BACHELOR THESIS – ME 141502

DECISION MAKING BETWEEN FULL SPEED, SLOW STEAMING, EXTRA SLOW STEAMING AND SUPER SLOW STEAMING BY USING TOPSIS

MIZAN LUBNAN
NRP. 4213 101 027

Supervisor :
Raja Oloan Saut Gurning, ST., M.Sc, Ph.D.

Co-Supervisor :
Dr.-Ing. Wolfgang Busse

DOUBLE DEGREE PROGRAM OF
MARINE ENGINEERING DEPARTMENT
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember
Surabaya

2017

SKRIPSI – ME 141502

PENGAMBILAN KEPUTUSAN ANTARA KECEPATAN PENUH, *SLOW STEAMING, EXTRA SLOW STEAMING DAN SUPER SLOW STEAMING* DENGAN MENGGUNAKAN METODE TOPSIS

MIZAN LUBNAN
NRP. 4213 101 027

Dosen Pembimbing 1 :
Raja Oloan Saut Gurning, ST., M.Sc, Ph.D.

Dosen Pembimbing 2 :
Dr.-Ing. Wolfgang Busse

PROGRAM DOUBLE DEGREE
DEPARTEMEN TEKNIK SISTEM PERKAPALAN
Fakultas Teknologi Kelautan
Institut Teknologi Sepuluh Nopember
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2017

APPROVAL FORM

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

Prepared By:

MIZAN LUBNAN

NRP. 4213 101 027

Approved by Supervisor and Co-Supervisor :

1. Raja Oloan Saut Gurning, ST., M.Sc, Ph.D. (   )

2. Dr.-Ing. Wolfgang Busse (   )

SURABAYA
July, 2017

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Prepared By:

MIZAN LUBNAN

NRP. 4213 101 027

Approved by Head of Marine Engineering Department :

Dr. Eng. M. Badrus Zaman, ST. MT.
NIP. 197708022008011007

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Institut Teknologi Sepuluh Nopember Surabaya

Prepared By:
MIZAN LUBNAN
NRP. 4213 101 027

Approved by Representative Hochschule Wismar in Indonesia :

Dr.-Ing Wolfgang Busse

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Name : Mizan Lubnan
NRP : 4213 101 027

Bachelor Thesis Title	:	Decision Making Between Full Speed, Slow Steaming, Extra Slow Steaming and Super Slow Steaming by Using TOPSIS
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DECISION MAKING BETWEEN FULL SPEED, SLOW STEAMING, EXTRA SLOW STEAMING AND SUPER SLOW STEAMING BY USING TOPSIS

Name : **Mizan Lubnan**
NRP : **4213101027**
Department : **Double Degree Program of Marine Engineering**
Supervisor : **Raja Oloan Saut Gurning, ST., M.Sc, Ph.D.**
Co-Supervisor : **Dr.-Ing. Wolfgang Busse**

ABSTRACT

Many shipping companies were trying to deliver their cargoes as quickly and reliably as possible. But in the beginning of the latest economic crisis on 2007, the containership fleet is slowing down. Even though world oil prices are now declining, but based on the prediction of World Bank, the price of oil will rise again in 2017.

Nowadays shipping company implements slow steaming method on the operation of their ships. But they do not know whether these methods are effective or not due to any negative effects arising from an implement of slow steaming like increased sailing time so may result in losses to the shippers.

In this thesis will discuss the decision-making process between full speed, slow steaming, extra slow steaming and super slow steaming. This study aims to give suggestions on which ship speed is most optimal for shipping companies by considering technical and operational, financial and also environmental factors. Then, will be selected one the most optimal by using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. While for criteria and sub criteria weighting are calculated by Analytic Hierarchy Process (AHP) method using Expert Choice software.

From the TOPSIS method, super slow steaming is chosen to be the first rank with a value of 0,8625 while the second rank is extra slow steaming with a value of 0,5455; then slow steaming with a value of 0,3587; and finally followed by full speed with a value of 0,1283.

Keyword : Slow steaming, Decision Making, Ship Speed, TOPSIS, Maritime Economic

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PENGAMBILAN KEPUTUSAN ANTARA KECEPATAN PENUH, *SLOW STEAMING, EXTRA SLOW STEAMING* DAN *SUPER SLOW STEAMING* DENGAN MENGGUNAKAN METODE TOPSIS

Nama	**: Mizan Lubnan**
NRP	**: 4213101027**
Departemen	**: Teknik Sistem Perkapalan Double Degree**
Dosen Pembimbing	**: Raja Oloan Saut Gurning, ST., M.Sc, Ph.D.** **Dr.-Ing. Wolfgang Busse**

ABSTRAK

Banyak perusahaan pelayaran mencoba mengirimkan kargo mereka secepat dan seaman mungkin. Namun pada awal krisis ekonomi di tahun 2007, armada kapal kontainer melambat. Meski harga minyak dunia kini turun, namun berdasarkan prediksi Bank Dunia, harga minyak dunia akan naik kembali di tahun 2017.

Saat ini perusahaan pelayaran menerapkan metode *slow steaming* pada pengoperasian kapal mereka. Tapi mereka tidak tahu apakah metode ini efektif atau tidak karena efek negatif yang timbul dari penerapan *slow steaming* seperti waktu pelayaran yang meningkat sehingga dapat menyebabkan kerugian pada pengirim barang.

Dalam skripsi ini akan dibahas proses pengambilan keputusan antara kecepatan penuh, *slow steaming, extra slow steaming dan super slow steaming*. Penelitian ini bertujuan untuk memberikan saran mengenai kecepatan kapal yang paling optimal untuk perusahaan pelayaran dengan mempertimbangkan faktor teknis dan operasional, keuangan dan juga lingkungan. Kemudian, akan dipilih yang paling optimal dengan menggunakan metode *Technique for Order of Preference by Similarity to Ideal Solution* (TOPSIS). Sedangkan untuk pembobotan kriteria dan sub kriteria menggunakan metode *Analytic Hierarchy Process* (AHP) yang dihitung dengan menggunakan program komputer *Expert Choice*.

Dari metode TOPSIS, *super slow steaming* terpilih menjadi peringkat pertama dengan nilai 0,8625 sedangkan peringkat kedua adalah *extra slow steaming* dengan nilai 0,5455; Kemudian *slow steaming* dengan nilai 0,3587; dan peringkat terakhir adalah kecepatan penuh dengan nilai 0,1283.

Kata Kunci : Slow steaming, Pengambilan keputusan, Kecepatan kapal, TOPSIS, Ekonomi maritim

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PREFACE

Alhamdulillahirobilalamin huge thanks to Allah SWT the Almighty for giving me the chance, health, and prosperity so the author finally can make it to finish this Bachelor Thesis.

This thesis report entitled "Decision Making Between Full Speed, Slow Steaming, Extra Slow Steaming and Super Slow Steaming by Using TOPSIS" is submitted to fulfill one of the requirements in accomplishing the bachelor degree program at Marine Engineering Department, Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember Surabaya. Conducting this research study is not possible without all helps and supports from various parties. Therefore, the author would like to thank to all people who has support the author for accomplishing this bachelor thesis, among others:

1. Firstly, to my parents, Mr. Lubnan Umar and Mrs. Lubnah who always give their loves, prayers, supports, and encouragements for every single path the author chooses. In addition, my beloved brother Zaidan Lubnan and my beloved sister Milza Lubnan.
2. Mr. Raja Oloan Saut Gurning, ST., M.Sc, Ph.D. and Mr. Dr.-Ing. Wolfgang Busse as supervisor in this Bachelor Thesis, who provide assistance, knowledge, guidance, and motivation through the completion of this Bachelor Thesis.
3. Mr. Dr. Eng. Muhammad Badrus Zaman, ST., MT. as the Head of Marine Engineering Department FTK-ITS.
4. Mr. Prof. Semin, ST., MT., Ph.D as the Secretary of Marine Engineering Department.
5. Mr. Sutopo Purwono Fitri, ST., M.Eng., Ph.D as Author's Lecturer Advisor since first semester until eighth semester.
6. Mr. Ir. Dwi Priyanta, M.SE as Secretary of Double Degree Program in Marine Engineering Department who has giving the motivation and every necessary information to help finish the bachelor thesis.
7. Mr. A.A. Bagus Dinariyana Dwi P., ST., MES., Ph.D as the Head of RAMS Laboratory who has giving permission to do any activities inside the lab and provides place during the working of bachelor thesis.
8. Mr. Aldrin Dewabrata ST. as Assistant Superintendent and Mr. Henman Nugroho as Data Analyst at PT. Meratus Line, who provide the data and advisory during the completion of this Bachelor Thesis.

10. All of BARAKUDA 13 members for all the cooperation during author's 4 year study.

The author realizes that this Bachelor Thesis still far from perfect. Therfore, every constructive and supportive suggestion and idea to to improve this Bachelor Thesis are highly expected by the author so that the better version of this Bachelor Thesis can be reach in the future.

Finally last but not least may Allah SWT bestow his grace, mercy, and blessing to all of us and hopefully this Bachelor Thesis can be advantegeous to corresponding parties who may concern.

Surabaya, July 2017

Author

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CHAPTER I
INTRODUCTION

I.1 Background

Bunker fuel is a considerable expense to shipping lines. Especially in 2007, when bunker costs soared (July 2007 to July 2008: 350-700 USD/ton) ship operational cost becomes higher, the liner shipping industry decreases the commercial speed of their ships to save bunker cost ('Slow Steaming' 2017). Maersk Line and CMA-CGM was the first liner shipping industry that introduces slow steaming to their commercial speeds for Europe- Far-East services. It aims to reduce fuel consumption, so they can competitive in such market (Elswijk 2011).

In shipping, the best method to decrease the operational costs are by reducing the fuel consumption. The reasons for this because fuel consumption costs make up approximately 47% of a ship's total operating expense (Valentito et al. 2012). One of strategy to reduce fuel consumption by using slow steaming. In slow steaming, container ship usually sails at speed 20-24 knots lowered to be only 12-19 knots only. At lower speeds, less fuel is consumed by ship, which has also its effect on the emission.

It is expected that the liner shipping industry in Indonesia can save considerable costs by implementing slow steaming, by calculating how many operating costs can be saved by reducing speed of the ship. 20.63% reduction in ship speed causes the fuel consumption savings approximately 49.01% (Anye et al. 2013). Slow steaming has a positive effect for ship owners and operators as benefit from savings on fuel costs and also causes a reduction in a number of emissions. However, slow steaming has a negative impact like reducing the number of ship trips in one year that can reduce the company's income.

In this thesis, author makes a selection of the most efficient ship speed by using decision support system or a system that can help in decision-making by applying method in accordance with the decisions selected. It can be assumed with comparing ship speed at full speed, slow steaming, extra slow steaming and super slow steaming by considering the elements of technical, financial and also environmental aspects.

One approach that often used to resolve the issue of Multi-Criteria Decision Making (MCDM) is using technique for order of preference by similarity to ideal solution (TOPSIS) method based on the concept that selected is the best alternative, not only has the shortest distance from positive ideal solution, but it also has the longest distance from negative ideal solution.

I.2 Statement Of Problems

Based on the description above the statement problem of this thesis are:

a. What criteria are selected in determining the method of ship speed?
b. Which are the most efficient full speed, slow steaming, extra slow steaming and super slow steaming in terms of corporate profit?
c. How many shipments of cargo that can be delivered by the ship in a month at full speed, slow steaming, extra slow steaming and super slow steaming?

I.3 Research Limitation

a. Focuses on the technical, operational, financial and environmental aspects to consider of full speed, slow steaming, extra slow steaming and super slow steaming on container shipping industry.
b. Did not discuss the specifics effect main engine after applying slow steaming.

I.4 Research Objectives

a. To conduct technical studies comparing the most efficient ship speed in accordance with established criteria.
b. Determine any criteria priority before applying slow steaming method.
c. Determine the lowest fuel consumption cost could be obtained from four ship speed scenarios.
d. Determine the highest engine efficiency values could be obtained from four ship speed scenarios.
e. Determine the highest revenue could be obtained from four ship speed scenarios.
f. Determine the lowest emissions could be generated from four ship speed scenarios.

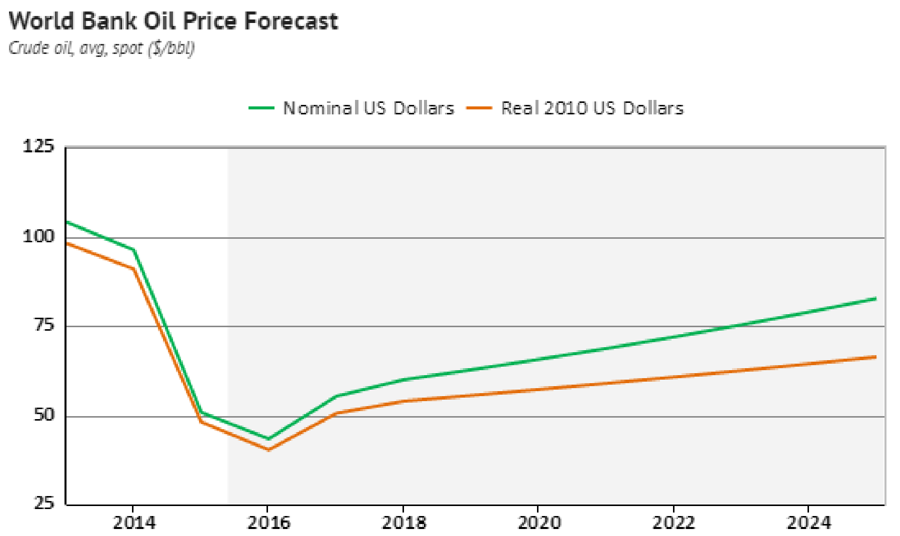
I.5 Research Benefits

a. Knowing one of the methods to reduce fuel consumption by using slow steaming.
b. Knowing effects that can occur when applying slow steaming.
c. Knowing the technical analysis resulting from propulsion power produced by ship engine.
d. Knowing the financial analysis resulting from fuel consumption cost savings.
e. Knowing the environmental analysis resulting from emissions produced by ship engine

CHAPTER II
BASIC THEORY

II.1 Overview

Slow steaming is increasingly used by ship-owners in times of high fuel prices, low shipping demand and high shipping supply to reduce operational costs. In slow steaming, ships usually sail at speed of around 24-20 knots lowered only be 19-12 knots. The impact of speed reduction are reducing engine power so causes lower fuel consumption needed for the operation and also causes a decrease in carbon emissions.



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Nominal US Dollars	43.3	55.2	59.9	62.7	65.6	68.6	71.9	75.3	78.8	82.6
Real 2010 US Dollars	40.2	50.5	53.9	55.5	57.1	58.9	60.6	62.4	64.3	66.3

Figure 2.1 World Bank oil price forecast 2013-2025
Reference: World Bank Commodities Price Forecast 2016

Since the last few years, container shipping companies were trying to deliver their goods as quickly and reliably as possible. But when fuel price soared in 2008, Maersk Line was the first liner shipping industry that introduces slow steaming and became the standard operating procedure in their fleet. In the figure 2.1 can be seen even though world oil prices dropped dramatically in 2013-2016 but predicted by the World Bank if the oil price will rise again in 2017 until 2025. This is the consideration of whether its slow steaming method is required for operation of the ship in the shipping industry.

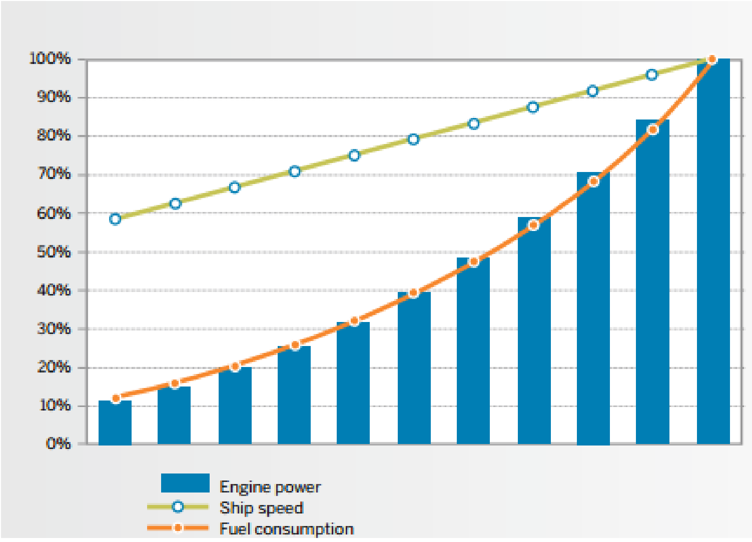


Figure 2.2 Correlation between ship speed, required engine power and fuel consumption

Reference: Wiesman 2010

As figure 2.2 presents, by increasing speed of ship will result fuel consumptions are increased. The power produced by the engine is comparable to the speed of the ship. So change of ship speed can affect to engine power and lead to changes in fuel consumption. There are several factors to reduce fuel consumption, such as ship capacity, type of engine, auxiliary engine usage and weather conditions as well as other technical conditions that affect fuel consumption. Therefore, more and more companies are now trying use slow steaming method to save fuel costs at available opportunities.

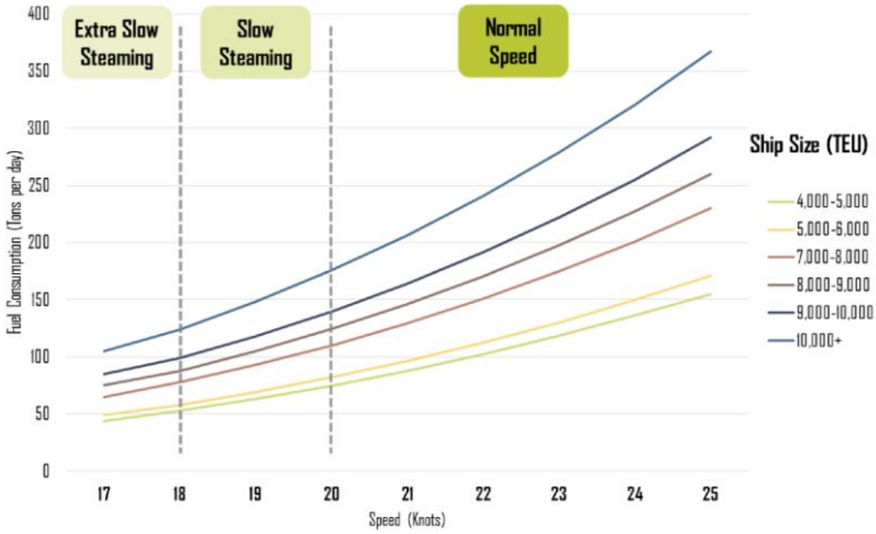


Figure 2.3 Fuel consumption by containership size and speed

Reference: Dagkinis & Nikitakos 2015

Most of ship are designed to sail at full speeds which around 85-90% of maximum enginen load. Based on figure 2.3 there are several ship speed when ships are sailing, there are full speed, slow steaming, extra slow steaming and super slow steaming.

a. Full speed

   Full speed is the maximum speed of the ship that has been designed by engine manufacture (Rahman 2012). Can be seen in Figure 2.3 the speed range for full speed is abfigureout 20 up to 25 knots.

b. Slow steaming

   The operation of ship below the normal speed capacity, about 15% from normal speed (Zanne et al. 2013). Can be seen in Figure 2.3 the speed range for slow steaming is about 18 up to 20 knots.

c. Extra slow steaming

   The operation of ship below the slow steaming speed capacity, about 25% from normal speed (Zanne et al. 2013). It can be seen in Figure 2.3 also, the speed range for extra slow steaming is about 17 up to 18 knots.

d. Super slow steaming

   This method also known as economic speed because it has a very significant change on fuel saving. Super slow steaming can use for higher reductions in operational ship speed. ((Zanne et al. 2013)

II.2 Slow Steaming Impact

Slow steaming has advantages in reducing fuel consumption and also lowers emissions produced by the engine. But slow steaming also cause new problems such as shippers had to wait a long time till their goods arrive at the destination due to a decrease of ship speed.

Tabel 2.1 Comparison of Results for 50000 DWT Product Tanker

M.E. load (%)	Speed (Knots)	Speed Reduction (%)	A.F.C (t/yr)	T.F.C (US$)	F.C ↓se (%)	CO_2 Emissions (t/yr)	SO_x Emissions (t/yr)	NO_x Emissions (t/yr)
100	17.00		18,912.87	11,347,724.16		58,629.91	1,323.90	1,613.08
90	16.41	3.45	17,091.14	10,254,682.18	9.63	52,982.52	1,196.38	1,456.29
75	15.45	9.14	14,231.36	8,538,815.99	24.75	44,117.22	996.20	1,219.83
60	14.34	15.66	11,520.83	6,912,499.30	39.08	35,714.58	806.46	981.66
50	13.49	20.63	9,644.40	5,786,642.51	49.01	29,897.65	675.11	821.77

Reference: Anye et al. 2013

Based on Table 2.1, 20.63% reduction in ship speed causes the fuel consumption savings approximately 49.01%. Slow steaming has a positive effect for ship owners and operators as benefit from savings on fuel costs. However, slow steaming is also reducing the number of ship trips in one year that can reduce the company's income.

In the shipping process, there are two inter-related parties, namely carriers and shippers. The shipping line is the party who has implemented a lower speed on their vessels and the consequences on shore are present for the shipper because it will take more time before he will receive his freight. (Elswijk 2011)

Schedule timeliness represents a fourth primary benefit of slow steaming. Delays in ocean shipping can arise from a broad spectrum of sources such as port congestion, terminal productivity, weather and mechanical issues. (Notteboom 2006). For shippers, better schedule reliability can reduce uncertainty and subsequent safety stock needs. (Maloni, Paul & Gligor 2013)

II.3 Engine Efficiency

The efficiency of a machine is a measure of how well a machine can convert available energy from fuel to mechanical output energy. The percentage difference of the input power and the output power are efficiency values. For example, the electric power used to turn on the lights is not all converted into light energy, some of electrical power turned into heat.

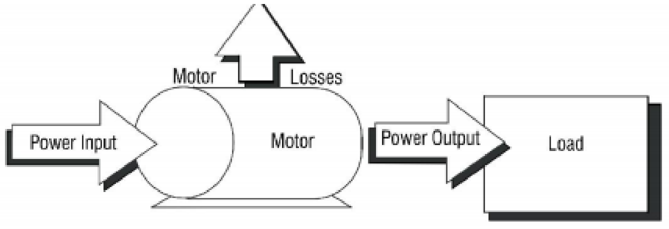


Figure 2.4 Input power and output power diagram
Reference: Ghazali 2011

From Figure 2.4 efficiency can be defined as ratio between the amount of power required and the amount of power generated. Then the efficiency value can be determined by the following equation:

$$\eta = \frac{P_{out}}{P_{in}} x\ 100\% \quad (2.1)$$

Where;
η = Efficiency (%)
P_{out} = Output power
P_{in} = Input power

II.4 Profit Optimizing Speed

The calculation of profit made in order to know at what speed that most optimal so shipping company obtain maximum profit. Profit is the difference between vessel income or total revenue that obtained, minus total operating cost that incurred. Here is the formula for calculating profit (Meyer 2012):

$$P_V = I_V - C_V \quad (2.2)$$

Where;
P_V = Profit Function
I_V = Vessel Income
C_V = Total Operating Cost

II.3.1 Total Operating Cost

Operating costs are costs that should be spent for the need of daily operations with the goal of keeping the ship is always in a ready condition to sail. Cost elements that are part of the total operating cost are as follows:

a. Consumption Cost
b. Port Cost
c. Usage Cost

The calculation of total operating cost using formula as follows (Meyer 2012):

$$C_V = C_U + C_H + C_C \quad (2.3)$$

Where;

C_V = Total Operating Cost
C_U = Usage Cost
C_H = Harbor Cost
C_C = Consumption Cost

II.3.1.1 Consumption Cost

Consumption cost is a combination of fuel oil consumption cost and lubricating oil consumption cost and then multiplied by the number of roundtrips. Consumption costs for shipping are the largest and most important part of the total operating costs, with fuel costs being the largest part of the consumption costs (Meyer 2012). Ship fuel consumption are determined by several variables such as size of the ship, shipping distance, speed and weather (waves, currents, wind). The formula used to calculate the consumption cost are (Meyer 2012):

$C_C = f_T \cdot (C_F + C_L)$ ....(2.4)

Where;
C_C = Consumption Cost
f_T = Maximum Number of Roundtrips
C_F = Fuel Cost
C_L = Lubricating Cost

To calculate the amount of fuel consumption on ship, it should be known how the amount of power that produced by the engine. And then can be calculated by measure mass of fuel consumed per unit time to produce per kilowatt (KWH).

$SFOC\ (g/kwh) = \frac{\text{Mass of fuel consumed per hour}}{\text{Power developed in kilowatt}}$ ....(2.5)

II.3.1.2 Port Cost

Port is a place consisting of land and surrounding waters with certain limits as a place of government activity and economic activity which is used as a place for mooring, anchorage, docking, loading and unloading of passengers or goods equipped with shipping safety facilities and supporting activities (UU 17/2008 Tentang Pelayaran). While the port cost is cost that should incurred by shipowner for continued use of the port such as anchorage services, pilotage services, tugboat services and mooring services.

a. Anchorage Services

Each ship that visiting and entering the port area within the working area of the port is required to pay the port costs service. This cost determination is based on ship gross tonnage per ship visit. If the ship visiting and in the port exceeds 10 days, an additional of cost service is provided for each subsequent 10 days as the base rate. In the determination of ships anchored in the port of Tanjung Perak, the service fee is Rp.112,-/GT and for foreign is US $ 0,1 / GT (tariff at Port of Tanjung Perak, 2014).

b. Pilotage Services

Ships with gross tonnage 150 or more, are required to use pilotage services while on sail in port area that mandatory of pilotage services. Tariff charged in pilotage services are fixed rates Rp. 225.000,- ship/movement and variable rates Rp. 45,- GT/movement (tariff at Port of Tanjung Perak, 2014). Then calculated using the following formula:

PSC = (Fr x movement) + (Vr x GT x movement)......................................(2.6)

Where;

PSC = Pilotage Services Cost
Fr = Fixed Rates
Vr = Variable Rates
GT = Gross Tonnage

Ships that use the pilotage services at the time of entry is charged 1 times the tariff of pilotage services at the time of entry, while leaving the port is charged 1 times the tariff of pilotage services at the time of exit. The rate set for pilotage service is calculated based on the number of moves.

c. Tugboat Services

Tugboat is a small ship that operating at the port to help manoeuvre large ships that will berth at the port, even though the tugboat is small but have a great thrust to be able to steer the berthing ships. Tugboats are created to pull or push ships or anything that floating. Tariff charged for tugboat services are fixed rates Rp. 1.443.149,- ship/hour and variable rates Rp. 30,- GT/ship (tariff at Port of Tanjung Perak, 2014). Then calculated using the following formula:

TSC = (Fr x unit x t) + (Vr x GT x t)...(2.7)

Where;

TSC = Tugboat Services Cost
Fr = Fixed Rates
Vr = Variable Rates
GT = Gross Tonnage
t = Time (hour)

d. Mooring Services

The mooring services tariff calculation for domestic ship is Rp. 116,- GT/etmal and for foreign ships US $ 0.131 GT/etmal. Where 1 etmal = 24 hours.

MSC = Fr x GT x etmal...(2.8)

Where;

MSC = Mooring Services Cost

Fr = Fixed Rates (Rp. 116,- GT/etmal)

GT = Gross Tonnage

Etmal = (1 etmal = 24 hour)

II.3.1.3 Usage Cost

Usage cost are those costs incurred for insurance, labor costs and maintenance. Usage costs can be considered as more or less fixed with respect to the vessel's speed (Meyer 2012). For the sake of simplicity, in this thesis are assumed fixed usage cost (does not depend on the speed of ship).

II.3.2 Vessel Income

Vessel income is the amount of money received by shipping company from their activities of carrying out the delivery services to customers. To calculate the vessel income by multiplying the freight rate with a maximum transport performance. In this thesis assumed vessel capacity is fully utilized. The formula used to calculate the vessel income are (Meyer 2012):

I_V = $\sum Ƥ_{FR,i} \cdot F_S$ ....(2.9)

Where;

I_V = Vessel Income

$Ƥ_{FR,i}$ = Freights Rates

F_s = Service Performance

Ship transport performance has become a critical aspect of ship's operation. In determining service performance is required effective capacity or the actual usable cargo space which is further multiplied by the maximum number of roundtrips during the operation time period. The formula used to calculate the service performance are (Meyer 2012):

F_s = $cap_{eff} \cdot f_T$

F_s = $cap_{eff} \cdot T_O / (T_H + T_S)$ ....(2.10)

Where;

F_s = Service Performance

cap_{eff} = Effective Capacity (ρ = 0,87)

f_T = Maximum Number of Roundtrips
T_O = Operating Time
T_H = Harbor Waiting Time
T_S = Sea (Shipping) Time

II.4 Air Pollution

Marine transportation, especially those use motor as the engine driving, is one source of air pollution. Pollution or air pollution is the mixing of substance, energy or other components into the atmosphere or changing composition of the air by human activities or natural processes, so that the air quality drops to a certain level which causes air to be less or may not work according the puRp.ose (MENKLH 1988).

In Indonesia today approximately 70% of air pollution caused by vehicle emissions that produce harmful substances that can cause negative effects, both to human health and the environment (Sugiarti 2009). Burning of fossil fuels produces carbon dioxide, nitrogen oxide, and sulfur dioxide compounds. The sources of emissions and the effects on environment are listed in the Table 2.2.

Tabel 2.2 Emissions of fuel combustion and the effect on environment

Emission	Source	Influence
Carbon dioxide (CO_2)	Perfect burning of carbon fuels	Global warming
Nitrogen oxide (NO_x)	By-product of most combustion processes	Acid rain
Sulfur dioxide (SO_2)	Fuel burning that contain sulfur	Smoke/fog, acid rain

Reference: Pinontoan 2012

II.4.1 Carbon Dioxide (CO_2)

Carbon dioxide is basically a natural product of a combustion reaction. Burning fossil fuels become the main source emitters of CO_2 in the earth (Kamal 2015). CO_2 is produced from gas which comprises one carbon atom and two oxygen atoms. Here is the reaction (Jaya 2014):

$C + O_2 = CO_2$

II.4.2 Nitrogen Oxide (NO_x)

Nitrogen oxide (NO_x) are gas compound contained in the air (atmosphere) which is largely composed of nitric oxide (NO) and nitrogen dioxide (NO_2) as well as various types of oxides in smaller amounts (Kamal 2015). Here is the reaction (Jaya 2014):

$N_2 + O_2 = 2NO$
$2NO + O_2 = NO_2$

II.4.3 Sulfur Dioxide (SO_2)

Sulfur dioxide is one type of sulfur oxide gases (SO_x). SO_2 is formed during a combustion of fossil fuels containing sulfur (Kamal 2015). Sulfur contained in almost all the crude material that unprocessed such as crude oil, coal and ores containing metals such as aluminum, copper, zinc, lead and iron (Yuligawati 2014). SO_2 formation mechanism can be written as follows (Wardhana 2001):
$S + O_2 = SO_2$

II.5 Calculation of Ship Emissions

CO_2 emissions are increasingly showing an increase from year to year, so it needed a strategy to reduce emissions. One of the strategy is apply slow steaming method. The advantage of slow steaming is to decrease the amount of CO2 emissions that are proportional with the amount of fuel combustion (Cariou 2011). To calculate an estimate of the ship's emissions, it can use the method of Puget Sound Maritime Air Emission Inventory that published in 2012. The formula used to calculate the emissions from the engine are (Puget Sound Maritime Air Emission Inventory 2012):

E = Energy x EF x FCF..(2.11)

Where;
E = Emissions from the engine
Energy = Energy demand (kWh)
EF = Emission factor (g/kWh)
FCF = Fuel Correction Factor

II.5.1 Energy

Energy output of the engine over the period of time. To calculate the energy can be used formula as follows (Puget Sound Maritime Air Emission Inventory 2012):

Energy = MCR x LF x A ....(2.12)

Where;
Energy = Energy output of the engine over the period of time (kWh)
MCR = Maximum continuous rated engine power (kW)
LF = Load factor
A = Activity (hours)

II.5.2 Load factor (LF)

Load factor is expressed as the ratio of a vessel's power output at a given speed to the vessel's MCR power. To calculate the load factor can be used formula as follows (Puget Sound Maritime Air Emission Inventory 2012):

LF = $(Speed_{Actual} / Speed_{Maximum})^3$..(2.13)

Where;

LF =load factor

$Speed_{Act}$ = actual speed (knots)

$Speed_{Max}$ = maximum speed (knots)

II.5.3 Activity

Time in mode or activity is measured in hours of operation. To calculate the activity can be used formula as follows (Puget Sound Maritime Air Emission Inventory 2012):

A = D / $Speed_{actual}$. ....(2.14)

Where;

A = activity (hours)

D = distance (nautical miles)

$Speed_{Act}$= actual ship speed (knots)

II.5.4 Emission Factors (EF)

The emission factors are listed by model year for slow and medium speed engines on the Table 2.3 and Table 2.4

Tabel 2.3 Fuel Correction Factors for NOx and SO2

Engine	Model Year	NO_x	SO_2
Slow Speed Diesel	≤ 1999	18.1	10.5
Medium Speed Diesel	≤ 1999	14.0	11.5
Slow Speed Diesel	2000-2010	17.0	10.5
Medium Speed Diesel	2000-2010	13.0	11.5
Slow Speed Diesel	2011-2015	14.4	10.5
Medium Speed Diesel	2011-2015	10.5	11.5
Gas Turbine	All	6.1	16.5
Steamship	All	2.1	16.5

Reference: Puget Sound Maritime Air Emission Inventory 2012

Tabel 2.4 Fuel Correction Factors for CO2

Engine	Model Year	CO_2
Slow Speed Diesel	All	620
Medium Speed Diesel	All	683
Gas Turbine	All	970
Steamship	All	970

Reference: Puget Sound Maritime Air Emission Inventory 2012

II.5.5 Fuel Correction Factors (FCF)

Fuel correction factors are used to account for variations in fuel parameters between different types of fuel, so these variations can be accounted for in the emission estimates. Can be seen in the table 2.5 lists the fuel correction factors.

Tabel 2.5 Fuel Correction Factors

Fuel Used	NO_x	SO_2	CO_2
HFO (2.7 % S)	1	1	1
HFO (1.5 % S)	1	0.555	1
MGO (0.5 % S)	0.94	0.185	1
MDO (1.5 % S)	0.94	0.555	1
MGO (0.1 % S)	0.94	0.037	1
MGO (0.3 % S)	0.94	0.111	1
MGO (0.4 % S)	0.94	0.148	1

Reference: Puget Sound Maritime Air Emission Inventory 2012

II.6 Multiple Criteria Decision Making (MCDM)

Multiple criteria decision making is a decision making method to establish the best alternative from a number of alternatives based on certain criteria. The criteria usually measures or rules or standards used in decision making. In general, it can be said that the MCDM selecting the best alternative from a number of alternatives. (Kusumadewi et al, 2006). For solve multiple criteria decision making problem, there are five basic method:

a. Simple Additive Weighting Method (SAW)
b. ELECTRE
c. Weighted Product (WP)
d. Analytic Hierarchy Process (AHP)
e. Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

In this thesis, will using AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method to solve the decision making problem. The reasons for using TOPSIS method are conceptually simple, efficiency computational process that can be easily programmed into a spreadsheet and has the ability to measure relative performance of the alternatives in decision of a simple mathematical form (Murnawan & Siddiq 2012). Another advantage of TOPSIS method are have sound logic that represents rationale of human choice and has proven to be one of the best methods for dealing with ranking issue (Sarraf et al, 2013). However on TOPSIS method, there are no formula to calculate weight of criteria, so that TOPSIS method needs another method to help weighting part in this process. So AHP method will be used on this thesis for weighting criteria then the weight of criteria will be used for deciding the best alternative with TOPSIS method.

II.6.1 Analytic Hierarchy Process (AHP) Method

AHP is a method has been developed by Thomas L. Saaty since 1970 and still developing until now. The advantages of this method is AHP gives us comprehensive hierarchy to solve the problem. The AHP simplifying complex problems into a hierarchy.

AHP method lets many people or group to build an idea and give definition for the problems to solve them. While for AHP method the weight of every component (criteria and alternatives) should know before. The weight of criteria will show us, how important every components each other. For weighting the component, this Saaty scale with 1-9 as the range number will use:

Tabel 2.6 Saaty's Fundamental Scale

Scale	Comparison of i and j factor
1	Equally important
3	Weakly important
5	Strongly important
7	Very strongly important
9	Extremely important
2,4,6,8	Intermediate value adjacent scales

Then, the matrix of comparison can make based on the Saaty scale. First, we have to make some questionnaire to collecting some data of some decision maker. In the questionnaire, the Saaty scale using for comparing either a pairwise of criteria or alternatives.

II.6.2 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) Method

TOPSIS method is a decision-making techniques from several alternative options available. TOPSIS aims to determine the positive ideal solution and negative ideal solution. Can be seen in Figure 2.4, there are two criteria goals namely positive ideal solution to maximize the benefits criteria and minimize the cost criteria, while the negative ideal solution to maximize cost criteria and minimize benefit criteria.

Benefits criteria is the criteria when the value of these criteria more greater, so these criteria is more feasible as well to been selected. While the cost criteria is opposite of the criteria benefits, the smaller value of these criteria will be more feasible to been selected.

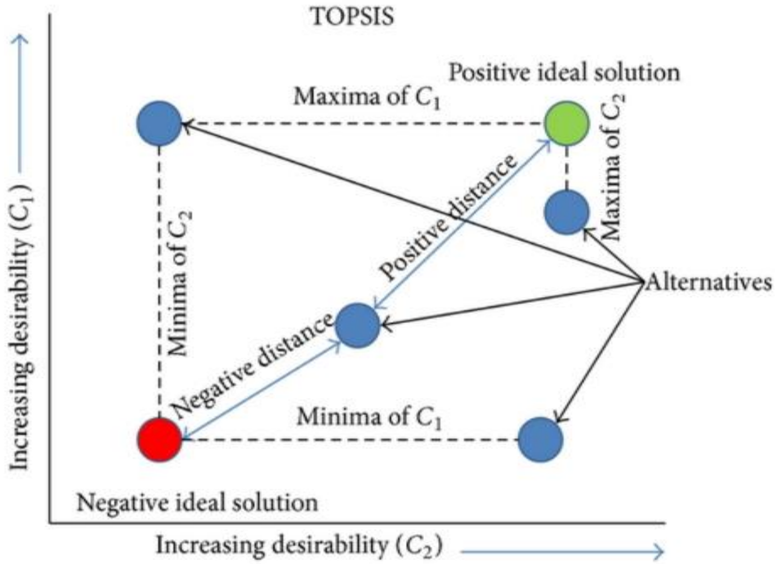


Figure 2.4 Illustration of distance to positive ideal solution and negative ideal solution
Reference: Chauhan & Vaish 2013

In TOPSIS method, the optimal alternative is closest to the positive ideal solution and farthest from the negative ideal solution. Based on Rahman, A. (2012), TOPSIS method can be expressed as Table 2.7, where A is an alternative that can be selected by the shipping company and C is the evaluation criteria that can be measured. While X is a value indicating the working rank of each alternative against the criteria.

Tabel 2.7 A decision matrix form in TOPSIS method

	C_1	C_2	...	C_n
A_1	x_{11}	x_{12}	...	x_{1n}
A_2	x_{21}	x_{22}	...	x_{2n}
A_m	x_{m1}	x_{m2}	...	x_{mn}

Steps to solve a problem using TOPSIS method are as follows:

a. Describe the alternatives and the criteria into a matrix, where Xij is a measurement of choice of alternatives to i and j criteria (Lotfi et al. 2011):
$$D = \begin{bmatrix} X_{11} & X_{12..} & X_{13} \\ X_{21} & X_{22..} & X_{23} \\ X_{i1} & X_{i2..} & X_{i3} \end{bmatrix} \quad (2.15)$$

b. Make matrix D that is normalized decision matrix. Every normalization of the r_{ij} values can be done by calculation using the following equation.
$$r_{ij} = \frac{x_{ij}}{\sqrt{\Sigma_{i=1}^{m} x_{ij}^2}} \quad (2.16)$$

c. Make weighting on the normalized matrix. After normalized, each column of the matrix D multiplied by the criteria weight (W_i) to produce matrix.
$$y_{ij} = W_i . r_{ij} \quad (2.17)$$

d. Determining the value of a positive ideal solution (PIS) and negative ideal solution (NIS). The ideal solution is denoted A+, while the negative ideal solution denoted A-. The equation for determining the ideal solution can be seen in the following equation.
$$A^+ = y_1^+, y_2^+, \ldots, y_j^+ \quad (2.18)$$
$$A^- = y_1^-, y_2^-, \ldots, y_j^- \quad (2.19)$$
Where;
J^+ = {j=1,2,3,...,n and j is benefit criteria}
J^- = {j=1,2,3,...,n and j is cost criteria}

e. Calculating separation measure. Separation of this measure is measuring the distance of an alternative to the positive ideal solution and the negative ideal solution.

$D_i^+ = \sqrt{\Sigma_{i=1}^{n}(y_i^+ - y_{ij})^2}$ ....(2.20)

$D_i^- = \sqrt{\Sigma_{i=1}^{n}(y_{ij} - y_i^-)^2}$ ....(2.21)

Where;

i = 1,2,3,....,m

f. Calculating the value of preference for each alternative. To determine the ranking of each alternative it is necessary to first calculated preference value of each alternative.

$V_i^+ = \frac{D_i^-}{D_i^+ + D_i^-}$ ....(2.22)

Where;

$0 < V_i^+ < 1$

i = 1,2,3,....,m

After the value of V_i^+ obtained, then alternatives can be ranked based on the sequence V_i^+. From the results of this ranking can be seen best alternative that is an alternative that has the shortest distance from the ideal solution and is furthest from the negative ideal solution.

CHAPTER III

RESEARCH PROCESS

III.1 General

Based on the statement of problems, the methodology has been arranged. Methodology has function to make this research can be done easily. Methodolgy show us the steps of all process in this bachelor thesis.

III.2 Flow Chart

For this bachelor thesis, the methodology will be devided into two flowcharts. They are general flowchart and selection flowchart. General flowchart show us the general step of this research, then the following is selection flowchart to show us the step of selection process.

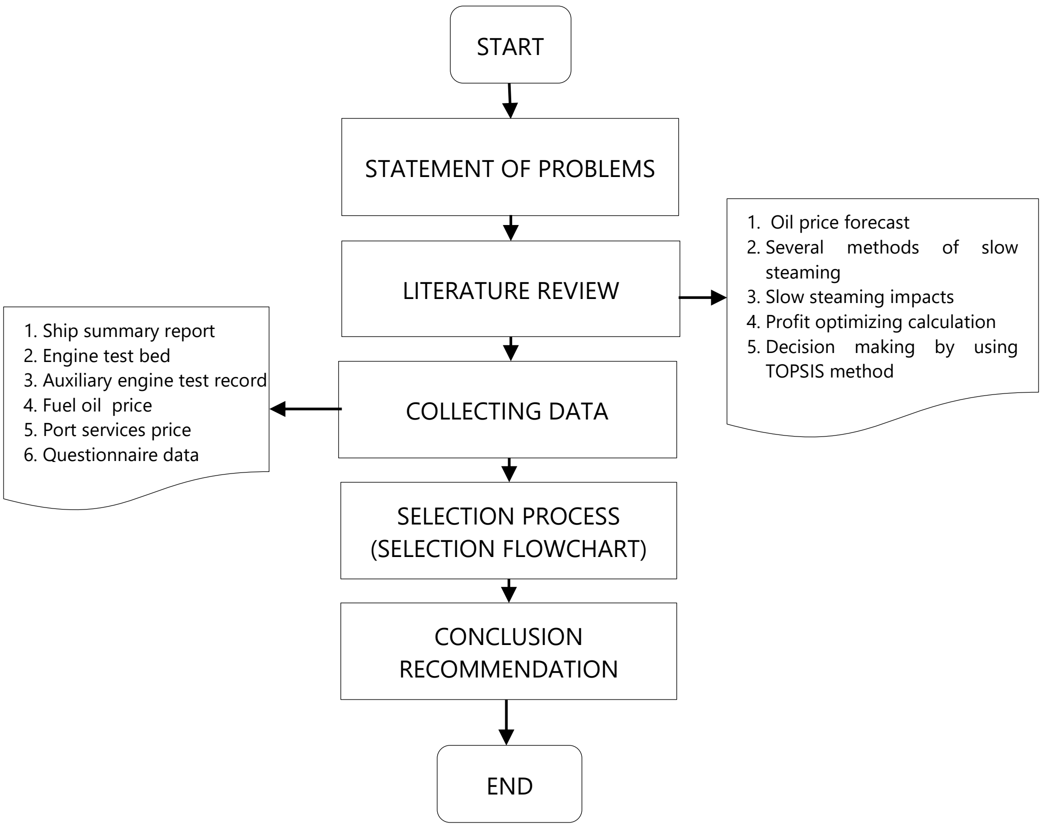


Figure 3.1 General Flowchart

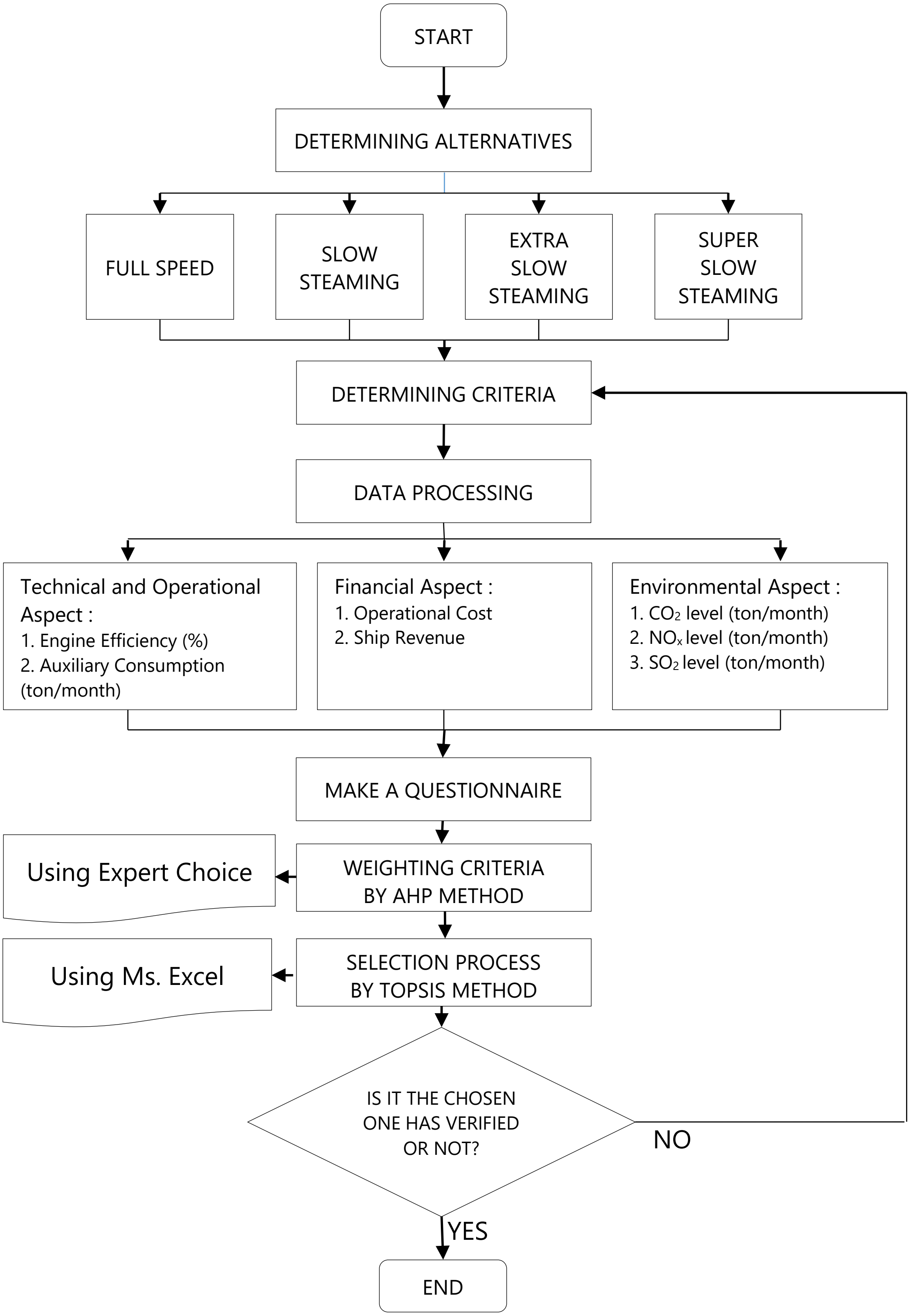


Figure 3.2 Selection Flowchart

Based on the general flowchart, we can describe all of steps as below:

1. **Statement of Problems**
   Identifying the problems is to determine what problem formulation to be taken. Formulation of the problem is an early stage in the implementation of the final project. This stage is a very important stage, which at this stage is why there is a problem that should be solved so worthy to be used as ingredients in the final work. Problem formulation is done by digging information about problems that occur at this time. From this stage, the purpose of why this thesis done is knowable.

2. **Literature Review**
   Once a problem is already known, the next step is to collect reference materials related to the final project from many sources about oil price forecast, correlation between ship speed, required engine power and fuel consumption, several methods of slow steaming, slow steaming impacts on ocean carriers and shippers, profit optimizing calculation, decision making by using TOPSIS method and weighting by using AHP method. Those references taken from:
   a. Paper
   b. Text Book
   c. Bachelor Thesis
   d. Article
   e. Information from the internet

3. **Data Collection**
   To support the thesis, needed to collect some ship operational data and also various cost for the ship operational. The detail of data will mention below:
   f. Ship particular
   g. Engine test bed
   h. Ship summary report
   i. Auxiliary engine test record
   j. Fuel oil price
   k. Port services price
   l. Questionnaire data

4. **Data Processing**

   At this stage there are three points which should have done to process the data and will be analysed, there are:

   a. Calculating the main engine efficiency.
   b. Calculating the auxiliary consumption (ton/month).
   c. Calculating the amount of operational cost.
   d. Calculating the amount of ship revenue.
   e. Calculating the amount of carbon dioxide emissions (ton/month) that generated by the ship.
   f. Calculating the amount of nitrogen oxide emissions (ton/month) that generated by the ship.
   g. Calculating the amount of sulfur dioxide emissions (ton/month) that generated by the ship.
   h. Questionnaire data processing.

5. **Selection Decision**

   The selection process doing by two selection methods, these are AHP and TOPSIS. The AHP method using for weighting the criteria by using expert choice software. Then the TOPSIS method used for selecting the most optimal speed. These are some questions that will use for determining the criteria:

   a. How much the engine efficiency when applying slow steaming on ship engines?
   b. Is slow steaming can lower ship operating costs?
   c. How much fuel consumption for main engine can be reduced by slow steaming?
   d. How much fuel consumption for auxiliary engine can be reduced by slow steaming?
   e. By applying slow steaming, can it reduce the amount of cargoes delivered in a month?
   f. How big the effect of slow steaming on ship emission reduction?

6. **Results of the Selection Decisions Based on Highest Ranked**

   At this stage, the analysis of data which has calculated to find the most effective method for ship speed decision by choosing the highest ranking in the selection.

7. **Conclusion and Recommendation**

   The final step is to make the conclusion that the whole process has been done before as well as provide answers to existing problems. The recommendation given based on the results of the analysis on which to base the next research, either directly related to this research or on the data and methodology that will be referenced.

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CHAPTER IV

DATA ANALYSIS

In chapter IV will contain the analysis and discussion of decision-making process to determine the optimal speed of the ship, based on the data obtained. The data required to do this thesis are ship summary report, engine test bed, main engine and auxilary engine project guides and ship particulars. These data are necessary for the calculations of each criteria in determining the most optimal ship speed.

After getting all data that will be used in the process of this thesis, then the next step is to calculate value of the sub-criteria to each load engine. After getting value for each sub-criteria can be continued by selecting the most optimal speed of ship. Selection of these speed will be conducted by using TOPSIS method.

In accordance with the formulation of the problem that had been predetermined, the subject is in this thesis include:

a. Determine the speed alternative.
b. Determine the criteria and sub-criteria that can be used in the selection of the most optimal speed.
c. Data collection process of all the criteria and sub-criteria.
d. Calculate the value on each criteria in determining the most optimal ship speed.
e. Performing the weighting vector calculation process using pairwise comparison.
f. Ranking the preference order of all the alternatives using the TOPSIS method.

IV.1 Deciding Criteria for Selection of Ship Speed

TOPSIS is one of method to select some alternatives based on same criteria. For this case, the criteria divided into 3 criteria and 7 sub-criteria. These criteria have to decide carefully, because the criteria will influence the selected alternative mostly.

The characteristic of every speed that selected as the alternative and the alternative have to understand well including how it work. So, the criteria can determined well. For this case, the criteria decide based on the study literature of paper review. The criteria devided into technical and operational aspect, financial aspect and also environmental aspect. Each group of the criteria has its associated sub criteria. All the criteria and sub-criteria will simplify the TOPSIS method to achieve the goal that is selecting the most efficient ship speed. There are two possible goals for each sub criteria which are benefit or cost goal. The benefit goal are sub criteria that are profitable or advantageous such as a vessel's profits, while the cost goal are sub criteria that are disadvantageous such as the amount of emissions incurred by ship engine. Detail explanation of these will describe in Table 4.1 (Rahman 2012):

Table 4.1 The list of criteria and sub-criteria associated with the goal

Main Criteria	Sub Criteria	Goal
Technical and Operational Aspect	Engine Efficiency	Benefit
	Auxiliary Consumption	Cost
Financial Aspect	Operational Cost	Cost
	Ship Revenue	Benefit
Environmental Aspect	Carbon Dioxide (CO_2)	Cost
	Nitrogen Oxide (NO_x)	Cost
	Sulfur Dioxide (SO_2)	Cost

Here is an explanation of each of the criteria and sub-criteria in table 4.1 are used in the selection of the ship's speed. This explanation is also included in the questionnaire so that the respondent be able more easily in providing an assessment in the questionnaire.

1. Technical and Operational Aspect

Which is the speed considerations that can work most optimally. The following sub criteria in the technical and operational aspect:

a. Engine Efficiency

Decreased engine efficiency due to low load operation of the engine. The efficiency of a machine is a measure of how well a machine can convert available energy from fuel to mechanical output energy.

b. Auxiliary Consumption

With increasing shipping time because the speed reduction will have an impact on the amount of fuel consumed by the auxiliary machinery.

2. Financial Aspect

Costs become a very important component for the management of companies involved in the implementation of activities to accomplish goals, including the ship's speed decisions. The following sub-criteria in financial calculations:

a. Operational Cost

Operational costs are the costs associated with the cost to run the operational aspects of the ship in order that the ship is always in a condition ready to sail.

Costs are included in ship operating expenses are fuel cost, lubricant cost and also port cost.

b. Ship Revenue

Fee income earned from the shipment of goods from the origin port to destination port. The negative impact of the engine load reduction will cause reduced of the ship revenue.

3. Environmental Aspect

Environmental aspect is a consideration the effect from ship emissions on the surrounding environment. The following sub criteria of environmental aspects were taken into consideration in measuring the emissions caused by the combustion of fuel:

a. Carbon Dioxide (CO_2)

Carbon dioxide emissions during voyage activity is caused by fuel combustion in the engine of the ship. The amount of carbon dioxide levels can result in causing the hot air trapped on earth and eventually becomes hot environment.

b. Nitrogen Oxide (NO_x)

Nitrogen oxide compounds come from the combustion of the fossil fuels. The air has been polluted by nitrogen oxide gas is not only harmful to humans and animals, but also dangerous for the life of the plant.

c. Sulfur Dioxide (SO_2)

Sulfur dioxide compounds formed during a combustion of fossil fuels containing sulfur. High levels of Sulfur dioxide in the air is one of the causes of acid rain.

IV.2 The Alternative

The alternative was determined based on the literature study. From the literature study that have been described before (Rahman 2012; Zanne et al. 2013), there are four alternative speed of the ship which will be evaluated to choose the method most appropriate speed. The four methods are:

a. Full speed

Full speed is the maximum speed of the ship that has been designed by engine manufacture (Rahman 2012). The engine load at full engine speed conditions is 100% of engine load.

b. Slow steaming

Slow steaming is process of reducing the speed of cargo ships to save money on fuel consumption and also cut down the emissions that produced by the engine. The operation of slow steaming is below the normal speed capacity that has been designed by engine manufacture, about 15% from normal load (Zanne et al. 2013).

c. Extra slow steaming

Extra slow steaming is process of reducing the speed of cargo ships to save more money on fuel consumption and also cut down the emissions that produced by the engine. The operation of extra slow steaming below the slow steaming speed capacity, about 25% from normal load (Zanne et al. 2013).

d. Super slow steaming

Super slow steaming method also known as economic speed because it has a very significant change on fuel saving. Super slow steaming can use for higher reductions in operational ship speed (Zanne et al. 2013). In this thesis the operation of super slow steaming is 50% from the full load.

IV.3 Ship Data Identification

In this discussion, the ship data that used as a calculation to determine the decision-making is a container ship owned by PT. Meratus Line, with the name MV. Meratus Medan 1. The following are various data required for a calculation, such as ship particular, engine test bed, ship summary report, and also auxiliary engine test record.

IV.3.1 Ship Particular

Table 4.2 Ship Particular

Ship's Name	MV. MERATUS MEDAN 1
Flag / Port of Registry	Indonesia / Surabaya
Owner	PT. Meratus Line
Built	Japan, 1996
Kind of Ship	Container Ship
L.O.A.	161,85 M
Draft	8,92 M
Pitch Propeller	4,789 M
Gross Tonnage	13853 Tons
DWT	17476
Vs	18,5 Knots
Main Engine	Hitachi B&W 7S50MC
Auxiliary Engine	Yanmar M220AL-UN X

Source: PT. Meratus Line

The above data are ship particular or a document containing information about the owner of the ship, year of the ship, ship draft, the amount of gross tonnage, the amount of ship length overall, service speed, main engine series and auxiliary engine series. This data was taken from the PT. Meratus Line.

IV.3.2 Engine Test Bed

Engine test bed is a test result of an engine which contains engine revolutions per minute (RPM) and fuel consumption. Furthermore, the engine test bed is used to find the engine speed and fuel consumption at each load. Table 4.3 contains engine test bed from MV. Meratus Medan 1 that obtained from PT. Meratus Line.

Table 4.3 Engine Test Bed

Load (%)	50%	75%	85%	100%
Power (KW)	4994	7491	8498,8	9988
Engine Speed (RPM)	115,3	115,3	120,37	127,14
FO Consump. (kg/h) MGO	1276,9	1276,9	1445,7	1739,8

Source: PT. Meratus Line

IV.3.3 Ship Summary Report

Ship summary report is a report that containing operational data such as the number of vessel routes, voyage distance, voyage time, anchorage time, activity time port and total mass of cargo for one month. Here is a list of activities MV. Meratus Medan 1 owned PT. Meratus Line for one month, in February 2017.

Table 4.4 Ship Summary Report

Vessel Route	**Total Manouvering**		**Sea Passage (BOSV to EOSV)**		**Anchorage Time (hours)**	**Port Activity Time (hours)**	**Total Mass of Cargo (Tons)**
	Distance (NM)	**Time (hours)**	**Distance (NM)**	**Time (hours)**			
SUB-JKT	25	2,4	377	266,6	0	22,9	5712
JKT-SUB	4	0,9	372	24,1	33,3	27	6644
SUB-BIT	25	2,7	1066	70,5	0	42,1	11388
BIT-GTO	12	0,7	197	13,3	1,4	52	8433
GTO-SUB	3	0,8	863	58,6	8,5	117,3	8708
SUB-JKT	24	2,8	375	24,4	3,9	12,6	5314
JKT-SUB	4	0,6	376	24,7	17,1	35,3	6797
TOTAL	97 NM	11 hrs	3626 NM	242 hrs	64 hrs	309 hrs	52996 Tons

Source: PT. Meratus Line

IV.3.4 Auxiliary Engine Test Record

Table 4.5 contains auxiliary engine test records data such as the amount of output (kW) and SFOC (gr/kWh) at each load that carried out on 21 May 1996. The series of the auxiliary engine in MV. Meratus Medan 1 is Yanmar M220AL-UN X.

Table 4.5 Auxiliary Engine Test Report

Load (%)	Time (H.M. - H.M.)	Output (kW)	SFOC (gr/kWh)
25	09.00-09.20	170	274
50	09.20-09.40	340	219,2
75	09.40-10.00	510	209,5
100	10.00-10.30	680	202,8

Source: PT. Meratus Line

V.3.5 Ship Speed Calculation

Before calculating the value of each sub criteria, It should be first complete the various data required, such as the ship speed at each load and also the length of sailing time that ship needed to sail at each speed. To calculate the engine speed at each load are by using the following formula:

Speed $= \frac{(\text{Pitch x RP.M x 60})}{1852}$

Where,

Pitch = The distance a propeller would move in one revolution

RPM = (Revolutions Per Minute) The number of rounds done in a minute

The result of the calculation speed of the ship at each load by using the above formula are obtained in Table 4.6.

Table 4.6 Ship Speed Calculation

Load %	**50%**	**75%**	**85%**	**100%**
Power (KW)	4994	7491	8489,8	9988
Engine Speed (RPM)	100,87	115,30	120,37	127,14
Speed (knot)	15,65	17,89	18,68	19,73

IV.3.6 Sailing Time Calculation

To calculate the length of sailing time in this thesis is done by dividing the distance of the voyage at speeds at each load engine. The data below are seven routes voyage on MV. Meratus Medan 1 in February 2017 via Jakarta, Surabaya, Bitung and Gorontalo.

Table 4.7 Sailing Time Calculation

Vessel Route	Distance (NM)	SSS	ESS	SS	FS
		15,65 knot	17,89 knot	18,68 knot	19,73 knot
SUB-JKT	377	24,09	21,07	20,19	19,11
JKT-SUB	372	23,77	20,79	19,92	18,86
SUB-BIT	1066	68,11	59,59	57,08	54,04
BIT-GTO	197	12,59	11,01	10,55	9,99
GTO-SUB	863	55,14	48,24	46,21	43,75
SUB-JKT	375	23,96	20,96	20,08	19,01
JKT-SUB	376	24,03	21,02	20,13	19,06
TOTAL (hours)		231,7	202,7	194,2	183,8

It can be seen in the table above that slow steaming greatly affects the amount of shipping time by adding time up to 100 hours from normal operational time. After getting the value of sailing time on each engine load, then the next will be calculated auxiliary consumption, service performance and bunker consumption at each engine load.

IV.4 Sub-Criteria Calculation

After obtaining the required data to calculate each sub criteria value, the next step is to calculate the value of all sub criteria that have been determined on each alternatives that are engine efficiency, auxiliary consumption, operational cost, ship revenue, carbon dioxide, nitrogen oxide and sulfur dioxide.

IV.4.1 Engine Efficiency Calculation

To calculate the percentage value of engine efficiency, needed SFOC (specific fuel oil consumption) data at each load using the formula:

$$\eta = \frac{P_{out}}{P_{in}} x \ 100\%$$

Where,

η = Efficiency (%)

P_{out} = Output power

P_{in} = Input power

In this calculation, the value of the output power used is 1 KW. So the efficiency formula used to calculate the percentage value of the engine efficiency are the amount of energy required by the engine to produce 1 KW output. To get the engine efficiency value by calculating the following steps:

a. Calculating the input power

In this calculation using 50% engine load that requiring 180 g/kWh of SFOC. However, the SFOC in the data using marine gas oil (MGO), but while sailing MV. Meratus Medan 1 using heavy fuel oil (HFO), then it should be changed first by using HFO heating value, amount 41.00 kJ/kg. Here is an example of the calculation:

Power In = $\frac{200\ gr/kWh}{1.000}\ x\ 41.000\ kJ/kg$

= $\frac{0,2\ kg/kWh\ x\ 41.000\ kJ/kg}{3.600}$

= 2,05 kJ/sec

= 2,05 KW

b. Calculates engine efficiency

By comparing between 1 KW of output power with the input power that has been calculated before, and then multiplied by 100%. Here is an example of the calculation:

$\eta \quad = \frac{P_{out}}{P_{in}}\ x\ 100\%$

= $\frac{1\ KW}{2,05\ KW}\ x\ 100\%$

= 48,8%

From the above calculation can be concluded that to produce 1 KW output power required 2,05 KW of input power. While the percentage value of the engine efficiency when the load condition 50% is 48,8%. By calculating as the same steps in the above calculation, Table 4.8 contains the percentage value of engine efficiency on each engine load.

Table 4.8 Engine Efficiency Calculation

	SSS	**ESS**	**SS**	**FS**
Load	50%	75%	85%	100%
Power (KW)	4994	7491	8489,8	9988
FO Consump. (kg/h) MGO	876,6	1276,9	1445,7	1739,8
FO Consump. (kg/h) HFO	962,1	1401,5	1586,7	1909,5
SFOC (g/KWh) MGO	180	174,03	173	176
Input Power (KW)	2,05	1,98	1,97	2,00
Efficiency Engine (%)	48,8	50,5	50,8	49,9

Can be seen the calculation results in the table above, the largest engine efficiency is at the time of slow steaming or 85% load from the normal load that is equal to 50.8%.

IV.4.2 Auxiliary Consumption Calculation

To calculate the total of auxiliary engine fuel consumption for each engine load are by using the following formula:

FC = P x SFOC x t

Where,

FC = Fuel Consumption

P = Power developed in kilowatt

SFOC = Specific fuel oil consumption (gr/kwh)

t = Auxiliary engine operation time

When sailing conditions, auxiliary engine load is at 75%. The first step to calculate the consumption of auxiliary engines in February 2017 by multiplying the number of auxiliary engine output at 75% load with the specific fuel oil consumption (SFOC) on the auxiliary engine test record and also by multiplying with the total time spent when shipping and at port.

Table 4.9 Auxiliary Consumption Calculation

	SSS	ESS	SS	FS
Shipping time (hours)	231,7	202,7	194,1	183,8
Port Time (hours)	384	384	384	384
1 AE. FC (g/month)	65783749,65	62684151,88	61768307,09	60664565,66
2 AE. FC (g/month)	131567499,3	125368303,8	123536614,2	121329131,3
FC (ton/month)	131,57	125,37	123,54	121,33

IV.4.4 Operational Cost

Operational cost of the ship as a cost related with the cost of operating for operational aspects. Operational costs consist of only fixed costs and not variable costs, which are actually depending on the length of time the ship sailed. Fixed cost of the vessel, which is the cost that ship owner should spend to make the ship ready to sail, such as port cost and bunker fuel costs. So the total cost of ship operations in this thesis are the total port cost that visited for one month then summed with total fuel cost to be spent for the sailing for one month.

IV.4.4.1 Port Cost

In this thesis the port cost calculation using two port pricing reference. For the port of Tanjung Priok and port of Tanjung Perak are using port of Tanjung Perak rates because it is assumed to be the same as including part of Pelindo III. Whereas for the port of Bitung and port of Gorontalo are using port of Makassar rates because it is assumed to be the same as including part of Pelindo IV. For rate service at port of Tanjung Perak Surabaya and rate service at port of Makassar are contained on Attachment A. at the end of this thesis.

To get the total port cost is by summing the rate of anchorage service, pilotage services, tugboat services and mooring services at each ports. As for the time of anchorage and port activity are contained in Table 4.10. Then in the calculation of port cost for MV. Meratus Medan 1 in February 2017 there are 7 ports that visited are :

a. Port of Jakarta (1701S/SUB-JKT)
b. Port of Surabaya (1702N/JKT-SUB)
c. Port of Bitung (1702N/SUB-BIT)
d. Port of Gorontalo (1702S/BIT-GTO)
e. Port of Surabaya (1702S/GTO-SUB)
f. Port of Jakarta (1702S/SUB-JKT)
g. Port of Surabaya (1703N/JKT-SUB)

Table 4.10 Port activities summary report in February 2017

No.	Voyage Number	Vessel Route	Port	Anchorage Time (hours)	Port Activity Time (hours)
1	(1701S/SUB-JKT)	SUB-JKT	Port of Jakarta	0	22,9
2	(1702N/JKT-SUB)	JKT-SUB	Port of Surabaya	33,3	27
3	(1702N/SUB-BIT)	SUB-BIT	Port of Bitung	0	42,1
4	(1702S/BIT-GTO)	BIT-GTO	Port of Gorontalo	1,4	52
5	(1702S/GTO-SUB)	GTO-SUB	Port of Surabaya	8,5	117,3
6	(1702S/SUB-JKT)	SUB-JKT	Port of Jakarta	3,9	12,6
7	(1703N/JKT-SUB)	JKT-SUB	Port of Surabaya	17,1	35,3

Source: PT. Meratus Line

1. Port of Jakarta (1701S/SUB-JKT)

The following table is the calculation for port cost at Port of Jakarta, at the time of voyage route from Surabaya to Jakarta with voyage number 1701S/SUB-JKT. From the data available in the MV. Meratus Medan 1 summary report data, mentioned that the time for anchorage at the port of

Jakarta is 0 hour then no anchorage service fee. While the length of time for mooring services is 22.9 hours which means included in 1 etmal (1 etmal = 24 hours). For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area. While for the tugboat services use 2 units of tugboat for 1 hour.

Table 4.11 Calculation of cost at Port of Jakarta (1701S/SUB-JKT)

1. Anchorage Services			
Rates	Rp. 112,00	GT/10 days	
			Rp. -
2. Pilotage Services			
Fixed Rates	Rp. 225.000	ship/movement	Rp. 900.000
Variable Rates	Rp. 45	GT/movement	Rp. 2.390.580
Total	(225.000 x 4 + (45 x 13281 x 4)) x 2		Rp. 6.581.160
3. Tugboat Services			
Fixed Rates	Rp. 1.443.149,00	unit / hour	Rp. 2.886.298,00
Variable Rates	Rp. 30,00	GT/hour	Rp. 398.430,00
	(1.443.149 x 2unit x1hour+(30 x 13281 x 1)x2		Rp. 6.569.456
4. Mooring Services			
Rates	Rp. 116	GT/Etmal	
	116 x 13281 x 1		Rp. 1.540.596
TOTAL			**Rp. 14.691.212**

Can be seen the port services cost calculation in the table above, the total port cost at port of Tanjung Priuk Jakarta is Rp. 14.691.21 . The total cost in port of Tanjung Priuk Jakarta is the total sum of pilotage service Rp.6.581.160, tugboat service Rp. 6.569.456 and mooring service RP.6.569.456 while for anchorage service there is no anchorage service in this voyage.

2. Port of Surabaya (1702N/JKT-SUB)

As for the second voyage is in the port of Tanjung Perak Surabaya, with the voyage route from Jakarta to Surabaya. The price used is the port of Tanjung Perak Surabaya tariff. From the existing data, mentioned that the time for anchorage at the port of Surabaya is 33,3 hours means only 2 days with a price of Rp. 112,00 GT/10 days. While the length of time for mooring services is 27 hours which means included in 2 etmal (1 etmal = 24 hours) with a price of Rp. 116,00 GT/etmal. For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area. While for the tugboat services use 2 units of tugboat for 1 hour. The following table is the calculation for port cost at Port of Surabaya:

Table 4.12 Calculation of cost at Port of Surabaya (1702N/JKT-SUB)

1. Anchorage Services			
Rates	Rp. 112,00	GT/10 days	
	112 x 13281		Rp. 1.487.472
2. Pilotage Services			
Fixed Rates	Rp. 225.000	ship/movement	Rp. 900.000
Variable Rates	Rp. 45	GT/movement	Rp. 2.390.580
Total	(225.000 x 4 + (45 x 13281 x 4)) x 2		Rp. 6.581.160
3. Tugboat Services			
Fixed Rates	Rp. 1.443.149,00	unit / hour	Rp. 2.886.298,00
Variable Rates	Rp. 30,00	GT/hour	Rp. 398.430,00
	(1.443.149 x 2unit x1hour+(30 x 13281 x 1)x2		Rp. 6.569.456
4. Mooring Services			
Rates	Rp. 116	GT/Etmal	
	116 x 13281 x 2		Rp. 3.081.192
TOTAL			**Rp. 17.719.280**

From the above table can be concluded that, the total port cost at port of Tanjung Perak Surabaya is Rp. 17.719.280 . The total cost of port of Tanjung Perak Surabaya is the total sum of anchorage services Rp. 1.478.472, pilotage services Rp 6.581.160, tugboat services Rp. 6.569.456 and mooring services RP. 3.081.192.

3. Port of Bitung (1702N/SUB-BIT)

The following table is calculation for port cost at Port of Bitung, at the time of voyage route from Surabaya to Bitung with voyage number 1702N/SUB-BIT. The price used is the port of Makassar because it is assumed that the price between ports which are part of Pelindo IV has a little difference. From the data available in the MV. Meratus Medan 1 summary report data, mentioned that the time for anchorage at the port of Bitung is 0 hour then no anchorage service fee. While the length of time for mooring services is 42,1 hours which means included in 2 etmal (1 etmal = 24 hours). For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area. While for the tugboat services use 2 units of tugboat for 1 hour.

Table 4.13 Calculation of *cost at Port of Bitung (1702N/SUB-BIT)*

1. Anchorage Services			
Rates	Rp. 85,36	GT/10 days	
			Rp. -
2. Pilotage Services			
Fixed Rates	Rp. 67.265	ship/movement	Rp. 269.060
Variable Rates	Rp. 20,638	GT/movement	Rp. 1.096.373
Total	(67.265 x 4 + (20,638x 13281 x 4)) x 2		Rp. 2.730.866
3. Tugboat Services			
Fixed Rates	Rp. 1.299.100,00	unit / hour	Rp. 2.598.200,00
Variable Rates	Rp. 10,00	GT/hour	Rp. 132.810,00
	(1.299.100 x 2unit x1hour+(10 x 13281 x 1)x2		Rp. 5.462.020
4. Mooring Services			
Rates	Rp. 92,84	GT/Etmal	
	92,84 x 13281 x 2		Rp. 2.466.016
TOTAL			**Rp. 10.658.902**

Can be seen the port services cost calculation in the table above, the total port cost at port of Bitung is Rp. 10.658.902. The total cost in port of Bitung is the total sum of pilotage service Rp. 2.730.866, tugboat service Rp.5.462.000 and mooring service RP. 2.466.016 while for anchorage service there is no anchorage service in this voyage.

4. Port of Gorontalo (1702S/BIT-GTO)

As for the fourth voyage is in the port of Gorontalo, with the voyage route from Bitung to Gorontalo. The price used is the port of Makassar because it is assumed that the price between ports which are part of Pelindo IV has a little difference. From the existing data, mentioned that the time for anchorage at the port of Gorontalo is 1,4 hours with a price of Rp. 85,36 GT/10 days. While the length of time for mooring services is 52 hours which means included in 3 etmal (1 etmal = 24 hours) with a price Rp. 92,84 GT/Etmal. For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area. While for the tugboat services use 2 units of tugboat for 1 hour.

Table 4.14 Calculation of cost at Port of Gorontalo (1702S/BIT-GTO)

1. Anchorage Services			
Rates	Rp. 85,36	GT/10 days	
	85,36 x 13281		Rp. 1.133.666
2. Pilotage Services			
Fixed Rates	Rp. 67.265	ship/movement	Rp. 269.060
Variable Rates	Rp. 20,638	GT/movement	Rp. 1.096.373
Total	(67.265 x 4 + (20,638 x 13281 x 4)) x 2		Rp. 2.730.866
3. Tugboat Services			
Fixed Rates	Rp. 1.299.100,00	unit / hour	Rp. 2.598.200,00
Variable Rates	Rp. 10,00	GT/hour	Rp. 132.810,00
	(1.299.100 x 2unit x1hour+(10 x 13281 x 1)x2		Rp. 5.462.020
4. Mooring Services			
Rates	Rp. 92,84	GT/Etmal	
	92,84 x 13281 x 3		Rp. 3.699.024
TOTAL			**Rp. 13.025.577**

From the above table can be concluded that, the total port cost at port of Gorontalo is Rp. 13.025.577. The total cost of port of Tanjung Perak Surabaya is the total sum of anchorage services Rp. 1.133.666, pilotage services Rp 2.730.866, tugboat services Rp. 5.462.020 and mooring services RP. 13.025.577.

5. Port of Surabaya (1702S/GTO-SUB)

The following table is the calculation for port cost at Port of Surabaya, at the time of voyage route from Gorontalo to Surabaya with voyage number 1702S/GTO-SUB. From the existing data, mentioned that the time for anchorage at the port of Surabaya is 8,5 hours with a price Rp. 112 GT/10 days. While the length of time for mooring services is 117.3 hours which means included in 5 etmal (1 etmal = 24 hours) with a price Rp. 116 GT/Etmal. For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area with a price Rp. 225.000 ship/movement for fixed rates and Rp. 45 GT/movement for variable rates. While for the tugboat services use 2 units of tugboat for 1 hour with a price Rp. 1.443.149,00 unit/hour for fixed rates and Rp. 30 GT/hour for variable rates.

Table 4.15 Calculation of cost at Port of Surabaya (1702S/GTO-SUB)

1. Anchorage Services			
Rates	Rp. 112,00	GT/10 days	
	112 x 13281		Rp. 1.487.472
2. Pilotage Services			
Fixed Rates	Rp. 225.000	ship/movement	Rp. 900.000
Variable Rates	Rp. 45	GT/movement	Rp. 2.390.580
Total	(225.000 x 4 + (45 x 13281 x 4)) x 2		Rp. 6.581.160
3. Tugboat Services			
Fixed Rates	Rp. 1.443.149,00	unit / hour	Rp. 2.886.298,00
Variable Rates	Rp. 30,00	GT/hour	Rp. 398.430,00
	(1.443.149 x 2unit x1hour+(30 x 13281 x 1)x2		Rp. 6.569.456
4. Mooring Services			
Rates	Rp. 116	GT/Etmal	
	116 x 13281 x 5		Rp. 7.702.980
TOTAL			**Rp. 22.341.068**

Can be seen the port services cost calculation in the table above, the total port cost at port of Tanjung Perak Surabaya is Rp. 22.341.068 . The total cost at port of Tanjung Perak Surabaya is the total sum of anchorage services Rp. 1.478.472, pilotage services Rp 6.581.160, tugboat services Rp. 6.569.456 and mooring services RP. 7.702.980.

6. Port of Jakarta (1702S/SUB-JKT)

As for the sixth voyage is in the port of Tanjung Priuk Jakarta, at the time of voyage route from Surabaya to Jakarta. The price used in this calculaion is from port of Tanjung Perak Surabaya because it is assumed that the price between ports which are part of Pelindo III has a little difference. From the data available in the MV. Meratus Medan 1 summary report data, mentioned that the time for anchorage at the port of Jakarta is 3,9 hours. While the length of time for mooring services is 12,6 hours which means included in 1 etmal (1 etmal = 24 hours). For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area. While for the tugboat services use 2 units of tugboat for 1 hour.

Table 4.16 Calculation of cost at Port of Jakarta (1702S/SUB-JKT)

1. Anchorage Services			
Rates	Rp. 112,00	GT/10 days	
	112 x 13281		Rp. 1.487.472
2. Pilotage Services			
Fixed Rates	Rp. 225.000	ship/movement	Rp. 900.000
Variable Rates	Rp. 45	GT/movement	Rp. 2.390.580
Total	(225.000 x 4 + (45 x 13281 x 4)) x 2		Rp. 6.581.160
3. Tugboat Services			
Fixed Rates	Rp. 1.443.149,00	unit / hour	Rp. 2.886.298,00
Variable Rates	Rp. 30,00	GT/hour	Rp. 398.430,00
	(1.443.149 x 2unit x1hour+(30 x 13281 x 1)x2		Rp. 6.569.456
4. Mooring Services			
Rates	Rp. 116	GT/Etmal	
	116 x 13281 x 1		Rp. 1.540.596
TOTAL			**Rp. 16.178.684**

From the above table can be concluded that, the total port cost at port of Tanjung Priuk Jakarta with voyage number 1702S/SUB-JKT is Rp.16.178.684. The total cost in port of Tanjung Priuk Jakarta is the total sum of anchorage services Rp. 1.487.472, pilotage services Rp.6.581.160, tugboat services Rp. 6.569.456 and mooring services RP.1.540.596.

7. Port of Surabaya (1703N/JKT-SUB)

The following table is contain calculation for port cost at Port of Surabaya, at the time of voyage route from Jakarta to Surabaya with voyage number 1703N/JKT-SUB. From the summary report data, mentioned that the time for anchorage at the port of Surabaya is 17,1 hours means only 1 days with a price Rp. 112,00 GT/10 days. While the length of time for mooring services is 35,3 hours which means included in 2 etmal (1 etmal = 24 hours) with a price Rp. 3.081.192. For pilotage services, 4 times movement to enter the port and 4 times the movement to get out from the port area with a price Rp. 225.000 ship/movement for fixed rates and Rp. 45 GT/movement for variable rates. While for the tugboat services use 2 units of tugboat for 1 hour with a price Rp. 1.443.149,00 unit/hour for fixed rates and Rp. 30 GT/hour for variable rates.

Table 4.17 Calculation of cost at Port of Surabaya (1703N/JKT-SUB)

1. Anchorage Services			
Rates	Rp. 112,00	GT/10 days	
	112 x 13281 x 2		Rp. 2.974.944
2. Pilotage Services			
Fixed Rates	Rp. 225.000	ship/movement	Rp. 900.000
Variable Rates	Rp. 45	GT/movement	Rp. 2.390.580
Total	(225.000 x 4 + (45 x 13281 x 4)) x 2		Rp. 6.581.160
3. Tugboat Services			
Fixed Rates	Rp. 1.443.149,00	unit / hour	Rp. 2.886.298,00
Variable Rates	Rp. 30,00	GT/hour	Rp. 398.430,00
	(1.443.149 x 2unit x1hour+(30 x 13281 x 1)x2		Rp. 6.569.456
4. Mooring Services			
Rates	Rp. 116	GT/Etmal	
	116 x 13281 x 2		Rp. 3.081.192
TOTAL			**Rp. 19.206.752**

Can be seen the port services cost calculation in the table above, the total port cost at port of Tanjung Perak Surabaya is Rp. 19.206.752. The total cost at port of Tanjung Perak Surabaya is the total sum of anchorage services Rp. 2.974.944, pilotage services Rp. 6.581.160, tugboat services Rp.6.569.456 and mooring service Rp. 3.081.192.

After calculating all port costs on each port, then totaled all of them in order to obtain the total cost of ports to be paid for one month. Then the total port cost of all port is Rp. 113.821.475. Table 4.18 summarizes the total port charges:

Table 4.18 Total Port Cost

Voyage Number	Port Cost
1701S/SUB-JKT	Rp. 14.691.212
1702N/JKT-SUB	Rp. 17.719.280
1702N/SUB-BIT	Rp. 10.658.902
1702S/BIT-GTO	Rp. 13.025.577
1702S/GTO-SUB	Rp. 22.341.068
1702S/SUB-JKT	Rp. 16.178.684
1703N/JKT-SUB	Rp. 19.206.752
TOTAL PORT COST	**Rp. 113.821.475**

IV.4.4.2 Bunker Fuel Cost Calculation

To calculate the cost of the fuel consumption for each engine load are by using the following formula:

FC = P x SFOC x t

Where,

FC = Fuel Consumption

P = Power developed in kilowatt

SFOC = Specific fuel oil consumption (gr/kwh)

t = Engine operation time

Due to the fuel oil consumption during engine test bed using marine diesel oil (MDO), but while sailing MV. Meratus Medan 1 using heavy fuel oil (HFO). Then it sould be changed first by using the equation of heating value (HV.):

FO Consumption MGO x HV.MGO = FO Consumption HFO x HV. HFO

Where,

HV. MGO = 45.000 KJ/KG

HV. HFO = 41.000 KJ/KG

To get the value of specific fuel oil consumption (SFOC) can be calculated using data from fuel oil consumption during engine test bed divided by engine power developed. After getting the amount of fuel consumption, then it can be multiplied by fuel oil 180 cSt prices for Rp. 6.350,00/liter. The table 4.19 below is the result of the calculation of fuel consumption for each engine load for a month.

Table 4.19 Bunker Fuel Cost Calculation

	SSS	ESS	SS	FS
Load	50%	75%	85%	100%
Power (KW)	4994	7491	8490	9988
Engine Speed (RP.M)	100,87	115,30	120,37	127,14
Activity (Hours)	231,69	202,70	194,16	183,82
FO Consump.(kg/h)MGO	876,6	1276,9	1445,7	1739,8
FO Consump.(kg/h)HFO	962,12	1401,48	1586,74	1909,54
SFOC (g/KWh) HFO	180,00	174,03	173,00	176,00
Fuel Consump. (gram)	208272397,78	264245320,19	285166166,01	323133280,07
Fuel Consump. (ton)	208,27	264,25	285,17	323,13
Fuel Consumpt. (liter)	210163,9	266645,1	287756,0	326067,9
Price (Rp.)	1.334.540.591	1.693.196.552,15	1.827.250.407,80	2.070.531.108

It can be seen in the table above that super slow steaming greatly affects the amount of bunker fuel cost by reducing up to Rp. 735.990.000 from normal operational load. Then after get the cost of fuel consumption of MV. Meratus Medan 1 for one month, the next step is sum it with the total port cost for a month. So the total operational costs for one month are obtained, the following table contains total operational cost at each speed:

Table 4.20 Total Operational Cost

	SSS	ESS	SS	FS
Bunker Fuel Cost (Rp.)	1.334.540.591	1.693.196.552	1.827.250.408	2.070.531.108
Port Cost (Rp.)	113.821.475	113.821.475	113.821.475	113.821.475
Operational Cost (Rp.)	1.448.362.066	1.807.018.027	1.941.071.883	2.184.352.583

From the calculation of table 4.20 it can be concluded that slow steaming or decrease the ship engine load is proven to reduce the operational cost that should be paid by the ship owner. Even a 50% decrease in ship engine load can reduce operational cost by up to Rp. 740,000,000.

IV.4.5 Ship Revenue

Service performance is the amount of cargo that can be delivered by ship within one month. To calculate the service performance at each engine load are by using the following formula:

$F_s = cap_{eff} . f_T$

$F_s = cap_{eff} . T_O / (T_H + T_S)$

Where,

F_s = Service Performance

cap_{eff} = Effective Capacity (ρ = 0,87)

f_T = Maximum Number of Roundtrips

T_O = Operating Time

T_H = Harbor Waiting Time

T_S = Sea (Shipping) Time

Effective capacity value obtained by multiplying the number of TEU'S on MV. Meratus Medan1 is 1001 TEUs with a constant value of effective capacity in a container ship that is 0.87. To find a number of roundtrips maximum value can be calculated by operational time (To) divided by the amount of time between voyage time (Ts) with a port time (Th). In this calculation assumed operational time period and the waiting time at the port are same on each engine load. The table below is the result of the calculation of service performance at every engine load for a month.

Table 4.21 Service Performance Calculation

	SSS	**ESS**	**SS**	**FS**
To (hours)	720	720	720	720
Th (hours)	373	373	373	373
Ts (hours)	231,69	202,70	194,16	183,82
Fs	1036,94	1089,16	1105,56	1126,09

From the calculation of table 4.21 it can be concluded that slow steaming or decrease the ship engine load is result in the amount of goods that can be shipped by the ship in a month are reduced due to the increase in the duration of the voyage. The next step is to calculate the amount of vessel income. Vessel income is the amount of money received by shipping company from their activities of carrying out the delivery services to customers. To calculate the vessel income by multiplying the freight rate with a maximum transport performance. In this thesis assumed vessel capacity is fully utilized. Formula used to calculate the vessel income are :

$I_V = \sum Ƥ_{FR,i} \, . \, F_S$

Where,

I_V = Vessel Income

$Ƥ_{FR,i}$ = Freights Rates

F_s = Service Performance

While for freight rate are obtained from total price of each route for one month that are Rp.18.800.000,- which has been described in the Table 4.22

Table 4.22 Freight rate at PT. Meratus Line

No.	**Vessel Route**	**Freight Rate**	
1	SUB-JKT	Rp. 2.500.000,00	/20 ft
2	JKT-SUB	Rp. 2.500.000,00	/20 ft
3	SUB-BIT	Rp. 1.350.000,00	/20 ft
4	BIT-GTO	Rp. 1.250.000,00	/20 ft
5	GTO-SUB	Rp. 6.200.000,00	/20 ft
6	SUB-JKT	Rp. 2.500.000,00	/20 ft
7	JKT-SUB	Rp. 2.500.000,00	/20 ft
TOTAL		**Rp. 18.800.000,00**	**/20 ft**

Source: PT. Meratus Line

After obtaining a monthly vessel income for each load, the next step is to decrease the amount of operational cost at the same load so that it gets the value of ship revenue for one month. Table 4.23 describes the amount of vessel income, operational cost and ship revenue.

Table 4.23 Ship Revenue Calculation

	Service Performance	Vessel Income (Rp.)	Operational Cost (Rp.)	Ship Revenue (Rp.)
FS	1126,09	21.170.426.167	2.184.352.583	18.986.073.583,29
SS	1105,56	20.784.515.550	1.941.071.883	18.843.443.666,90
ESS	1089,16	20.476.281.643	1.807.018.027	18.669.263.615,58
SSS	1036,94	19.494.387.411	1.448.362.066	18.046.025.344,50

From the calculation of table 4.23 it can be concluded that super slow steaming has a very much ship revenue difference when compared with full speed, slow steaming and extra slow steaming. This is because extra slow steaming only get very little vessel income than other load. While the largest ship revenue generated in the condition of full speed that is Rp. 18.986.073.583,29.

IV.4.6 Ship Emissions Calculation

In this thesis, the emissions that calculated are CO_2, NO_X and SO_2 from the operations of the ship for a month by using Puget Sound Maritime Air Emissions Inventory method that published in 2012. It is calculated by using the formula:

E = Energy x EF x FCF

Where;

E = Emissions from the engine

Energy = Energy demand (kWh)

EF = Emission factor (g/kWh)

FCF = Fuel Correction Factor

In calculating the estimated emissions of ships, the value needed are energy (kWh), emission factor (g/kWh) and fuel correction factor. To get the energy value are by multiplying the load factor with a maximum continuous rated engine power (MCR) and also the duration of ship activity.

Meanwhile, to get the value of NO_x and SO_2 emission factor obtained from Table 2.1, while the value of CO_2 emission factor obtained from Table 2.2. Furthermore, to the value of fuel correction factor at each emissions be obtained from Table 2.3. The result of the calculation of the total CO_2, NO_X and SO_2

emissions at the MV. Meratus Medan 1 in one month can be seen in the following table 4.24

Table 4.24 Ship Emissions Calculation

	SSS	ESS	SS	FS
Power (KW)	4994	7491	8490	9988
Engine Speed (RP.M)	100,87	115,30	120,37	127,14
Speed (knot)	15,65	17,89	18,68	19,73
LF	0,50	0,75	0,85	1,00
Activity (hours)	231,69	202,70	194,16	183,82
Energy (kWh)	577828,09	1132464,21	1398814,27	1835984,55
NOx (ton/month)	10,46	20,50	25,32	33,23
SO_2 (ton/month)	6,07	11,89	14,69	19,28
CO_2 (ton/month)	358,25	702,13	867,26	1138,31

From the calculation of table 4.24 it can be concluded that super slow steaming or decrease the ship engine load is greatly affects to reduction the ship emission that produced by the engine. The amount of ship emissions are 10,46 ton/month for NO_x, 6,07 ton/month for SO_2 and 358,25 for CO_2.

IV.5 Planning of Questionnaires

TOPSIS method is one way to choose the alternative that is based on data obtained from the questionnaire. The questionnaire will be filled out by the experts who work in the operational divisions at Meratus Line. Questionnaires become a very important aspect to determine the results of the alternative selected.

Before the questionnaires will gives to the expert, the description about criteria, sub criteria and alternatives have to describe before in. Based on the criteria and sub criteria we can make a matrix. This matrix can make this process simpler. The criteria and sub criteria will be converted into this matrix:

a. Matrix of Criteria

	Technical & Operational	Financial	Environmental
Technical & Operational			
Financial			
Environmental			

Technical & Operational: classified some sub criteria about technical and operational into technical and operational criteria

Financial : classified some sub criteria about technical and operational into financial criteria

Environmental : classified some sub criteria about technical and operational into environmental criteria

b. Matrix of Technical & Operational Sub Criteria

	Engine Efficiency	Auxiliary Consumption
Engine Efficiency		
Auxiliary Consumption		

Engine Efficiency : Decreased engine efficiency due to low load operation of the engine.

Auxiliary Consumption : With increasing shipping time because the speed reduction will have an impact on the amount of fuel consumed by the auxiliary machinery.

c. Matrix of Financial Sub Criteria

	Operational Cost	Ship Revenue
Operational Cost		
Ship Revenue		

Operational Cost : Operational costs are the costs associated with the cost to run the operational aspects of the ship in order that the ship is always in a condition ready to sail.

Ship Revenue : Fee income earned from the shipment of goods from the origin port to destination port.

d. Matrix of Environmental Sub Criteria

	Carbon Dioxide	Nitrogen Oxide	Sulphur Dioxide
Carbon Dioxide			
Nitrogen Oxide			
Sulphur Dioxide			

Carbon Dioxide : The amount of carbon dioxide levels can result in causing the hot air trapped on earth and eventually becomes hot environment.

Nitrogen Oxide : The air has been polluted by nitrogen oxide gas is not only harmful to humans and animals, but also dangerous for the life of the plant.

Sulphur Dioxide : High levels of Sulfur dioxide in the air is one of the causes of acid rain.

IV.5.1 Distribution of Questionnaires

The assessment of sub-criteria weighting scale for each criteria based on the results of the questionnaire that filled by respondents working in PT. Meratus who understand this field.

IV.5.2 Processing Questionnaire Data

TOPSIS method requires input data that are weights for each criteria and each sub criteria in order to choose the best alternative. Based on the flowchart of selection methodology, we have to make questionnaire. Then the questionnaire will answer by the expert. Respondents will give a value on each criteria and each sub criteria between the numbers 1 to 9 represent the important of one criteria with another. Then pairwise comparison matrix is used to assess the importance (weighting) of each criteria and each sub criteria by using expert choice software. Here are the steps of weighting criteria and sub criteria by using expert choice software:

IV.5.2.1 Insert all criteria and sub criteria

The first step to do in the expert choice software is to list the criteria and include the sub criteria for each criteria. Figure 4.1 shows criteria and sub criteria in expert choice software.

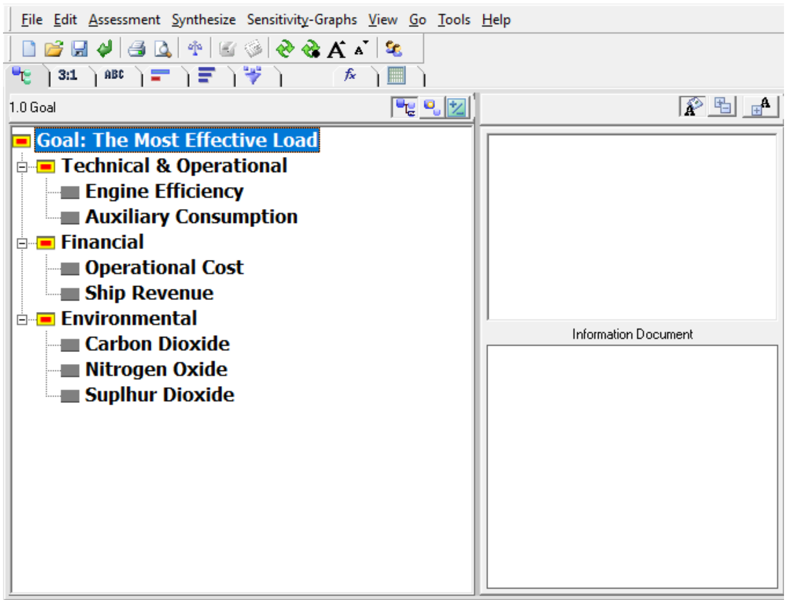

Figure 4.1 Criteria and sub criteria that insert to expert choice software

IV.5.2.2 Comparing the importance level of criteria and sub criteria

a. Assessment of criteria weight

The next step is to insert the importance level of the criteria. The importance level is obtained from the questionnaires data that have been filled by experts. Figure 4.2 shows the comparison of importance values between criteria.

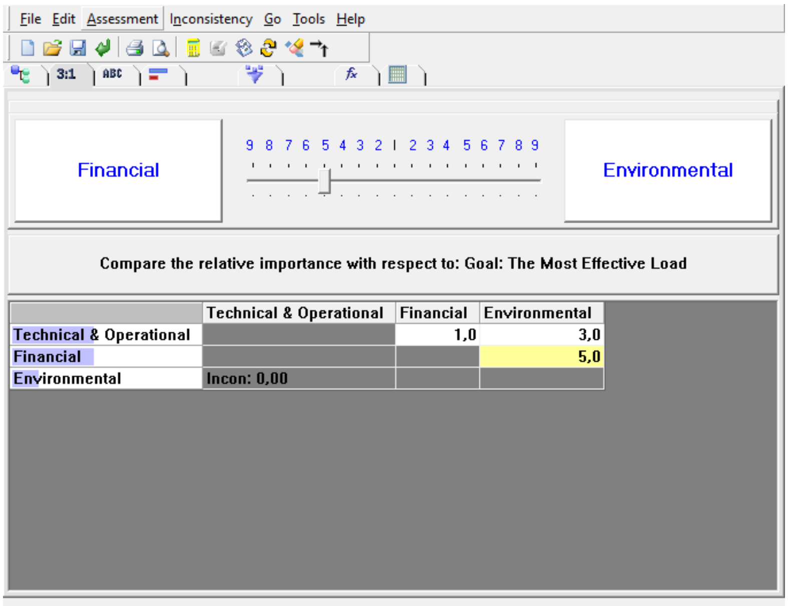

Figure 4.2 Weighted comparison between criteria

After completing the comparative value between the criteria, then the priority will appear as Figure 4.3, where the technical and operational are in the first priority.

Figure 4.3 Result of weighted calculation between criteria

Figure 4.3 shows the priority between the criteria from the AHP results, financial criteria are in the first priority with a weight of 0,514, then technical and operational 0,323 and environmental 0,164.

b. Assessment of sub criteria weight "Technical and Operational"

The next step is to insert the importance level of technical and operational sub criteria. The importance level is obtained from the questionnaires data that have been filled by experts. Figure 4.4 shows the comparison of importance values between technical and operational sub criteria.

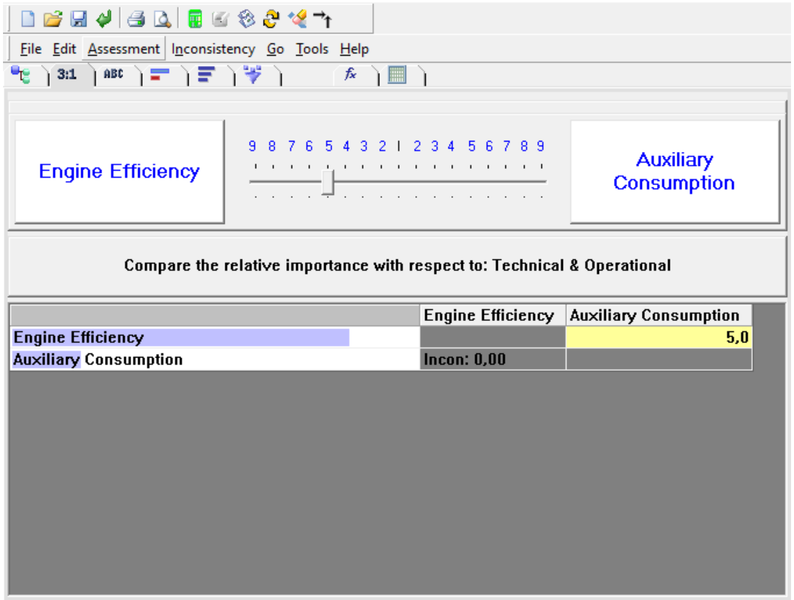

Figure 4.4 Weighted comparison between technical and operational sub criteria

After completing the comparative value between technical and operational sub-criteria, then the priority will appear as Figure 4.5, where engine efficiency is in the first priority.

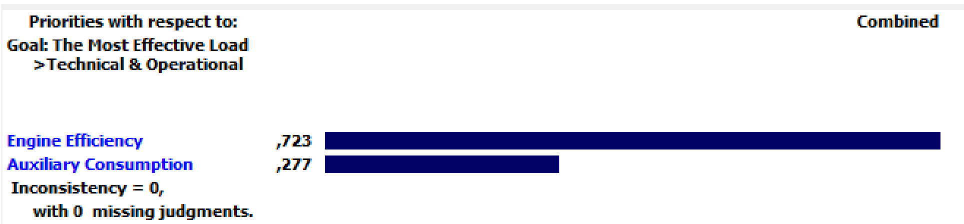

Figure 4.5 Result of weighted calculation between technical and operational sub criteria

Figure 4.5 shows the priority between technical and operational sub-criteria from the AHP results, engine efficiency are in the first priority with a weight of 0,723, then auxiliary consumption 0,277.

c. Assessment of sub criteria weight "Financial"

The next step is to insert the importance level financial sub criteria. The importance level is obtained from the questionnaires data that have been filled by experts. Figure 4.6 shows the comparison of importance values between financial sub criteria.

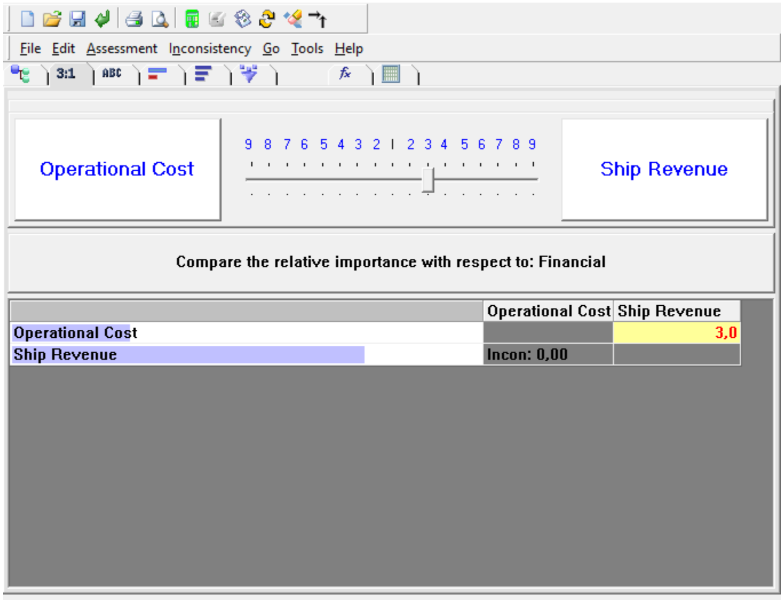

Figure 4.6 Weighted comparison between financial sub criteria

After completing the comparative value between financial sub-criteria, then the priority will appear as Figure 4.7, where ship revenue is in the first priority.

Figure 4.7 Result of weighted calculation between financial sub criteria

Figure 4.7 shows the priority between financial sub-criteria from the AHP results, ship revenue are in the first priority with a weight of 0,624, then operational cost 0,376.

d. Assessment of sub criteria weight "Environmental"

The next step is to insert the importance level of environmental sub criteria. The importance level is obtained from the questionnaires data that have been filled by experts. Figure 4.8 shows the comparison of importance values between environmental sub criteria.

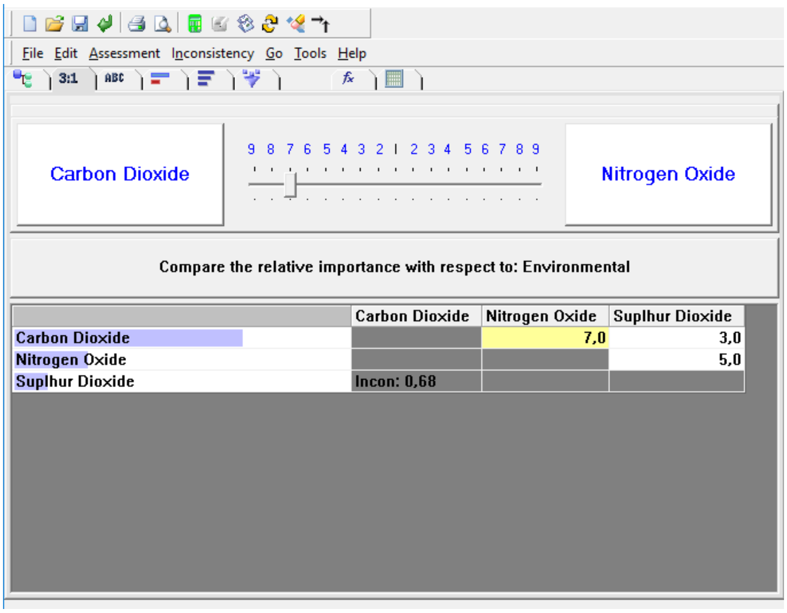

Figure 4.8 Weighted comparison between environmental sub criteria

After completing the comparative value between environmental sub-criteria, then the priority will appear as Figure 4.9, where carbon dioxide is in the first priority.

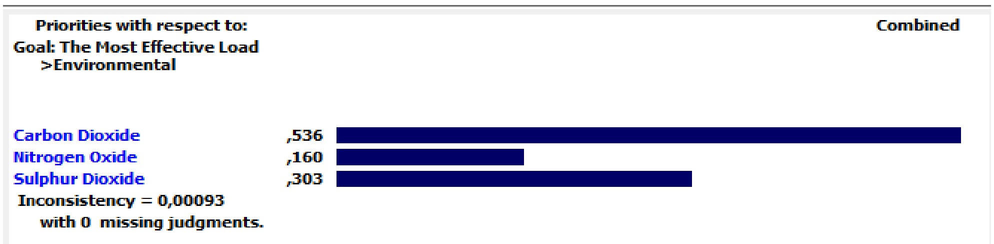

Figure 4.9 Result of weighted calculation between environmental sub criteria

Figure 4.9 shows the priority between environmental sub-criteria from the AHP results, carbon dioxide are in the first priority with a weight of 0,536, then sulphur dioxide 0,303 and nitrogen oxide 0,160.

After the assessment of various respondents obtained, then the results are averaged using geometric mean. The geometric mean is the average obtained by multiplying all the data in a sample group, then it is rooted by the amount of sample data. But in this thesis the geometric mean method can be processed by using expert choice software. This is done because AHP requires only one answer for the comparison matrix. When processed using expert choice, then the consistent value should be under 0,1 for each expert who becomes as respondent. This consistent value shows that the expert is worthy and understood with the answers and problems in the study. If the expert's consistent score is greater than 0.1 then there are two options to choose, there are to find another expert or to repeat the experts to fill out the questionnaire more thoroughly in answering questions on the questionnaire.

Based on the results of AHP questionnaires by experts who analyzed with expert choice software, then obtained 0,01 of inconsistency expert value. Next, shown in figure 4.11 the AHP results in determining the most influential criteria to determine the most important criteria and sub-criteria based on 4 respondents by using expert choice software. The results are shown in Figure 4.10.

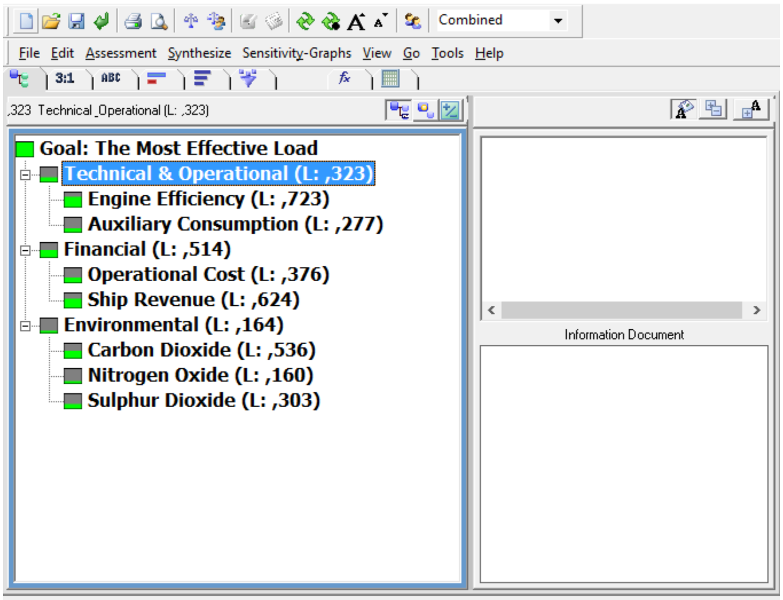

Figure 4.10 Result of weighted each criteria and each sub criteria

Figure 4.10 shows the result of weighted each criteria and sub criteria. Can be known the weight of criteria and sub criteria which have been determined. From the result of weighting analysis on each criteria, it can be concluded that financial are in the first priority with a weight of 0,514, then technical and operational with a weight of 0,323 and environmental with a weight of 0,164. For the highest weight sub criteria are engine efficiency with a weight of 0,723 and followed by ship revenue with a weight of 0,624 and carbon dioxide with a weight of 0,536 while the lowest sub criteria are nitrogen oxide with a weight of 0,160 and followed by auxiliary consumption with a weight of 0,277 and operational cost with a weight of 0,376.

All sub-criteria weights in one criteria if summed should be 1 as well as all the weights of all existing criteria if summed should be worth 1. To make it easier, the results of criteria and sub criteria weighting calculation can be seen in the table 4.25.

Table 4.25 The weighting values of all criteria and sub criteria

		Sub Criteria Values	**Criteria Values**
Technical & Operational			**0,323**
Engine Efficiency	=	0,723	
Auxiliary Consumption	=	0,277	+
	=	**1**	
Financial			**0,514**
Operational Cost	=	0,376	
Ship Revenue	=	0,624	+
	=	**1**	
Environmental			**0,164**
Carbon Dioxide	=	0,536	
Nitrogen Oxide	=	0,160	
Sulphur Dioxide	=	0,303	+
	=	**1**	
			1 +

The next step is to multiply each weighting sub criteria values with each criteria values. Given the technical and operational aspect as an example, the normalized weighting vector engine efficiency and auxiliary consumption values are as follows:

$$\text{Normalized weghting} = \begin{matrix} Engine\ Efficiency \\ Auxiliary\ Consumption \end{matrix} \begin{bmatrix} 0{,}723 \\ 0{,}277 \end{bmatrix} x\ 0{,}323$$

$$= \begin{matrix} Engine\ Efficiency \\ Auxiliary\ Consumption \end{matrix} \begin{bmatrix} 0{,}3051 \\ 0{,}1038 \end{bmatrix}$$

Then get value of normalized weighting engine efficiency 0,2335 and auxiliary consumption 0,0895. In a similar way, the normalized weighting values of all other sub-criteria are obtained as shown in Table 4.26

Table 4.26 The normalized weighting values of all the criteria

Engine Efficiency	Auxiliary Consumption	Operational Cost	Ship Revenue	NO_x	SO_2	CO_2
0,2335	0,0895	0,1933	0,3207	0,0262	0,0497	0,0879

IV.6 Selection Decisions

After the normalized weighting values for each criteria and sub criteria, then the selection of the best alternative can be done by using TOPSIS method. The steps are as follows:

IV.6.1 Construct the Normalized Decision Matrix (r_{ij})

Normalized decision matrix is a division between the matrix value with the sum value from each alternative value in the sub criteria. Given the engine efficiency sub criteria as an example, the normalized decision matrix (r_{ij}) values for full speed alternative on engine efficiency criteria are obtained as follows :

$$r_{ij} = \frac{x_{ij}}{\sqrt{\Sigma_{ij}^{2}}}$$

$$= \frac{49{,}889}{\sqrt{49{,}889^2 + 50{,}7543^2 + 50{,}45^2 + 48{,}78^2}}$$

$$= 0{,}4991$$

Then get the value of normalized decision matrix values for full speed alternative on engine efficiency criteria 0,4991. In a similar way, the normalized decision matrix values of all other alternative and sub-criteria are obtained as shown in following table :

Table 4.27 The normalized decision matrix

	Engine Efficiency	Auxiliary Consumption	Operational Cost	Ship Revenue	NO_x	SO_2	CO_2
FS	0,4991	0,4834	0,5858	0,5093	0,6967	0,6967	0,6967
SS	0,5078	0,4922	0,5206	0,5055	0,5308	0,5308	0,5308
ESS	0,5048	0,4994	0,4846	0,5008	0,4298	0,4298	0,4298
SSS	0,4880	0,5241	0,3884	0,4841	0,2193	0,2193	0,2193

IV.6.2 Calculate the Weighted Normalized Decision Matrix (y_{ij})

The weighted normalized decision matrix is the multiplication of the normalized decision matrix value with the weight of each sub criteria. Given the engine efficiency sub criteria as an example, the weighted normalized decision matrix (r_{ij}) values for full speed alternative on engine efficiency criteria are obtained as follows :

$$
\begin{aligned}
Y_{ij} &= w_i \times r_{ij} \\
&= 0{,}2335 \times 0{,}4991 \\
&= 0{,}1166
\end{aligned}
$$

Then get the value of weighted normalized decision matrix for full speed alternative on engine efficiency criteria 0,1166. In a similar way, the weighted normalized decision matrix values of all other alternative and sub-criteria are obtained as shown in following table :

Table 4.28 The weighted normalized decision matrix

	Engine Efficiency	Auxiliary Consumption	Operational Cost	Ship Revenue	NO_x	SO_2	CO_2
FS	0,1166	0,0432	0,1132	0,1633	0,0183	0,0346	0,0612
SS	0,1186	0,0440	0,1006	0,1621	0,0139	0,0264	0,0467
ESS	0,1179	0,0447	0,0937	0,1606	0,0113	0,0214	0,0378
SSS	0,1140	0,0469	0,0751	0,1553	0,0058	0,0109	0,0193

IV.6.3 Determine the Positive Ideal Solution (PIS) and Negative Ideal Solution (NIS)

Positive ideal solution (PIS) is the maximum value of benefit criteria and also the minimum value of cost criteria while negative ideal solution (NIS) is the minimum value of benefit criteria and also the maximum value of cost criteria. The formula used to find the value of PIS and NIS are as follows:

$A^+ = y_1^+, y_2^+, \ldots, y_j^+ = y_i^+ = \{\max(y_{ij}) \text{ if } j \in J^+; \min(y_{ij}) \text{ if } j \in J^-\}$
$A^- = y_1^-, y_2^-, \ldots, y_j^- = y_i^- = \{\min(y_{ij}) \text{ if } j \in J^+; \max(y_{ij}) \text{ if } j \in J^-\}$
Where:
$J^+ = \{j=1,2,3,\ldots,n$ and j is benefit criteria$\}$
$J^- = \{j=1,2,3,\ldots,n$ and j is cost criteria$\}$
The output values of the positive ideal solution (PIS) are summarised in Table 4.29.

Table 4.28 The positive ideal solution (A^+)

	Benefit	Cost	Cost	Benefit	Cost	Cost	Cost
	Engine Efficiency	**Auxiliary Consumption**	**Operational Cost**	**Ship Revenue**	**NO_x**	**SO_2**	**CO_2**
FS	0,1166	0,0432	0,1132	0,1633	0,0183	0,0346	0,0612
SS	0,1186	0,0440	0,1006	0,1621	0,0139	0,0264	0,0467
ESS	0,1179	0,0447	0,0937	0,1606	0,0113	0,0214	0,0378
SSS	0,1140	0,0469	0,0751	0,1553	0,0058	0,0109	0,0193

The goal of each criteria in the positive ideal solution (PIS) changes to the opposite way from the negative ideal solution (NIS), for instance, from "Benefit" to "Cost" and the other way around. Table 4.30 shows the output values of NIS:

Table 4.29 The negative ideal solution (A^-)

	Benefit	Cost	Cost	Benefit	Cost	Cost	Cost
	Engine Efficiency	**Auxiliary Consumption**	**Operational Cost**	**Ship Revenue**	**NO_x**	**SO_2**	**CO_2**
FS	0,1166	0,0432	0,1132	0,1633	0,0183	0,0346	0,0612
SS	0,1186	0,0440	0,1006	0,1621	0,0139	0,0264	0,0467
ESS	0,1179	0,0447	0,0937	0,1606	0,0113	0,0214	0,0378
SSS	0,1140	0,0469	0,0751	0,1553	0,0058	0,0109	0,0193

IV.6.4 Calculate the Distance of Positive Ideal Solution (D^+) and Negative Ideal Solution (D^-)

The distance of positive ideal solution is square root result from the reduction of positive ideal solution on each criteria with weighted normalized. Likewise the negative ideal solution has the same steps as the ideal positive solution. The formula used to find the distance of positive ideal solution and negative ideal solution are as follows:

$$D_i^+ = \sqrt{\Sigma_{i=1}^{n}\left(y_i^+ - y_{ij}\right)^2}$$

$$D_i^- = \sqrt{\Sigma_{i=1}^{n}(y_{ij} - y_i^-)^2}$$

The output values of the positive ideal solution distance (D^+) and negative ideal solution (D^-) are summarised in following table :

Table 4.30 The distance separation measure of each alternative

	D⁺	**D⁻**
FS	0,0628	0,0092
SS	0,0414	0,0231
ESS	0,0289	0,0347
SSS	0,0100	0,0627

IV.6.5 Calculate the Relative closeness to the Ideal Solution

The final stage of TOPSIS method is to calculate the preference value of each alternative.The best alternative of the steaming speed will be chosen by shipping companies based on the value closest to one which has the shortest distance from the PIS point and the farthest distance from the NIS point. Given the full speed alternatives as an example, the relative closeness to the ideal solution calculation are obtained as follows :

$$V_i^+ = \frac{D_i^-}{D_i^+ + D_i^-}$$

$$V_i^+ = \frac{0{,}0092}{0{,}0628 + 0{,}0092}$$

$$= 0{,}1283$$

Then get the relative closeness to ideal solution values for full speed alternative 0,1283. In a similar way, the relative closeness to the ideal solution values of all other alternative are obtained as shown in following table :

Table 4.31 The relative closeness to the ideal solution

Result	V
FS	0,1283
SS	0,3587
ESS	0,5455
SSS	0,8625

IV.6.6 Rank the Preference Alternatives

The alternative super slow steaming is ranked as the top of the alternatives list in the Table 4.32. It can be concluded that such an alternative is the most efficient steaming speed of liner business industry into consideration all criteria described. Super slow steaming was chosen to be the first rank with a value of 0,8625 while the next rank is extra slow steaming slow steaming with a value of 0,5455, slow steaming with a value of 0,3587 and the last full speed with a value of 0,1283.

Table 4.32 Rank the preference alternatives

Result	V	Rank
FS	0,1283	4
SS	0,3587	3
ESS	0,5455	2
SSS	0,8625	1

IV.7 Implemantation Strategy

Based on calculations of the effects caused by reducing in ship operating speed or slow steaming. Slow steaming can reduce ship operating costs such as fuel consumption costs, as shown in Table 4.19 that super slow steaming greatly affects to the amount of fuel consumption cost by reducing up to Rp. 735.990.000 from normal operational load. In addition, the application of slow steaming in ship speed operations also has a positive impact for environment that is reduction in the amount of emissions produced by main engine. As shown in Table 4.24 the amount of ship emissions in super slow steaming condition are 10,46 ton/month for NO_x, 6,07 ton/month for SO_2 and 358,25 ton/month for CO_2. However, from the calculation Table 4.23 can be seen that super slow steaming also decreases the value of ship revenue up to Rp. 940.000.000,00 from normal speed due to decreasing number of container that can be delivered by ship within one month because ship require longer time to arrive at destination.

Of all these considerations, different aspects of slow steaming operations are to be considered by superintendent (decision makers) when deciding on voyage planning of each ship. So here are the factors that should be considered in implementing slow steaming strategy:

1. Market conditions
   When weak market conditions can lead to decline demand for goods and will result in reduced number of goods that should be delivered. At this condition, slow steaming or speed reductions are suitable to apply because shipping companies still have to operate their ships to deliver goods.
2. Fuel price
   As fuel prices rise dramatically, shipping companies look for the best alternative to reduce the fuel consumption cost to be paid by company. Moreover, fuel consumption cost becomes the largest cost of ship operating costs. The current fuel price is very difficult to predict due to various phenomena that can happen at any time. In this condition, the decrease in ship operating speed or slow steaming is suitable to be applied by shipping company.
3. Voyage time
   Shipping companies should consider the delay in delivery of goods due to the length of voyage time, so it can make customers disappointed. Slow steaming has a negative impact such as increased shipping time that should be taken to arrive at destination due to reducing of ship speed. So before considering the application of the slow steaming method on ship operations, shipping company should ensure to the customer that there will be additional shipping time required by the ship. Shipping companies also should consider the arrival time of ships at the port from a determined time before. Due to ship delays from determined time before should pay penalty charge from the port.

CHAPTER V

CONCLUSION

V.1 Conclusion

Based on the results of the discussion in this report which refers to the relevant data and references, it can be concluded for the results of studies that have been implemented are as follows:

1. The speed of ship is the most important factor affecting the operational activities of ship both in terms of operational costs and also the ship revenue. From the most efficient steaming speed, it could help shipping companies to saving of fuel, which results a reduction of fuel costs.
2. From the calculation for choosing the most efficient steaming speed based on the multiple criteria requirement by using TOPSIS (technique for order preference by similarity to ideal solution), to sort alternatives from the largest value to the smallest value, so expected the most efficient ship speed will be chosen. Then from the TOPSIS method gives the following results:
   a. By using TOPSIS method, super slow steaming was chosen to be the first rank with a value of 0,8625 while the next rank is extra slow steaming slow steaming with a value of 0,5455, slow steaming with a value of 0,3587, full speed with a value of 0,1283.
   b. Super slow steaming can be ranked first due to the very large difference in the number of ship emissions generated during the super slow steaming conditions.
   c. TOPSIS method suitable for selection of a simple alternative with criteria and sub criteria that are not too much because there is no software that can be used.
   d. By using expert choice software, can be known the weight of criteria and sub criteria which have been determined. From the result of weighting analysis on each criteria, it can be concluded that financial are in the first priority with a weight of 0,514, then technical and operational with a weight of 0,323 and environmental with a weight of 0,164.

V.2 Suggestion

Based on the results of the discussion and conclusions that have been obtained regarding the selection of ship speed with decreased load or slow steaming, There are several things that need to be done related to slow steaming analysis in order to develop this thesis in the future. The suggestions in this thesis are:

1. Questionnaires to obtain data in priority weighting on each criteria of the most optimal speed should be distributed to more respondents and diverse so that the data obtained more balanced.
2. The present study can be extended by analyzing the influence of slow steaming on the engine, because in the slow steaming conditions engine should work under normal conditions that has been designed by engine manufacture.

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ATTACHMENT 1

Ship Rate Services in the Port of Tanjung Perak

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No.	Description	Tariff		Explanation
		Domestic	Foreign	
		Rp.	US $	
1.	Anchorage Services	112	0,1	GT / 10 days
2.	Mooring Services			
	a. Concrete Pier	116	0,131	GT / Etmal
	b. Breasting Dolphin	58	0,065	GT / Etmal
	c. Coast	41	0,046	GT / Etmal
3.	Pilotage Services			
	Fixed Rates	225.000	102	Ship / Movement
	Variable Rates	45	0,03	GT / Movement
4.	Tugboat Services			
	a. Up To 3.500 GT			
	Fixed Rates	670.500	187	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	b. 3.501 Up To 8.000 GT			
	Fixed Rates	958.367	460	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	c. 8.001 Up To 14.000 GT			
	Fixed Rates	1.443.149	696	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	d. 14.001 Up To 18.000 GT			
	Fixed Rates	2.043.824	936	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	e. 18.001 Up To 26.000 GT			
	Fixed Rates	2.850.000	1.498	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	f. 26.001 Up To 40.000 GT			
	Fixed Rates	3.300.000	1.605	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	g. 40.001 Up To 75.000 GT			
	Fixed Rates	3.750.000	1.766	Ship / Hour
	Variable Rates	30	0,005	GT / Ship
	h. More Than 75.001 GT			
	Fixed Rates	4.500.000	2.001	Ship / Hour
	Variable Rates	30	0,005	GT / Ship

Reference: Tariff Port of Tanjung Perak Surabaya – September 2014

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ATTACHMENT 2

Engine Characteristic Curve

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CHARACTERISTIC CURVE

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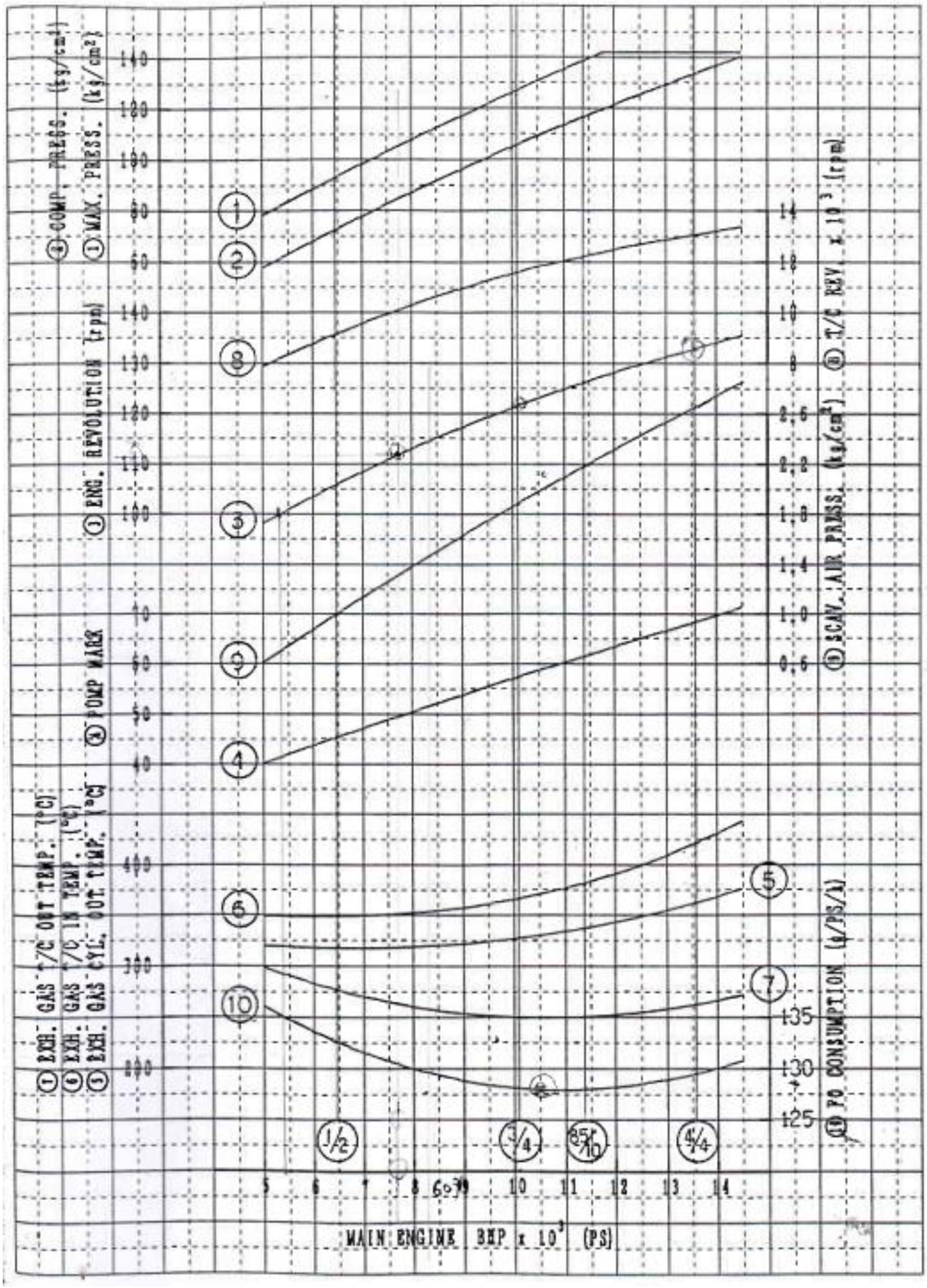

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ATTACHMENT 3

Ship Speed Selection Questionnaire

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KUESIONER STUDI PEMILIHAN KECEPATAN KAPAL DENGAN MENGGUNAKAN METODE TOPSIS

Kepada Yth.
Bapak/Ibu/Saudara/i
PT. Meratus Line
Di tempat.

Dengan Hormat,

Sehubungan untuk memenuhi kelengkapan penyusunan skripsi, saya bermaksud mengadakan penelitian yang berjudul "Decision Making Between Full Speed, Slow Steaming, Extra Slow Steaming And Super Slow Steaming By Using TOPSIS" sebagai salah satu syarat tugas akhir di Jurusan Teknik Sistem Perkapalan ITS Surabaya. Maka dengan segala kerendahan hati penulis, memohon kesediaan Bapak/Ibu/Saudara/i untuk sedikit meluangkan waktu dalam mengisi kuesioner yang telah dilampirkan.

Kuesioner ini dibuat untuk mendapatkan data tugas akhir yang digunakan pada studi pemilihan kecepatan kapal MV. Meratus Medan 1 yang paling optimal milik PT. Meratus dengan menggunakan metode TOPSIS *(*Technique for Order of Preference by Similarity to Ideal Solution*).* Saya mengerti bahwa catatan atau data mengenai penelitian ini akan dirahasiakan. Semua berkas yang mencantumkan identitas subjek penelitian hanya dipergunakan untuk pengolahan data. Oleh karena itu, saya mengharapkan bantuan Bapak/Ibu/Saudara/i selaku responden penelitian, untuk mengisi daftar pertanyaan kuesioner ini sesuai dengan petujuk pengisian yang disediakan.

Mengingat kuesioner ini sangat dibutuhkan oleh saya, maka saya sangat berharap Bapak/Ibu/Saudara/i dapat meluangkan waktu sebentar untuk mengisi kuesioner ini. Atas segala bantuan dan partisipasi yang Bapak/Ibu/Saudara/i berikan, saya ucapkan terima kasih.

Hormat Saya,

Mizan Lubnan

Explanation of Questionnaire

One strategy in reducing fuel consumption is use slow steaming method. In the slow steaming method, ships that sail at speeds of 20-24 knots will be lowered to 12-19 knots. Fuel consumption and emissions will decline as the speed decreases, but the number of shipments by ship will also decrease due to the decrease in speed of the ship resulting in reduced ship revenue.

There are 4 alternative offered speed methods namely full speed, slow steaming, extra slow steaming and super slow steaming.

1. Full speed
   Where ship engine is operated at designed speed. In MCR engine condition, speed of MV. Meratus Medan 1 is 19,7 knots.
2. Slow steaming (85% Engine Load)
   The operation of ship below the normal speed capacity, about 15% load from normal speed. In slow steaming engine condition, speed of MV. Meratus Medan 1 is 18,6 knots.
3. Extra slow steaming (75% Engine Load)
   The operation of ship below the slow steaming speed capacity, about 25% load from normal speed. In extra slow steaming engine condition, speed of MV. Meratus Medan 1 is 17,8 knots.
4. Super slow steaming (50% Engine Load)
   This method also known as economic speed because it has a very significant change on fuel saving. Super slow steaming used for even higher reductions in operating speed. In super slow steaming engine condition, speed of MV. Meratus Medan 1 is 15,6 knots.

These four alternatives will be analyzed and selected which are more suitable on the MV. Meratus Medan 1 uses TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. Input data in the form of weighting value required in TOPSIS study were obtained through this questionnaire.

Identity of Respondents

Name :

Division of Works :

Last education :

Filling Instructions

Put a circle (O) on the criteria scale column (A) or on the criteria scale column (B) that matches your opinion:

Number Definition:

1: both criteria are equally important

3: criterion (A) is slightly more important than (B)

5: criterion (A) is more important than (B)

7: criterion (A) is more important than (B)

9: criterion (A) is absolutely more important than (B)

* Vice versa

For Example:

As a consumer, what do you think is more important between cleanliness and price to determine Product Competitiveness:

Cleanliness					Price			
9	7	5	3	1	3	5	7	9

If you think cleanliness is more important than price then you can circle the available number. Example:

Cleanliness					Price			
9	(7)	5	3	1	3	5	7	9

1.) Weighting for criteria

Here's an explanation of each criteria:

a. Technical and Operational Aspect

Which is the speed considerations that can work most optimally. Criteria included in considerations technical and operational aspect are engine efficiency and auxiliary consumption.

b. Financial Aspect

Costs become a very important component for the management of companies involved in the implementation of activities to accomplish goals, including the ship's speed decisions. The financial aspect consists of operational cost and ship revenue.

c. Environmental Aspect

Environmental aspect is a consideration the effect from ship emissions on the surrounding environment. Environmental aspects to be considered in determining the speed of ships are carbon dioxide, nitrogen oxide and sulfur dioxide.

Based on the above explanation, please fill in the questionnaire below:

Technical & Operational					**Financial**			
9	7	5	3	1	3	5	7	9

Technical & Operational					**Environmental**			
9	7	5	3	1	3	5	7	9

Financial					**Environmental**			
9	7	5	3	1	3	5	7	9

2.) Weighting for sub criteria on "Technical & Operational Aspect"

a. Engine Efficiency

Decreased engine efficiency due to low load operation of the engine. The efficiency of a machine is a measure of how well a machine can convert available energy from fuel to mechanical output energy.

b. Auxiliary Consumption

With increasing shipping time because the speed reduction will have an impact on the amount of fuel consumed by the auxiliary machinery.

Based on the above explanation, please fill in the questionnaire below:

Engine Efficiency					**Auxiliary Consumption**			
9	7	5	3	1	3	5	7	9

3.) Weighting for sub criteria on "Financial Aspect"

a. Operational Cost

Operational costs are the costs associated with the cost to run the operational aspects of the ship in order that the ship is always in a condition ready to sail. Costs are included in ship operating expenses are fuel cost, lubricant cost and also port cost.

b. Ship Revenue

Fee income earned from the shipment of goods from the origin port to destination port. The negative impact of the engine load reduction will cause reduced of the ship revenue.

Based on the above explanation, please fill in the questionnaire below:

Operational Cost					Ship Revenue			
9	7	5	3	1	3	5	7	9

4.) Weighting for sub criteria on "Environmental Aspect"

a. Carbon Dioxide (CO_2)

Carbon dioxide emissions during voyage activity is caused by fuel combustion in the engine of the ship. The amount of carbon dioxide levels can result in causing the hot air trapped on earth and eventually becomes hot environment.

b. Nitrogen Oxide (NO_x)

Nitrogen oxide compounds come from the combustion of the fossil fuels. The air has been polluted by nitrogen oxide gas is not only harmful to humans and animals, but also dangerous for the life of the plant.

c. Sulfur Dioxide (SO_2)

Sulfur dioxide compounds formed during a combustion of fossil fuels containing sulfur. High levels of Sulfur dioxide in the air is one of the causes of acid rain.

Based on the above explanation, please fill in the questionnaire below:

Carbon Dioxide					Nitrogen Oxide			
9	7	5	3	1	3	5	7	9

Carbon Dioxide					Sulphur Dioxide			
9	7	5	3	1	3	5	7	9

Nitrogen Oxide					Sulphur Dioxide			
9	7	5	3	1	3	5	7	9

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ATTACHMENT 4

TOPSIS Calculations

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The Data of All Evaluation Criteria

	Benefit	Cost	Cost	Benefit	Cost	Cost	Cost
Weighting	0,2335	0,0895	0,1933	0,3207	0,0262	0,0497	0,0879
	Engine Efficiency	Auxiliary Consumption (ton/month)	Operational Cost (Rp.)	Ship Revenue (Rp.)	Nox (ton/month)	SO2 (ton/month)	CO2 (ton/month)
FS	49,8891	121,3373	2.184.352.583,22	18.986.073.583,29	33,2313	19,2778	1138,3104
SS	50,7543	123,5465	1.941.071.882,61	18.843.443.666,90	25,3185	14,6875	867,2648
ESS	50,4539	125,3709	1.807.018.026,95	18.669.263.615,58	20,4976	11,8909	702,1278
SSS	48,7805	131,5672	1.448.362.066,04	18.046.025.344,50	10,4587	6,0672	358,2534
∑ij	99,95024	251,02639	3728568503,50855	37279307853,28620	47,69575	27,66881	1633,77719

Normalised Decision Matrix

	Engine Efficiency	Auxiliary Consumption	Operational Cost	Ship Revenue	NOx	SO2	CO2
FS	0,4991	0,4834	0,5858	0,5093	0,6967	0,6967	0,6967
SS	0,5078	0,4922	0,5206	0,5055	0,5308	0,5308	0,5308
ESS	0,5048	0,4994	0,4846	0,5008	0,4298	0,4298	0,4298
SSS	0,4880	0,5241	0,3884	0,4841	0,2193	0,2193	0,2193

Weighted Normalized Decision Matrix

	Engine Efficiency	Auxiliary Consumption	Operational Cost	Ship Revenue	NOx	SO2	CO2
FS	0,1166	0,0432	0,1132	0,1633	0,0183	0,0346	0,0612
SS	0,1186	0,0440	0,1006	0,1621	0,0139	0,0264	0,0467
ESS	0,1179	0,0447	0,0937	0,1606	0,0113	0,0214	0,0378
SSS	0,1140	0,0469	0,0751	0,1553	0,0058	0,0109	0,0193
A+	0,1186	0,0432	0,0751	0,1633	0,0058	0,0109	0,0193
A-	0,1140	0,0469	0,1132	0,1553	0,0183	0,0346	0,0612

Distance Separation Measure of Each Alternative

	D+	D-
FS	0,0628	0,0092
SS	0,0414	0,0231
ESS	0,0289	0,0347
SSS	0,0100	0,0627

Relative Closeness to The Ideal Solution

Result	V
FS	0,1283
SS	0,3587
ESS	0,5455
SSS	0,8625

AUTHOR'S BIOGRAPHY

The author named Mizan Lubnan was born in Bekasi, January 5th, 1995. The author studied Elementary School at SD Al-Azhar Kelapa Gading in 2001, Junior High School at SMP Al-Azhar Kelapa Gading in 2007 and Senior High School at SMA Krida Nusantara Bandung in 2010. Then the author continue the education at Department of Marine Engineering Double Degree, Insitut Teknologi Sepuluh Nopember - Hochschule Wismar in 2013. During the lecture, the author became a member of ITS Marine Solar Boat Team at Department of Marine Engineering, became a part of sponsorship division at ITS Expo 2014. On the Job Training experience has already done in PT. Bandar Abadi Shipyard (Batam, Riau Island) and PT. Pertamina Shipping Persero (Tanjung Priok, DKI Jakarta). In the 3 years of study, the author joined with the reliability, availability, management, and safety laboratory (RAMS) and completed studies for 8 semesters.