FINAL PROJECT (TI141501)

COMPARING ROUTE ALTERNATIVES OF SEA TOLL PROGRAM USING COST-EFFECTIVENESS ANALYSIS

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Faculty of Industrial Technology
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COMPARING ROUTE ALTERNATIVES OF SEA TOLL PROGRAM USING COST-EFFECTIVENESS ANALYSIS

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ABSTRACT

The Ministry of Transportation *Republik Indonesia* has proposed 4 options to implement Sea Toll Program 2018. However, in order to choose the option, The Ministry of Transportation only considered the cost and qualitative advantages - disadvantages of each option. This research aims to help The Ministry of Transportation to choose the route option by considering costs and quantitative benefits of each option using Cost-Effectiveness Analysis. This research also aims to give additional option of Sea Toll Program 2018 implementation that can maximize the benefit obtained by the people who are living in *Daerah Tertinggal, Terpencil, Terluar, dan Pedalaman* (3TP Area).

This research is started by benefit and cost identification of each option, routing algorithm creation, benefit and cost calculation, Incremental Cost-Effectiveness Analysis, and Sensitivity Analysis. From this research, it is known that the new option proposed by the author is chosen with benefit point 0.6244 and total cost Rp345,581,964,670.00.

Keywords : Sea Toll Program, Cost-Effectiveness Analysis, Routing Problem

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PERBANDINGAN ALTERNATIF RUTE TOL LAUT MENGGUNAKAN ANALISIS EFEKTIVITAS BIAYA

Nama Mahasiswa	: Ahmad Avisiena Gaza
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ABSTRAK

Kementerian Perhubungan Republik Indonesia menawarkan 4 opsi penyelenggaraan tol laut. Tetapi, dalam pemilihan opsi tersebut, Kementerian Perhubungan hanya mempertimbangkan biaya dan manfaat kualitatif. Penelitian ini bertujuan untuk membantu Kementerian Perhubungan untuk memilih opsi rute yang terbaik dengan mempertimbangkan biaya dan manfaat secara kuantitatif dengan menggunakan Analisis Efektivitas Biaya (AEB). Penelitian ini juga bertujuan memberikan rekomendasi opsi baru penyelenggaraan Tol laut 2018 yang mampu memaksimalkan benefit yang diterima oleh masyarakat Daerah Tertinggal, Terpencil, Terluar, dan Pedalaman (Daerah 3TP).

Penelitian ini diawali dengan identifikasi biaya dan manfaat tiap opsi, pembuatan algoritma penyusunan rute, perhitungan biaya dan manfaat masing – masing opsi, perhitungan AEB secara inkremental, dan analisis sensitivitas. Dari penelitian ini, diketahui bahwa opsi baru yang disusun penulis dapat dipilih dengan poin manfaat sebesar 0.6244 dan total biaya Rp345.581.964.670,00.

Keywords : Kebijakan Tol Laut, Analisis Efektivitas Biaya, Permasalahan Penyusunan Rute

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Every suggestion is expected by the author to improve the research. Hopefully, this research is beneficial ass consideration for Sea Toll Program

implementation, as reference for the future research, and as the knowledge enrichment for the readers.

Surabaya, July 16^{th} 2018

Ahmad Avisiena Gaza

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ABBREVIATION LIST

3TP *Tertinggal, Terpencil, Terluar, dan Pedalaman*

A/E Auxiliary Engine

DWT Dead Weight Tonnage

GT Gross Tonnage

HP Horse Power

KTI *Kawasan Timur Indonesia*

M/E Main Engine

MCR Maximum Continuous Rate

NCR Normal Continuous Rating

SFOC Specific Fuel Oil Cons Main Engine

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CHAPTER 1
INTRODUCTION

In this chapter there will be explained the introduction to the research. This chapter contains the background of the research, problem formulation, research objectives, research benefits, research scopes, and the outlines of the research.

1.1 Background

Sea Toll Program is a program proposed by Joko Widodo on president election campaign 2014. (Sahid, 2014). Sea Toll Program was proposed because of price disparity of several commodities between *Kawasan Timur Indonesia (KTI*, eastern Indonesia region) and *Kawasan Barat Indonesia* (KBI, western Indonesia region). The price disparity was caused by the high shipping cost from the centers of Indonesian economy --such as Jakarta, Surabaya, and Makassar -- to *Daerah Tertinggal, Terpencil, Terluar, dan Pedalaman* (3TP) such as Miangas, Rote, and Merauke. By the concept of effective maritime connectivity, it was expected that the 3TP areas become more accessible so that the shipping cost can be reduced.

Table 1.1 Reduction of Price Disparity in Timika

No	Commodities	Price Reduction (%)
1	Cement	22.5
2	Rice	15
3	Wheat Flour	15
4	Sugar	11
5	Chicken	20

Source : The Ministry of Transportation, 2018

In 2017, Sea Toll Program had been implemented for 2 years. Started in 2016 by serving only 6 routes, Sea Toll Program 2017 was developed so that it could serve 13 routes. As it was budgeted Rp355.05 billion, Sea Toll Program could serve 41 ports and reduce 15 - 20 % price disparity. The example of Sea Toll Program is the price disparity reduction of several staple commodities in

Timika is shown in Table 1.1. Because of the positive impact of additional routes in 2017, The Ministry of Transportation proposed to add Sea Toll Program routes from 13 to become 15 routes in 2018. The government is willing to budget Rp447billion.

However, it cannot be neglected that the good intention of the government is still constrained by the infrastructure condition of several 3TP areas. Not all ports of 3TP areas are able to handle high-DWT vessels. Several 3TP areas do not have considerable depth so that high-DWT vessels are not able to berth. The government certainly cannot wait for all ports readiness, since in the beginning of 2018 the routes must be decided.

In order to solve the problem, The Ministry of Transportation proposed 5 route options with 4 diverse ways of implementation. Those 4 options are Multiport (Option 1 A & 1 B), Hub Spoke Mother & Feeder Vessel (Option 2), Hub Spoke Mother & Feeder Vessel with Container Subsidy (Option 3) and Crossing Vessel (Option 4). The route configuration of each option is also different. Because the different option may serve different ports, The Ministry of Transportation must decide which option must be chosen so that the benefit can be maximized.

In order to decide the options that will be implemented, The Ministry of Transportation considered the cost incurred on each option. However, even though it is already balanced by considering the technical advantages and disadvantages of each option, the cost consideration is not balanced with the consideration of quantitative benefit. The advantages and disadvantages are still in qualitative form and give technical consideration of each option. It must be ensured that the chosen option is really beneficial to the public welfare.

Therefore, in order to become the consideration to decide which option will be implemented in 2018, the author proposes to measure the quantitative value of the benefit generated by each option. This quantitative value will be considered with the cost of each option so that The Ministry of Transportation can select Sea Toll Program implementation option with Cost-Effectiveness Analysis. The author expects that by considering the quantitative benefits and the costs of each option, The Ministry of Transportation can decide the option which generates the most benefit within the determined budget.

The author attempts to propose new option. Since the Ministry of Transportation has not considered the benefits of each option yet, there is any possibility that the routes of proposed options have not maximized the benefits received by the people who are living in 3TP Areas. Furthermore, there has not been any specific consideration used by The Ministry of Transportation to arrange the routes. Therefore, it is expected that by that additional option The Ministry of Transportation will have guidance and example to determine Sea Toll Program routes configuration.

-

1.2 Problem Formulation

The problem that the author attempts to solve is that The Ministry of Transportation has not considered the benefits received by people who are living in 3TP Areas quantitatively to decide which option is going to be chosen. Since the benefit has not been considered, the routes of the options cannot maximize the benefit received by the people who are living in 3TP Areas.

1.3 Objectives

Based on the problem identification, there will be several objectives that the author attempts to achieve in this research. The objectives of this research are mentioned below.

1. To obtain a new option that can maximize the benefits received by the people who are living in 3TP areas.
2. To choose Sea Toll Program implementation option (multiport, hub and spoke, hub and spoke with container subsidy, and container crossing) that is able to give the highest benefit within the budget available for Sea Toll Program 2018.

1.4 Benefits

By this research, there are several benefits that can be obtained. The benefits of this research are mentioned below.

1. Measuring the benefit of each Sea Toll Program implementation option.
2. Obtaining new option as additional alternative.
3. Obtaining additional considerations to make and to choose routes configuration of Sea Toll Program.

1.5 Scope of This Study

1.5.1 Assumptions

In this subchapter there will be several assumptions used in this research. The assumptions are mentioned below.

1. All deliveries are assumed to obey the regulations (subsidy given is only for 115 TEUs and container used is dry container 20 ft).
2. The voyages are assumed to carry the commodities with quantities and configuration that are going to be determined in data processing.
3. The commodities are only consumed by the people who are living in the listed area of Sea Toll Program.
4. The vessel velocity is constant at 10 Knott.

1.5.2 Limitations

Besides the assumptions, there will be several limitations that constrains the research. The limitations are listed below.

1. Only listed ports of 3TP area from 2016 until 2018 are going to be considered.
2. The commodities that are going to be considered are staple materials (rice, sugar, cooking oil, and wheat flour).
3. The pickup of commodities from 3TP areas is not going to be considered.

1.6 Research Outline

These are the outlines of this research. There are 6 chapters in this research that are listed below.

CHAPTER I: INTRODUCTION

This chapter covers background of the research, problem formulation, research objectives, benefits, research scope, and rsearch outline.

CHAPTER II: LITERATURE REVIEW

In this chapter there will be explained some related theories that can help the researcher and the reader to understand the flow of research. There will be also several previous researches that will be compared with this research.

CHAPTER III: RESEARCH METHODOLOGY

In this chapter there will be two sections. The first section explains the research steps by using flowchart. The next section explains the research methodology with narration explanation.

CHAPTER IV: DATA COLLECTION AND PROCESSING

In this chapter there will be shown all data gathered by the author. There will also be explained the data processing to obtain the output of the result.

CHAPTER V: ANALYSIS AND INTERPRETATION

After the output from the data processing is obtained, the information obtained will be analyzed so that the result is able to help the researcher and the reader to the conclusion and recommendation.

CHAPTER VI: CONCLUSION AND RECOMMENDATION

There will be two sections in this chapter. The first section explains the conclusion that answers the research objectives. The next section explains the actions that can be executed by either Kementerian Perhubungan, the researcher who will continue the research, or other related parties.

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CHAPTER 2
LITERATURE REVIEW

In this chapter there will be explained some basic theories that are able to help the author and the reader to understand this research. The theories consist of introduction and the development of Sea Toll Program, the options of Sea toll Program 2018, Vehicle Routing Problem (VRP), Cost-Effectiveness Analysis, and previous research of Sea Toll Program.

2.1 Logistics System

According to Council of Logistics Management (Ballou, 2004) the definition of logistic management is the process of planning, executing, and controlling to achieve efficient, cost-effective flow and storage of materials, work in-process, finished products and related information from its origin point to consumption point so that the customer requirements are conformed.

Nowadays the role of logistics management is very important. There are some urgency to manage logistics. Some of urgencies are mentioned below.

1. The costs of logistics are significant

   Stated by International Monetary Fund (IMF) the average logistics cost reaches 12% of the world's Gross Domestic Product. For a single firm, the logistic cost ranges from 4 to over 30%. Therefore, if the cost can be reduced, the reduction will be significant.

2. Logistics customer service expectations are increasing

   The emergence of internet that has eased a lot of activities makes the expectation of customers also changes. The customers demand for rapid order processing, quick delivery, and high rate of product availability. Those all are covered by managing the logistics system.

3. The lines of supply and distributions are lengthened and becoming more complex.

   Globalization successfully forces the companies to take more on worldview of their operations. As the demand and supply now may come from other part of the world, the cost to store and to distribute the product from and to other countries must be pressed so that the companies can still obtain the expected number of profit.

Logistics system consists of several key and supporting activities. The key activities of logistics become the main concern in logistics strategy. The key activities according are mentioned below.

1. Customer Service Standards. This key activity cooperates with marketing division to determine the customer needs and wants related to logistic requirement and to set customer service level
2. Transportation. This activity covers selecting the mode of transportation, consolidating freight, routing, and scheduling vehicle.
3. Inventory Management. This activity consists of making raw materials and finished good policies, forecasting short-term sales, and managing location, size, and number of stocking point
4. Information Flows and Order Processing. This activity consists of making sales order-inventory interface procedure ad rules.

Besides those key activities, there are several activities that support those key activities. These activities may become only supportive, however if the function of these activities is maximized, then it can give significant impact to whole logistics activities. Those supporting activities are mentioned below.

1. Warehousing. Warehousing activities consist of space determination, stock layout and dock design, warehouse configuration, and stock placement
2. Materials handling. Activities related to materials handling are equipment selection, equipment replacement decision, order-picking procedures, and stock-storage and retrieval
3. Purchasing. Activities related to purchasing are supply source selection, timing and quantity determination policies
4. Protective packaging. This covers the decision to select packaging for handling, storage, and protection for the materials or products.
5. Cooperation with production / operation division. There are several activities that must be coordinated between logistician and productions /

operations division. It includes the determination of production quantities, sequence and production time.

6. Information maintenance. This activity is related to information collection, data analysis, and control procedures.

2.1.1 Logistic Challenges in Indonesia

From the previous subchapter there is small insight obtained related to logistic system. It is known that there are several urgencies to manage logistics and supply chain. And it is also known what activities that become the main concern of logistics. Then, if the insights obtained are reflected to the current condition of Indonesia, there will be several challenges for Indonesian government. Some of the challenges for Indonesia related to logistic system are mentioned below.

a. According to Study of Macro Economy Indicator, logistics cost of Indonesia is one of the highest logistic cost among ASEAN. The cost of logistics Indonesia achieves for about 24% of Indonesia Gross Domestic Product. If in 2011 Indonesia had Gross Domestic Product (GDP) as much as $707 billion, then the logistic cost was equivalent with $141 billion.

b. Indonesia maritime is still lack of connectivity. In order to transport big products from an island to another island, it takes a lot of time. The problem along with the lack of maritime infrastructure makes the cost needed to move product interisland becomes so much high. (Hermawanyadi, 2017)

c. The usage of Information Technology & Communication (ICT) is still ineffective. There is also problem with the technological gap between an island with another island. There are still some islands that are lack of ICT infrastructure. This condition makes company as the shipper from an island with a good condition of ICT infrastructure experiences difficulties to contact the product receivers from the island with bad condition of ICT infrastructure. The shipper cannot also track the movement of the products so that if the product is received in a bad condition, the shipper must resend a new product. This activity doubles the cost of product shipping.

d. Provided infrastructure is less-maintained. The unavailability of infrastructure in some regions is getting worse by the condition of infrastructure in several areas. Some regions may have already infrastructure to connect with other areas. However, because of lack of maintenance, the condition of the infrastructure also gives a risk to logistic system. A damaged road can be taken as one example. The damaged road makes the products carried by the truck passing on the road easier to be broken. In such roads there are also risk of accidents and risk of criminality. Therefore, the distribution cost to the area with bad condition of infrastructure will be higher.

2.2 Sea Toll Program Introduction

According to Joko Widodo in his campaign (Sahid, 2014), Sea Toll Program is a program to realize the connectivity of Indonesia maritime through an availability of scheduled big ships that routinely sail from the west to the east of Indonesia. This program aims to access the 3TP area, to ensure the availability of several commodities, and to reduce the price disparity so that the public welfare is able to be maximized. (Kementerian Perhubungan Republik Indonesia, 2017). The legal basis of Sea Toll Program implementation are listed below.

1. *UU Nomor 17 Tahun 2008 tentang Pelayaran*
2. *PP Nomor 20 Tahun 2010 tentang Angkutan di Perairan*
3. *PP Nomor 78 Tahun 2014 tentang Percepatan Pembangunan Daerah Tertinggal yang Berkaitan degan Distribusi Pangan dan Logistik*
4. *Peraturan Presiden Nomor 70 Tahun 2017 tentang Penyelenggaraan Kewajiban Pelayanan Publik untuk Angkutan Barang dari dan ke Daerah Tertinggal, Terpencil, Terluar, dan Perbatasan, as the replacement of Peraturan Presiden Nomor 106 Tahun 2015 tentang Penyelenggaraan Kewajiban Publik untuk Angkutan Barang di Laut*
5. *Peraturan Presiden Nomor 71 Tahun 2015 tentang Penetapan dan Penyimpanan Barang Kebutuhan Pokok dan Barang Penting*
6. *Peraturan Menteri Perhubungan Nomor 4 Tahun 2016 tentang Perubahan atas Peraturan Menteri Perhubungan Nomor 161 tahun 2015*

tentang Penyelenggaraan Kewajiban Pelayanan Publik untuk Angkutan Barang di Laut

7. *Peraturan Menteri Perhubungan Nomor 7 Tahun 2017 Perubahan Permenhub No. 10 th 2016 tentang Tarif Angkutan Barang di Laut Dalam Rangka Pelaksanaan Kewajiban Pelayanan Publik (PSO).*

By implementing Sea Toll Program, there are several impacts that are expected in logistics point of view. Several logistic impacts by the implementation of Sea Toll Program are mentioned below.

- According to Budi Karya Sumadi (Chandra, 2017), the minister of transportation, Sea Toll Program can ensure the certainty of supply, especially food material. By the certainty of supply, the ship schedule that moves toward 3TP areas also becomes certain. Thus, the shippers who are willing to deliver their products to 3TP areas can consolidate their product with other shippers so the charge loaded by a vessel approaches full container load. This can make the freight approaches economic of scale.
- After performing delivery to 3TP areas, the ship can also carry the commodities of 3TP areas back to their basic loading port so that the ship can return to the basic loading port with carrying charge. This can make the cost to return the ship and container to their departure point more beneficial. The merchants from 3TP areas can also market their product to western part of Indonesia.
- The availability of the ship delivering several construction materials such as cement, iron, and steels to the 3TP areas can reduce the price of those commodities in the 3TP areas. Those commodities become more affordable so that the cost to construct infrastructure in 3TP areas can also be reduced. The development of infrastructure, especially logistics infrastructure, in 3TP areas can increase the accessibility of the areas. The process to deliver the products around the areas becomes easier.

2.3 Sea Toll Policy Development

Sea Toll Program has been implemented since 2016. And every year its implementation is evaluated and adjusted. In this subchapter there will be explained the development of Sea Toll Program from the previous implementation years.

2.3.1 Sea Toll Program 2016

In the first year of implementation, Sea Toll Program only served 6 routes. The government budgeted Rp218.99 billion. There were 31 ports passed by the routes which are listed in the Table 2.1. In this year, the system used was port-to-port (multiport). The main vessels distributed commodities only to ports which were able to handle vessels with capacity more than 1000 DWT.

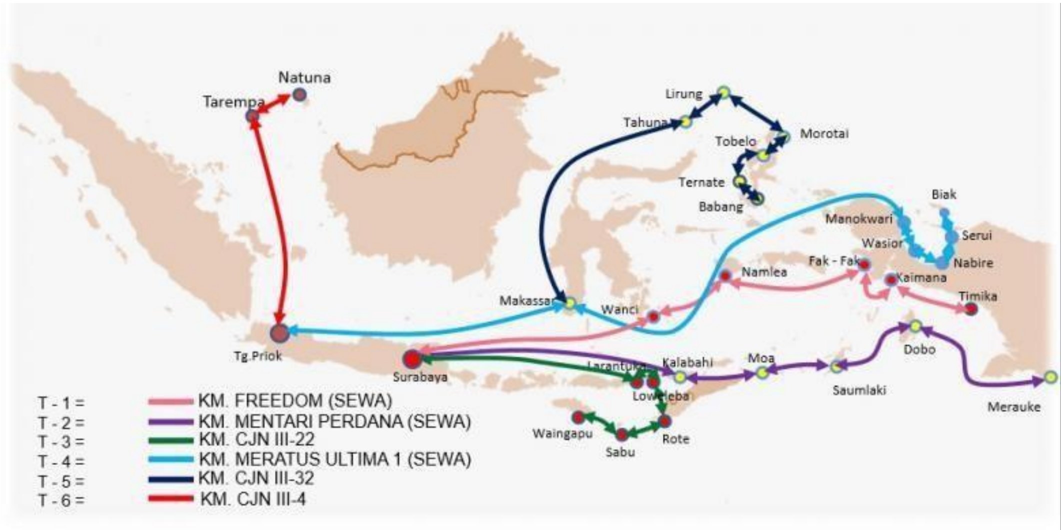

Figure 2.1 Sea Toll Program Routes 2016 (Fauzi, 2017)

Table 2.1 Sea Toll Routes 2016

Route	Route Network
R-1	Tanjung Perak – Wanci – Namlea – Fakfak – Kaimana – Timika – Kaimana – Fakfak – Namlea – Wanci – Tanjung Perak
R-2	Tanjung Perak – Kalabahi – Moa – Saumlaki – Dobo – Merauke – Dobo – Saumlaki – Moa – Kalabahi – Tanjung Perak
R-3	Tanjung Perak – Larantuka – Lewoleba – Rote – Sabu – Waingapu – Sabu – Rote – Lewoleba – Larantuka – Tanjung Perak

Table 2.1 Sea Toll Routes 2016 (con't)

Route	Route Network
R-4	Tanjung Priok – Makassar – Manokwari – Wasior – Nabire – Serui – Biak – Serui – Nabire – Wasior – Manokwari – Makassar – Tanjung Priok
R-5	Makassar – Tahuna – Lirung – Morotai – Tobelo – Ternate – Babang – Ternate – Tobelo – Morotai – Lirung – Tahuna – Makassar
R-6	Tanjung Priok – Tarempa – Natuna – Tarempa – Tanjung Priok

Source : The Ministry of Transportation, 2017

2.3.2 Sea Toll Program 2017

In the second year of implementation, Sea Toll Program served 13 routes. The government added the budget so the total budget was Rp355.05 billion. There were 41 ports passed by the routes which are listed in the Table 2.2. In this year, the system used was still port-to-port (multiport). The main vessels distributed commodities only to ports which were able to handle vessels with capacity more than 1000 DWT.

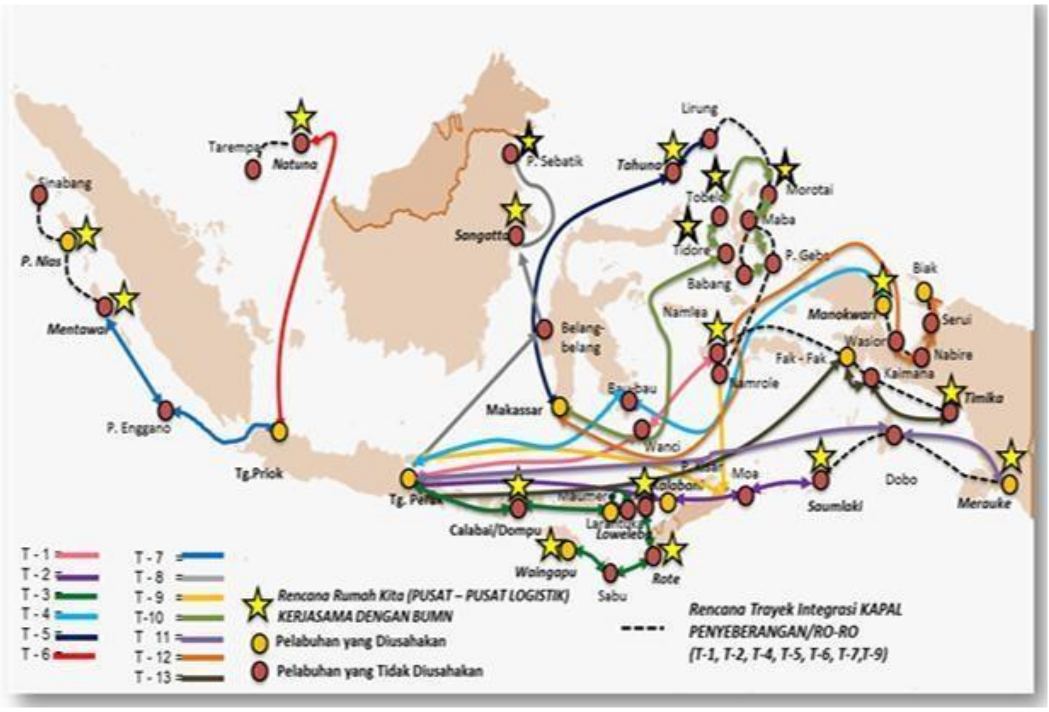

Figure 2.2 Sea Toll Program Routes 2017 (Kementerian Perhubungan Republik Indonesia, 2017)

Table 2.2 Sea Toll Routes 2017

Route Code	Route Network

Route Code	Route Network
R-1	Tanjung Perak – Wanci – Namlea – Wanci - Tanjung Perak
R-2	Tanjung Perak-Kalabahi-Moa-Saumlaki-Moa-Kalabahi-Tanjung Perak
R-3	Tanjung Perak-Calabai (Dompu)-Maumere-Larantuka-Lewoleba-Rote-Sabu-Waingapu-Sabu-Rote-Lewoleba-Larantuka-Maumere-Calabai (Dompu)-Tanjung Perak
R-4	Makassar-Tahuna-Lirung-Tahuna-Makassar
R-5	Tanjung Perak-Bau Bau-Manokwari-Bau Bau-Tanjung Perak
R-6	Tanjung Priok-Natuna-Tanjung Priok
R-7	Tanjung Priok-Enggano-Mentawai-Enggano-Tanjung Priok.
R-8	Tanjung Perak-Belang Belang -Sangatta-P Sebatik-Tanjung Perak
R-9	Tanjung Perak-Kisar (Wonreli)-Namrole-Kisar (Wonreli)-Tanjung Perak.
R-10	Makassar-Tidore-Tobelo-Morotai-Maba-Pulau Gebe-Maba-Morotai-Tobelo-Tidore-Makassar.
R-11	Tanjung Perak-Dobo-Merauke-Dobo-Tanjung Perak.
R-12	Makassar-Wasior-Nabire-Serui-Biak-Serui-Nabire-Wasior-Makassar.
R-13	Tanjung Perak-Fakfak-Kaimana-Timika-Kaimana-Fakfak-Tanjung Perak.

Source : Kementerian Perhubungan Republik Indonesia, 2018

2.4 Sea Toll Program 2018 Implementation Option

2.4.1 Option 1 Port to Port / Multiport

This option is similar with Sea Toll Program 2017 implementation. All routes are served directly from the basic loading port to each port in the route without transshipment. High-sized vessels are used to distribute the commodities from the basic loading port to other ports which its size is also huge. The difference with the previous implementation is the number of ports served. In order to serve all routes, 3 general cargo ships (break bulk) and 12 crane-equipped container vessels are used, with total capacity as much as 3300 DWT and 1200 DWT. Subsidy is given in form of vessel operation (as time charter benefit in vessel operators).

2.4.2 Option 2 Hub Spoke Mother and Feeder Vessel

This route uses Hub Spoke pattern with Tahuna, Tobelo, and Biak as the hub ports. Hub Spoke pattern means that 9 route uses multiport principle and other 6 routes use feeder method. This system used a vessel with higher capacity to transport big number of commodities to a port named hub port. After the commodities are unloaded from the ship, the commodities are then distributed to smaller ports using smaller vessels. By this system, ports with small size and swallow depth can be accessed. In order to serve all routes, 3 general cargo ships (break bulk), 10 crane-equipped container vessels, and several feeder vessels are used. Subsidy is given in form of vessel operation (as time charter benefit in vessel operators).

2.4.3 Option 3 Hub Spoke Mother and Feeder Vessel with Container Subsidy

This option is almost similar with option 2. The difference is that this option only has Bitung as its feeder port. The charge from Surabaya is carried by commercial vessel. The subsidy for this route is in form of container subsidy. In order to serve all routes, 3 general cargo ships (break bulk), 10 crane-equipped container vessels, and several feeder vessels are used.

2.4.4 Option 4 Crossing Vessel

Crossing vessel is a system to use transshipment system to shorten the cycle time of the vessels. To reach the ports in Papua, it takes longer days from Tanjung Perak Port, Surabaya. Therefore, by transshipping the container from one vessel in another vessel, it is expected that the first vessel can return to the basic loading port to load more commodities while another vessel is distributing the transshipped commodities to several ports in Papua. By using crossing vessel pattern, charge distribution to ports around Papua is able to achieve 2 voyage cycle time in a month. Other routes keep using direct shipment. In order to serve all routes, 3 general cargo ships (break bulk) and 10 crane-equipped container vessels are used.

2.5 Commodities Prioritization

Based on *Peraturan Presiden Nomor 71 Tahun 2015,* the commodities that are loaded into marine transportation are classified into three types. The types of commodities are staple materials and important materials. The classification is used to determine the proportion of space that can be filled by the commodities.

The staple materials are the materials that concern the lives of many people, have high fulfillment scale, and become the supporting factor of public welfare. People allocate most of their budget to fulfill the necessity of staple foods. Besides that, the staple materials are the biggest contributor of inflation rate and human nutrition fulfillment.

Staple materials are then classified based on the way to produce the products. There are three types of staple foods. They are agricultural staple foods, industrial staple foods, and staple materials from fishery and farms. The commodities that are categorized as staple materials and their classification are shown in the Table 2.3.

Table 2.3 Staple Foods Classification

Agricultural Staple Materials	Industrial Staple Materials	Staple Materials from Farms and Fishery
Rice	Sugar	Beef
Soybean	Cooking Oil	Chicken
Chili	Wheat Flour	Egg
Onion		Fish

Source : Ministry of Transportation (2018)

The next type commodities are important materials. Important materials are strategic materials that have important role to accelerate national development. Besides that, the materials which their price in some areas is diverse can also be categorized as important materials. The materials that are categorized as important materials are seeds of rice; corn; and soybean, fertilizer, LPG, plywood, cement, construction steel and iron, and light iron.

Besides those classifications, there is also prioritization to determine which commodity that is firstly loaded into Sea Toll Program vessels. The quantity of the commodities is determined after the commodities that have higher priority are loaded into the vessels. The commodities are going to be loaded with the prioritization as below.

- Priority 1 : Rice, sugar, cooking oil, wheat flour, cement
- Priority 2 : soybean, chili, onion, beef, chicken, egg
- Priority 3 : seeds of corn & rice, fertilizer, LPG 3 kg, plywood, construction steel and iron, light iron

After knowing the classification and prioritization of the commodities, it is decided that the commodities that are going to be considered in this research are rice, cooking oil, wheat flour, and sugar. It is because those commodities are classified as the staple materials that are also categorized as priority 1. It means that those materials have the biggest affection on human needs and inflation rates.

2.6 Vehicle Routing Problem (VRP)

Vehicle Routing Problem (VRP), according to Irnich (2014) is a problem to determine a set of routes to fulfill delivery request from a fleet of vehicles which is able to achieve the minimum cost. To conclude, from a known set of demand points and determined number of vehicles, determining set of routes to perform delivery process becomes the main objective.

There are several conditions that must be fulfilled for a problem so that it can be stated as VRP. The conditions are mentioned below.

1. Each route is started and finished at the depot (the point which becomes the departure point of the vehicles)
2. Every consumer (demand point) is visited once only by one vehicle
3. The demand of each route does not exceed the vehicle capacity
4. The cost to perform the delivery process must be minimized

Based on the definition and the condition of VRP, there are several characteristics of VRP. The characteristics of VRP are mentioned below.

1. There is a depot which becomes the departure point of vehicles, symbolized by O
2. The Depot has k vehicles to perform delivery process. Each vehicle has capacity C.
3. All vehicles are assigned to perform delivery process to n consumers which each consumer demand the product as much as q_i which i = 1, 2, 3, …n
4. The distance passed by each vehicle is attempted to be minimized because there is transportation cost incurred from a point to another point.

After several years since it was firstly introduced, VRP concept now experiences development. In some cases, some of conditions and characteristics mentioned are not fulfilled, however the case is still categorized as VRP. Nowadays, there are a lot of types of VRP based on the modification of the characteristics and conditions. The type of VRP is then classified based on these variations.

1. The network structures
2. The type of transportation requested
3. The constraints that affect the route individually
4. The fleet composition and location
5. The inter-route constrains
6. The optimization objectives

Sea Toll Program can also be solved by VRP with necessary modification. Each route of Sea Toll Program is started and finished at the determined loading ports. Some vessels are assigned to deliver several commodities to the 3TP areas as the demand points. Each vessel has also maximum capacity so that it should be ensured that all 3TP regions receive the demanded commodities.

2.8 Cost-Effectiveness Analysis

Cost-Effectiveness Analysis is an analysis about how resources should be used within a program (Anthony E. Boardman, 2001). This method is similar with Benefit Cost Analysis because it also measures the benefits generated per several units of resource used. However, the difference is that Benefit Cost Analysis measures the benefits and the costs in monetary value, meanwhile cost-effectiveness must not be in monetary value, but it may be assessed in their own units. The characteristics of Cost-Effectiveness are listed as below.

- Geared to technological efficiency
- Measured by the units of the benefits itself
- Either benefits or costs are fixed
- Has narrow and focused scope

It is reasonable to measure the benefits. It is because in order to increase public welfare the government is going to invest a much number of money. Moreover, the government also must spend some costs periodically to assure that the benefits will last in a long-term period. Therefore, it should be ensured that the cost that is spent by the government are used efficiently. There are 2 versions of Cost-Effectiveness Ratio. The first version of of Cost-Effectiveness is shown in Equation 2.1.

$$CE_i = \frac{C_i}{E_i} \quad (2.1)$$

CE_i = Cost-Effectiveness Ratio of project-i

C_i = the cost incurred to conduct project-i

E_i = the effectiveness (benefit) generated by project-i

This version of Cost-Effectiveness Ratio shows the average cost needed by project-i to generate a unit of benefit. The smaller the cost needed to generate a unit of benefit, the more effective the project is. If this version of Cost-Effectiveness Ratio is used, then the alternatives should be ordered from the smallest value of CE to the highest value.

The second version of Cost-Effectiveness Ratio is shown in the Equation 2.2 below.

$$CE_i = \frac{E_i}{C_i} \quad (2.2)$$

CE_i = Cost-Effectiveness Ratio of project-i

C_i = the cost incurred to conduct project-i

E_i = the effectiveness (benefit) generated by project-i

This version of Cost-Effectiveness Ratio shows the average unit of benefit generated by project-i from a unit of monetary value. The more the benefit generated per $1 (or other monetary value), the more effective the project is. If this version of Cost-Effectiveness Ratio is used, then the alternatives should be ordered from the highest value of CE to the smallest value.

Cost-Effectiveness concerns not only to compare quantitatively the benefits generated by several costs or resources of a project, but it is also important to state the consequences which is irreducible and non-quantifiable. It is because there are several benefits and costs that are difficult to be quantified. All significant benefits and costs must be included in consideration. Therefore, it should be assured that the significant benefits and costs which are non-quantifiable

If there are more than one project and all projects are mutually exclusive one another and not in a same scope, then incremental analysis is used. For instance, it is assumed that there is an existing project (it is then called project-E). A new project (it is then called project-N) is considered to replace the project-E. The formula to determine the incremental analysis is shown in equation 232.

$$Incremental\ CE\ ratio = \frac{C_N - C_E}{E_N - E_E} \tag{2.3}$$

Incremental CE Ratio	=	Incremental value of project-N & project E
E_N	=	Benefit generated by project-N (new project)
E_E	=	Benefit generated by project-E (existing project)
C_N	=	Cost incurred to conduct project-N (new project)
C_E	=	Cost incurred to conduct project-E (existing project)

If the result of incremental cost-effectiveness is negative, It means that there is any dominating – dominated relation. The cost and the benefit of each option should be compared. If the benefit of project-N is less than or equal to project-E but it spends more budget than project-E, it means that project-N is dominated by project-E. Project-E should not be considered.

2.9 Related Researches

In this subsection there will be compared several researches about Sea Toll Program evaluation. There will be 2 researches that are compared to this research. One of them is an undergraduate thesis researched by Vitasari (2017), an undergraduate student of Marine Engineering. Another one is a postgraduate thesis of Adiliya (2017), a postgraduate student of Erasmus University Rotterdam. The researches and the summary are shown in the Table 2.4.

Table 2.4 Researches Related to Sea Toll Program Evaluation

Previous Research			This Research
Year	2017	2017	2018
Type	Undergraduate Research	Postgraduate Research	Undergraduate Research
Author	Lutfia Nur Vitasari	Ana Adiliya	Ahmad Avisiena Gaza
Title	Analisis Evaluasi Implementasi Kebijakan Tol Laut	Analyzing an Integrated Maritime Transportation System: The Case The Port of Tenau Kupang As A Potential Transshipment Port for South-East Indonesia	Analysis of Sea Toll Program Alternatives Selection Using Cost-Effectiveness Analysis
Object	Routes 2016	Routes 2016 & 2017	Routes Option 2018
Method to Evaluate Route	Consumer Price Index (CPI), Herfindhal - Hierschman Index (HHI), Load factor comparison	Cost comparison	Cost-Effectiveness Analysis
Additional Route Alternative	Not adding new route alternative. Just evaluating the existing routes by comparing commercial and noncommercial routes	Adding new route from Tanjung Perak with Tenau kupang port as feeder port. The method used is linear programming	Adding new route by Modified VRP

In her undergraduate research, Vitasari (2017) has similar objectives by the author. She researches the efficiency of Sea Toll Program. However, the routes observed are for 2016 implementation year, which is the first-year implementation of Sea Toll Program whilst the author conducted her research in 2017. In her research, the author uses several points of view, which are economical point of view, market point of view, and ship operational point of view. To measure Sea Toll Program efficiency in economy point of view, the author uses Consumer Price Index (CPI) of commodities loaded from several cities before and after the implementation year. In market point of view, the author uses Herfindhal-Hierschman Index (HHI) to measure the normality of market share owned by the Sea Toll voyage. And the ship operational point of view is measured by the load factor of Sea Toll voyage and the number of vessel used. The author also recommends which route that should be reconfigured by comparing the route with the commercial one. The route which is also passed by the commercial route is suggested to change.

Adiliya (2017) in her postgraduate research analyzes the efficiency of Sea Toll Program in 2016 and 2017. The author takes shipping cost of cargo distribution as themain aspect. The author focuses the research only on the routes which depart from Tanjung Perak port. The author also attempts to recommend a new route if Tenau Kupang port as one of strategic ports establishment project becomes the feeder port. The efficiency of Sea Toll Program and the decision to implement the route is decided by comparing the cost incurred by those 3 options. In this research the author attempts to measure the benefits and costs generated by options proposed and implemented in 2018. By knowing the benefits and costs of each option, the option which is able to give more benefits within the budget determined by government. The author also attempts to give new option which can maximize the benefit obtained using modified Vehicle Routing Problem.

CHAPTER 3
METHODOLOGY

In this chapter there will be explained the methodology of this research. This chapter covers the flowchart of the research and the explanation.

3.1 Preliminary Study

In the preliminary study the author attempts to understand the fundamentals of Sea Toll Program. The existing condition of Sea Toll Program also becomes the most important point to be understood by the author before identifying the problem. There are two methods attempted by the author. The methods are literature review and interview.

3.1.1 Literature Review

Literature review is the first way to gain knowledge about Sea Toll Program. By doing literature review, the author gained fundamental knowledge about Sea Toll Program. The author is also able to obtain knowledge about Sea Toll Program from various sources and points of view, realizing that the source of literature review comes not only from ministry of transportation as the main executor of Sea Toll Program, but also from media, academics, and people from 3TP regions.

3.1.2 Interview

The other way to gain basic knowledge about Sea Toll Program is by conducting interview. During research, the author interviews several interviewees from kementerian Perhubungan to understand the detail plan of Sea Toll Program. By doing interviews, the author obtains knowledge that is not detailly explained in the literature.

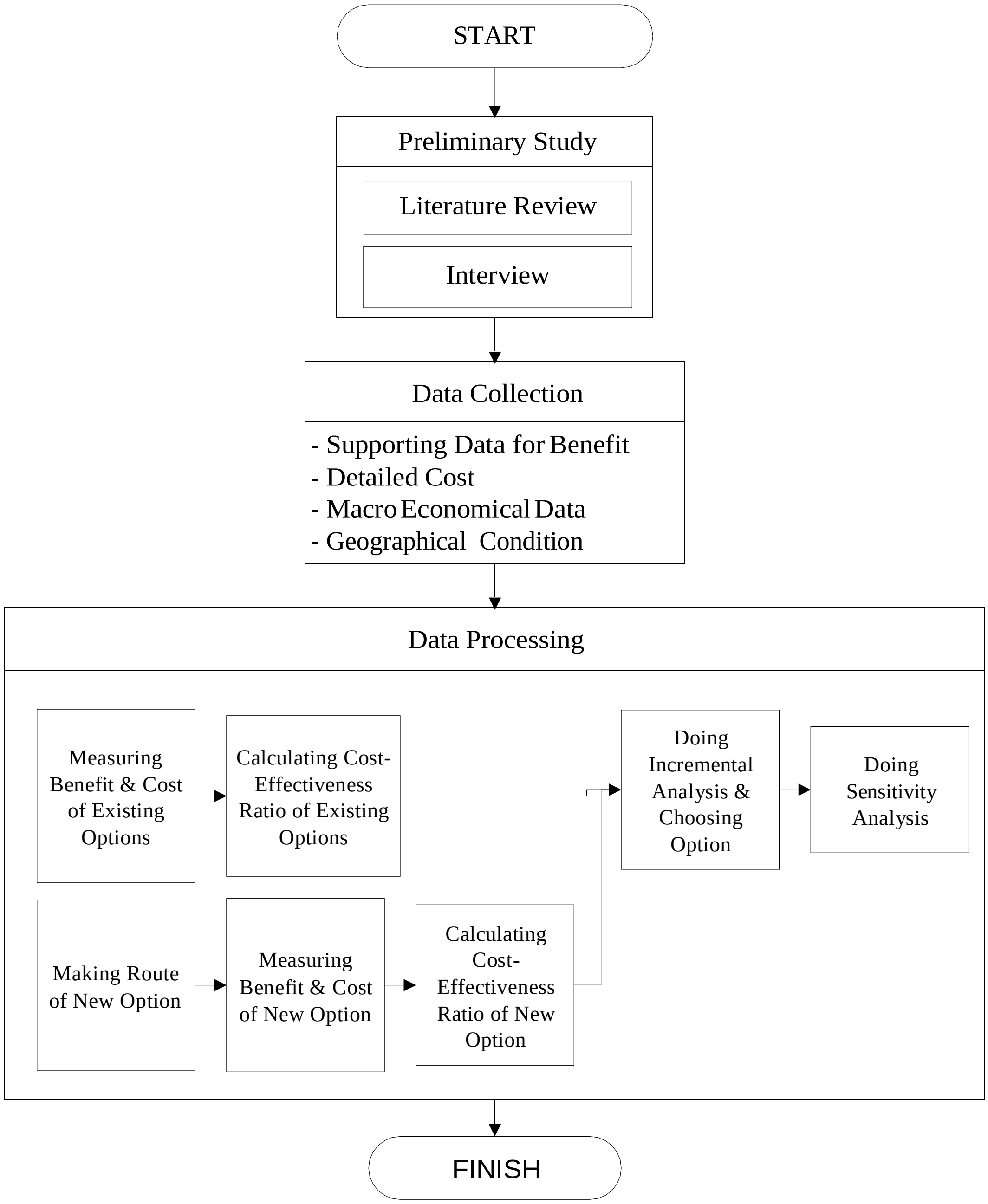

Figure 3.1 Flowchart of Research Methodology

3.2 Data Collection

After the problem has been identified, the data can collection stage can be started. There are several data needed by the author to conduct the research. The data needed are supporting data of benefit such as commodities consumption rate per capita per day by 3TP area and the quantity loaded by the vessel. The detail data of cost to implement Sea Toll Program are also needed by the author. Both data are needed to calculate cost-effectiveness of each option.

Besides those two data, macro-economy data such as inflation rate and geographical data such as coordinate of each 3TP area and total population of each region are also needed. Economy data are needed to adjust each monetary value so that it fits the periodical framework. Geographical data are needed to make new route alternative.

Similar to preliminary study, those data are obtained by literature review and interview. The difference is that the study becomes more focus. The data are obtained by the literature given by the ministry of transportation. Other data are also obtained from *Badan Pusat Statistika* (BPS*)*. The main interviewee for this research is Capt. Wisnu Handoko as *Kasubdit Angkutan Laut Dalam Negeri* from ministry of transportation Capt. Wisnu is the Person in Charge (PIC) of Sea Toll Program 2018. The author also makes several subordinates of Capt. Wisnu Handoko as the interviewees to gather more knowledge and insight about measuring benefits and costs of Sea Toll Program.

3.3 Data Processing

There are some sub-phases in the data processing phase. The sub-phases of data processing phase are explained below.

3.3.1 Calculating Cost-Effectiveness of Existing Route

1. Benefit Identification

The first step is identifying the benefit. The benefits are derived from the objectives of Sea Toll Program. There are three aspects of benefits that are going to be measured, they are number of node, the average deviation, and standard deviation of fulfilled demand proportion. Because those three aspects are not in same units, the measurement uses normalization as the formula of Point of Number of Node (PoN), Point of Average Deviation (PoA), and Point of Standard Deviation (PoSD). These three aspects are combined into benefit point with determined weight. The weights are obtained from reference and expert judgement by using pairwise comparison.

2. Data Collection

After the benefit has been identified, the data that are needed to measure the benefit and cost. The data that are needed are daily consumption rate of commodities, number of population of each 3TP areas, and basic geographical data. These data are used to calculate the demand of each 3TP Area.

3. Benefit Calculation

After the data needed have been calculated, firstly the quantity delivered to each destination must be calculated. Quantity of delivered container to each area is the main factor that determines the benefit point. The quantity is determined using nonlinear programming. After the quantity of delivered container is known, the fulfilled demand proportion is calculated. From this proportion of fulfilled demand, Point of Number of Node (PoN), Point Of Average Deviation (PoA), Point of Standard Deviation (PoSD), and benefit point can be calculated.

4. Cost Calculation

Firstly, the benefit and cost of Sea Toll Program should be identified. The way to quantify the benefit and cost must also be considered. Then, after the value is ensured to be in same periodical framework, the quantitative value of benefit and cost are measured to get cost-effectiveness ratio.

3.3.2 Making Routes of New Option

Simultaneously with calculating cost-effectiveness of existing route, the routes of new alternative will be determined. The steps to arrange routes for new option is mentioned below.

1. Creating algorithm

    The problem is firstly modelled and the algorithm to solve the problem is arranged. The process to solve the problem is modelled using flowchart. This model is then translated into Visual Basic Application (VBA) for Microsoft Excel.

    In this research, there is modification of the algorithm. The ship can still serve one more node although the quantity of commodities carried by the vessel is less than the demanded quantity, only if the demanded quantity is not more than the determined threshold. This method intends to increase the number of nodes served in a route.

2. Areas clustering

Before inputted into the VBA, the areas are firstly clustered based on their basic loading port and the type of vessel that will serve the area. It is because the areas that their ports can only be served by feeder vessel is not routed with other ports.

3. Distance calculation

The distance between each port must be calculated. This distance will be inputted to the model to determine the nodes that will be combined in a route.

4. Creating VBA Code

The model is then converted to be VBA language. From this result it can be obtained the nodes that are passed in each route, the period, the daily demand, and the demand per period. These results will be used to calculate the quantity of delivered container.

5. Benefit Calculation

Quantity of delivered container to each area is the main factor that determines the benefit point. The quantity is determined using nonlinear programming. After the quantity of delivered container is known, the fulfilled demand proportion is calculated. From this proportion of fulfilled demand, Point of Number of Node (PoN), Point of Average Deviation (PoA), Point of Standard Deviation (PoSD), and benefit point can be calculated.

6. Cost Calculation

Firstly, the benefit and cost of Sea Toll Program should be identified. The way to quantify the benefit and cost must also be considered. Then, after the value is ensured to be in same periodical framework, the quantitative value of benefit and cost are measured to get cost-effectiveness ratio.

3.3.3 Calculating Cost-Effectiveness Ratio of New Route Alternative

After the routes of new option are configured, its cost-effectiveness ratio will be calculated. The benefit and the total cost of the new option is firstly calculated. After that, the Cost-Effectiveness Ratio is calculated and compared with the other options.

3.3.4 Comparing Cost-Effectiveness Ratios of All Options

After all cost-effectiveness ratios of all options have been determined, then their cost-effectiveness ratios will be compared one another. The cost-effectiveness ratios are compared using incremental analysis. It is expected to select one option of Sea Toll Program option implementation.

3.3.5 Doing Sensitivity Analysis

After the best option is selected, sensitivity analysis should be conducted. Several factors that affects the choice will be simulated to be changed. This is conducted to know in what extend of factor change the selected option still gives the best impact.

3.4 Result Analysis and Interpretation

In this phase the result obtained from data processing phase will be interpreted and analyzed. If the options are more than one, incremental analysis will be conducted. The result of sensitivity analysis should also be analyzed. The result shows in which condition affected by the factors the selected option may change. The objectives of the research are then answered by the conclusions. And in recommendation there will be some actions that are suggested as the follow-up of the result.

CHAPTER 4
DATA COLLECTION AND PROCESSING

In this chapter there will be explained the data that have been collected and the data processing.

4.1 Benefit & Cost Identification

There are three benefits there are going to be measured. These benefits are identified from the objectives of Sea Toll Program. The benefits that will be measured in this research are mentioned below.

1. Number of nodes. The less the cycle time, the more destinations can be visited by a vessel. Number of nodes is important to be measured as the more the number of nodes, the more 3TP Areas can be accessed.
2. Proportion of fulfilled demand. Not only visiting the 3TP Areas. It should be ensured that the accessibility of the ship in 3TP Areas are useful to provide several commodities that are demanded by the people of 3TP Areas, especially staple materials. How useful the availability of the ship in 3TP Areas can be identified by how much the demand of the area can be covered. If the number of visited 3TP Areas are high but the number of commodities delivered to the areas are still less than the necessity, it fails to accomplish the second objective of Sea Toll Program, "Ensuring the availability of several commodities ".
3. The standard deviation of fulfilled demand rate in a route. There is any possibility that the proportion of fulfilled demand rate in a route is high only because of an area. The demand of an area can be fulfilled 100%. However, because it is concentrated in the area, the proportion of fulfilled demand rate in other areas that are located in the same route should be satisfied. Therefore, the availability of this parameter can complete the indicator of fulfilled demand proportion.

After the benefits are identified, the way to quantify the benefit should be formulated. The first is the formula of Point of Number of Node (PoN). The point obtained from number of node is obtained by dividing the number of node served per route by its maximum possible value. In this case, from all options, it is known that there is no route that served more than 10 nodes.

$$PoN = \frac{n}{n_{max}}$$

$$PoN = \frac{n}{10} \qquad (4.1)$$

With :

PoN	=	Point of Number of Node
n	=	number of node (area) served in a route

The next formula is Point of Average Difference to 1 (PoA). Firstly, the fulfilled demand proportion of all nodes served in a route is averaged. The deviation between the average and 1 is found. It symbolizes that the closer the average proportion to 1, the better the performance of the route. The number 1 states that the demand of all nodes in a route is perfectly fulfilled, without shortage or excess.

$$\mu_d = |\mu - 1|$$

$$PoA = \frac{\mu_{d_{Max}} - \mu_d}{\mu_{d_{Max}} - \mu_{d_{Min}}}$$

$$PoA = \frac{1 - \mu_d}{1 - 0}$$

$$PoA = 1 - \mu_d \qquad (4.2)$$

With :

µd	=	the average deviation to 1
µ	=	the average of fulfilled demand proportion in a route
μ_{dmax}	=	maximum accepted average deviation
μ_{dmin}	=	minimum accepted average deviation
PoA	=	Point of Average

The last point is Point of Standard Deviation (PoSD). The formula is obtained by normalizing the standard deviation. The formula of Point of Standard Deviation (PoSD) is shown in the Equation 4.3.

$$PoSD_1 = \frac{\sigma_{Max} - \sigma_1}{\sigma_{Max} - \sigma_{Min}}$$

$$PoSD_1 = \frac{1 - \sigma_1}{1 - 0}$$

$$PoSD = 1 - \sigma \qquad (4.3)$$

σ = the standard deviation

σ_{max} = maximum accepted standard deviation

σ_{min} = maximum accepted standard deviation

PoSD = Point of Standard Deviation

Those PoN, PoA, and PoSD are combined in one formula. The weight of each pointis obtained by using pairwise comparison with condition PoN > PoA > PoSD.

$$Point = \tfrac{3}{6}(PoN) + \tfrac{2}{6}(PoA) + \tfrac{1}{6}(PoSD) \qquad (4.4)$$

The point obtained in all routes in an option is then averaged. This average will be compared to other option and will be inputted as benefit in Cost Effectiveness Ratio.

4.2 Data Collection and Initial Data Processing

4.2.1 Routes of Sea Toll Program 2018

The first data collected are about the routes of Sea Toll Program 2018 implementation options. The data were obtained from Ministry of Transportation. The data are needed to know what cities are planned to be passed by Sea Toll Program 2018. Some cities passed by each option are diverse from one option by other options. It is because not all cities are able to be passed by a-115 TEUs vessel. Another reason is because some cities are quietly far to be reached by a voyage so that it needs to implement crossing vessel option (Option 4).

The options that their routes are found are the mentioned 5 options (1A, 1B, 2, 3, and 4). The routes of Sea Toll Program 2017 are also considered because if the options are all infeasible, it is decided to re-implement the routes of 2017. Besides that, there are also option 2018, the option that is currently implemented by the government in 2018. At last, there are total 7 options that are going to be considered, plus an option that is arranged by the author.

4.2.2 Consumption Rate of Each Commodity

The next data needed are consumption rate of each commodity. Consumption rate of each commodity shows how much commodities are consumed by people in Indonesia in a period of time. These data are needed because the data of demand of each commodity per area are unavailable. Even the company of commodities provider still generate a trial-and-error to determine the demand of each commodity on each area. This data can help the author to identify the demand of each commodity. However, because the data are only available for national consumption rate, it is assumed that the consumption rate for all area are same. The data of consumption rate are obtained from *Badan Pusat Statistika.*

Table 4.1 Consumption Rate per Commodity

Staple Materials	Rice (kg)	Sugar (kg)	Cooking Oil (liter)	Wheat Flour (kg)
2011	0.2459	0.0202	0.0279	0.004
2012	0.2393	0.0177	0.0293	0.0033
2013	0.2346	0.0182	0.0281	0.0034
2014	0.2323	0.0176	0.0293	0.0037
2015	0.233	0.0186	0.0319	0.0059
2016	0.2383	0.0205	0.0329	0.0057
2017	0.2351	0.0199	0.0333	0.0061
2018	0.2327	0.0194	0.0338	0.0066

Source : Badan Pusat Statistika, 2016

4.2.3 Geographical Data

Geographical data are several data that are related to the identity of the area. Geographical data contains the number of population, the population growth rate, the distance of each port of an area to other ports, and the coordinate of each area. The data are needed to determine the demand of each commodity per area and also to make new route alternative. The data about number of population are obtained from World Bank Data. The population growth rates are obtained from the Outlook Economic Country & Development (OECD). The coordinates of each area are obtained from Google Maps. And the distances between each port are obtained from *ports.com* and *marinetraffic.com* as the website that provides information related to marine traffic. Those data, besides the distance of each port, are combined and shown in the table below. These are the example of the data and the remained data are shown in the Appendix.

Table 4.2 Geographical Data

Area	Total Population 2017	Growth Rate per Year	Total Population 2018	Longitude	Magnitude
Adonara	250,931	8.50%	272,269	123.15	-8.25
Babang	102,288	10.43%	112,960	125.3431	-1.8456
Belang-belang	277,594	9.95%	305,218	119.174	-2.5044
Biak	143,969	9.42%	157,527	135.9801	-1.0381
Biaro	65,939	4.93%	69,192	125.22	2.6
Belinyu	322,653	11.00%	358,152	105.829	-1.65
Buhias	65,939	4.93%	69,192	125.455	2.6818
Enggano	2,691	7.97%	297,334	102.2139	-5.4737
Kahakitang	130,377	4.93%	136,808	125.5302	3.1785
Kakorotan	90,467	4.93%	94,929	127.0239	4.576

Source : World Bank,2018 and *Badan Pusat Statistika, 2016*

4.2.4 Maximum Number of Commodities Loaded by 20 feet Container

The next data gathered are the maximum number of commodities that can be loaded in a 20-feet container. The data are needed as the converter of demand and capacity in TEUs unit. The maximum number of commodities loaded in a container is determined the weight and the volume of the commodities. A 20-ft container has dimension 20 feet x 8 feet x 8 feet and is able to handle 20,000 kg load. If it is assumed that a container is only filled by a commodity and it is given 10% for free space in the container, then a container can load commodities with 18,000 kg maximum weight and volume 32.6101 m^3 . These number will be the constrain of maximum number of commodities loaded. If the commodity has weight less than or equal to 18,000 kg but the volume is already more than 32.6101 m^3, then the maximum number of commodities that are going to be loaded is equal to 32.6101 m^3 converted to kg. And if the volume of the commodity is still less than 32.6101 m3 but the weight already exceeds 18,000 kg, then the maximum number of commodities that can be loaded is 18,000 kg. Because it needs a converter to calculate the equivalent mass of 32.6101 m3 volume, the density of each commodity is needed as additional data.

This is the example to determine the maximum number of commodities loaded. It is known that the density of rice is 753 kg/m^3. It means that 32.6101 m^3 is equivalent with 32.6101 m^3 x 753 kg/ m^3 = 24,563.62 kg rice. Because it exceeds 18,000 kg as the maximum weight, then the maximum number rice that can be loaded in a 20-feet container is 18,000 kg.

Table 4.3 Commodities Quantity per Container

Commodities	Density (kg/m3)	Maximum mass (kg)	Maximum Volume (converted into kg)	Maximum Number Loaded (kg)
Rice	753	18000	24563.62	**18000**
Sugar	849	18000	27695.24	**18000**
Cooking Oil	930	18000	30337.54	**18000**
Wheat Flour	593	18000	19344.26	**18000**

Source : Elgas.com, 2017

4.2.5 Daily Demand of Each Area

Daily demand of each area is obtained by the multiplication of population number per area with the daily consumption rate of each commodity. To remind the reader, it is assumed that the daily consumption rate for all area is same. Below it is shown the example of calculation.

Known :

Adonara population number in 2018 = 272,269 people

Daily consumption rate of rice in 2018 = 0.2327 kg/people

$$Daily\ Rice\ Demand_{Adonara}$$

$$= Number\ of\ Population_{Adonara}\ x\ Daily\ consumption_{Rice}$$

$$Daily\ Rice\ Demand_{Adonara} = 272{,}269\ x\ 0.2327\ kg/people$$

$$Daily\ Rice\ Demand_{Adonara} = 63{,}358.76\ kg \quad (4.5)$$

Because this number of demand is still in kilogram, it needs to convert the unit into TEUs (Twenty-feet container Equivalent Unit) so that the number of daily demand of all commodities can be summed. The example of calculation and the recapitulation of daily demand all shown below. And the example of calculation result is shown in Table 4.5.

$$Daily\ Rice\ Demand\ (TEUs)\ _{Adonara} = \frac{Daily\ Rice\ Demand\ (kg)_{Adonara}}{Maximum\ Number\ of\ Rice\ per\ TEUs}$$

$$Daily\ Rice\ Demand\ (TEUs)\ _{Adonara} = \frac{63{,}358.76\ kg}{18{,}000\ kg/TEUs}$$

$$Daily\ Rice\ Demand\ (TEUs)_{Adonara} = 3.52\ TEUs \quad (4.6)$$

Table 4.4 Daily Container Demand

Area	Daily Rice Demand (TEUs)	Daily Sugar Demand (TEUs)	Daily Cooking Oil Demand (TEUs)	Daily Wheat Flour Demand (TEUs)	Daily Container Demand (TEUs)
Adonara	3.5199	0.2927	0.5109	0.0997	**4.4232**
Babang	1.4604	0.1214	0.2120	0.0414	**1.8351**
Belang -belang	3.9459	0.3281	0.5728	0.1118	**4.9585**
Biak	2.0365	0.1693	0.2956	0.0577	**2.5592**
Biaro	0.8945	0.0744	0.1298	0.0253	**1.1241**
Belinyu	4.6302	0.3850	0.6721	0.1311	**5.8185**
Buhias	0.8945	0.0744	0.1298	0.0253	**1.1241**

Table 4.4 Daily Container Demand (con’t)

Area	Daily Rice Demand (TEUs)	Daily Sugar Demand (TEUs)	Daily Cooking Oil Demand (TEUs)	Daily Wheat Flour Demand (TEUs)	Daily Container Demand (TEUs)
Enggano	3.8440	0.3196	0.5580	0.1089	**4.8304**
Kahakitang	1.7687	0.1471	0.2567	0.0501	**2.2226**
Kakorotan	1.2273	0.1021	0.1781	0.0348	**1.5422**

Source : Processed by Author

4.2.6 Benefit Calculation

Daily demand of each 3TP Area and the cycle time of each route become important input to calculate benefit. The cycle time of each route is the time needed by vessel to travel from basic loading port, to visit all ports in a route, and then return to the basic loading port must be calculated, plus the loading and unloading time in each port. It is assumed that loading and unloading time in the basic loading port at the beginning of a cycle is equal to 2 days (Handoko, 2018). Meanwhile loading and unloading time besides that is assumed 1 day for each stop in a port.

After calculating the cycle time per route, the demand of each area can be calculated. It is obtained by multiplying the daily demand of each port in a route with the cycle time of the route. The demand will be roundup as integer as it shows how many containers should be delivered to the area.

$$Demand_i = DailyDemand_i x \ Cycle\ Time_A \quad (4.7)$$

With :

Demand-i = the demand of area – i (Container)

Daily Demand-i = the daily demand of area-I (Container)

Cycle Time-A = The cycle time of route A in which area-i belongs

This will be given the example of calculation. The daily demand of Sikakap is 1.45 container. If Sikakap is in route 1 of option 1 A and the cycle time of route 1 is 8 days, then the demand of Sikakap in option 1 A is calculated below.

$$Demand_{Sikakap} = DailyDemand_{sikakap} x\ Cycle\ Time_1$$

$$Demand_{Sikakap} = 1.45\ {}^{container}/_{day}\ x\ 8\ days$$

$$Demand_{Sikakap} = 11.6\ container$$

$$Demand_{Sikakap} = 12\ containers\ (rounded\ up) \quad (4.8)$$

The example of demand calculation for option 1 A is shown in the Table 4.5. The other results are shown in Appendix 8.

After demand of each area has been calculated, the quantity delivered to each area simultaneously with the point of each route. The quantity delivered will affect the proportion of fulfilled demand per area. The formula of fulfilled demand proportion is shown in the Equation 4.8.

$$Proportion_i = \frac{x_i}{Demand_i} \quad (4.9)$$

With :

Proportion-i	=	proportion of fulfilled demand in area – i
xi	=	quantity of containers delivered to area – I (containers)
Demand-i	=	demand of area-i (containers)

The proportion of all areas in one route will be measured its average and standard deviation. These standard deviation and average will be used to calculate Point of Average (PoA) and Point of Standard Deviation (PoSD) along with Point of Number of Node (PoN). The formula of PoN, PoA, amd PoSD can be looked in Equation 4.1, Equation 4.2, and Equation 4.3. In order to determine the delivered containers quantity that can maximize the point. The objective function is to maximize the point and quantity of delivered container as decision variable.

Index

i = area in the route

Decision Variables

x_i = quantity of containers delivered to area-i

Parameters

n = number of nodes served in the route

Objective Function

$$Max\ Point = \frac{3}{6} PoN + \frac{2}{6} PoA + \frac{1}{6} PoSD \qquad (4.10)$$

Constrains

Subject to

$$\sum_{1}^{n} x_i \leq 102 \qquad (4.11)$$

$$\sum_{2}^{n} x_i \leq 89 \text{ (for feeder only)} \qquad (4.12)$$

$$x_i \ni integer \qquad (4.13)$$

$$x_i > 0 \qquad (4.14)$$

Equation 4.10 shows the objective function is maximizing the benefit point obtained. There are several constrains that must be fulfilled. Equation 4.11 shows the capacity constrain of big vessel. Equation 4.12 shows the capacity constrain for feeder vessel. That is why the first destination port (the hub port) is not included in this constrain. Equation 4.13 and 4.14 are constrain for the quantity of commodities loaded must be in positive integer. The average of benefit points of all routes in an option are then become the final point that is going to be compared per option. The example of calculation result is shown in Table 4.6 and 4.7.

Table 4.5 Demand Per Area Calculation (Option 1 A)

Port 1	Port 2	Port 3	Port 4	Port 5	Cycle Time	Demand per Day					Demand per Period				
Sikakap	Enggano				8	1.45	4.83				12	39			
Tanjung Pandan	Pangkal Balam	Tarempa	Natuna		14	3.09	3.41	1.27	1.27		44	48	18	18	
Belang - Belang	Sangatta	Sebatik			15	4.59	5.72	3.18			69	86	48		
Tahuna	Melangoane	Lirung			21	2.14	1.48	1.48			45	32	32		
Tidore	Tobelo	Morotai	Maba	Gebe	19	2.14	3.07	1.05	1.48	0.87	41	59	21	29	17
Wanci	Namlea				16	1.58	2.22				26	36			
Wasior	Nabire	Serui	Biak		25	0.51	2.39	1.57	2.38		13	60	40	60	
Fakfak	Kaimana	Timika			24	1.26	0.94	3.46			31	23	83		
Fakfak	Kaimana	Timika			24	1.26	0.94	3.46			31	23	83		
Merauke					27	3.68					100				
Saumlaki	Dobo				21	1.84	1.54				39	33			
Kisar	Namrole				14	1.84	2.22				26	32			
Kalabahi	Moa				14	3.34	1.84				47	26			
Dompu	Maumere	Larantuka	Adonara	Lewoleba	14	4.02	5.23	4.14	4.14	2.26	57	74	58	58	32
Rote	Sabu	Waingapu			17	2.61	6.08	4.16			45	104	71		

Table 4.6 Quantity of Delivered Container per Area and Proportion of Fulfilled Demand (Option 1A)

Route	Delivered Container					Proportion of Fulfilled Demand				
1	12	39				1.00	1.00			
2	34	38	15	15		0.77	0.79	0.83	0.83	
3	35	43	24			0.51	0.50	0.50		
4	42	30	30			0.93	0.94	0.94		
5	24	36	13	18	11	0.59	0.61	0.62	0.62	0.65
6	26	36				1.00	1.00			
7	8	35	24	35		0.62	0.58	0.60	0.58	
8	24	18	60			0.77	0.78	0.72		
9	24	18	60			0.77	0.78	0.72		
10	100					1.00				
11	39	33				1.00	1.00			
12	26	32				1.00	1.00			
13	47	26				1.00	1.00			
14	21	27	21	21	12	0.37	0.36	0.36	0.36	0.38
15	21	49	32			0.47	0.47	0.45		

Table 4.7 Point Calculation (Option 1 A)

Route	Average Difference	Standard Deviation	Number of Node Served	PoA	PoSD	PoN	Point
1	0.0000	0.0000	2	1.0000	1.0000	0.2000	0.6000
2	0.1922	0.0305	4	0.8078	0.9695	0.4000	0.6308
3	0.4976	0.0042	3	0.5024	0.9958	0.3000	0.4834
4	0.0639	0.0024	3	0.9361	0.9976	0.3000	0.6283
5	0.3835	0.0222	5	0.6165	0.9778	0.5000	0.6185
6	0.0000	0.0000	2	1.0000	1.0000	0.2000	0.6000
7	0.4045	0.0154	4	0.5955	0.9846	0.4000	0.5626
8	0.2401	0.0323	3	0.7599	0.9677	0.3000	0.5646
9	0.2401	0.0323	3	0.7599	0.9677	0.3000	0.5646
10	0.0000	0.0000	1	1.0000	1.0000	0.1000	0.5500
11	0.0000	0.0000	2	1.0000	1.0000	0.2000	0.6000
12	0.0000	0.0000	2	1.0000	1.0000	0.2000	0.6000
13	0.0000	0.0000	2	1.0000	1.0000	0.2000	0.6000
14	0.6335	0.0054	5	0.3665	0.9946	0.5000	0.5379
15	0.5372	0.0107	3	0.4628	0.9893	0.3000	0.4692
Average Point							0.5740

4.2.6 Cost Component

There are 3 types of cost related to Sea Toll Program. Those are fixed costs, variable costs, and overhead costs. Variable costs are the costs which are vary & dependent on the number of containers carried and the ports that are visited. Fixed costs are the costs which are relatively similar among the options. Fixed costs are only affected by the type and the number of vessels used. Before knowing the formula, it must be known the assumption to calculate the total cost. The assumption that must be known are listed in the Table 4.9.

Table 4.8 Fixed & Variable Cost

Fixed Cost	Variable Cost
Charter Rate	Fuel Cost
Labor Expenses : Salary Compensation Health Compensation Insurance Laundry Freshwater	Port Dues : Berthing Mooring Postponement
Ship Insurance	Lubricant Cost
Fumigation Cost	Loading/Unloading Cost : Forklift Rent Crane Rent Cost Loading/Unloading Cost
Maintenance Cost	Marketing Cost
	Labor Premium

Source : Kementerian Perhubungan Republik Indonesia, 2018

Table 4.9 Assumption for Cost Calculation

Cost Component	Assumed Value	Related Reference
NCR	0.7 x Horse Power	(Kementerian Perhubungan Republik Indonesia, 2018)
HP M/E for Big Vessel 115 TEUs	2635 HP	(Adiliya, 2017)
HP A/E for Big Vessel 115 TEUs	1137 HP	(Adiliya, 2017)
SFOC M/E	0.22 gram/HP.hour	(Adiliya, 2017)
SFOC A/E	0.293 gram/HP.hour	(Adiliya, 2017)
Fuel Price	Rp10,550.00/liter	(Shell Indonesia, 2018)
Contract Day	275 Days	(Handoko, 2018)
GT for Big Vessel 115 TEUs	2997 Ton	(Adiliya, 2017)
DWT for Big Vessel 115 TEUs	3106 Ton	(Adiliya, 2017)
DWT for Feeder Vessel 100 TEUs	2000 Ton	(Adiliya, 2017)
GT for Feeder Vessel 100 TEUs	1800 Ton	(Adiliya, 2017)
HP M/E for Feeder Vessel 100 TEUs	1900 HP	(Adiliya, 2017)
HP A/E for Feeder Vessel 100 TEUs	1000 HP	(Adiliya, 2017)
Loading Tariff per TEU	Rp100,000.00	(Klik Logistic, 2018)
Basic Salary per Position	On Appendix	(Kementerian Perhubungan Republik Indonesia, 2018)
Price Water	Rp600,000.00 per ton	(Supply Air Bersih, 2017)
Vessel Age	1 year	(Kementerian Perhubungan Republik Indonesia, 2018)

Table 4.9 Assumption for Cost Calculation,(con't)

Cost Component	Assumed Value	Related Reference
Big Vessel Price	10,000,000,000.00	(Idris, 2017)
Feeder Vessel Price	6,000,000,000.00	(Idris, 2017)
Charter Rate 2015	$1900 per day	(Adiliya, 2017)
Inflation Rate per April 2018	3.41%	(Bank Indonesia, 2018)
Exchange Rate per May 28th 2018	1 US$ = Rp14,022.00	(Bank Indonesia, 2018)

After that, the cost calculation can be calculated. The costs that are going to be calculated are the cost which are listed on *Peraturan Menteri Perhubungan Nomor 22 Tahun 2018* and *Peraturan Presiden Nomor 71 Tahun 2015.* The costs that are going to be calculated and their formula are shown in the Table 4.8.

Table 4.10 Formula for Cost Component Calculation

Cost Component	Formula
Fuel Cost	$\frac{1}{0.86} \; x \; FCt \; x \; Fuel \; Price \; x \; Travel \; Time \; x \; Voyage$ $FCt = NCR \; x \; SFOC \; x \; 24 \; hour \; x \; \frac{10^{-3} \; kg}{gram} \; x \; 1.05 \; kg/hour$
Loading Charge (Revenue)	Voyage Frequency x Loaded Quantity per Voyage x Loading Tariff per TEUs
Labor Salary	Basic Salary per Position x (1 + 0.35) x Operational Months
Health Compensation	Number of Labor x Number of Operation Days x Rp20,000.00 per Labor per Day
Freshwater Cost	Operation Days x (Number of Labor + Maximum 23 Additional Crew + Deck Necessity + Accommodation Necessity) x 200 liter/person/day x Water Price per Liter
Laundry Cost	Operation Weeks x Number of Labor x Rp10,000.00 per labor per week
Maintenance Cost	Vessel age x DWT x Rp500,000.00 per DWT per year
Ship Insurance	1% of Vessel Price
Fumigation Cost	Rp25,000,000.00
Lubricant Cost	(1/0.89) x 2gram/HP/hour x 24 hours x MCR x 10^{-3} x 1.05 x Voyage Frequency x Travel Time
Marketing Cost	2% of Revenue
Berthing Cost	Vessel GT x BNBP Tariff x Voyage Frequency
Mooring Cost	Vessel GT x BNBP Tariff x Voyage Frequency
Postponement Cost	Vessel GT x (BNBP Variable Tariff + BNBP Fixed Tariff) x 2 Motion In x 2 Motion Out
Container Loading/Unloading Cost	Filled Container Tariff x Filled Container Loaded/Unloaded + Blank Container Tariff x Blank Container Loaded/Unloaded
Overhead Cost	5% Fixed Cost
Profit Margin	10% Total Cost

Source : Kementerian Perhubungan Republik Indonesia, 2018

4.3 Determining Routes of New Option

4.3.1 Algorithm Creation

A. Main Algorithm

The new routes are arranged by Visual Basic Application for Microsoft Excel. The first step to make new routes are creating the algorithm. The problem is modelled in a flowchart diagram. The flowchart is shown in Figure 4.2.

The model is started by defining the capacity. The capacity is defined by the type of the ship used by each route. There are 2 types of ship used : big vessel and feeder vessel. If the big vessel is used, the capacity is 102 TEUs. If the feeder vessel is used, the capacity is 89 TEUs.

The next step is defining the basic loading port (the depot) of each route. There are 3 basic loading ports of Sea Toll Program 2018. They are Tanjung Perak (Surabaya), Tanjung Priok (Jakarta), and Teluk Bayur (Padang). Besides that, the hub ports which becomes the charge exchange place from mother vessel to feeder vessel or from mother vessel to crossing vessel are also considered as the depot. In this case, Tahuna, Tobelo, and Timika is chosen as the hub port between mother vessel and feeder vessel and Biak is chosen as the hub port between mother vessel and crossing vessel.

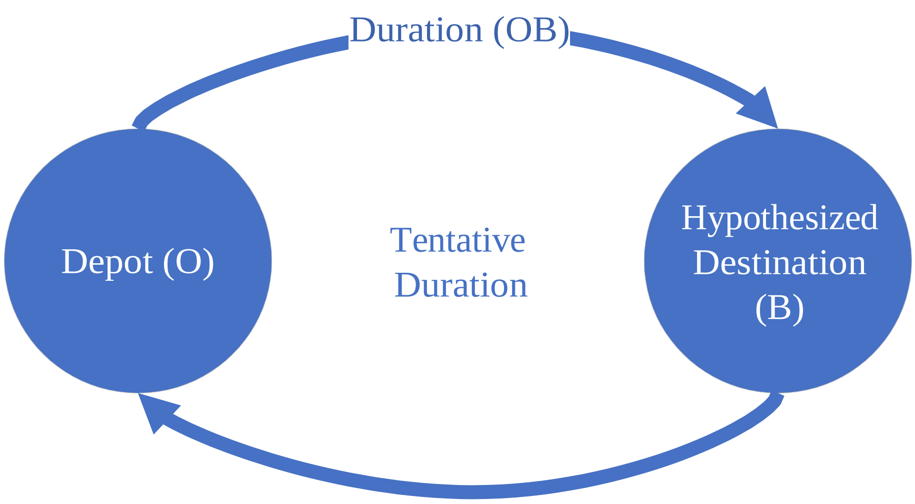

Figure 4.1 Illustration of Tentative Duration for First Iteration

After defining the basic loading port, the initial port should be determined. Initial port is the port that its destination is going to be found. In the first iteration of a route, the initial port is the depot. The distance travelled from the depot to the initial port must be calculated. Let this duration to travel the distance be defined as Duration OA. Thus, the value of OA in the first iteration is 0.

Then, the next step is finding the hypothesized destination port. Hypothesized port is actually destination port that is going to be checked its feasibility to be visited. The detail way to find hypothesized part is explained in the next subchapter. After that, the duration to travel from the initial point to the hypothesized destination point is calculated. Let the duration be defined as Duration AB. The duration travelled from the depot to the hypothesized should also be calculated. Let the duration be called as Duration OB.

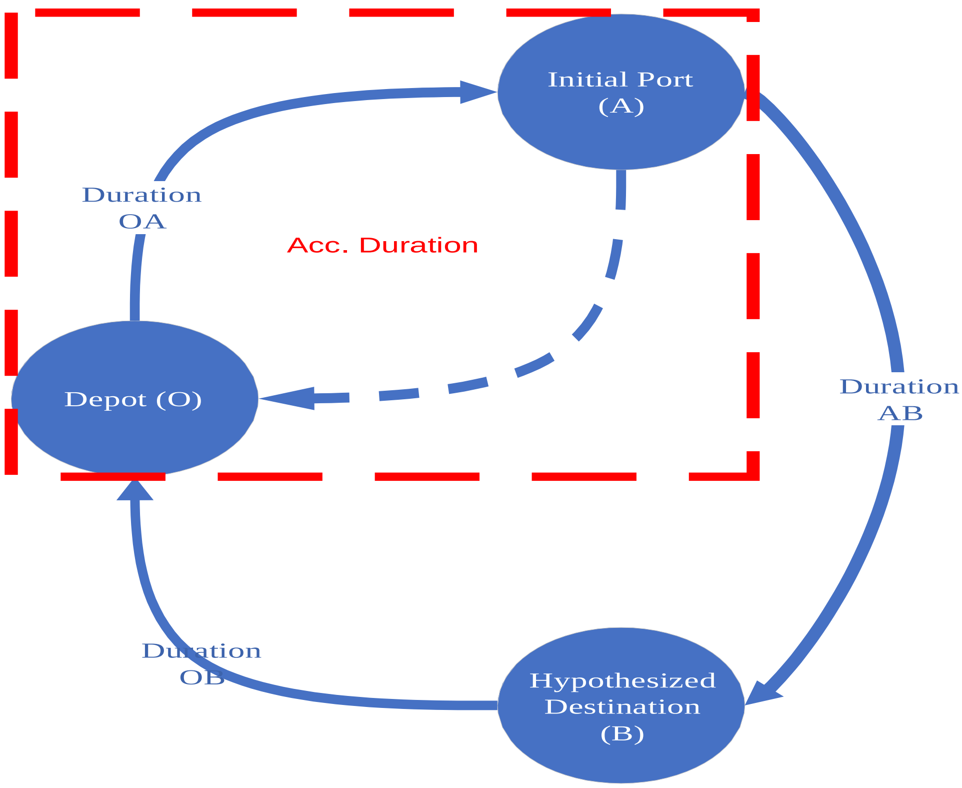

Figure 4.2 Illustration of Tentative Duration for Second Iteration

After the tentative daily demand and tentative period are updated, the tentative demand should also be updated. Tentative demand is the total demand that should be fulfilled in a route. The formula is shown in Equation 4.17.

$$Tentative\ Demand = Tentative\ Daily\ Demand\ x\ Tentative\ Cycle\ Time \quad (4.15)$$

Tentative demand is actually the demand that will be compared to the capacity of the ship. If the tentative demand is still within the capacity, the hypothesized destination becomes the fix destination and it will be included in the route. Tentative daily demand will become the accumulated daily demand and tentative cycle time will become accumulative period.

If the tentative demand is out of the capacity, it will firstly be checked whether it is still within the threshold or not. Threshold is the difference between tentative demand and the capacity that is acceptable to be served. In this case, threshold is determined as 35. This number comes from the biggest daily demand multiplied by the minimum distance between 2 ports. If the difference between tentative demand and capacity is still within the threshold, then the hypothesized destination is accepted as fixed destination, the tentative daily demand is updated as accumulated daily demand, and tentative cycle time is updated as accumulated period. On the other hand, if the difference between capacity and tentative daily demand is out of threshold, the basic loading port will become the destination and the accumulated period and daily demand will not be updated.

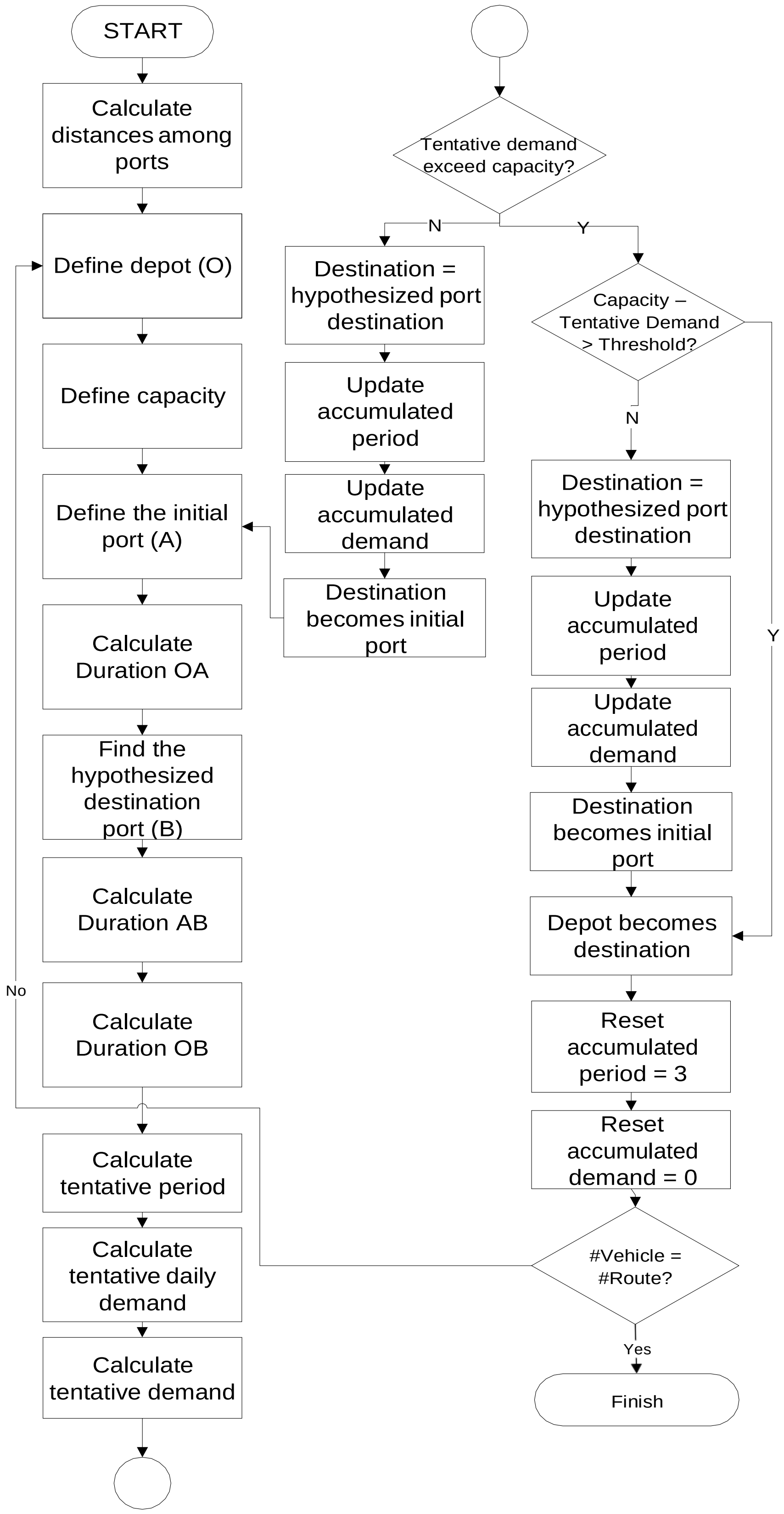

Figure 0.3 Algorithm to Create New Routes

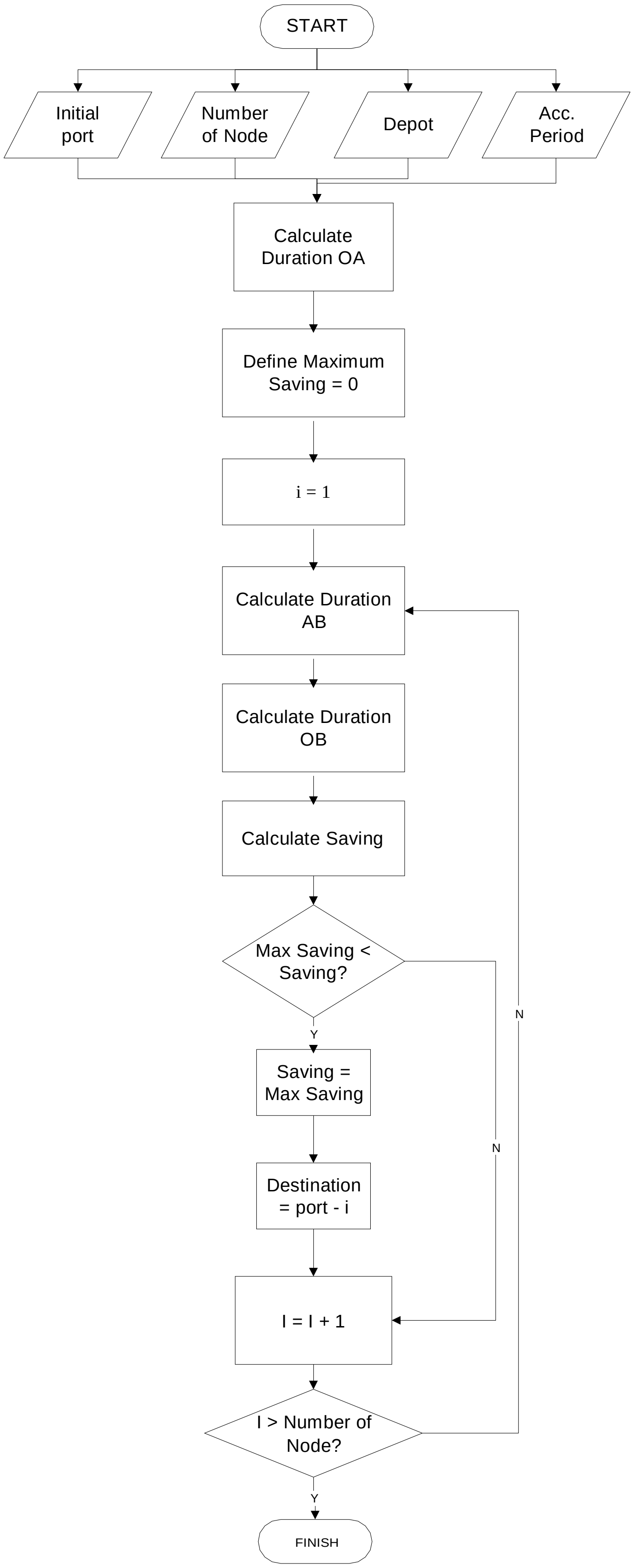

Figure 4.3 Algorithm for Saving

B. Saving Algorithm

Saving algorithm is the algorithm needed to find the hypothesized destination. The input needed for this algorithm are the index of the depot and the initial port, the accumulated period, and the total number of nodes in the data. The duration to travel from a node to another node must also be calculated. The model of saving algorithm is explained in flowchart in Figure 4.4.

The algorithm is started by calculating Duration OA (the duration travelled from depot to the initial port). After that, the counter variable (i) is started by 1 as the looping start. The current value of maximum saving is also defined as 0 as the initial value. The hypothesized destination is the area which has index value as counter variable (i).

Duration from the depot to the hypothesized destination (Duration OB) and the duration from the initial port to the hypothesized destination (Duration AB) must be calculated. Both of them will become the input to calculate saving.

$$Saving = Duration\,OB + Duration\,OA - Duration\,AB \tag{4.16}$$

The saving resulted from the calculation will be compared to maximum saving. If it is more than maximum saving, the value of saving will replace the value of maximum saving and the index of hypothesized destination will be saved as the tentative output. On the other hand, if it is less or equal to the maximum saving, the value of maximum saving and the tentative output will not be replaced. Then the counter variable (i) will be added by 1 as the update of the number of iteration. The number of iteration is equal to the number of node. The tentative output that stands until the end of iteration will become the output of the algorithm and it will become input for the main algorithm.

4.3.2 Areas Clustering

Before creating the route, the listed areas are clustered, depends on the basic loading port that is going to serve the cluster and the type of ship. This clustering process is done related to the type of ship so that the areas which has small ports can be served by feeder vessel and the areas that are quietly far from the depot can be served by crossing vessel.

Table 4.11 Cluster of 3TP Areas Based on Basic Loading Port

Tanjung Perak (9 Routes)			Teluk Bayur (1 Route)	Tanjung Priok (1 Route)
Kalabahi	Bau Bau	Mangole	Bengkulu	Blinyu
Larantuka	Wanci	Namlea	Enggano	Midai
Lewoleba	Calabai	Namrole	Pulau Nias	Natuna
Maumere	Waileko	Taliabu	Sikakap	Pangkal Balam
Adonara	Waingapu	Sangatta		Tanjung Pandan
Kisar	Sebatik	Rote (Baa)		Tanjung Batu
Larat	Dobo	Sabu (Biru)		Tarempa
Saumlaki	Moa	Belang-belang		Serasan

Table 4.12 Clustering of 3TP Areas Based on Type of Ships

Biak (Crossing Vessel)	Timika	Tobelo	Tahuna
Sarmi	Fakfak	Babang	Biaro
Serui	Kaimana	Maba	Bit6ung
Teba	Agats	Morotai	Buhias
Waren (Waropen)	Merauke	Obi	Kahakitang
Manokwari		P. Gebe	Kakorotan
Oransbari		Sanana	Lirung
Nabire		Tidore	Marore
Wasior			Melonguane
			Miangas
			Tagulandang

4.3.3 Distance Calculation

In order to make routes, the distance of among each port has to be known. Because there are 75 ports, there are 75 x 75 distances that has to be found from *ports.com* and *marinetraffic.com* as the official website to measure the distance between ports. Because the number of distances that must be known is too much, the author attempted to measure the distance using 'cityblock' formula distance instead of Euclidean. The formula is used to know the distance between two nodes by adding the difference of the axis with the difference of the ordinate. The formula is written in Equation 4.19.

$$Distance_{ij} = |xi - xj| + |yi + yj| \quad (4.17)$$

Distance $_{ij}$	= the distance between port-I and port-j
x_i	= the longitude of port-i
x_j	= the longitude of port-j
y_i	= the magnitude of port-i
y_j	= the magnitude of port-j

The distances are then calculated in form of duration (time). However, because the distance is still in the form of longitude difference (^{o}), it must be converted first to the nautical mile. In order to obtain the duration, the distance will be divided by the speed of the vessel. As assumed in the introduction chapter, the speed of the vessel is assumed constant as much as 10 Knott. The formula to convert the distance (^{o}) to the duration (days) is shown below. The formula is then written on VBA for Excel.

Known

1^o longitude = 60 nautical miles

1 Knott = 24 nautical miles per day

10 Knott = 240 nautical miles per day

$$Duration_{ij} \quad (day) = \frac{Distance_{ij} \ x \ 60 \ nm}{10 \ knott \ x \ 24 \ nmi/day} \quad (4.18)$$

$$Duration_{ij} \quad (day) = \frac{Distance_{ij}}{4 \ nmi/day} \quad (4.19)$$

In order to validate whether the distance result of VBA for Excel and from official website to measure distance among the port (*ports.com and marinetraffic.com),* t-test for paired sample is conducted. In Table 4.47 there are the example of travel duration obtained from VBA and from official website. The data show the duration needed from Tanjung Perak to several ports.

Table 4.13 Comparison of Duration from VBA and Website

City	Duration in VBA (Days)	Duration from Website (Days)
Adonara	2.8615	2.7333
Bau Bau	2.8949	2.5917
Bitung	5.2630	4.4000
Calabai (Dompu)	1.4975	1.4000
Babang	4.4968	3.7417
Belang-Belang	2.7899	2.2417
Biak	7.3580	8.3625
Biaro	5.5775	4.5750
Buhias	5.6567	4.7083
Dobo	5.7824	5.4768
Fakfak	5.8850	8.2208
Kahakitang	5.7996	2.8667
Kaimana	6.1378	8.6708
Kakorotan	6.5224	8.0167
Kalabahi	3.1946	2.6667
Larantuka	2.8311	6.4125
Larat	4.8390	4.8042
Lewoleba	2.9589	4.0875
Lirung	6.2816	6.4125
Maba	5.9181	4.0875
Mangole	4.6541	3.8875
Manokwari	6.9226	8.0750
Marore	3.7675	3.0042
Maumere	2.7213	8.1958
Melonguane	6.3125	6.4125
Merauke	6.7178	11.3333
Miangas	6.6578	5.4625
Moa	3.9265	3.8042
Morotai	6.3141	5.0917
Nabire	6.6831	7.9834

First, the hypothesis should be defined. The definition of null hypothesis and alternative hypothesis are mentioned in Equation 4.22. It is assumed that α = 0.05 and the population is normally distributed. Then the data are inputted to Data Analysis in Microsoft Excel.

$$H0 : \mu_d = 0 \quad (4.20)$$

$$HA : \mu_d \neq 0 \quad (4.21)$$

Table 4.14 Result of t-test Paired Sample

	Variable 1	Variable 2
Mean	5.044404	5.316568
Variance	2.575876	4.898202
Observations	55	55
Pearson Correlation	0.638176	
Hypothesized Mean Difference	0	
Df	54	
T Stat	-1.17709	
P(T<=T) One-Tail	0.122161	
T Critical One-Tail	1.673565	
P(T<=T) Two-Tail	0.244322	
T Critical Two-Tail	2.004879	

The result shows that the null hypothesis cannot be rejected at $\alpha = 0.05$. It means that the difference between two populations are not significant. The duration resulted from VBA from Excel can be used.

4.3.5 Routing Result and Cost & Benefit Calculation

From the VBA for Excel, it is obtained 15 routes as the new option. Similar to option 2018, it also collaborates the other 4 options. Besides multiport, there are also 3 routes which are served by feeder vessel, which their hub ports are Tahuna, Tobelo, and Timika. It is a little different from option 2018 which has Biak as the hub port from Papua instead of Timika. The author exchanges the role of Biak and Timika because the demand for Biak cluster is bigger. Therefore, it is more suitable if the cluster of Timika is served by feeder vessel that has smaller capacity. The result of routing is shown in Table 4.15. The Calculation of benefit and cost of new option are available in Appendix 8 - 11.

Table 4.15 The Routes of New Option

No	Type	Routes
1	Mother Vessel	Tanjung Perak -Sangatta – Pulau Sebatik – Tanjung Perak
2	Mother Vessel	Tanjung Perak – Kisar – Moa – Larat – Saumlaki – Tanjung Perak
3	Mother Vessel	Tanjung Perak – Rote – Sabu – Tanjung Perak
4	Mother Vessel	Tanjung Perak – Biak – Tanjung Perak

Table 4.15 The Routes of New Option (con't)

No	Type	Routes
	Crossing Vessel	Biak – Sarmi – Manokwari – Serui – Biak
5	Mother Vessel	Tanjung Perak – Tobelo – Tanjung Perak
	Feeder Vessel	Tobelo – Maba – Sanana – Morotai – Tobelo
6	Mother Vessel	Tanjung Perak – Adonara – Lewoleba – Kalabahi – Tanjung Perak
7	Mother Vessel	Tanjung Perak – Larantruka – Maumere – Tanjung Perak
8	Mother Vessel	Tanjung Perak – Tahuna – Tanjung Perak
	Feeder Vessel	Tahuna – Biaro – Lirung – Bitung – Tahuna
9	Mother Vessel	Tanjung Perak – Bau Bau = Wanci – Mangole - Tanjung Perak
10	Mother Vessel	Tanjung Perak – Dompu – Waileko – Waingapu – Tanjung Perak
11	Mother Vessel	Tanjung Perak – Namlea – Namrole – Dobo – Tanjung Perak
12	Mother Vessel	Tanjung Perak – Taliabu – Belang Belang – Tanjung Perak
13	Mother Vessel	Tanjung Priok – Tarempa – Pangkal Balam – Natuna – Tanjung Priok
14	Mother Vessel	Teluk Bayur – Enggano – Pulau Nias – Teluk Bayur
15	Mother Vessel	Tanjung Perak – Timika – Tanjung Perak
	Feeder Vessel	Timika – Agats – Kaimana – Timika

4.4 Cost-Effectiveness & Incremental Analysis

After the benefit point and the total cost of all options have been calculated, then the cost-effectiveness analysis can be generated. The summary of the benefit point, total cost, and Cost-Effectiveness Ratio of each option is shown in Table 4.16..

Table 4. 16 Summary of Cost-Effectiveness Ratio of Each Option

Option	Benefit	Cost	Cost Effectiveness Ratio
Option 1 A	0.541651	Rp279,688,971,591.55	Rp516,363,843,097.61
Option 1 B	0.600346	Rp280,081,342,149.88	Rp466,533,342,209.69
Option 2	0.58485	Rp323,999,646,635.75	Rp553,987,709,035.10
Option 3	0.587505	Rp328,114,047,810.47	Rp558,487,287,144.24

Table 4. 16 Summary of Cost-Effectiveness Ratio of Each Option (con't)

Option	Benefit	Cost	Cost Effectiveness Ratio
Option 4	0.564821	Rp309,264,537,457.12	Rp547,544,736,919.21
Option 2017	0.570184	Rp244,575,206,055.68	Rp428,940,705,687.49
Option 2018	0.569556	Rp347,789,771,600.22	Rp 610,633,549,149.26
New Option	0.62436	Rp345,581,964,670.24	Rp553,497,884,199.28

From the summary, firstly the options that are dominated by other option should be excluded. In order to eliminate the dominated option, incremental analysis must be done. The example of calculation is shown below. The example shows the incremental CER between option 2 and option 1 B.

$$Incremental\ CER_{2\ to\ 1B} = = \frac{C_2 - C_{1B}}{E_2 - E_{1\ B}}$$

$$Incremental\ CER_{2\ to\ 1B} = \frac{Rp280 billion - Rp323\ billion}{0.6004 - 0.5845}$$

$$Incremental\ CER_{2\ to\ 1B} = -2{,}704\ billion/point \qquad (4.22)$$

The incremental shows the negative value. If option 2 is going to be changed with option 1 B, it can give more benefit with less cost. Therefore, option 2 is dominated by option 1 B. From Table 4.16, it is known that the remaining options are option 1 A, option 1 B, option 2017, and new option. As all remained options are financially feasible, then from the remaining options there will be chosen the option that has the biggest benefit point. The biggest benefit point as much as 0.62346 is obtained by implementing new option. Therefore, new option is chosen.

Table 4.17 Dominating/Dominated

No	Option	Dominating or Dominated
1	Option 1 A	Dominating Option 4
2	Option 1 B	Dominating Option 2,3,4, & Option 2018
3	Option 2	Dominated by 1 B
4	Option 3	Dominated by 1 B
5	Option 4	Dominated by 1 A, 1 B, & Option 2017
6	Option 2017	Dominating Option 4
7	Option 2018	Dominated by 1 B & New Option
8	New Option	Dominating Option 2018

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CHAPTER 5
ANALYSIS AND INTERPRETATION

In this chapter there will be explained the analysis of the result obtained in the previous chapter.

5.1 Analysis of New Option

The new routes that are arranged in this research are able to give the highest point. It is because naturally the algorithm of Vehicle Routing Problem only makes routes from the nodes that their demands can be fulfilled 100%. If the demand of a node exceeds the current quantity loaded by the vessel, the vessel will either find another node or return to basic loading port.

However, by that principle, the number of a node that can be served is very limited. Furthermore, number of node that can be served is an important indicator of Sea Toll Program. The government prefers to serve a lot of 3TP ports even though the commodities loaded to the nodes cannot fulfill their 100% demand. Therefore, by modifying the algorithm, the vessel which is approaching its quantity limitation still can visit a nearby node, unless the node does not exceed the threshold. Although the percentage is not all 100%, the demand of the nodes is still fulfilled in high percentage. And the number of served nodes is not as few as usual Vehicle Routing Problem.

The cost incurred by this new option is the second highest compared to the other options, only lower than the option 2018. The cost is high because it already considers the type and the number of vessels that are going to be used by the government. It is known that there are 16 big vessels and 3 feeder vessels available (Handoko, 2018). The government intends to combine other 4 options so that all advantages of each option can be obtained. The areas that have small ports can be served by feeder vessels and the cycle time from basic loading port to areas in Papua can be reduced by using container crossing principles. Because the type and the number of vessels is similar to option 2018 and more than the other options, the fixed cost of new option is high.

According to Capt. Wisnu Handoko (2018), actually all routes are operationally feasible, including the routes of the new option. The routes will not disturb the commercial ones unless *Direktorat Jenderal Perhubungan Laut Dalam Negeri* as the organization that is in charge to manage marine traffic in Indonesia register the routes as applied international regulation. This issue should be concerned, as routes from the previous year has not been listed in *ports.com* and *marinetraffic.com* as the platform that shows the listed marine routes in the world. The option is also financially feasible. The total cost incurred which is calculated based on *Peraturan Menteri Perhubungan Nomor 22 Tahun 2018* is still under the budget provided (Rp447,628,808,000.00). Within the budget, the new option is able to give the maximum point of benefit.

5.2 Analysis of Cost-Effectiveness & Incremental

After calculating total cost and benefit of all options, the next step is ensuring that all options are financially feasible. The total cost of each option is checked whether it exceeds Rp447,628,808,000.00 or not. It is known that there is no option that is out of the budget.

The next step is conducting incremental analysis. This step aims to eliminate options which are dominated by other options. What is meant by dominated is that if an option is changed by another option, the benefit will increase simultaneously with the decrease of the cost. The current option will give same or even less benefit with more cost compared to another option. Therefore, the dominated options will not be considered.

From the incremental analysis it is known that the dominated options are option 2, option 3, option 4, and option 2018. Those options are dominated by option 1 B and new option. Option 1 B can give more point with less cost than option 2, option 3, option 4, and option 2018 whilst new option can give more point with less cost than option 2018. Therefore, option 2, option 3, option 4, and option 2018 are eliminated.

After that, the remained options are going to be chosen. There are 4 options remained. They are option 1 A, option 1 B, option 2017, and new option. Because all remained options are within the budget, the option is chosen based on the value of the benefit. Unless the option is within the budget, the option which gives the highest benefit is worth to be implemented by the government. It is known that the option which gives the most benefit is new option.

The new option can serve 45 areas. This number is still more than the number of areas served by Sea Toll Program 2017 so that the intention of Transportation Ministry to increase the budget of Sea Toll Program is accomplished. Furthermore, the number of nodes served by new option is only less than option 3 and option 2018. Because the number of served nodes has the most weight compared to other indicators, this will keep an important portion of benefit point for new option.

Furthermore, because modified Vehicle Routing Problem algorithm is used, the average proportion of fulfilled demand is high, even for the routes that are served by feeder vessels. It is not like option 2 and option 2018 which emphasize on the number of node without considering its fulfilled demand rate. Because it has secured the two indicators that have the highest weight, the new option can obtain high point of benefit.

5.3 Analysis of Sensitivity

There are several factors that are going to be tested in sensitivity analysis. The factors are the change of demand (increase and decrease), the increase of cost, and the change of weight. The demand will be increased from range 0 – 100% with scale 10%. The demand will also be decreased from range 0% to 90% also with scale 10%. The cost will be increased from 0% to 100% with scale 10%. And the weight will be changed as the determined scenario by using pairwise comparison.

When demands of all areas increase 10%,20%, even 40%, the new option is still becoming the best option to choose. However, started from 50% demand increases, the new option is dominated by option 1 B. If the demand increases up to 50%, the new option starts to experience difficulties to fulfill the demand. The benefit point that is obtained by the new option is not more than the benefit point of 1 B with lower cost. If the demand increases 50% or more, it is recommended to implement option 2018, as it has the biggest benefit within the budget.

Table 5.1 Sensitivity Analysis : Factor of Demand Increase

No	Demand Increase	Option Chosen	Point of Benefit	Total Cost	CER
1	0%	New Option	0.6235	Rp 345,581,123,390.24	Rp 554,221,788,502.79
2	10%	New Option	0.6070	Rp 345,654,502,850.24	Rp 569,420,142,732.92
3	20%	New Option	0.5862	Rp 345,716,131,450.24	Rp 589,779,933,517.65
4	30%	New Option	0.5741	Rp 345,715,469,690.24	Rp 602,212,272,914.08
5	40%	New Option	0.5576	Rp 345,730,229,270.24	Rp 619,989,404,162.63
6*	50%	Option 2018	0.5491	Rp 347,916,809,720.22	Rp 633,593,837,689.29
7	60%	Option 2018	0.5430	Rp 347,947,697,280.22	Rp 640,769,507,024.06
8	70%	Option 2018	0.5367	Rp 347,976,484,940.22	Rp 648,402,923,549.31
9	80%	Option 2018	0.5300	Rp 347,995,895,540.22	Rp 656,608,121,106.20
10	90%	Option 2018	0.5234	Rp 348,008,219,060.22	Rp 664,869,488,327.68
11	100%	Option 2018	0.5162	Rp 348,014,113,300.22	Rp 674,127,148,233.27

*The red row symbolizes the extent of demand increase in which the chosen option begins to change

The second factor that is tested is the decrease of demand of all commodities in all area. The new option still becomes the chosen option even though the demand of all commodities in all area decreases 10% to 30%. If the demand decreases more than 30%, the new option is dominated by option 2 and option 2018. Option 2018 becomes the best option once, exactly when the demand decreases 50%. Other than that condition, option 2 is the best option to be chosen. The decrease of the demand makes the quantity loaded in option 2 and option 2018 fits with the demand. And because both of them are the options which serve the most number of nodes and the number of nodes has the biggest weight on point calculation, therefore those 2 options dominate new option. The result of sensitivity analysis of this factor is shown in Table 5.2.

Table 5.2 Sensitivity Analysis : Factor of Demand Decrease

No	Demand Decrease	Option Chosen	Point of Benefit	Total Cost	CER
1	0%	New Option	0.6235	Rp 345,581,123,390.24	Rp 554,221,788,502.79
2	10%	New Option	0.6400	Rp 345,454,397,010.24	Rp 539,794,372,041.89
3	20%	New Option	0.6462	Rp 345,273,525,660.24	Rp 534,320,151,317.42
4	30%	New Option	0.6500	Rp 345,074,655,890.24	Rp 530,884,085,984.98
5	40%	Option 2	0.6601	Rp 323,748,149,455.75	Rp 490,470,680,463.54
6	50%	Option 2018	0.6685	Rp 347,447,421,240.22	Rp 519,744,187,843.38
7	60%	Option 2	0.6819	Rp 323,436,040,735.75	Rp 474,305,346,805.84
8	70%	Option 2	0.7000	Rp 323,216,279,435.75	Rp 461,737,542,051.08
9	80%	Option 2	0.6868	Rp 346,784,952,840.22	Rp 504,932,356,198.19
10	90%	Option 2	0.7000	Rp 322,941,925,795.75	Rp 461,345,608,279.65

*The red row symbolizes the extent of demand decrease in which the chosen option begins to change

In the cost increase factor, the new option is still recommended with no more than 20% cost increase. It is because if the all costs that are listed on *Peraturan Menteri Nomor 22 Tahun 2018* increases 30%, then the total cost of new option exceeds Rep447 billion. It makes the new option becomes infeasible so that it is excluded from the alternatives. Then 1 B becomes the chosen option as it has total cost within the budget and gives the most benefit.

In sensitivity analysis of the factor of cost increase, it should be noted when the all costs listed on the regulation increase 70% to 90%, the government is recommended to re-implement option 2017. Even, up to 90%, the best option is by doing nothing. It is because all options incur costs out of budget for Sea Toll Program 2018. From that issue it can be stated that all options are quiet sensitive to the cost increase.

Table 5.3 Sensitivity Analysis : Factor of Cost Increase

No	Cost Increase	Option Chosen	Point of Benefit	Total Cost	CER
1	0%	New Option	0.6235	Rp 345,581,123,390.24	Rp 554,221,788,502.79
2	10%	New Option	0.6205	Rp 380,149,160,875.26	Rp 612,628,580,378.70
3	20%	New Option	0.6205	Rp 414,708,175,500.28	Rp 668,322,087,685.86
4	30%	Option 1 B	0.6003	Rp 364,105,744,794.85	Rp 606,493,344,872.60
5	40%	Option 1 B	0.6003	Rp 392,113,879,009.84	Rp 653,146,679,093.57
6	50%	Option 1 B	0.6003	Rp 420,122,013,224.82	Rp 699,800,013,314.54
7	60%	Option 1 A	0.5730	Rp 447,452,770,066.48	Rp 780,832,008,800.36
8	70%	Option 2017	0.5702	Rp 415,709,221,294.66	Rp 729,078,836,807.07
9	80%	Option 2017	0.5702	Rp 440,162,704,900.23	Rp 771,965,827,207.49
10	90%	Do Nothing			
11	100%	Do Nothing			

*The red row symbolizes the extent of cost increase in which the chosen option begins to change

The other factor that is changed in sensitivity analysis is the weight of each indicator. The importance order of number of node, average deviation, and standard deviation is changed based on several scenarios. The weight is then determined using pairwise comparison. From the result it is known that the new option does not become the chosen option only if the weight of number of node is same as the weight of standard deviation and the weight of average has the least weight. At that condition, the new option becomes dominated by option 3. The remained condition shows that the new option always has the highest benefit point within the budget.

Table 5.4 Sensitivity Analysis : Weight Factor

No	Weight	Option Chosen	Point of Benefit	Total Cost	CER
1	A>B>C	New Option	0.6235	Rp 345,581,123,390.24	Rp 554,221,788,502.79
2	A>B=C	New Option	0.6709	Rp 345,590,146,250.24	Rp 515,109,269,580.63
3	A=B>C	New Option	0.6640	Rp 345,590,146,250.24	Rp 520,457,631,770.25
4	A>C>B	New Option	0.6286	Rp 345,590,146,250.24	Rp 549,808,206,315.46
5	A=C>B	Option 2018	0.6856	Rp 347,741,805,440.22	Rp 507,209,809,056.45
6	B>A>C	New Option	0.7247	Rp 345,590,146,250.24	Rp 476,886,063,873.66
7	B>A=C	New Option	0.7602	Rp 345,590,146,250.24	Rp 454,612,681,341.90
8	B=C>A	New Option	0.8564	Rp 345,590,146,250.24	Rp 403,557,218,896.54
9	C>A>B	New Option	0.7408	Rp 345,590,146,250.24	Rp 466,529,712,233.41
10	C>B>A	New Option	0.8449	Rp 345,590,146,250.24	Rp 409,017,745,437.08
11	A=B=C	New Option	0.7327	Rp 345,590,146,250.24	Rp 471,651,044,601.26

*The red row symbolizes the extent of demand increase in which the chosen option changes

** A = Point of Number of Node (PoN). B = Point of Average Deviation (PoA), C = Point of Standard Deviation (PoSD)

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CHAPTER 6
CONCLUSION AND RECOMMENDATION

In this chapter there will be explained the conclusion and recommendation of this research.

6.1 Conclusion

From the research there are several conclusions that can be obtained. The conclusions are mentioned below.

1. This research successfully creates new option by combining port-to-port, hub port, and crossing vessel principles. There are 11 routes served by port-to-port principle, 3 routes served by feeder vessel, and 1 route served by using crossing vessel principle. This route can serve 45 ports. The new option created in this research is able to give the highest benefit point compared to other options as much as 0.6244. This value shows that this new option visits more nodes, quantity of delivered container is more suitable with demand, and the proportion of fulfilled demand among areas in a route has less standard deviation.
2. From Cost-Effectiveness Analysis, the new option is chosen as the best option with benefit point 0.6244 and total cost Rp345,581,964,670.00. The chosen option will change either if the demand increases 50%, demand decreases 40%, all costs increase 30%, or the weight of number of node and standard deviation are same, and both of them have bigger weight than fulfilled demand average.

6.2 Recommendation

There are some recommendations obtained by the author during conducting the research. The recommendations that can be implemented by related stakeholders of Sea Toll Program or by the researcher that is interested to continue this research. The recommendations are mentioned below.

1. It is better for Ministry of Transportation, Ministry of Trade, the shippers, and the local government to share the information especially

related to the demand rate of 3TP Areas so that the Sea Toll Program routes can be arranged more suitable with the real demand of each area.

2. Not only about the demand, all related stakeholders can start to gather the information about the commodities produced by the 3TP Areas, its production rate, and its demand so that the space from 3TP Areas to the basic loading port can be more maximized.
3. If the previously mentioned data are already available, the future research can start to consider it to make new routes and to decide which becomes the best option.

REFERENCES

Adiliya, Ana, (2017). *Analyzing an Integrated Maritime Transportation System: The Case The Port Of Tenau Kupang As A Potential Transshipment Port For South-East Indonesia,* Postgraduate Thesis, Erasmus University Rotterdam, Rotterdam.

Ballou, Ronald H., (2004), *Business Logistics / Supply Chain Management*, 5th edition, Pearson Education International, Ohio.

Bank Indonesia, (2018), *Bank Indonesia.* [Online] Available at: www.bi.go.id [Accessed on 30 April 2018].

Berita Trans, (2017). *Hubla Tawarkan 4 Opsi Pola Trayek Tol Laut Tahun 2018.* [Online] Available at: http://beritatrans.com/2017/11/22/hubla-tawarkan-4-opsi-pola-trayek-tol-laut-tahun-2018/, [Accessed on 17 January 2018].

Boardman, Anthony, (2001), *Cost-Benefit Analysis : Concept and Practice*, 2nd edition. Prentice Hall., New Jersey.

Chandra, A. A., (2017), *Jokowi-JK Bikin Tol Laut, Ini Dampaknya.* [Online] Available at: https://finance.detik.com/berita-ekonomi-bisnis/d-3687862/jokowi-jk-bikin-tol-laut-ini-dampaknya [Accessed on 21 March 2018].

Fajriah, L. R., (2017), *Tol Laut Kini Memiliki 13 Rute.* [Online] Available at: https://ekbis.sindonews.com/read/1225611/34/tol-laut-kini-memiliki-13-rute-1501484851 [Accessed on 16 March 2018].

Fauzi, A., 2017. *Lelang Rute Tol Laut Tunggu Penetapan Tarif Angkut Barang.* [Online] Available at: https://ekonomi.kompas.com/read/2017/01/18/203234726/lelang.rute.tol.laut.tunggu.penetapan.tarif.angkut.barang [Accessed on 3 March 2018].

Fitrah, Aini, (2014), *The Application of Quality Function Deployment (QFD) and Benefit Cost Analysis (BCA) to Reduce Employee Turnover in PT. X,* Undergraduate Thesis, Institut Teknologi Sepuluh Nopember, Surabaya.

Handoko, C. W., (2018), *Opsi Tol Laut 2018* [Interview] (3 May 2018).

Hermawanyadi, R., (2017), *4 Permasalahan Logistik di Indonesia.* [Online] Available at: https://www.kompasiana.com/reza_hermawanyadi/599261e02d7acb729345acc2/4-permasalahan-logistik-di-indonesia [Accessed on 25 March 2018].

Idris, M., (2017), *Masalah Kapal Tol Laut: Banyak Muatan Kosong Pas Balik ke Jawa.* [Online] Available at: https://finance.detik.com/berita-ekonomi-bisnis/d-3687690/masalah-kapal-tol-laut-banyak-muatan-kosong-pas-balik-ke-jawa [Accessed on 2 June 2018].

Kementerian Kesehatan Republik Indonesia, (2013), *Buku Pedoman Farmakoekonomi*, Kementerian Kesehatan Republik Indonesia, Jakarta.

Kementerian Perhubungan Repubik Indonesia, (2018). *Peraturan Menteri Nomor 22 Tahun 2018,* Kementerian Perhubungan Repubik Indonesia, Jakarta.

Kementerian Perhubungan Republik Indonesia, (2017). *Penyelenggaraan Angkutan Barang di Laut (Tol Laut),* Kementerian Perhubungan Republik Indonesia, Surabaya.

Khairani, (2014), *Optimasi Rute dan Jumlah Feeder untuk Surabaya Mass Rapid Transit Boyorail.* Undergraduate Thesis, Institut Teknologi Sepuluh Nopember, Surabaya.

Klik Logistic, 2018. [Online] Available at: https://www.kliklogistics.co.id/biaya-pengiriman-container/ [Accessed 20 May 2018].

NZ Transport Agency, (2013), *Economic Evaluation Manual.* 1st edition, NZ Transport Agency, Wellington

Pujawan, I Nyoman, (2009), *Ekonomi Teknik.* 2nd edition, Guna Widya, Surabaya.

Sabrina, I. N, (2012), *Pengembangan Metode Risk-Cost Benefit Analysis sebagai Alat Evaluasi Proyek Kerjasama Pemerintah dan Swasta,* Undergraduate Thesis, Institut Teknologi Sepuluh Nopember, Surabaya.

Sahid, R., (2014), *Jokowi-JK Janji Upayakan Jalan Tol Laut Aceh-Papua.* [Online] Available at:

https://nasional.sindonews.com/read/870645/113/jokowi-jk-janji-upayakan-jalan-tol-laut-aceh-papua-1401976739 [Accessed on 16 March 2018].

Shell Indonesia, (2018), *Harga Bahan Bakar Shell.* [Online] Available at: https://www.shell.co.id/in_id/pengendara-bermotor/bahan-bakar-shell/how-shell-price-fuel.html [Accessed on 28 May 2018].

Stefan Irnich, P. T. D. V., 2014. *SIAM.* [Online] Available at: http://www.siam.org/journals/ojsa.php [Senest hentet eller vist den 21 March 2018].

Sugihartanto, Mushonnifun Faiz, (2016), *Analisis Cost and Benefit Antara Sistem Palletizing Delivery dan Non-Palletizing Delivery dengan Mempertimbangkan Workload Pekerja Pada Raw Material Store Pt Unilever Rungkut Surabaya.* Undergraduate Thesis, Institut Teknologi Sepuluh Nopember, Surabaya.

Supply Air Bersih, (2017), *Daftar Harga.* [Online] Available at: http://supplyairbersih.com/daftar-harga/ [Accessed on 20 May 2018].

Vanany, Iwan, (2015), *Pengantar : Definisi dan Ruang Lingkup Manajemen Logistik,* Handout, Teknik Industri Institut Teknologi Sepuluh Nopember, Surabaya.

Vitasari, Nurul, (2017), *Analisis Evaluasi Implementasi Kebijakan Tol Laut.* Undergraduate Thesis, Institut Teknologi Sepuluh Nopember, Surabaya.

Vishnu, Vincentius Kaisar, (2016), *Benefit-Cost Analysis to Evaluate Alternative Technologies for Value Added Services in Warehouse,* Undergraduate Thesis, Institut Teknologi Speuluh Nopember, Surabaya.

Zaman, Muhammad Badrus, (2014), Connectivity Analysis of Port in Eastern Indonesia. *Procedia,* Issue 14, pp. 118 - 127.