FINAL PROJECT – TI 141501

TECHNICIANS WORKLOAD ANALYSIS AT PT. SURYA SEGARA SAFETY MARINE BY CONSIDERING FULL TIME EQUIVALENT (FTE), NASA-TLX, AND HUMAN RELIABILITY ASSESSMENT

MENTARI RIZKI AMELIA

NRP 024 1 14 40000 065

Supervisor

Ratna Sari Dewi, S.T., M.T., Ph.D.

NIP. 198001132008122002

INDUSTRIAL ENGINEERING DEPARTMENT

Faculty of Industrial Technology

Institut Teknologi Sepuluh Nopember

Surabaya 2018

APPROVAL SHEETS

TECHNICIANS WORKLOAD ANALYSIS AT PT. SURYA SEGARA SAFETY MARINE BY CONSIDERING FULL TIME EQUIVALENT (FTE), NASA-TLX, AND HUMAN RELIABILITY ASSESSMENT

FINAL PROJECT

Proposed as a Requisite to Graduate in Industrial Engineering Major and to Achieve a Bachelor Degree in Department Industrial Engineering
Faculty of Industrial Technology
Institut Teknologi Sepuluh Nopember
Surabaya, Indonesia

Written By:

MENTARI RIZKI AMELIA
NRP 02411440000065

Acknowledge and approved by:

Supervisor

Ratna Sari Dewi, S.T., M.T., Ph.D.
NIP. 198001132008122002

DEPARTEMEN TEKNIK INDUSTRI

SURABAYA, JULY 2018

ANALISIS BEBAN KERJA TEKNISI DI PT. SURYA SEGARA SAFETY MARINE MARINE DENGAN MEMPERTIMBANGKAN FULL TIME EQUIVALENT(FTE), NASA-TLX, DAN PENILAIAN KEANDALAN MANUSIA

Nama	: Mentari Rizki Amelia
NRP	: 02422440000065
Pembimbing	: Ratna Sari Dewi, S.T., M.T., Ph.D.

ABSTRAK

Indonesia dikenal sebagai negara maritim, dimana terdapat 40% kapal dunia yang melewati laut Indonesia setiap tahun (Kementrian Perhubungan Republik Indonesia, 2018). Salah satu hal penting yang harus diperhaitkan oleh pemilik kapal ialah keselamatan kapal. Oleh karena itu, bisnis di bidang keselamatan kapal pun diuntungkan. Salah satunya ialah PT. Surya Segara Safety Marine, perusahaan yang menyediakan layanan inspeksi, perbaikan, dan perawatan alat keselamatan kapal. Saat ini, perusahaan ini memiliki 20 teknisi. Terdapat indikasi bahwa jumlah teknisi tersebut tidak cukup untuk memenuhi permintaan dan beban kerja mental teknisi juga diindikasikan naik. Selain itu, aktivitas inspeksi, perbaikan, dan perawatan membutuhkan keahlian khusus dan harus dilakukan secara hati-hati untuk menghindari kegagalan dan kesalahan. Dalam penelitian ini, akan dilakukan penilaian beban kerja teknisi dengan menggunakan metode *Full Time Equivalent* (FTE). Untuk mendukung penilaian tersebut, dalam penelitian ini juga terdapat penilaian beban kerja mental menggunakan metode NASA-TLX dan penilaian keandalan teknisi dengan menggunakan metode *Cognitive Reliability and Error Assessment Meth*od (CREAM).

Kata Kunci: inspeksi, perbaikan, teknisi, Full Time Equivalent (FTE), NASA-TLX, CREAM

(This page is intentionally left blank)

TECHNICIANS WORKLOAD ANALYSIS AT PT. SURYA SEGARA SAFETY MARINE BY CONSIDERING FULL TIME EQUIVALENT (FTE), NASA-TLX, AND HUMAN RELIABILITY ASSESSMENT

Name : Mentari Rizki Amelia
Student ID : 02422440000065
Supervisor : Ratna Sari Dewi, S.T., M.T., Ph.D.

ABSTRACT

Indonesia is known as a maritime country, where 40% of world trade ship passing through Indonesia’s sea territory every year (Kementrian Perhubungan Republik Indonesia, 2018). One of essential thing that must be considered by the ship owner is the ship safety. Thus, businesses in the field of marine safety are growing. One of the company that is well known in this field is PT. Surya Segara Safety Marine Surabaya that provides inspection, service, and maintenance to the ship’s safety equipment. The company now has 20 technicians. There is indication that the technicians is not sufficient to fulfill the demand and the mental workload of technicians is also increasing. Besides, inspection, service, and maintenance activities need specified skills and must be conducted carefully in order to evade failure and error. This research will focus on workload assessment to the technicians by using Full Time Equivalent (FTE). To support the assessment, this research will also cover the mental workload assessment by using NASA-TLX and technicians’ reliability assessment by using CREAM.

Keyword: inspection, service, technician, Full Time Equivalent (FTE), NASA-TLX, CREAM

(This page is intentionally left blank)

PREFACE

First of all, the writer wants to thank to Allah the Almighty God, because of His bless and grace, the writer could finish this research report on time. In this opportunity, the writer also wants to express gratitude towards several parties, who gives significant contribution and continuous support for the writer to finish this research report. Those parties are:

1. Mrs. Ratna Sari Dewi, S.T., M.T., Ph.D., as writer's supervisor who guided and gave advice fot the writer to improve this report
2. Mr. Teguh Julianto, Mr. Ginanjar Basuki, Mr. Ryan, Mr. Ali Mustofa, and all technicians at PT. Surya Segara Safety Marine who provided necessary information for this research and guided the writer during the data collecting process.
3. The examiners of proposal seminar and thesis defense (Mrs. Dyah Santhi Dewi, ST., M.Eng.Sc, Mrs. Anny Maryani ST., M.T., and Mr. Adithya Sudiarno, ST., MT) who gave their critical thinking, guidance, and recommendation for the betterment of this research.
4. The management board of Industrial Engineering Department ITS for the
5. Writer's beloved parents, Teguh Heru Pribadi and Siti Rochana, for the motivation and endless support for the writer to finish this report.
6. Many others that cannot be mentioned one by one.

The writer realizes that this report is far from excellent, therefore comments and advices are accepted for futre improvements. The writer also apologizes if there is any mistake that exists in this report.

Surabaya, July 2018

Mentari Rizki Amelia

(This page is intentionally left blank)

TABLE OF CONTENTS

(This page is intentionally left blank)

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

This chapter elucidates of the research background, problem formulation, research objective, research benefit, research limitation, and research assumption. There is also a brief explanation about the structure of this research report in the end of the chapter.

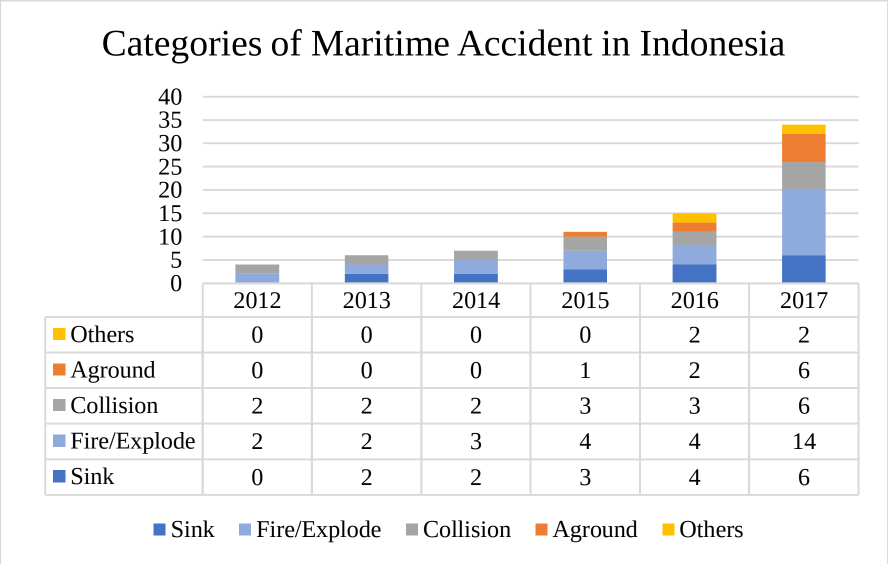
1.1 Background

Indonesia is known as a maritime country with 6,315,222 km^2 of sea territory and a long coastline of 99,093 km^2 (Badan Informasi Geospasial, 2015). With this geographical characteristic, Indonesia has a great potential for marine industry that also significantly affects the development of the other sector in Indonesia. A study by Nurkholis et al. (2015) found that in 2010, the output from marine sector's contribution to Indonesia's economy covered approximately 6.06% to the community income and 4.12% to the workforce. This specially came from sub-sector of marine infrastructure such as roads, bridges, and ports that contributed 4.60% while sub-sector of fishery and its products contributed 1,83% to the national economy. The number is predicted to be increasing as the Indonesian government now has a strong vision for the country's maritime industry and aims to position Indonesia as a strong and well respected player in the global maritime sector.

Figure 1. 1 Number of Indonesian Shipping Fleet (INSA, 2017)

One of the programs to achieve the objective is “Sea Toll Road”, an idea of connecting islands accross the nation to improve maritime commerce and decrease the price disparity in Indonesia (Jakarta Globe, 2016). To support the development of this program, Indonesian government regularly deploy new container ships each year to accomodate logistic needs in Indonesia. Furthermore, the number of Indonesian shipping fleets from 2005 to 2016 is also increasing as shown in the Figure 1.1. The increasing number of ship resulted in the number of total shipbuilding volume capacity of gross tonnage which tripled from 5.67 million in 2005 to 17.89 million in 2013 (Danish Export Association, 2015).

Other than that, the government also speed up the development of Indonesia’s ports by improving the facility and increasing the capacity, especially for small ports in remote area that are previously have less facility compared to big ports in Indonesia (Bisnis Indonesia, 2017). This developed and integrated sea transportation system support Indonesia’s position as the World’s Maritime Axis. This is also supported by a fact that Indonesia is located in a strategic area between Malaka Strait, Sunda Strait, Lombok Strait, and Makassar Strait. Thus, there are 40% of world trade ship passing through Indonesia’s sea territory every year (Kementrian Perhubungan Republik Indonesia, 2018).



	2012	2013	2014	2015	2016	2017
Others	0	0	0	0	2	2
Aground	0	0	0	1	2	6
Collision	2	2	2	3	3	6
Fire/Explode	2	2	3	4	4	14
Sink	0	2	2	3	4	6

Figure 1. 2 Categories of Maritime Accident in Indonesia (KNKT, 2017)

In the other hand, safety is one of essential thing that must be concerned about in a maritime industry. *Komite Nasional Keselamatan Transportasi* (KNKT) or National Committee of Transportation Safety (2017) reported that the number of maritime accident in Indonesia keeps increasing from 2012 to 2017. According to the chart shown in Figure 1.2, it is known that the number of accident is doubled from the previous year. It is also recorded that the maritime accidents happened in Indonesia between 2010-2016 have caused 337 people died and 474 people injured (KNKT, 2016). Not only that, there were some maritime accidents happened in the world that caused even bigger fatalities. Some of the accident are the sinking of Sewol Ferry in South Korea that made 304 people died (CNN, 2014) and the collision between MV Doña Paz and a petroleum tanker in 1987 that caused more than 4000 people died in Philippines (Perez, et al., 2011). In order to avoid a greater fatalities from a maritime accident, the safety procedures and equipment on a ship must be considered.

The government of Indonesia through Ministry of Transportation establish regulations to ensure every ship sailed in Indonesia's sea territory must be in safe condition. According to *Undang-Undang Republik Indonesia No. 17 Tahun 2008* (Law of The Republic of Indonesia Number 17 Year 2008) and *Peraturan Pemerintah No. 51 Tahun 2002 Tentang Perkapalan* (Government Regulation Number 51 Year 2002 about Shipping), a ship must be equipped with some certificates. The certificates are Ship Safety Certificate that is also known as Seaworthiness Certificate, Ship Pollution Certificate, Load and Loading Certificate, Safety Management and Pollution Prevention Certificate, and Ship Security Management Certificate in accordance with the sailing area. Seaworthiness Certificate certified the safety of the ship's material, construction, ship building, machinary and electricity, and stability. The certificate is valid for one year so it must be updated every year. The safety management certificate consist of Document of Compliance (DOC) for the shipowner company and Safety Management Certificate (SMC) for the ship itself. Those are issued only after ensuring that the company has a Safety Management System (SMS) and all ships are operated as per the SMS. The validity period of temproary SMC is 6 months and 2.5 years for a permanent SMC.

Considering the increasing number of ships passing through Indonesia’s sea territory and the government’s regulation on ship seaworthiness, businesses in the field of marine safety are growing. One of the company that is well known in this field is PT. Surya Segara Safety Marine Surabaya. PT. Surya Segara Safety Marine Surabaya is a company who concerns about the ship safety by providing service in inspection, reparation, and maintenance for the ship’s safety equipment. The company also has authority to issue certificate declaring that a ship has fulfilled the safety equipment requirements. The certificate also becomes the supporting document for SMC.

In order to run the business, PT. Surya Segara Safety Marine Surabaya now has 20 technicians who are responsible to inspect the safety equipment in the ship and do maintenance as well as reparation to ensure that the ship fulfill the safety requirements. Hence, a work measurement and workload assessment are needed to adjust the technicians workload so they can achieve their best performance. The method used to perform the work measurement is Stopwatch Time Study and National Aeronautics and Space Administration Task Load Index (NASA-TLX) for the mental workload assesment.

Furthermore, mental workload is also one of factors affecting the occurance of human error (Moon, et al. 2011). Human error can be defined as a inappropriate human decision or behaviour that can reduce or potentially reduce the effectiveness, safety, or performance of the system (Sanders and McCormick, 1993). Unsafe acts is one of human failure that can cause error (Reason, 1990). According to Shappell & Wiegmann (2000), three basic error types that is caused by unsafe acts includes skill-based errors, perceptual errors, and decision errors. The inspection, reparation, maintenance that are done by the technicians of PT. Surya Segara Marine Safety Surabaya are activities that need specified skills and must be conducted carefully in order to evade failure and error. Moreover, the consequence of human error happens to the technicians is related with the service quality provided by the company to the client. When the client noticed that there were some procedures of inspection and service that were not done well according to the certificate issued, PT. Surya Segara Safety Marine had a responsibility to do the inspection and service again. In the other hand, once human error happens and the technician fail to detect upnormallity of the equipment inspected, the worst consequence that can happen is the unreliability of the equipment itself.

Human Reliability Assessment (HRA) can be useful to reduce the probability of human error. This is because HRA can capture the contribution of human to the system failure so prevention actions can be identified earlier (Spurgin, 2010). The HRA method used in this research is Cognitive Reliability and Error Analysis Method (CREAM). Together with A Technique for Human Error Analysis (ATHEANA), CREAM is HRA method that more focus on human performance-shaping factors such as workload, stress, sociological issues, illness, and cognitive process.

1.2 Problem Formulaiton

Based on the background explained in the previous subchapter, this research will focus on workload assessment to the technicians of PT. Surya Segara by using Full Time Equivalent (FTE). To support the assessment, this research will also cover the mental workload assessment by using NASA-TLX and technicians' reliability assessment by using CREAM.

1.3 Research Objective

The objectives of this research are:

1. To calculate the workload of the technicians in PT. Surya Segara Safety Marine.
2. To determine the optimal number of technicians in PT. Surya Segara Safety Marine.
3. To assess the mental workload of technicians in PT. Surya Segara Safety Marine.
4. To assess the human reliability of the technicians of PT. Surya Segara Safety Marine Surabaya.
5. To propose improvement planning in reducing the workload of technicians in PT. Surya Segara Safety Marine.

1.4 Research Benefit

The expected benefits of this research are:

1. The company will be able to know the current workload of the technicians.
2. The company is triggered to adjust the number of technicians according to the result of the research.
3. The company will be able to prioritize the improvement plan to reduce the mental workload of technicians.
4. The company will be able to know the technicians' reliability and make a plan to improve the reliability.
5. The company can increase its service efficiency.

1.5 Research Limitation

The limitations for this research are:

1. The data collecting process is conducted on March to June 2018.
2. The data collecting process is only conducted to the activity occurred in the workshop of PT. Surya Segara Safety Marine and ports located in Tanjung Perak, Surabaya.
3. The workload assessment and work measurement are done for 20 technicians that works for Service Department in PT. Surya Segara Safety Marine Surabaya.
4. This research focuses on assessing service of Inflatable Life Raft (ILR), annual inspection of lifeboat, service of Portable Fire Extinguisher, service of CO_2 System, and service of Life Saving Appliances (LSA).

1.6 Research Assumption

The assumptions used for this research are:

1. There is no additional workers during the data collecting process.
2. The technicians under observation works in a normal condition and environment.
3. The judgment made by the manager and vice manager of Service Department represents the actual condition.

1.7 Report Writing Systematic

The research report consisted of several systematical chapters that are used to record the process of the research. The chapters used in this report are exlained below.

CHAPTER 1 INTRODUCTION

In this chapter, there will be explanation about the research background includes the existing condition of the research objects. The problem formulation, reearch objectives, research benefits, and scope of the research are also explained in this chapter.

CHAPTER 2 LITERATURE REVIEW

Literature review is the collection of existing theories, theoritical framework, and previous related research that support the research idea.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter consists of methods that will be used in the research. Research methodology describe the steps to undertake the research, includes formulation and development of the model, as well as research framework and instruments to find solution of the problem.

CHAPTER 4 DATA COLLECTION AND PROCESSING

This chapter consists of the data collection and processing that will be used in this research. The collected data includes primary and secondary data. The data will be collected and then procesed using suiTable method.

CHAPTER 5 DATA INTERPRETATION AND ANALYSIS

This chapter explains the analysis and interpretation of the processed data, includes the conformity of the output to the existing theory and research hypotheses.

CHAPTER 6 CONCLUSIONS AND SUGGESTIONS

In this chapter, based on the research objectives and results, the conclusion is made. The writer should also give tactical recommendation on how to solve the problem found in the research based on the data processing and analysis as well as improve the existing condition of the research object.

(This page is intentionally left blank)

CHAPTER 2
LITERATURE REVIEW

This chapter emphasizes on the theories that support this research. The theories are about the ship safety requirements, time study, workload analysis,

2.1 Ship Safety

Safety is the condition of being protected from or unlikely to cause danger, risk, or injury (Murray, 1989). Nowadays, it is an important factor that affects all element in maritime industry, includes in a maritime transportation. In term of maritime transportation, safety implies the measures aiming at performing the carriage of cargo by sea without harmful effects on human life, cargo, vessel, and environment (Galic, et al., 2014). Kopacz (2001) describes the main components of maritim safety into four components, which are:

1. Institutions, standards, and procedures of technological and operational safety of ships and persons
2. Maritime navigation safety system
3. Global Maritime Distress and Safety System (GMDSS)
4. Search and Rescue (SAR) System
5. Prevention of pollution of maritime environment from ship system

The components compose a maritime safety system which each compoent can impact another and/or construct a coordination line. The system is shown in Figure 2.1

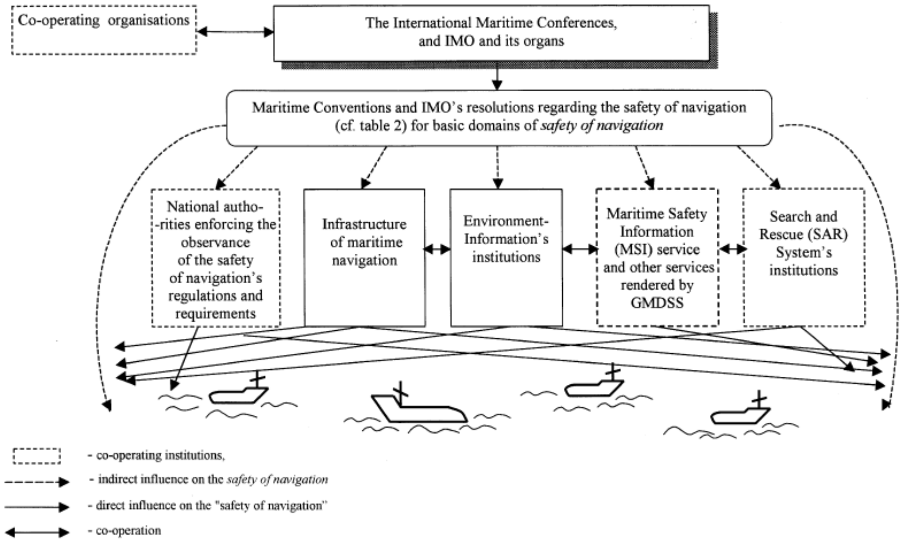


Figure 2. 1 The elements of maritime safety system (Kopacz, et al., 2001)

One of the component in the maritime safety system is the legal instruments. This includes the requlations and requirements which are related to the basic domains of safety at sea, such as:

Table 2. 1 The basic domains of safety at sea

No.	Substance of the domain
1	Safety of navigation
2	Radio communication
3	Life-saving appliances and SAR
4	Standards of seafarers training, certification and watchkeeping
5	Ships' design and equipment
6	Ships' fire protection
7	Ships' stability and load lines
8	Carriage of container goods and dangerous goods
9	Carriage of chemical bulk, liquids and gases
10	Fishing vessel safety
11	Prevention of pollution of maritime environment from ships

Source: (Kopacz, et al., 2001)

2.1.1 Ship's Life-saving Appliances

The life-saving appliances is one of the basic domains of maritime safety system that supports the SAR system of a ship. The SAR system's objective is to rescue crews and passengers of the ship in distress in as short as possible time. This system is considered as a part of the special system, which is the ‘Protection of the human life’ system (Kopacz, et al., 2001). According to SOLAS (2012), the life-saving apliances that must be available in ship are lifeboat, life jacket, and life raft. Ship also has to be equipped with fire protection system to prevent fatalities when ship is caught on fire.

2.1.1.1 Life Jacket

Life jaket is a sleeveless jacket made up of buoyant or inflaable material used to keep human body floating in water (Marine Insight, 2017). Two types of llife jacket includes inflatable life jacket and non-inflatable life jacket, that are categorized based on the abilities of jacket to automatically inflated when immersed in water. The non inflatable life jacket is fitted with buoyant material, so it does not need to inflate as it will automatically floating in the water.

Figure 2. 2 Illustration of: (a) Inflatable life jacket; (b) Non-inflatable life jacket (Hansenprotection.com, 2018)

According to SOLAS (2012), the requirements for life jacket in ship are:

a. Each life jacket shall be fitted with a whistle firmly secured by a lanyard.
b. Life jacket lights and whistles shall be selected and secured to the lifejacket in such a way that their performance in combination is not degraded.

c. Each life jacket shall be provided with a releasable buoyant line or other means to secure it to a lifejacket worn by another person in the water.
d. Each life jacket shall be provided with a suiTable means to allow a rescuer to lift the wearer from the water into a survival craft or rescue boat.
e. Jacket must not sustain burning or melting when exposed to fire for a period of 2 seconds.
f. It is clearly capable of being worn in only one way or, as far as is practicable, cannot be donned incorrectly.
g. When jumped from a height of at least 4.5 m into the water no injury and dislodging or damaging the lifejacket.
h. Should have buoyancy which is not reduced by more than 5% after 24 hour submersion in fresh water

The number of life jackets that should be on a ship depends on the number of ship passenger. There must be a life jacket for every person on the ship. However, it is highly recommended to carry excess life jacket as in case of damage to any, it can replaced with another one (Marine Insight, 2017).

2.1.1.2 Lifeboat

Lifeboat is a small rigid vessel that is attached to the ship and launched over the side of ship at the time of emergency for an early escape of the ship's passengers (Marine Insight, 2017). Lifeboat can be categorized into three types, which are open lifeboat, closed lifeboat, and free fall lifeboat.

1. Open Lifeboat has no roof and is normally propelled by manual power (Marine Insight, 2017). Some open lifeboat is equipped with compression ignition engines for the propulsion purpose.

Figure 2. 3 Open Lifeboat (Marine Insight, 2017)

2. Closed Lifeboat is the most popular lifeboats that are used on ship, since it is most reliable to save the passengers from sea water, strong wind, and rough weathe (Marine Insight, 2017)r. This kind of lifeboar can get upright on its own when toppled over by the waves.

Figure 2. 4 Closed Lifeboat (Marine Insight, 2017)

3. Free Fall Lifeboat is similar to closed lifeboat, unless it is launched differently. Free fall lifeboat is aerodynamic in nature, so it can penetrate the water without damaging the body when launched from the ship (Marine Insight, 2017).

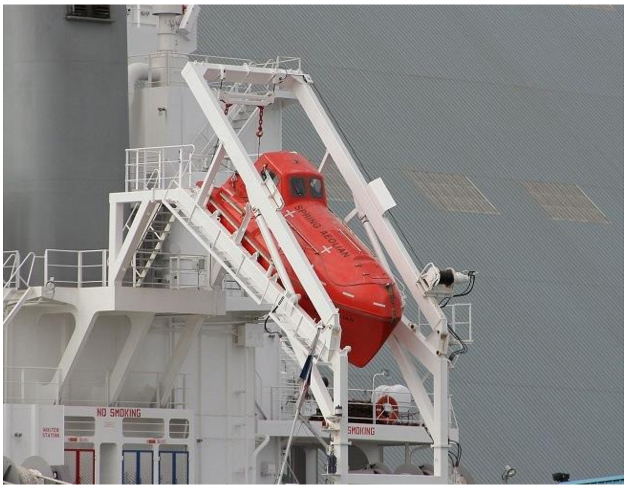


Figure 2. 5 Free fall lifeboat (Marine Insight, 2017)

A lifeboat must fulfill the requirements descibed by SOLAS, which are set for the survival of the passengers at sea. The requirements are:

a. The size, number and the capacity of the lifeboat for a merchant vessel is decided by the type of the ship and number of ship's crew, but it should not be less than 7.3 m in length and minimum two lifeboats are provided on both side of the ship (port and starboard).
b. The requirement for the lifeboat of a cargo ship with 20,000 GT is that the boat must be capable of launching when the ship is heading with a speed of 5 knots.
c. The lifeboat must carry all the equipment described under SOLAS which can be used for survival at sea. It includes rations, fresh water, first aid, compass, distress signaling equipment like rocket etc.
d. The ship must carry one rescue boat for rescue purpose along with other lifeboats. One lifeboat can be designated as a rescue boat if more then one lifeboat is present onboard ship.
e. The gravity davits must be held and slide down the lifeboat even when the ship is heeled to an angle of 15 degrees on either side. Ropes are used to hold the lifeboat in the stowed position with the cradle. These ropes are called gripes.
f. The wires which lift or lower the lifeboat are known as falls and the speed of the lifeboat descent should not be more than 36m/ min which is controlled by means of centrifugal brakes.

g. The hoisting time for the boat launching appliance should not be less than 0.3 m/sec with the boat loaded to its full capacity.
h. The Lifeboat must be painted in international bright orange color with the ship's call sign printed on it.
i. The lifeboat station must be easily accessible for all the crew members in all circumstances. Safety awareness posters and launching procedures must be posted at lifeboat station.
j. Regular drills must be carried out to ensure that the ship's crew members are capable of launching the boat with minimal time during a real emergency.

2.1.1.3 Life raft

Life raft is one of life-saving appliances that is used for crews and passengers evacuation in addition to the lifeboat. Compared to the lifeboat, life raft is easier to launch in case of emergency situation since it is designed with auto inflatable system (Marine Insight, 2017). Different type and size of ship will need different type of life raft. SOLAS (2012) gives the detailed specification for types and number of life raft that must be carried by the ship.

Life raft according to SOLAS' standard is approved for use by all vessels in any waters. It consists of insulated floors and double skinned canopies which interior should not be in colour that can induce nausea. Inside the life raft, there must be emergency pack containing 1.5 litres of water and food with 10000 kkal for per person, flares, waterproof first aid kit, anti sea sickness medicine, and a seasickness bag for each person. Some basic survival items such as rations, pyrotechnics, and life jacket are also includes in the life raft. The features of life raft that supports its safety are the pressure relief valve, stabilizing pocket, and insulted canopy with two layers for protection against heat and cold.

Figure 2. 6 Illustration of life raft (Elcome.com, 2018)

SOLAS listed the general requirements of life raft, considering the possible event that can happen during the emergency. The general requirements are as follows:

a. Capable of withstanding exposure for 30 days afloat in all sea conditions
b. When dropped into the water from a height of 18 metres, the life raft and all equipments in it will operate satisfactorily
c. The floating life raft should be capable of withstanding repeated jumps on it from a height of at least 4.5 metres above its floor both with and without the canopy erected
d. Can be towed at 3 knots with its full equipment, compliment of persons and one anchor streaming
e. Canopy to provide insulation and protection against heat and cold by two layers of material separated by air gap
f. It shall admit sufficient air for the occupants at all times, even when the entrance is closed
g. It shall be provided with at least one viewing port
h. It shall be provided with a means of collecting rainwater
i. It shall be provided with a means to mount a survival craft radar transponder (SART) at a height of at least 1 meter above the sea level
j. It shall have sufficient headroom for the sitting occupants under all parts of the canopy

k. Minimum carrying capacity must be at least 6 persons
l. Maximum weight of its container as well as the equipment should not exceed 185 kilos
m. The life raft shall be fitted with an efficient painter of length equal to miniumum 10 metres plus the distance from the stowed position to the waterline in the lightest seagoing condition or 15 metres, whichever is greater
n. A manually controlled lamp shall be fitted on the top of the canopy and the light shall be white and it must operate for at least 12 hours with a luminous intensity of not less than 4.3 candela
o. If the flash light is fitted, it shall flash at a rate of not less than 50 flashes and not more than 70 flashes per minute for the 12 hours that it burns
p. A manually controlled lamp shall be fitted inside the life raft capable of continuous operation for a period of at least 12 hours
q. When the life raft is loaded with full complement of persons and equipment, it should be capable of withstanding a lateral impact against the ship side at an impact velocity of not less than 3.5m/s and also drop into the water from a height of not less than 3 metres without damage
r. Inflation is done by CO_2 with a small quantity of N_2 which acts as an anti freezing element. CO_2 is non flammable and weighs more than air hence adds buoyancy to the raft. Freezing point of CO_2 is -78 degrees so it can inflate life raft at really low temperatures
s. The painter breaking strength should be 15 kN for 25 people and more, 10 kN for 9 to 24 people, and 7.5 kN for less than 9 people.

Life raft is normally located on the muster station, on port and starboard side near the lifeboat, and in the fwd and aft of the ship. The life raft location depends on the size of the ship and is stored in a fiberglass container that is integrated with a high pressure gas. The high pressure gas is used for inflating the life raft automatically when it comes to emergency. There is also a Hydrostatic Release Unit (HRU) which is connected to the life raft container and ship so that the life raft can be released even after the ship sinks in the water.

2.1.1.4 Fire Fighting System

The fire safety system on a ship is needed to prevent the occurance of fire and explosion. The functional requirements of fire fighting system in a ship according to SOLAS (2012) are:

a. division of the ship into main vertical and horizontal zones by thermal and structural boundaries
b. separation of accommodation spaces from the remainder of the ship by thermal and structural boundaries
c. restricted use of combustible materials
d. detection of any fire in the zone of origin
e. containment and extinction of any fire in the space of origin
f. protection of means of escape and access for fire-fighting
g. ready availability of fire-extinguishing appliances
h. minimization of possibility of ignition of flammable cargo vapour

The fire fighting system on a vessel is categorized into two kind of system, whcih are fire main system and local fire fighting. The fire main system is system that is integrated in the ship. It includes sea water hydrants, foam, and emergency fire pumps. The local fire fighting consists of fixed fire fighting and Portable fire extinguishing. The component of fixed fire fighting such as sprinkles, foam, carbon dioxide, and high pressure water-mist, while Portable fire extinguishing are carbon dioxide, foam, and powder.

2.2 Job Analysis

Job analysis is a procedure to collect the information about a job in order to study the patterns and determine the tak, duties, skills, knowledge required, and responsibilities needed for every job (Dessler, 2011). It can also be described as a detailed and systematic process of breaking down work performed into a number of separate tasks and duties (Heron, 2005). The job analysis is useful to describe the job specifications and job description.

According to Dessler (2011), job description is process of identifying the information related to the job, such as job title, job location, reporting to and of employees, job summary, nature and objectives of the job, task and duty to be performed, working condition, machines, tools and equipment, and hazard involved in it. The purpose of job description is to collect the job information in order to advertise for a particular job to attract the right candidate for the job. It is also useful to determine what the employee are supposed to do. Dessler (2011) also described the job specification as a statement of specification needed to perform a job, includes the educational qualifications, skills, level of experience, and general health. Its objective is to help recruiting the most appropriate people to do the job.

Heron (2005) elucidates the five elements that involves in the job analysis process, which are purposes, tasks, environment, working conditions, and qualifications. These five elements should apply to the analysis of all job for all people. One of the element is task, which concerned on the task performed by the workers while performing the job, includes how many tasks undertaken by the workers, the sequence of the task, the tools and equipment to perform the task, and the tasks involve close cooperation with other workers. Heron (2005) also stated that it is needed to elaborate the task by specifying its dimensions and context precisely. To help studying about task more comprehensively, breaking down task into work element may be necessary. Work element is a single task that cannot be subdivided anymore (The McGraw-Hill Editorial Staff, 2003). It is also defined as the smallest increment of work that can be moved to another person (Lean Enterprise Institute, 2018).

2.3 Time Study

Time study is one of techniques that can be used to conduct a work measurement. According to Kanawaty (1992), the principle of this technique is to record the times of performing a certain specific job or its elements carried out under specified conditions. Time study is also useful to analyze the data in order to obtain the time necessary for an opreator to carry out the task at a defined rate of performance. Time study will result a standard time, that is defined by Meyers (2002) as the time required to produce a product at a work station with the three conditions: (1) a qualified, well-trained operator, (2) working at a normal pace, and (3) doing a specific task. Wignjosoebroto (2008) mention that standard time may be necessary in some areas, which are:

1. Man power planning
2. Estimate the labour costs
3. Production planning and cost analysis
4. Plan the system of giving rewards or incentive to the workers
5. Indicate the output that can be provided by the workers

Basically, there are two methods that are commonly used to conduct time study, which are direct and indirect measurement. Direct measurement is done by directly observe the workers while performing their jobs, whereas indirect measurement does not need direct observation since the standard time can be determined as long as the methods and work elements to perform the task are known (Wignjosoebroto, 2008). In this research, the method used is direct measurement, especially Stopwatch Time Study (STS). Other than STS, the method for direct measurement is work sampling.

2.3.1 Stopwatch Time Study

Stopwatch Time Study (STS) was firstly developed by Frederick W. Taylor in 1881. This method is best used for measuring the time standard of a repetitive work (Wignjosoebroto, 2008). The objective of STS is to measure the time needed for an normal operator to complete a task at a normal pace. Normal operator is defined as a qualified, thoroughly experienced operator who is working under conditions as they customarily prevail at the work station. Normal pace is pace that is neither fast nor slow, but representative of an average (Marovic, et al., 2007). Shown in Figure 2.7 is the steps for conducting STS according to Wignjosoebroto (2008).

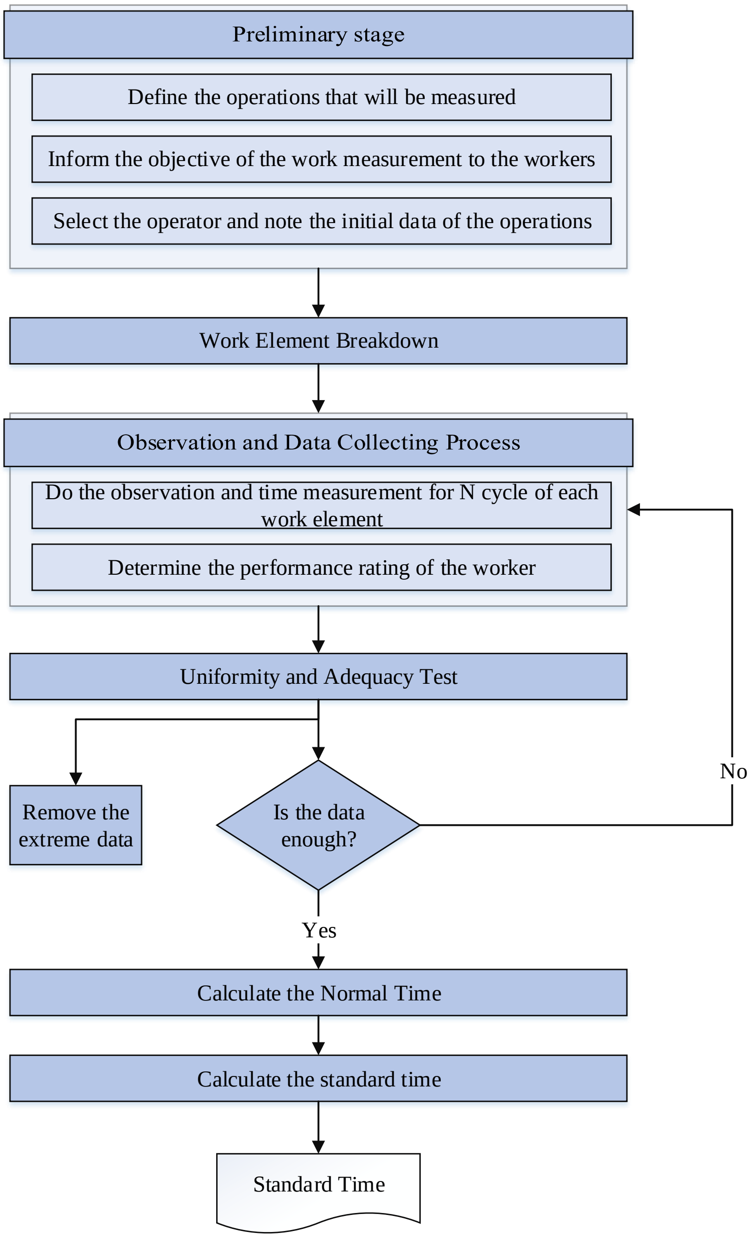


Figure 2. 7 Steps for Conducting STS (Wignjosoebroto, 2008)

Step 1. In the preliminary stage, the researcher must define the operation that will be measured, considering the needs of the company. The operator under observation should also be determined in this stage by considering their qualifications.

Step 2. Then, the operation should be brokedown into work elements according to the procedures to perform the operation.

Step 3. In the observation and data collecting process, the observer must directly observe the operator and measure the time needed for them to complete each work elements by using stopwatch. The performance rating for the operator can also be obtained from either the observation or interview to the supervisors. The performance rating is determined by following the Westinghouse Rating System as shown in the Table 2.2.

Table 2. 2 Westinghouse Rating System

SKILL			EFFORT		
+ 0.15	A1	Superskill	+ 0.13	A1	Superskill
+ 0.13	A2		+ 0.12	A2	
+ 0.11	B1	Excellent	+ 0.10	B1	Excellent
+ 0.08	B2		+ 0.08	B2	
+ 0.06	C1	Good	+ 0.05	C1	Good
+ 0.03	C2		+ 0.02	C2	
0.00	D	Average	0.00	D	Average
- 0.05	E1	Fair	- 0.04	E1	Fair
- 0.10	E2		- 0.08	E2	
- 0.16	F1	Poor	- 0.12	F1	Poor
- 0.22	F2		- 0.17	F2	Poor
CONDITION			**CONSISTENCY**		
+ 0.06	A	Ideal	+ 0.04	A	Ideal
+ 0.04	B	Excellent	+ 0.03	B	Excellent
+ 0.02	C	Good	+ 0.01	C	Good
0.00	D	Average	0.00	D	Average
- 0.03	E	Fair	- 0.02	E	Fair
- 0.07	F	Poor	- 0.04	F	Poor

Source: (Wignjosoebroto, 2008)

Step 4. After the data is collected, it must be processed into uniformity and adequacy test. The uniformity test can be done by using Minitab software. Extreme data, which is data above the Upper Control Limit (UCL) and below the Lower Control Limit (LCL), must be removed. Whereas the adequacy test is in accordance to the formula:

$$N' = \left[\frac{Z.S}{\overline{X}.k}\right]^2 \tag{2.1}$$

Where:

Z = confidence level

S = standard deviation

$\bar{X}$ = mean of the operation time

k = error rate

The data is said to be adequate when the N is equal to or greater than N'.

Step 5. Calculate the normal time by using the formula:

$$Normal\ time = \ actual\ time\ x\ performance\ rating \tag{2.2}$$

Step 6. Standard time is calculated by using the formula:

$$Standard\ time = normal\ time\ x\ \left(\frac{100\%}{100\% - \%allowance}\right) \tag{2.3}$$

The allowance is determined based on the recommended allowance from International Labour Organisation (ILO) as shown in the Table 2.3.

Table 2. 3 ILO Recommended Allowances

		Men	Woman
A.	CONSTANT ALLOWANCES:		
	Personal Needs	5	7
	Basic Fatigue	4	4
B.	VARIABLE ALLOWANCE		
	1. Standing Allowance	2	4
	2. Abnormal Position Allowance		
	a. Slightly awkward	0	1
	b. Awkward (bending)	2	3
	c. Very awkward (lying, stretching)	7	7

Table 2. 3 ILO Recommended Allowances (cont)

		Men	Woman
	3. Use of force, or mucular energy (lifting, pulling, or pushing). Weight lifted (pounds):		
	5	0	0
	10	1	1
	15	2	2
	20	3	3
	25	4	4
	30	5	5
	35	7	7
	40	9	9
	45	11	11
	50	13	13
	60	17	17
	70	22	22
C.	BAD LIGHT		
	1. Slightly below recommended	0	0
	2. Well below	2	2
	3. Quite inadequate	5	5
D.	ATMOSPHERIC CONDITIONS		
	1. Well ventilated, or fresh air	0	0
	2. Badly ventilated, but no toxic fumes or gases	5	5
	3. Work close to furnace severe, heat, etc	5-15	5-15
E.	CLOSE ATTENTION		
	1. Fairly fine work	0	0
	2. Fine or exacting	2	2
	3. Very fine or very exacting	5	5
F.	NOISE LEVEL		

Table 2. 3 ILO Recommended Allowances (cont)

		Men	Woman
	1. Continuous	0	0
	2. Intermittent – loud	2	2
	3. Intermittent – very loud	5	5
	4. High pitched – loud	5	5
G.	MENTAL STRAIN		
	1. Fairly complex process	1	1
	2. Complex or wide span of attention	4	4
	3. Very complex	8	8
H.	MONOTONY		
	1. Low	0	0
	2. Medium	1	1
	3. High	4	4
I.	TEDIOUSNESS		
	1. Rather tedious	0	0
	2. Tedious	2	2
	3. Very tedious	5	5

Source: ILO (1992)

2.4 Workload Analysis

Mental workload is the difference between the capacities of the information processing system that are required for task performance to satisfy performance expectations and the capacity available at any given time (Backs & Ryan, 1992).

2.4.1 NASA-TLX

National Aeronautics and Space Administration Task Load Index (NASA-TLX) is a mental workload assessment method proposed by Hart and Staveland (Hart & Staveland, 1988) that uses six dimensions for the assessment, which are mental demand, physical demand, temporal demand, performances, effort, and frutration. The explanation about the dimensions is shown in the Table 2.4. To obtain the rating for each dimensions, the first procedure is to ask the workers to assess their workload according to the six dimensions listed. They assess by using scale, which is twenty-step bipolar scales that results a score from 0-100 (assigned to the nearest poin 5).

Table 2. 4 Rating Scale Definitoins and Endpoints of the NASA-TLX

Title	Endpoints	Descriptions
Mental Demand (MD)	Low/High	How much mental and perceptual activity was required (e.g thinking, deciding, calculating, remembering, looking, searching, etc)? Was the task easy or demanding, simple or complex, exacting or forgiving?
Physical Demand (PD)	Low/High	How much physical activity was required (e.g pushing, pulling, turning, controlling, activating, etc)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
Temporal Demand (TD)	Low/High	How much time pressure did you feel due to the rate or pace at which the task or task elements occured? Was the pace slow and leisurely rapid and frantic?
Performance (P)	Good/Poor	How successful do you think you were in accomplishing the goals of the task set by the experimenter? How satisfied were you with your performance in accomplishing these goals?
Effort (EF)	Low/High	How hard did you have to work mentally and physically to accomplih you level of performance?

Table 2. 4 Rating Scale Definitoins and Endpoints of the NASA-TLX (cont)

Title	Endpoints	Descriptions
Frustration Level (FR)	Low/High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed, and complacent did you feel during the task?

Source: (Hart & Staveland, 1988)

The procedures to condusct the NASA-TLX is The next procedure is to determine the weighing of each dimensions that can be obtained from the pairwise coparison method. This procedure require the workers to choose which dimensions is more relevant to workload across all pairs of the six dimensions (Rubio, et al., 2004). Then, the value of Weighted Worload (WWL) is resulted by sum up the value from multiplying the rating scale with the weigh of each dimensions, then divided by 15 a the total number of paired comparisons. To put the WWL value into category, there are two categorization. The first categorization is from (Simanjuntak, 2010) as shown in the Table 2.5.

Table 2. 5 Workload Category of Average WWL

No.	Average WWL Value Range	Workload Category
1	0 – 9	Low
2	10 – 29	Medium
3	30 – 49	Medium-High
4	50 – 79	High
5	80 – 100	Very High

Source: (Simanjuntak, 2010)

Another categorization of WWL score is developed by Grier (2015), where the task type is taken into consideration to categorize the WWL score of NASA-TLX. Grier (2015) describe task type, including mechanical task and cognitive task. Example of mechanical task are assembly tasks, crane operation, and mechanical maintenance. Cognitive task is defined as task that requires mental actions, such as computer programming, flight planning, proof-reading, and speech shadowing. The cumulative frequency distributions of NASA-TLX global workload scores by task types is shown in Table 2.6.

Table 2. 6 Cumulative Frequency Distributions of NASA-TLX Global Workload Scores by Task Types

Task	Percentile				
	Min	25%	50%	75%	Max
	Low	Medium	Medium-High	High	Very High
Cognitive Task	13.08	38.00	46.00	54.66	64.90
Mechanical Task	20.10	24.90	27.95	33.68	51.03

Source: (Grier, 2015)

2.4.2 Full Time Equivalent (FTE)

Full Time Equivalent (FTE) is a workload analysis method where the task completion time is compared to the effective working time (Adawiyah, 2013). According to Oesman (2012), the output of the FTE is the determination of number of optimal worker to do the job. As a parameter to assess the worker's workload, according to Workload Analysis Guidebook by the State Employment Agency, when the FTE value is less than 1, it indicates that the work is underload. It is said to be overload when the FTE value is more than 1.28, while 1-1.28 is determined as the FTE value when the workload is normal. To calculate the FTE value, the formula used is:

$$FTE = \frac{total\ working\ hours}{effective\ working\ time}$$

$$= \frac{\sum(task\ completion\ time\ x\ \ task\ frequency)}{effective\ working\ time} \quad (2.4)$$

In accordance to the Regulation from Ministry of Administrative and Bureucratic Reform Number KEP/75/M.PAN/7/2004, the effective working days is calculated by considering the total number of days, the number of Saturday and Sunday, leaving allotment, and the number of holiday in a year. Then, according to Regulation from Ministry of Internal Affairs Number 12 Year 2008 about the Workload Analyis Guidebook, the effective working time an be calculated by multiplied the effective working days with the standardized working hours in a day. The formulas are as follows:

$$Effective\ working\ days = A - (B + C + D) \quad (2.5)$$

$$Effective\ working\ time =$$

$$Efefctive\ working\ days\ x\ E\ x\ \frac{100\% - \%allowances}{100\%}) \quad (2.6)$$

Where:

A = total number of days in a year

B = number of holidays in a year

C = number of Satuday and Sunday in a year

D = number of leaving allotment

E = standardized working hours

The allowance used to calculate the effective working time can be determined by using ILO Recommended Allowances as shown in Table 2.3. In conclusion, the steps to conduct FTE calculation are:

a. Determine the standard time to complete the tasks
b. Determine the frequency of the tasks in a year
c. Determine the effective working time
d. Calculate the FTE
e. Determine the number of optimal workers

2.5 Human Error

Human Error can be defined as a inappropriate human decision or behaviour that can reduce or potentially reduce the effectiveness, safety, or performance of the system (Sanders, 1993). Thus, human error is an undesired condition of human or human failure that can harm the system performance. Human error can be classified into several categories. The classification is useful for data collection of human error and give a guide to investigate the cause of human error and how to overcome it. According to Swain and Guttman (1983), the classification of human error are:

a. Error of omission which is caused by forgetting to do something. As an example is a woman forget to turn off the stove before leaving the kitchen.

b. Error of comission happens when someone do something in a wrong way. As an example is when a mechanic turn on the conveyor in a full speed while actually it should be in medium speed.
c. Sequence error is caused by someone who do not the their jobs in the right sequence. The example of sequence error is an operator who should adjust the speed first before turn on the machine, but he turns on the machine first.
d. Timing error is when someone failed to do a certain job due to his late or too fast respond to something.

Once the cause of human error is known, the frequency and consequence of human error in a workplace can be minimized by selecting appropriate workers, conducting training, and designing suiTable equipments, procedure, and working environment (Sanders, 1993). Select appropriate workers according to their skills and job description can decrease the probability of human error. It can be considered as a hard thing to do, since finding workers that meet certain requirements is also not easy. Training can be a way to improve the skill of the workers so the probability of human error can be minimized. In the other hand, designing suiTable equipments, procedure, and working environment is also important to maintain or imporve the workers performance so it can decrease the probaility of human error and working accidents.

2.5.1 Theory of Human Error

There are many theories to explain about human error. The theories explain different approach to determine tha causes of human error.

2.5.1.1 The Domino Theory of Accident Causation

In 1931, H.W. Heinrich presented a set of theorems known as *The Axioms of Industrial Safety*. Heinrich presented a model known as the Domino Theory. This theory explained that the cause of an accident is a sequence of event that likened to a row of dominoes knocking each other down in a row (Heinrich, 1931). The event sequence is:

- Injury, caused by an;

- Accident, due to an;
- Unsafe act and/or mechanical or physical hazard, due to the;
- Fault of the Person, caused by their;
- Ancestry and Social Environment.

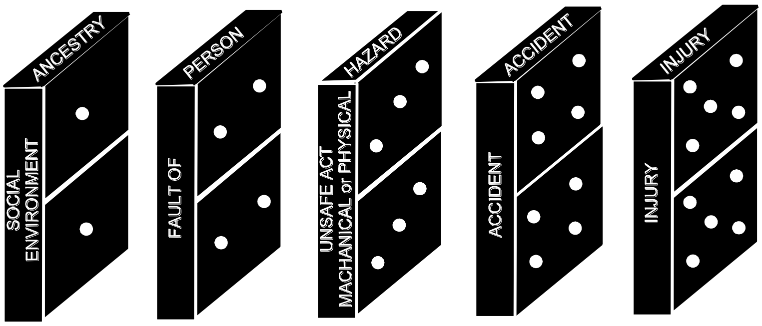


Figure 2. 8 Domino Theory (Heinrich, 1931)

The theory also explained that accident can be avoided by removing one of the dominoes. Normally, the removed one is the unsafe act. Bird and Loftus (1986) was then update the Domino Theory by introducing two new concepts, which are:

- The influence of management and managerial error;
- Loss as the result of an accident could be production losses, property damage or wastage of other assets, as well as injuries.

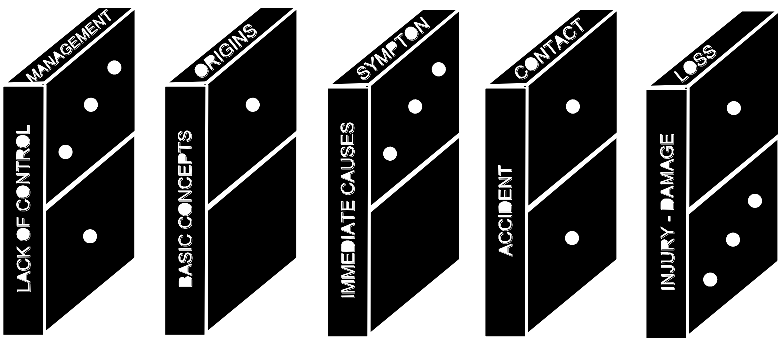


Figure 2. 9 Updated Domino Theory Bird and Loftus (1986)

The Domino Theory lead to the principle of multiple causation. According to Peterson (1978), behind every accident there lies many contributing factors, causes, and sub-causes. The theory of multiple causation is that these factors combine together, in random fashion, causing accidents. So, during accident investigations, there is a need to identify as many of these causes as possible, rather than just one for each stage of the domino sequence.

2.5.1.2 The Human Factors Theory of Accident

Another theory of human error said that human error is caused by human factor which are overload, inappropriate activities, and inappropriate response (Geotsch, 1996). Overload happens when someone have to do job beyond their limits. Working pressure, false method of training, and fatigue also influence the occurance of overload. Inappropriate activities is when someone do activity that does not give any value added to the process. Inappropriate response includes detecting hazard but not correcting it and ignoring safety.

2.5.1.3 The Accident/Incident Theory of Accident Causation

Accident/Incident Theory is continuation of Human Factors Theory. This theory is developed by Dan Petersen (1982)who state that human error factors are ergonomic traps, a wrong decision making, and failed system. Pressure, deadline, and cost factors also cause people to do unsafe manner. System failure is essential in this theory, since it shows that there is cause-and-effect relation between decision made by management and accident. This theory can also explain the role of management to prevent the accident.

2.5.1.4 Epidomiological Theory of Accident Causation

This theory explains about a model used to learn and determine the relation between environmental factors and accident. The key of this theory is the predisposition characteristics and situasional characteristics. As an example, when a worker experience pressure from his friend in the workplace to improve his operation skill, it will increase the probability of accident.

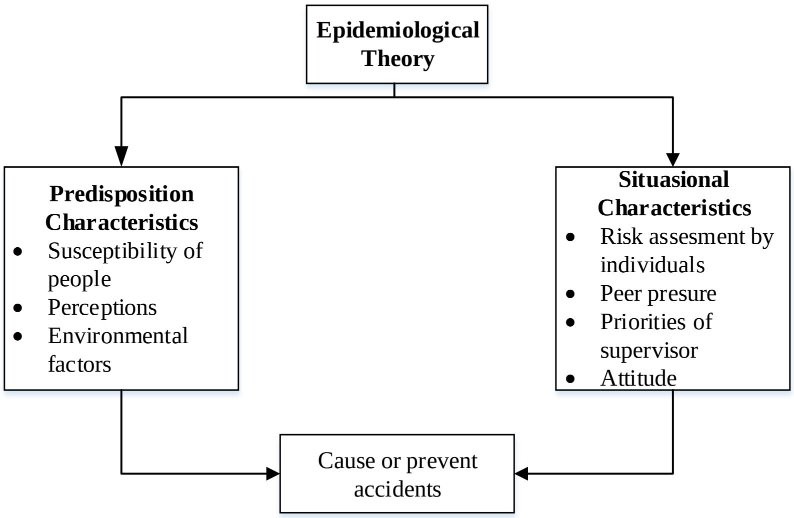


Figure 2. 10 Epidomiological Theory of Causation (Geotsch, 1999)

2.5.1.5 System Theory of Causation

This theory explains that an possible accident is a system consisting of human (host), machinery (agency), and the environment. The frequency of working accidents depends on how those components intract with each other. The changes happens in the interaction pattern can increase or decrease the probability of working accident. The example is when the operator of a machine is changed by more experienced operator who have better skill. This change can decrease the probability of human error. System Theory of Causation can be described as shown in Figure 2.5.

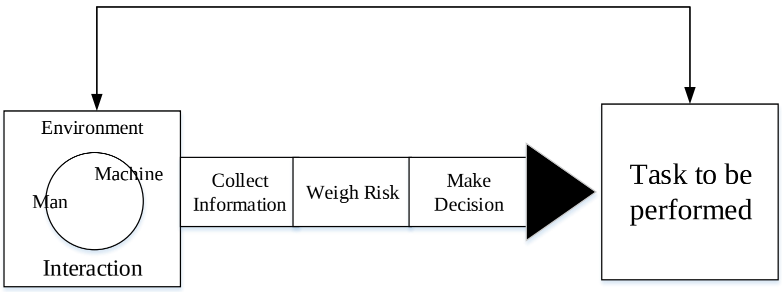


Figure 2. 11 System Theory of Causation (Geotsch, 1999)

2.6 Human Reliability

Human reliability definition according to Neboit et al. Al. (1990) is the probability that an individual, a team or an organization carry out a mission within the limits of the data and the conditions needed for a certain period of time. Human reliability can not be separated from human error. As a methodology, human reliability is a procedure of quantitative analsis to predict the probability of human error. Theoritically, human reliability explains how human errors occur. While as a measurement tool, human reliability calculate the likelihood of successful event or activities done by human (Sanders, 1993). Human reliability makes a considerable contribution to maintain the performance, safety, and cost-efficiency of any production process.

2.6.1 Human Reliability Assessment

Human Reliability Assesment (HRA) is a process of assessing the probabilities of human error under certain circumstances (Spurgin, 2010). Basically, the human error probability, P(HE), is defined as follow (Bell and Holroyd, 2009):

$$P(HE) = \frac{N_E}{N_{EO}}$$

where N_E is defined as number of errors and N_{EO} as number of error opportunities.

One of the most challenging steps in HRA is the quantification of human reliability. Human reliability data are difficult to obtain and can be uncertain (Kirwan 1994). Different type of data can be used for the quantification of human reliability, including historical records, collected data, estimation techniques, judgement, and experience (Taylor-Adams and Kirwan 1997).

In addition, to choose the appropriate HRA approach, it is necessary to know about human reliability method characteristics, their objectives, and limitations. Technique selection for a specific case depends on the nature of the assessment, availability of data, applicability of data, ease of use (time, cost, resources, information), data validity, experience of assessor, and level of assessment needed (Taylor-Adams and Kirwan 1997; McLeod 2015). The HRA techniques used are shown in Table 2.1.

Table 2. 7 Human Reliability Assesment Techniques

Description	Tools
Focus on human error probabilities and human operational errors	Technique for Human Error Rate Prediction (THERP)
	Operator Action Tree (OAT)
	Success Likelihood Index Methodology, Multi-Atribute Utility Decomposition (SLIM-MAUD)
	Socio-Technical Assessment of Human Reliability (STAH-R)
	Human Error Assessment and Reduction Technique (HEART)
Focus on human performance-shaping factors such as workload, stress, sociological issues, illness, and cognitive process	A Technique for Human Error Analysis (ATHEANA)
	Cognitive Reliability and Error Analysis Method (CREAM)
Focus on human performance-shaping factors, relations, and dependencies	Bayesian Network

2.6.2 Cognitive Reliability and Error Assessment Method (CREAM)

Cognitive Reliability and Error Assessment Method (CREAM) is firstly developed by Erik Hollnagel in 1993 for use in the nuclear industry. However, the method is generic and suiTable for use in other major hazard sector (Bell & Holroyd, 2009). According to Kirwan (2007), CREAM is one of the most noTable second generation tools for human reliability assessment, together with ATHEANA, MERMOS, and CAHR. This method is suiTable to analyze a system in order to achieve these following (Hollnagel, 1998):

a. Identify those parts of the work, as tasks or actions, that require or depend on human cognition, and which therefore may be affected by variations in cognitive reliability,

b. Determine the conditions under which the reliability of cognition may be reduced, and where therefore these tasks or actions may constitute a source of risk,
c. Provide an appraisal of the consequences of human performance on system safety which can be used in a PRA/PSA,
d. Develop and specify modifications that improve these conditions, hence serve to increase the reliability of cognition and reduce the risk.

To analyze the human reliability by using CREAM, there are two method that must be conducted, which are the basic method and extended method. The difference about the extended method is that the requirement to build a cognitive demand profiles for each task (Bell & Holroyd, 2009). According to Salvendy (2012), the steps to perform CREAM analysis are:

1. Basic Method
   a. Task Analysis

      In this step, the tasks performed by the workers should be brokedown into work element.

   b. Common Performance Condition (CPC) Assessment

      After the task analysis, the next step is to assess the CPC according to the CPC listed in the Table 2.7. The assessment should be done based on the expert judgement (Maulida, et al., 2015).

Table 2. 8 Common Performance Condition

CPC Name	Level/descriptors
Adequacy of organisation	The quality of the roles and responsibilities of team members, additional support, communication systems, Safety Management System, instructions and guidelines for externally oriented activities, role of external agencies, etc.
	Very efficient / Efficient / Inefficient / Deficient
Working conditions	The nature of the physical working conditions such as ambient lighting, glare on screens, noise from alarms, interruptions from the task, etc.
	Advantageous / Compatible / Incompatible
Adequacy of MMI and operational support	The Man-Machine Interface in general, including the information available on control panels, computerised workstations, and operational support provided by specifically designed decision aids.

CPC Name	Level/descriptors
	Supportive / Adequate / Tolerable / Inappropriatible
Availability of procedures / plans	Procedures and plans include operating and emergency procedures, familiar patterns of response heuristics, routines, etc.
	Appropriate / AccepTable / Inappropriate
Number of simultaneous goals	The number of tasks a person is required to pursue or attend to at the same time (i.e., evaluating the effects of actions, sampling new information, assessing multiple goals etc.).
	Fewer than capacity / Matching current capacity / More than capacity
Available Time	The time available to carry out a task and corresponds to how well the task execution is synchronised to the process dynamics.
	Adequate / Temporarily inadequate / Continuously inadequate
Time of day (circadian rythm)	The time of day (or night) describes the time at which the task is carried out, in particular whether or not the person is adjusted to the current time (circadian rhythm). Typical examples are the effects of shift work. It is a well-established fact that the time of day has an effect on the quality of work, and that performance is less efficient if the normal circadian rhythm is disrupted.
	Day-time (adjusted) / Night-time (unadjusted)
Adequacy of training and experience	The level and quality of training provided to operators as familiarisation to new technology, refreshing old skills, etc. It also refers to the level of operational experience.
	Adequate, high experience / Adequate, limited experience / Inadequate
Crew collaboration quality	The quality of the collaboration between crew members, including the overlap between the official and unofficial structure, the level of trust, and the general social climate among crew members.
	Very efficient / Efficient / Inefficient / Deficient

(Hollnagel, 1998)

The relationship between the CPC evaluation and the level of performance reliability is shown in Table 2.8.

Table 2. 9 Relationship Between the CPC and the Level of Performance Reliability

CPC Name	CPC Level/Description	P	Effects
Adequacy of organisation	Very efficient	-0.6	Improved
	Efficient	0	Not significant
	Inefficient	0.6	Reduced
	Deficient	1	

CPC Name	CPC Level/Description	P	Effects
Working conditions	Advantageous	-0.6	Improved
	Compatible	0	Not significant
	Incompatible	1	Reduced
Adequacy of MMI and operational support	Supportive	-1.2	Improved
	Adequate	-0.4	Not significant
	Tolerable	0	Not significant
	Inappropriate	1.4	Reduced
Availability of procedures / plans	Appropriate	-1.2	Improved
	AccepTable inappropriate	0	Not significant
	Appropriate Improved	1.4	Reduced
Number of simultaneous goals	Fewer than capacity	0	Not significant
	Matching current capacity	0	Not significant
	More than capacity	1.2	Reduced
Available Time	Adequate	-1.4	Improved
	Temporarily inadequate	1	Not significant
	Continously inadequate	2.4	Reduced
Time of day (circadian rythm)	Day time (adjusted)	0	Not significant
	Night time (unadjusted)	0.6	Reduced
Adequacy of training and experience	Adequate, high experience	-1.4	Improved
	Adequate, limited experience	1	Not significant
	Inadequate	1.8	Reduced
Crew collaboration quality	Very efficient	-1.4	Improved
	Efficient	0	Not significant
	Inefficient	0.4	Not significant
	Deficient	1.4	Reduced

c. Probable Control Mode

The CPC assessment will result a reliability interval that will determine the control mode for each task. The interpretaiton of CPC to control mode is described as Contextual Control Model (COCOM) shown in Figure 2.12.

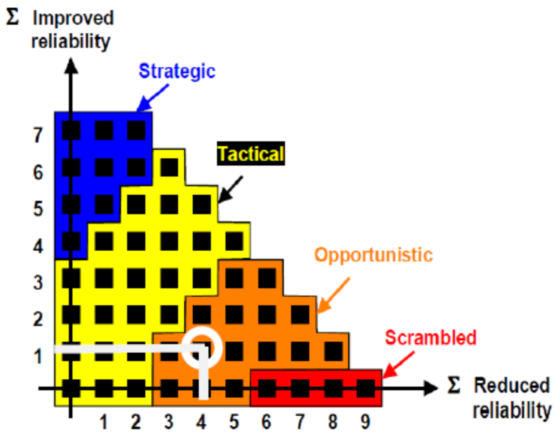


Figure 2. 12 The Relation between CPC and Control Mode

At this step, the number of activities that reduced the performance were subtracted from the number of activities that improved performance. The obtained value will be coefficient of control mode (β), which is obtained from equation 2.7.

$$\beta = \sum R - \sum I \qquad (2.7)$$

where R is the total activities that decrease performance and I is total activities that improve performance. The description of each control mode are explained in the Table 2.8.

Table 2. 10 The Control Mode Features in CREAM

Control Modes	**Features and Possible Cause**
Scrambled Control	The choice of next action is in practice unpredicTable or haphazard. Scrambled control characterises a situation where there is llittle or no thinking involved in choosing what to do. This typically the case then the task demands are very high, when the situation is unfamiliar and changed in unexpecred ways, when thinking is pralaysed and there accordingly is a complete loss of situation awareness.

Table 2. 10 The Control Mode Features in CREAM (cont)

Control Modes	Features and Possible Cause
Opportunitic Control	The next action is determined by the saliend features of the current context rather than on more sTable intentions or goals. The person does very little planning or anticipation, perhaps because the context is not clearly understood or because time is too constrained.
Tactical Control	performance is based on planning, hence more or less follows a known procedure or rule. The planning is, however, of limited scope and the needs taken into account may sometimes be *ad hoc.* If the plan is a frequently used one, performance corresponding to tactical control may seem as if it was based on a procedural prototype - corresponding to e.g. rule-based behaviour. Yet the regularity is due to the similarity of the context or performance conditions, rather than to the inherent "nature" of performance.
Strategic Control	The person considers the global context, thus using a wider time horizon and looking ahead at higher level goals. The strategic mode provides a more efficient and robust performance, and may therefore seem the ideal to strive for. The attainment of strategic control is obviously influenced by the knowledge and skills of the person, i.e., the level of competence. The functional dependencies between task steps (pre-conditions) assume importance as they are taken into account in planning.

Source: (Hollnagel, 1998)

By using the obtained β value, the cognitive failure probability total (CFPt) can be calculated by using Equation 2.8.

$$CFPt \ = 0.0056 \ x \ 10^{0.25\beta} \qquad (2.8)$$

2. Extended Method

   a. Determine the cognitive needs for each task

      For each task, determine what kind of cognitive funtion that is needed to perform the task. The cognitive function are observation, interpretation, planning, and execution (Salvendy, 2012).

   b. Identify and calculate the cognitive function failure

      In this step, the likely failure that might happen during the cognitive function activity must be identified. The cognitive failure probability (CFP) associated with the cognitive function failure is as shown in the Table 2.10.

Table 2. 11 Cognitive Failure Probability

Cognitive function	Generic Failure Type		Basic Value
Execution	E1	Action of wrong type	0.003
	E2	Action at wrong time	0.003
	E3	Action on wrong object	0.0005
	E4	Action out of sequence	0.003
	E5	Missed action	0.003
Interpretation	I1	Faulty diagnosis	0.02
	I2	Decision error	0.01
	I3	Delayed interpretation	0.01
Observation	O1	Wrong object observed	0.001
	O2	Wrong identification	0.007
	O3	Observation not made	0.007
Planning	P1	Priority error	0.01
	P2	Inadequate plan	0.01

The Cognitive Failure Probability is calculated by using Equation 2.9 and 2.10.

$$PII = \sum_{i=1}^{9} Pi \qquad (2.9)$$

$$CFPi = CFP \ x \ 10^{0.25PII} \qquad (2.10)$$

Where P is the value obtained from CPC evaluation and CFP is the basic value obtained from cognitive function failure evaluation.

   c. Assess the effect of CPC on the nominal of CFP to etermine which of the control modes is governing performance of the task.

2.7 Previous Research

This research's objectives are to determine the number of optimal technicians and the reliability and mental workload of the technicians. To support the writer's understanding about the research method, some previous research are reviewed. In this sub-chapter, the explanation about the previous research found by the writer are explained.

A research by Mochamad Nigel Aldaikina titled *Determination of The Number Of Optimal Workers and Analysis Of The Relation Between Mental Workload and Productivity* focused on the workload and productivity of workers in PT. PLN Region Krian, as one of factor that is indicated affecting productivity is mental workload. The objectives of this research are to determine the number of optimal workers and the relation between productvity and mental workload in PT. PLN Region Krian. The method used is Subjective Workload Assessment Technique (SWAT) for the mental workload assessment, while the productivity is measure by how far the workers can achieve the Key Performance Indicator (KPI). The result of the research shows that the mental workload of the workers is in range of 59.7% - 80.30% which is categorized as moderato to high. However, it is not recommended to add worker because the number of worker is sufficient, but dividing workload equally is still needed for the improvement. This research also found that there is a relaiton between mental workload and productivity of workers in PT. PLN Region Krian, but it is only in term of the working output.

In the other hand, a research titled *Analysis of Workload and Reliability of Train Centralized Traffic Control (CTC) (Case Study: PT. KAI DAOP 8 Surabaya)* by Ahmad Furqoni assess the workload and reliability of train CTC workers in PT. KAI DAOP 8 Surabaaya. The workload analysis method used is NASA-TLX and THERP for the human reliability assessment method. The background of the research is because there is an indication that the mental workload will influence the reliability of the workers. The result shows that the mental workload vary between each shift, which are 63.43 for morning shift, 67.74 for afternoon shift, and 53.97 for the night shift. This is correpond to the result of reliability assessment, which shows that the morning and afternoon shift workers has the lower reliability than workers in the night shift. The reliability of workers in morning and afternoon shift is 93%, while the night workers' is 95%. But, the reliability assessment result shows that the train CTC workers have quite good relaibility.

Table 2. 12 Comparison of Previous Researches

No.	Writer	Year	Title	Object	Method
1.	Mochamad Nigel Aldaikina	2014	Determination of The Number Of Optimal Workers and Analysis Of The Relation Between Mental Workload and Productivity	PT. PLN (Persero)	Stopwatch Time Study, KEP/75/M.PAN/7/2004, Subjective Workload Assessment Technique, Regression
2.	Ahmad Furqoni	2015	Analysis of Workload and Reliability of Train Centralized Traffic Control (CTC) (Case Study: PT. KAI DAOP 8 Surabaya)	PT. KAI DAOP 8 Surabaya	NASA-TLX, THERP
3.	Mentari Rizki Amelia	2018	Determination of Optimal Number of Technicians and Analysis of the Reliability and Mental Workload of Technician in PT. Surya Segara Safety Marine Surabaya	PT. Surya Segara Safety Marine Surabaya	Stopwatch Time Study, CREAM, NASA-TLX

CHAPTER 3
RESEARCH METHODOLOGY

This chapter explains the methodology of this research. It is used to show the systematic plan of the research, in form of flowchart that is explained narratively.

3.1 Research Flowchart

The structural procedures in conducting the research is shown in Figure 3.1.

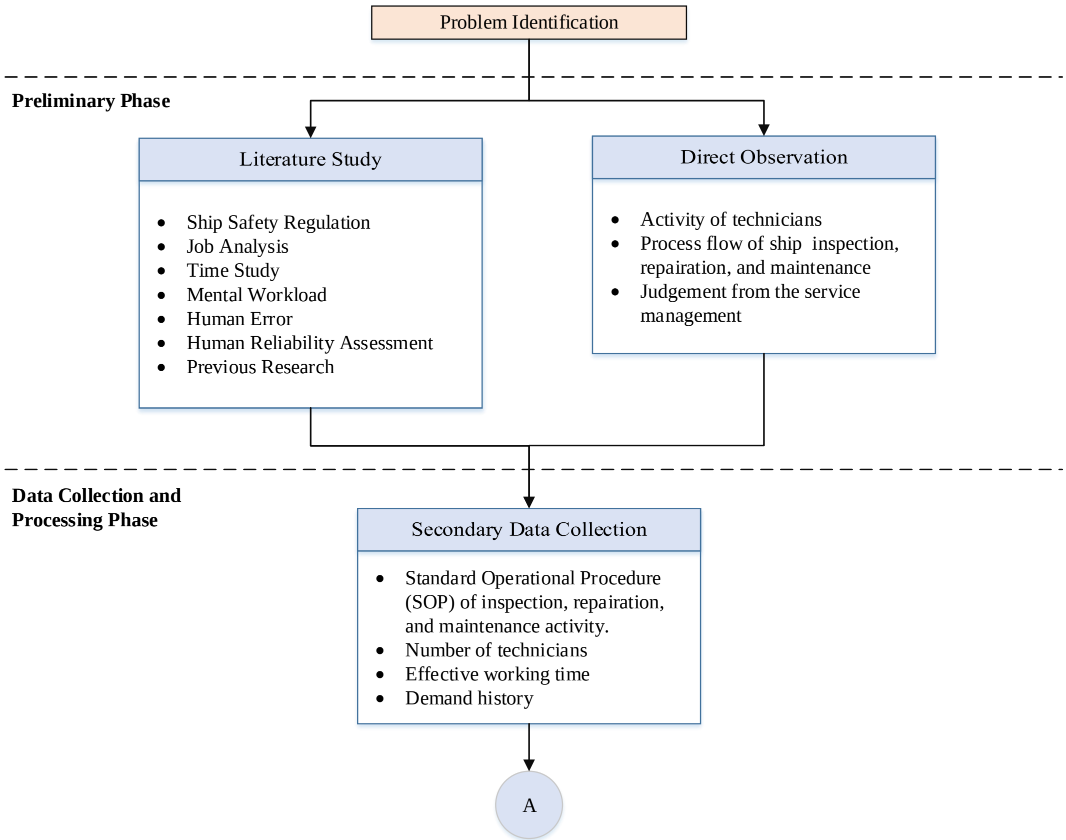


Figure 3. 1 Research Flowchart

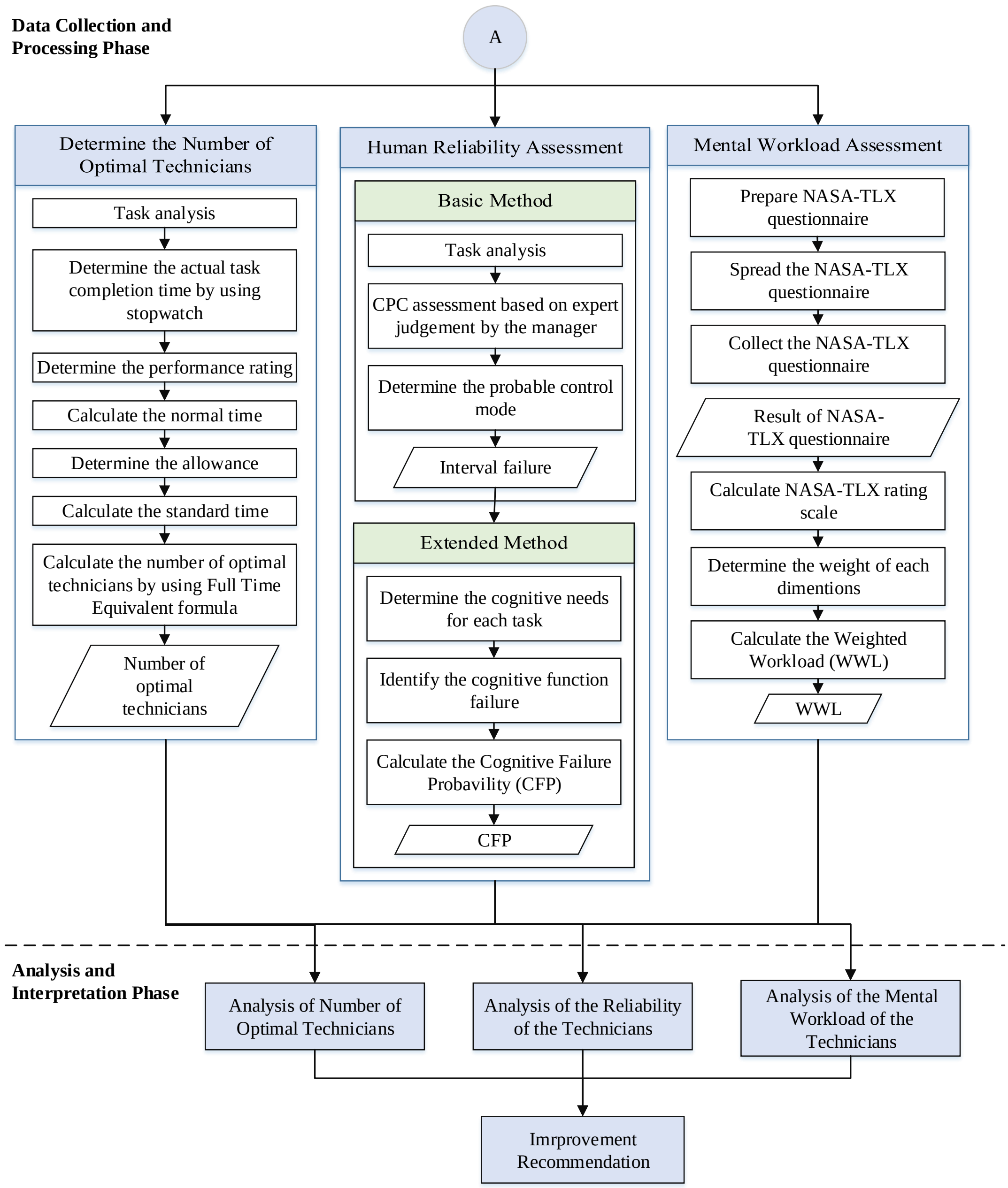


Figure 3.1 Research Flowchart (cont)

CHAPTER 4
DATA COLLECTING AND PROCESSING

This chapter provides information about the data collection and data processing result. It consists of the company profile of PT. Surya Segara Safety Marine Surabaya, technicians task analysis, workload measurement using FTE and NASA-TLX, and human reliability assessment by using CREAM.

4.1 Company Profile of PT. Surya Segara Safety Marine Surabaya

PT. Surya Segara Safety Marine Surabaya was firstly established in 1974 in Surabaya, concerned on selling maritime equipment. During the development, the company started to provide service in inspection, reparation, and maintenance for the ship's safety equipment, such as life raft, lifeboat, fire extinguisher, and life saving appliances. In order to fulfill increase the efficiency and quick handling of customers' orders, the company was developed into a business group called Segara Group that has a fairly wide working network to cover customers' needs in Indonesia. Segara Group now has five companies that provide service in their own covering area, which are:

1. PT. Surya Segara Safety Marine Surabaya
2. PT. Segara Permai Merak
3. PT. Segara Permai Jakarta
4. PT. Segara Permai Batam
5. PT. Surya Segara Safety Marine Balikpapan

Figure 4. 1 Logo of PT. Surya Segara Safety Marine Surabaya (Source: suryasegara.com, 2018)

The company vision is “With pioneering spirit, able to create a maritime safety and provide sustainable service to the customers in Indonesia and overseas”. To achieve the vision, in accordance with Safety of Life At Sea (SOLAS) and International Maritime Organization (IMO) regulation, PT. Surya Segara Safety Marine endeavors to fulfill the standard determined by the world safety organization by continuing establishing and improving system and equipment in order to meet the aforesaid applicable standard in safety services internationally. The company has adopted ISO management system 9002, ISO 14001 for environment and OHSAS 18001 for health and safety. Besides, the company also approved by International Association of Classification Societies (IASC) members, such as American Bureau of Shipping (ABS), Lloyd’s Register (LR), DNV, and Bureau Veritas (BV). The approval means that the company have fulfilled international standard service implementation and maintenance of safety equipment.

4.2 Technicians Tasks during Providing Service

The task analysis is done to determine the activities done by the technicians. In order to do this, the working instruction of each services are analyzed. Based on the working instruction, writer also directly observe the process of delivering service to the client and conduct interview with the expert, who is the manager of Service Department. According to the document, direct observation, and interview, the activity lists of technicians are described in this sub-chapter.

4.2.1 Activity List of Portable Fire Extinguisher Service

For Portable Fire Extinguisher service, the activity conducted by the technicians depends on the type of the extinguisher. There are five types of Portable Fire Extinguisher, which are AB Foam, CO_2, Dry Powder, Liquid Cartridge System, and Liquid Nitrogen System. The service activities conducted are shown in the Table 4.4.

Table 4. 1 Activity List of Portable Fire Extinguisher Service

Activity Code	Activity
AB Foam Fire Extinguisher	
FE.P1.1	Record the FE inspected in the Form Survey and Test Report
Liquid FE - Nitrogen System	
FE.P5.1	Record the type of Portable FE and fill the Form Survey and Test Report

4.3 Full Time Equivalent (FTE) Calculation

To determine the number of optimal technicians, there are several steps that must be conducted. The first thing to do is to determine the activities done by the technicians in order to provide services for the client. Then, the additional data needed are effective working time of the technicians and the standard time of each activities. In addition to that, the frequency of each activity done in a year can be obtained from the historical data of the company. The number of optimal technicians will be calculated by using Full Time Equivalent (FTE) formula.

4.3.1 Determine the Effective Working Time of the Technicians

To determine the effective working time of the technicians, the data needed are the number of holidays and leaving allotment in a year. Listed below is the data used to calculate the effective working time. The working hours of the company that varies in a week is also one of factor considered to determine the effective working time of the technicians. The data are obtained from interview with the manager of Service Department in the company. From the interview, it is known that the technicians starts working at 08.30 and finish at 16.15 on Monday to Friday. On Saturday, they works at 09.30 to 12.00. In between the working hours, there are rest time at 11.30 to 13.00 and 14.45 to 15.00 on Monday to Friday.

Number of Saturdays in a year : 52 days
Number of Monday – Friday : 236 days
Effective working time on Saturday : 2.5 hours
Effective working time on Monday – Friday : 6 hours

So, the effective working time of the technicians in the company is as calculated below:

Effective working time = (52 days x 2.5 hours) + (236 days x 6 hours)

= 130 hours + 1416 hours

= 1546 hours / year

= 92760 minutes / year

4.3.2 Determine the Number of Optimal Technicians

To determine the standard time of tasks, there are two methods used in this research. For tasks that have a repetitive cycle and occurs during the observation time, the actual time is obtained from Stopwatch Time Study. For tasks that do not occur during the observation time, the actual time is obtained from an interview with the technicians and verified by the expert which is the manager of Service Department. Once the actual time is obtained, the calculation of standard time is done by considering the time allowance and performance rating of the technicians. In this sub-chapter, standard time calculation for Portable Fire Extinguisher will be conducted as an example.

Step 1. Determine the Actual Time of Tasks

In this research, the actual time of Portable Fire Extinguisher service activities are obtained from both Stopwatch Time Study and interview. This is because during the observation time, there were only order from customers to service Liquid Fire Extinguisher – Nitrogen System, so the actual time of Liquid Fire Extinguisher – Nitrogen System service activities are obtained from stopwatch time study, whereas the actual time for other type of Portable Fire Extinguisher are obtained from interview. The activities' actual time that are conducted from stopwatch time study is as shown in the Table 4.7.

Table 4. 2 Actual Time Calculation of Liquid Fire Extinguisher – Nitrogen System

Activity Code	Activity	n-th observation (seconds)								
		1	2	3	4	5	6	7	8	9
FE.P5.1	Record the type of Portable FE and fill the Form Survey and Test Report	125	121	135	119	128	114	132	124	131
FE.P5.2	Release the content of Liquid Nitrogen System FE	188	194	173	189	192	197	181	194	184
FE.P5.3	Clean the cylinder of Liquid Nitrogen System FE	198	214	208	233	243	181	226	151	163

Once the actual time is obtained, the uniformity test is conducted by using Minitab software. This test is done to know whether there are outlier data or not. Since there is no outlier data, the other test that must be conducted is adequacy test. The test is using confidence level of 90% and 10% level of error. In the other hand, for the activities that did not occur during the observation, the actual time is obtained from interview. The recapitulation of actual time of Portable Fire Extinguisher service is shown in the Table 4.9.

Table 4. 3 Recapitulation of Actual Time of Portable Fire Extinguisher Service

Activity Code	Activity	Actual Time	
		Duration (minutes)	Time Measurement Method
AB Foam Fire Extinguisher			
FE.P1.1	Record the FE inspected in the Form Survey and Test Report	0.50	Interview
Liquid FE - Nitrogen System			
FE.P5.1	Record the type of Portable FE and fill the Form Survey and Test Report	2.09	Stopwatch Time Study

The actual time calculation for the lifeboat, life raft, CO_2 system, and life saving appliances are explained in the Appendix 1 and Appendix 2.

Step 2. Calculate the Normal Time

To calculate the normal time, it is important to consider the performance rating of the technicians who does it. By using Westinghouse Table, the technicians' performance rating are obtained from interview with the manager of Service Department. The technicians' performance rating is shown in the Table 4.10.

Another consideration to conduct normal time calculation is the number of operator doing the activity. There are some activities that must be carried out by more than one person, as shown in the Table 4.11.

Table 4. 4 Number of Technicians Carry Out the Activity

Activity Code	Activity	Actual Time (minutes)	Technician			
			Technici-an 1	PR	Technici-an 2	PR
AB Foam Fire Extinguisher						
FE.P1.1	Record the FE inspected in the Form Survey and Test Report	0.50	Zainul Maarif	0.26		
Liquid FE - Nitrogen System						
FE.P5.1	Record the type of Portable FE and fill the Form Survey and Test Report	2.09	Ali Mustofa, ST	0.15		

The number of technicians doing the activity will be considered to calculate the normal time of the activity. The following calculation is an example of normal time calculation when the activity is carried out by one person. The calculation of normal time when there are more than one person carrying out the activity is shown in the following example. The normal time calculation of Refill the Liquid Cartridge System FE:

Normal time = actual time $x \sum(1 + Performance\ Rating)$

= 15 minutes x ((1+0.26) + (1+0.14))

= 15 minutes x 2.4

= 36 minutes

Step 3. Calculate the standard time

Once the normal time is calculated, the standard time calculation is done by considering the allowance of each activity. The allowance percentage is obtained from the judgment of Service Department's manager by using ILO Recommendation Allowances. The allowance of the activities are shown in the Appendix 2. The standard time calculation for activity of Refill the Liquid Cartridge System FE is:

Standard time = $36\ minutes\ x\ \frac{100\%}{100\%-13\%}$

= 36 minutes x 1.15

= 41.38 minutes

Step 4. Full Time Equivalent (FTE) calculation

The next step is to calculate the technicians' workload time by considering the frequency of each activity in a year. The frequency is obtained from an approach to the company's demand. The company's demand in 2017 is classified into two seasons, which are medium season and peak season, according to the demand history and justification from the manager of Service Department. Once the frequency recorded, the technicians' workload time can be calculated by multiplying the standard time with the frequency as shown in the Table 4.13.

According to the FTE calculation, it is known that the optimal number of technician is 55.043, while the existing number of technician is 20. This result means that there are 35 additional technicians needed by the company.

4.4 Workload Measurement Using NASA-TLX

NASA-TLX is a subjective mental workload measurement method that covers six indicators of mental workload. Those six indicators are mental demand, physical demand, temporal demand, own performance, effort, and frustration level. The workload measurement is done by giving questionnaire to all technicians of PT. Surya Segara Safety Marine. They were asked to fulfill the questionnaire once they finished doing their job according to their expertise. The result of the NASA-TLX questionnaire of lifeboat technicians is shown in Table 4.15, for life raft technicians is shown in Table 4.16, and for fire extinguisher technicians is shown in Table 4.17.

There are three categorization used in this research, which are according to Simanjuntak (2010) and Grier (2015). Grier (2015) take the task type into consideration to categorize the WWL score of NASA-TLX. The assessment to fire extinguisher technicians shows result that the 83% and 17% of the technicians are having ‘high’ and ‘very high’ mental workload respectively. In reverse, when the score is classified according to the cognitive task classification, 17% and 83% technicians have ‘high’ and ‘very high’ mental workload. Meanwhile, according to the mechanical task classification, all fire extinguisher technicians are indicated having ‘very high’ mental workload.

In the other hand, the calculation shows that effort put biggest effect to the technicians of fire extinguisher inspection with percentage of 34%. It indicates that the technicians feel that they put big effort in working, both mentally and physically to accomplish a good level of performance. The possible reason is because the fire extinguisher service activities need both mental and physical work, since it needs skills to operate some machines that are more advanced than it is used by life raft and lifeboat technicians. The fire extinguisher service also require the technicians to do some physical works, such as lifting the cylinders. Besides, the demand of fire extinguisher service is high and the number of technicians is limited, so it needs an extra effort to complete the tasks properly and on time.

4.5 Human Reliability Assessment Using CREAM

The human reliability assessment aimed to identify and analyze human error. In this research, the method used is Cognitive Reliability and Error Assessment Method (CREAM). The study is conducted on 20 people working as technicians in the company and an interview with the manager of Service Department. To use and implement CREAM in this research, the following steps are carried out:

Step 1. Task Analysis

The CREAM assessment is conducted by firstly doing job task analysis. The result of job task analysis has already explained in the sub chapter 4.2.

Step 2. Evaluation of Common Performance Conditions (CPC)

The evaluation of common performance condition is done for all technicians that provides four type of service in PT. Surya Segara Safety Marine, which are lifeboat, life raft, fire extinguisher, and life saving appliances.

Step 3. Determine the Control Mode and Cognitive Failure Probability Total (CFPt)

The third step is determining the cognitive failure probability total. According to the Equation 2.7 and 2.8, the coefficient of control mode (β) is calculated. From the CPC evaluation, the control mode of technicians can also be identified according to the classification explained in the previous chapter. The result of human reliability assessment by using CREAM shows that the highest level of cognitive failure probability total (CFPt) were observed in the tasks performed by the fire extinguisher's technicians with CFPt of 0.056. The result is due to the five activities that reduce the performance with only one activity that improve performance. The activities that reduce performance are adequacy of organization, working condition, adequacy of MMI and operational support, number of simultaneous goals, and available time, while the activity improving performance is only the availability of procedure/plan. One of activity that reduce performance is working condition. The other activity reducing performance is adequacy of MMI and operational support. The CPC evaluation result also indicates that fire extinguisher technicians' probable control mode is opportunistic.

Step 4. Error Analysis using extended CREAM and Quantification of CFP

The extended CREAM covers the identification of cognitive function and cognitive function probability of each technician's task. The value of CFPi is obtained from Equation 2.9 and 2.10. Cognitive function that mostly performed by the fire extinguisher technicians is execution, where the most generic failure type is E4 which is 'action out of sequence' with percentage of 23.53%.

CHAPTER 5
DATA ANALYSIS AND INTERPRETATION

This chapter discuss the interpretation analysis from the data collecting and processing in the previous chapter, including the analysis of workload assessment using FTE, recommendation of optimal technicians, mental workload assessment by using NASA-TLX, and human reliability assessment by using CREAM.

5.1 Analysis of Workload Assessment using FTE

The task analysis is done to determine the activities done by the technicians. In order to do this, the working instruction of each services are analyzed. Based on the working instruction, writer also directly observe the process of delivering service to the client and conduct interview with the expert, who is the manager of Service Department. According to the document, direct observation, and interview, the activity lists of technicians are made. Then, actual time to perform each activity is collected by using two method, which are Stopwatch Time Study (STS) and interview. STS is conducted to obtain actual time of activities that have a repetitive cycle and performed during the data collecting process, while the interview to the manager of Service Department is done to collect the actual time of activities that do not occur during the data collecting process.

Once the actual time is collected, the normal time is calculated by considering the performance rating of the technicians that is determined by the manager of Service Department. Another consideration to determine the normal time is the number of technicians performing the activity. When there are more than one person performing a certain activity, then the normal time of all technicians are summed up. When the workload assessment is done by using FTE, the time efficiency resulted from parallel activity and team work cannot be included in the calculation. Then, to calculate the standard time, the allowances of activity is taken into consideration. The allowance is determined according to the ILO Allowances Recommendation that considers factors such as personal needs, basic fatigue, working posture, and environmental condition of the work place.

5.2 Recommendation of Number of Optimal Technicians

To determine the number of optimal technicians, the FTE index is taken into consideration. The workload classification by using FTE stated that the normal workload happens when the FTE score is between 1 and 1.28. From the calculation, there should be additional 17 technicians for fire extinguisher service, and 6 people for each of life raft and life saving appliances service. However, for lifeboat service, the existing number of technicians is 6 while based on the FTE calculation, there should be only 2 technicians. However, the total number of optimal technicians according to the calculation is 45 people. That means that the company have to recruit 25 more people to achieve ideal individual workload of the technician.

5.3 Analysis of Technicians Mental Workload using NASA-TLX

The mental workload assessment is using NASA-TLX method, where there are six indicators under consideration. The indicators are mental demand, physical demand, temporal demand, own performance, effort, and frustration level. The assessment was done by using questionnaire that was filled by all technicians in the company and grouped based on their expertise. The result of the assessment is a Weighted Workload (WWL) which then divided by 15 to obtain the mental workload score. The score of technicians' mental workload in PT. Surya Segara Safety Marine is presented in Figure 5.1. The score is then classified into some categories, which are 'low', ' medium', 'medium-high', 'high', 'very high'. The classification of each type of activity is explained in the following sub-chapter.

5.3.1 Analysis of Fire Extinguisher Technicians' NASA-TLX Score

The assessment to fire extinguisher technicians shows result that the 83% and 17% of the technicians are having 'high' and 'very high' mental workload respectively. In reverse, when the score is classified according to the cognitive task classification, 17% and 83% technicians have 'high' and 'very high' mental workload. Meanwhile, according to the mechanical task classification, all fire extinguisher technicians are indicated having 'very high' mental workload.

In the other hand, the calculation shows that effort put biggest effect to the technicians of fire extinguisher inspection with percentage of 34%. It indicates that the technicians feel that they put big effort in working, both mentally and physically to accomplish a good level of performance. The possible reason is because the fire extinguisher service activities need both mental and physical work, since it needs skills to operate some machines that are more advanced than it is used by life raft and lifeboat technicians. The fire extinguisher service also require the technicians to do some physical works, such as lifting the cylinders. Besides, the demand of fire extinguisher service is high and the number of technicians is limited, so it needs an extra effort to complete the tasks properly and on time.

5.4 Analysis of Technicians Reliability using CREAM

In this sub chapter, the results of human reliability assessment to the technicians are analyzed according to its CFPt, CPC evaluation, and cognitive function performed by the technicians.

5.4.1 Analysis of Fire Extinguisher Technicians Reliability

The result of human reliability assessment by using CREAM shows that the highest level of cognitive failure probability total (CFPt) were observed in the tasks performed by the fire extinguisher's technicians with CFPt of 0.056. The result is due to the five activities that reduce the performance with only one activity that improve performance. The activities that reduce performance are adequacy of organization, working condition, adequacy of MMI and operational support, number of simultaneous goals, and available time, while the activity improving performance is only the availability of procedure/plan. One of activity that reduce performance is working condition, since the fire extinguisher service require a special place with certain level of temperature in order to refill the cylinder with pressure and powder. Besides, the place is also full of powder that is not convenient for the technicians. The other activity reducing performance is adequacy of MMI and operational support, because some machines used for fire extinguisher service are not equipped with a manual and the unskilled technicians only rely on the instruction from their fellow technicians when they used it for the first time.

The CPC evaluation result also indicates that fire extinguisher technicians' probable control mode is opportunistic. The possible cause are technicians selecting next action without considering the identified characteristics and condition, or the context and instruction is not clearly understood by technicians, or it might be due to lack of available time and experience, too. In the other hand, Figure 4.12 shows that cognitive function that mostly performed by the fire extinguisher technicians is execution, where the most generic failure type is E4 which is ‘action out of sequence’ with percentage of 23.53%.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

This chapter consists of the research conclusions and recommendation according to the process performed during the research.

6.1 Conclusion

According to the research that has been conducted, the conclusions can be inferred as follow:

1. According to the calculation by using Full Time Equivalent (FTE), it is known that all technicians have an overload workload with FTE score of 16.63, 12.64, 1.4, 16.9, and 7.45 respectively for technicians of Portable fire extinguisher, CO2 system, lifeboat, life raft, and life saving appliances.
2. The number of optimal technicians is obtained from a calculation considering the FTE index. The result generated shows that the company need 45 technicians, consists of 23 fire extinguisher technicians, 2 lifeboat technicians, 14 life raft technicians, and 6 LSA technicians. With existing number of technicians of 20 people, the company needs to recruit 25 more technicians so that their technicians will have normal workload according to FTE classification, which is 1-1.28.
3. The mental workload assessment by using NASA-TLX shows a result that the most affecting indicator to the mental workload of lifeboat technicians is physical demand with percentage of 35%. For the life raft technicians, the most affecting indicator to mental workload is temporal demand with percentage of 32%, while for the fire extinguisher technicians is effort with percentage of 34%.
4. According to the result of human reliability assessment by using CREAM, it is known that the highest CFPt is owned by the fire extinguisher technicians with CFPt value of 0.056, followed by life raft technicians with CFPt value of 0.00958, and LSA technicians with probability value of 0.003149. The lowest CFPt value is owned by the lifeboat technicians with probability value of 0.000996.

6.2 Recommendation

To improve the future research, some recommendation are listed below:

1. The research should be conducted in longer period of time to obtain more accurate data.
2. The company should start using an integrated database to record the orders in detail. So, a more advanced demand forecasting can be conducted in order to provide more accurate data for the FTE calculation.
3. A further research should be conducted to develop a man power planning and scheduling of the technicians in the company.
4. A further research should be conducted to include mental workload and human reliability assessment as a consideration to determine the number of optimal workers.
5. A particular research focusing on decision making of man power recruitment by considering cost, workload, and human reliability should be conducted.

REFERENCES

Adawiyah, 2013. *Analisis Beban Kerja Sumber Daya Manusia dalam Aktivitas Produksi Komoditi Sayuran Selada (Studi Kasus: CV Spirit Wira Utama),* Bogor: Institut Pertanian Bogor.

Badan Informasi Geospasial, I., 2015. *Badan Informasi Geospasial.* [Online] Available at: http://big.go.id/berita-surta/show/pentingnya-informasi-geospasial-untuk-menata-laut-indonesia
[Accessed 21 March 2018].

Bell, J. & Holroyd, J., 2009. *Review of Human Relaibility Assesment Method,* Norwich: Health and Safety Executive.

Bell, J. & Holroyd, J., 2009. *Review of Human Reliability Assessment Methods,* Harpur Hill: Health and Safety Laboratory.

Bisnis Indonesia, 2017. *PELAYARAN : Kemenhub Tambah Fasilitas Pelabuhan Tol Laut,* Jakarta: Bisnis Indonesia.

Danish Export Association, 2015. *The Indonesian maritime industry is on the move.* [Online]
Available at: https://www.dk-export.dk/nyt-og-presse/nyheder/the-indonesian-maritime-industry-is-on-the-move/
[Diakses 21 March 2018].

Dessler, G., 2011. *Human Resources Management.* 12th penyunt. s.l.:Prentice Hall.

Elcome.com, 2018. *Elcome.* [Online] Available at: Elcome.com
[Diakses 09 April 2018].

Galic, S., Lusic, Z. & Skoko, I., 2014. *The Role and Importance of Safety in Maritime Transportation.* Solin, 6th International Maritime Science Conference.

Geotsch, D., 1996. *Occupational Safety and Health.* 1st penyunt. New Jersey: Prentice Hall.

Grier, R. A., 2015. How High Is High? A Meta-Analysis of NASA-TLX. *Proceedings of the Human Factors and Ergonomics Society 59th Annual Meeting*, p. 1727.

Hansenprotection.com, 2018. *Life Jacket.* [Online] Available at: https://hansenprotection.com/lifejacket/navy-life/index.html [Diakses 09 April 2018].

Hart, S. & Staveland, L., 1988. Development of NASA-TLX (Task Load Index): Results of empirical and theoritical research. *Advances in Psychology,* Volume 52, pp. 139-183.

Heinrich, H. W., 1931. *Industrial Accident Prevention.* 4th Edition penyunt. New York: McGraw-Hill.

Heron, R., 2005. *Job and Work Analysis: Guidelines on Identifying Jobs for Persons with Diabilities.* 1st penyunt. Geneva: International Labour Office.

Hollnagel, E., 1998. *Cognitive Reliability and Error Analysis Method - CREAM.* 1st Edition penyunt. Norway: Elsevier.

IndonesiaExpat, 2016. *Indonesia Expat.* [Online] Available at: http://indonesiaexpat.biz/business-property/government-prepare-sea-toll-container-ships/
[Diakses 21 March 2018].

International Maritime Organization (IMO), 2012. *The International Convention on Safety of Life at Sea.* s.l.:s.n.

Jakarta Globe, 2016. *New Chief Maritime Minister Speed Sea Toll Road Program,* Jakarta: Jakarta Globe.

Kanawaty, G., 1992. *Introduction to Work Study*. 4th penyunt. Geneva: International Labour Organization.

Kementrian Perhubungan Republik Indonesia, 2018. *Empat Puluh Persen Jalur Perdagangan Dunia Melewati Indonesia,* Jakarta: Biro Komunikasi dan Informasi Publik Kementrian Perhubungan Republik Indonesia.

Kirwan, R. B., 2007. *CARA: A Human Reliability Assessment Tool for Air Traffic Safety Management - Technical Basis and Preliminary Architecture.* Bristol, Safety-critical Systems Symposium, pp. 197-214.

Kopacz, Z., Morgas, W. & Urbanski, J., 2001. The Maritime Safety System, its Main Components and Elements. *The Journal of Navigation*, 54(2), pp. 199-211.

Lean Enterprise Institute, 2018. *Lean Enterprise Institute.* [Online] Available at: https://www.lean.org/lexicon/work-element [Diakses 10 April 2018].

Marine Insight, 2017. *Everything You Ever Wanted to Know About Life Jackets on Ships.* [Online] Available at: https://www.marineinsight.com/marine-safety/everything-you-ever-wanted-to-know-about-life-jackets-on-ships/ [Diakses 09 April 2018].

Marine Insight, 2017. *Life Raft on Ships: A General Overview*. [Online] Available at: https://www.marineinsight.com/marine-safety/life-raft-on-ships-a-general-overview/ [Diakses 9 April 2018].

Marine Insight, 2017. *Types of Lifeboats Used On Ship.* [Online] Available at: https://www.marineinsight.com/marine-safety/types-of-lifeboats-used-on-ship/ [Diakses 09 April 2018].

Marovic, I., Car-Pusic, D. & Zavrski, I., 2007. *Application of Chronometry Method Towards Calculation of Regulation,* Croatia: University of Rijeka.

Maulida, Z., Santiasih, I. & Handoko, L., 2015. *Human Reliability Analysi degan Pendekatan CREAM,* Semarang: JTI Undip.

Meyers, F. E., 2002. *Motion and time study for lean manufacturing.* Third Edition penyunt. New Jersey: Prentice Hall.

Murray, J., 1989. *Oxford Living Dictionaries,* United Kingdom: Oxford University Press.

Oesman, O., 2012. Penerapan Penggunaan FTE RACI dan Head Count Analysis dalam Pengelolaan SDM. Dalam: *Pengelolaan SDM dalam Rangka Modernisasi Layanan Publik Berbasis Teknologi Informasi.* Jakarta: s.n.

Perez, A. R., Antonio, C. . A. T. & Consunji, R. J., 2011. The Sinking of the MV Doña Paz – A Critique on Maritime Disaster Preparedness in the Philippines: An analysis of the event. *ACTA MEDICA PHILIPPINA,* 45(3), pp. 1-5.

Petersen, D., 1978. *Techniques for Safety Management.* 2nd Edition penyunt. New York: McGraw Hill.

Petersen, D., 1982. *Human Error Reduction and Safety Management.* 1st Edition penyunt. Michigan: Garland STPM Press.

Rubio, S., Diaz, E. & Martin, J., 2004. Evaluation of Subjective Mental Workload: A Comparison of SWAT, NASA-TLX, and Workload Profile Methods. *Applied Psychology: An International Review,* 53(1), pp. 61-86.

Salvendy, G., 2012. *Handbook of Human Factors and Ergonomics.* 1st penyunt. New Jersey: John Wiley & Sons.

Sanders, M., 1993. *Human Factors In Engineering and Design.* 7th Edition penyunt. Michigan: McGraw-Hill Education.

Shappell, S. A. & Wiegmann, D. A., 2000. *The Human Factors Analysis and Classification System,* Springfield: National Technical Information Service.

Simanjuntak, R., 2010. *Analisis Beban Kerja Mental dengan Metode NASA-TLX,* Yogyakarta: APKRIND.

Swain, A. & Guttmann, H., 1983. *Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Application,* California: Sandia National Laboratories.

The McGraw-Hill Editorial Staff, 2003. *McGraw-Hill Dictionary of Scientific and Technical Terms.* 6th penyunt. New York: McGraw-Hill Education.

Wignjosoebroto, S., 2008. *Ergonomi Studi Gerak dan Waktu.* Fourth Edition penyunt. Surabaya: Guna Widya.

BIOGRAPHY

Mentari Rizki Amelia was born in Pasuruan, May 19th 1997. She was a student of SD Al Kautsar Pasuruan (2003-2009), MTsN Malang 1 (2009-2011), and SMAN 10 Malang Sampoerna Academy (2011-2014). After graduated from senior high school, she was accepted to study in Industrial Engineering Department Institut Teknologi Sepuluh Nopember. Since then, she was active in several academic and non-academic activities.

The writer was a reporter of ITS Online, under the coordination of Protocol, Promotion, and Public Relation Unit of ITS. The news she wrote were published in ITS' official website (http://www.its.ac.id). She was also involved in Industrial Engineering Student Association ITS (HMTI ITS) as the staff of Communication in Information Department in 2015-2016 and head of Journalistic Bureau in 2016-2017. Not only actively involved in organizational activities, the writer was also took part as committee of some events both national and international scale, such as Young Engineers and Scientist Summit, ASEAN Youth Collaboration Festival, Industrial Challenge, and Industrial Engineering Games.

As she has big interest in ergonomics and work measurement field, the writer was also a laboratory assistant of Ergonomics and Work System Design Laboratory in Industrial Engineering ITS. She was also an intern at PT. Dirgantara Indonesia, where she was assigned to conduct a safety assessment to the shopfloor of Major Assembly CA3000 Department in the company. As a vibrant student, the writer gained several achievements: 1) Finalist of ECSOTIC National Essay Competition (2014), 2) Finalist of Chemical Product Design Competition (2016), 3) Awardee of *Djarum Beasiswa Plus* (2016-2017), and 4) Finalist of Design Competition for Industrial Tools and Environment (2018). For any occasions or inquiries, the writer can be contacted via e-mail amelia.mentaririzki@gmail.com.