabaya. The author also continues his journey as National Manager of Public Relations with Specialization in University Relations Coach at AIESEC In Thailand (2018). The author has been joined the internship in PT. Dumas Tanjung Perak Shipyard and PT. Pelindo III Branch Tanjung Perak Surabaya. During the journey in AIESEC author interested in business management and people management. Therefore, he took his bachelor thesis at Reliability, Availability, Management, and Safety (RAMS) Laboratory to discover knowledge about human reliability in the maritime industry.

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