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ANALYSING AN INTEGRATED MARITIME TRANSPORTATION SYSTEM: THE CASE THE PORT OF TENAU KUPANG AS A POTENTIAL TRANSHIPMENT PORT FOR SOUTH-EAST INDONESIA

by

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Abstract

Indonesia faces a number of crucial issues regarding cargo distribution. In this study, we address one of them - the issue of high logistics costs and price disparity between the Western and Eastern regions of Indonesia. In an attempt to solve this issue, the government of Indonesia adopted the Sea Toll Road Programme in 2016 by stipulating six routes connecting the hub port and the sub-feeder ports. In 2017, some of these routes have been changed by dividing them into two different networks. The network used both in 2016 and 2017 is a multi-port-calling network where the ship sails directly from the main port to the several sub-feeder ports on one route. This choice of this network is different from the design of the Sea Toll Road Programme that will be implemented in 2019 where a hub-and-spoke model is considered to be applied.

In this study we construct three scenarios. Scenarios I and II apply a multi-port-calling network and are based on the implementation of the Sea Toll Road Programme of 2016 and 2017. And scenario III uses a hub-and-spoke network by involving the port of Tenau Kupang as a transhipment port of container distribution from the port of Tanjung Perak to the South-East of Indonesia

As the result, scenario III generates the lowest total shipping costs which is $ 27,797,543 compared to scenario I and scenario II which are $ 34,960,423 and $ 38,077,514, respectivaly. In other words, involving the port of Tenau Kupang as a transhipment port can help to reduce total shipping costs.

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List of Abbreviation

DBO	Dobo
DWT	Deadweight
FAK	Fak-Fak
GT	Gross Tonnage
HP	Horse Power
KLB	Kalabahi
KMN	Kaimana
LRK	Larantuka
LWB	Lewoleba
LWS	Low Water Spring
MP3EI	Masterplan for Acceleration and Expansion of Indonesia Economic Development
MRK	Merauke
NM	Nautical Miles
NML	Namlea
O/D	Origin Destination
Pelindo	Pelabuhan Indonesia
RTE	Rote
SBU	Sabu
SML	Saumlaki
TEU	Tweenty-foot Equivalent Unit
TMK	Timika
TKP	Tenau Kupang
TPR	Tanjung Perak
WGP	Waingapu
WNC	Wanci
w.r.t	With regard to

Chapter 1 Introduction

1.1 Introduction

Indonesia is an archipelagic country with an abundance of natural resources, located strategically between the Indian and the Pacific oceans, with approximately two-thirds of its area being the seas. Currently, Indonesia faces a number of crucial issues regarding cargo distribution, which requires an advanced and reliable maritime transport system. According to The World Bank (2016), Logistics Performance Index (LPI) ranked Indonesia as 63rd out of the 150 countries surveyed, which is lower than Singapore (5), Malaysia (32) and Thailand (45). Moreover, Indonesian LPI declined to 2.76 from 3.01 in 2010. It rose gradually and reached its peak at 3.08 in 2014 but then fell to 2.98 in 2016.

In addition, Indonesia also faces an imbalanced economic situation between its Western and Eastern regions which is proved by the share of GDP. As shown in Figure 1, more than 80 percent of GDP is produced by the Western regions while Eastern regions contribute only less than 20 percent (Central Statistical Bureau of Indonesia, 2016). Cargo distribution is one of the major problems that held back some regions especially in the East region of Indonesia from economic development. This issue creates the price disparity between both of the regions where price in the Eastern regions is higher than in the Western regions.

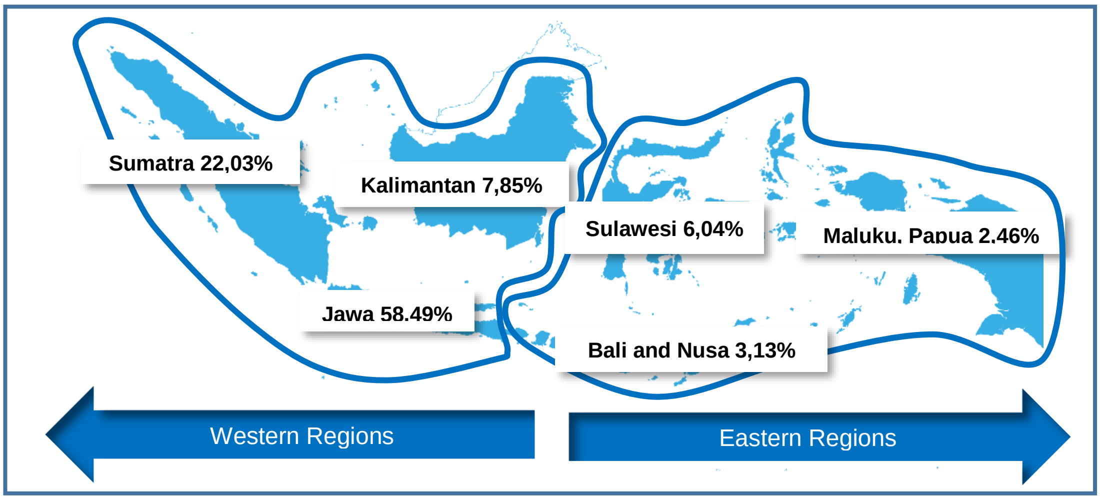

Figure 1. Indonesian Contribution GDP Island based
Source: Modified from Central Statistical Bureau, 2016

As it was mentioned above, distributing cargo has become a crucial issue at the national level that shows the weakness of Indonesia's logistics distribution. Moreover, global distribution has changed significantly due to the growth of economic cooperation among the inter-regional countries in the world. Based on national issues and commitments to global economic cooperation, the Indonesian government has set up the Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3EI) 2011-2025. One of the primary elements of MP3EI is to enhance national connectivity locally and internationally related to the maritime transportation system. Because Indonesia consists of 13,466 islands, an effective and efficient integrated maritime transportation system has a significant role in distributing cargo in Indonesia and potentially reducing logistics cost.

Following the MP3EI 2011-2025, the Indonesian government has formulated the national connectivity to serve the six economic corridors namely the maritime highway project or better known as sea toll road programme. This programme suggests an integrated system using the hub-and-feeder concept where port operators and other stakeholders provide container shipping routes domestically. Furthermore, this programme is intended to create domestically integrated maritime system across the archipelago, reducing the national logistics costs and lowering the price disparity between the Western and Eastern regions of Indonesia.

1.2 Problem Statement

Nowadays, the Indonesian government is trying to implement the design of sea toll road programme in order to address several issues related to the distribution of cargo and to decrease price disparities. The design involves 24 strategic ports spread out from the west to the east of Indonesia.

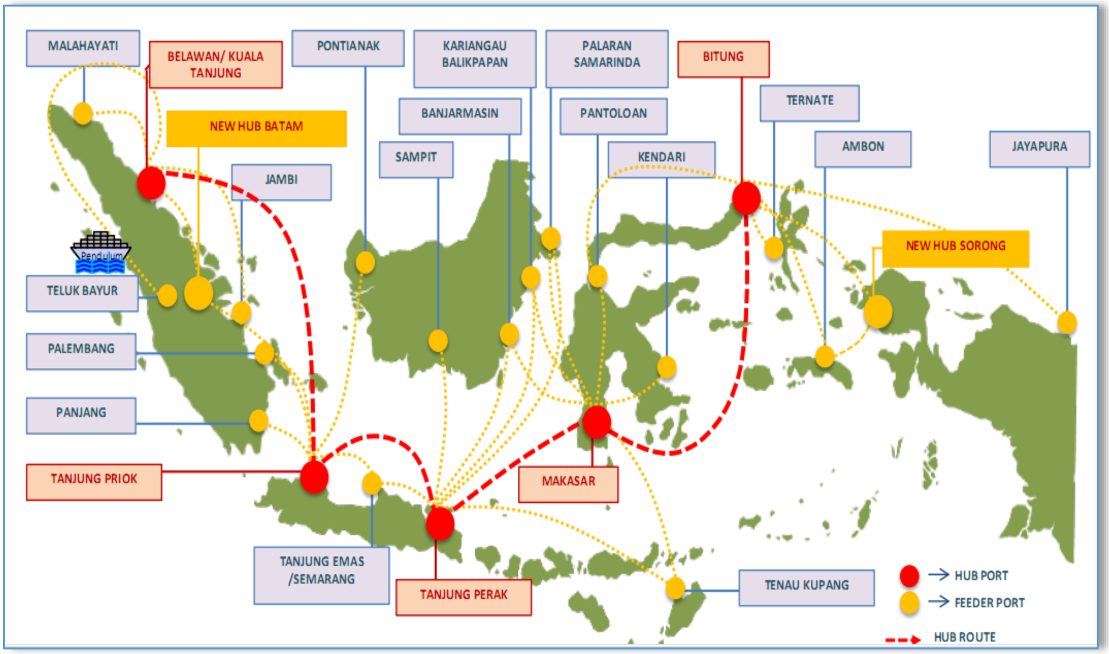

Figure 2. Sea toll road design in the medium-term development plan 2015-2019
Source: Ministry of National Development Planning (BAPPENAS), 2015

During 2015-2019, the Indonesian government has been focused on developing 24 strategic ports for the new facilities and upgrading their capacity. However, the price disparity problem as a result of the higher logistics costs in Indonesia has to be solved as soon as possible. Therefore, the government of Indonesia took initiative to implement the sea toll programme in 2016 which consisting of six routes connecting the western and eastern regions of the country. This programme is devoted to the distribution of staple and essential goods as stated in the Presidential Decree No. 71 of 2015.

The sea toll road programme of 2016 was set through the decree of the General of Sea Transportation Number: Al.108/7/8/DJPL-2015 on route network of the sea freight transport. These six routes were started in early 2016 and were operated by PELNI, a state-owned enterprise. To implement this programme, the Indonesian government provided subsidies to PELNI to operate its vessels serving the predetermined routes. The government defined the route, size of the ships, annual frequency and commission days per voyage (the number of days specified for ships sailing from the original port to the final port until returning to the port of origin). Following these six routes, the ships have limited capacity and sail to several sub-feeder ports. As a result, sometimes it takes a month for a ship to sail from its origin to the destination port and back.

In the beginning of 2017, this programme was changed by the decree of the General of Sea Transportation Number. AL.108/1/9/DJPL-17. The reason behind this change was high operational costs which consequently kept logistics costs high as well while the goal of this programme was to reduce logistics costs. There are 13 routes that are used within the sea toll road programme. Four of these routes are the result of crossing the previous routes. The network design used in the implementation of this programme is multi-port-calling which involved several calls on one route. Running this strategy in 2017, the Indonesian government also involved private companies through an open bidding process.

The Sea toll road programme of 2016 and 2017 used the concept of direct network connecting the hub port to sub-feeder ports or multi-port-calling network. The port of Tanjung Perak was appointed as one of the main ports in the western part of the country to serve as an origin port for distributing cargo to the eastern regions of Indonesia. Referring to the master plan of sea toll road programme to be implemented in 2019, the concept that should be operated is a hub-and-spoke network where the feeder port has a major role of connecting port between the hub port and the sub-feeder ports. This concept allows the use of larger sized vessels that are expected to reduce operating costs because of the ability to create economies of scale.

In line with the issues described, this research paper will analyse the efficiency in terms of the shipping costs for distributing cargo under the implementation of sea toll road programme of 2016 and 2017. This thesis will be focused on the routes starting from the Tanjung Perak port since this port has an important role of the gateway to the eastern regions of Indonesia. Furthermore, this thesis also suggests another potential route by involving the Port of Tenau Kupang as a feeder port using the hub-and-spoke network. Since the feeder port in Indonesia acts as a connecting port between the hub port and the sub-feeder port, Tenau Kupang port will have a function of a transhipment port in this study. The main idea behind this consideration is that Tenau Kupang port as one of the 24 national strategic ports involved in the master plan of the 2019 sea toll road programme. In other words, through implementation this research, it will be possible to quickly align between the current sea toll routes and the master plan of the 2019 sea toll road programme. Furthermore, as this study is in line with the National Development Planning, it may be possible to accelerate and expand the economic development in Indonesia by strengthening domestic connectivity.

1.3 Research Question

Based on the identified problem, the main research question that needs to be answered is the following:

"*What is the potential impact of the port of Tenau Kupang as a transhipment port in terms of reducing shipping costs from the Port of Tanjung Perak to the South-Eastern part of Indonesia?*"

To answer the main research question, the following sub-research questions need to be taken into account:

1. *How does the implementation of container distribution from the Port of Tanjung Perak to South-Eastern part of Indonesia fit in the sea toll road programme set in 2016 and 2017?*
2. *How do we calculate the shipping costs of the route from the port of Tanjung Perak to the ports located in South-East of Indonesia using a multi-port calling following sea toll road programme of 2016 and 2017 and using a hub-and-spoke network that includes the Port of Tenau Kupang as a transhipment port?*
3. *Are the routes from the port of Tanjung Perak to South-Eastern areas of Indonesia specified in the sea toll road programme of 2016 and 2017 effective and efficient in lowering the shipping costs compared to the proposed network of involving the port of Tenau Kupang as a transhipment port?*

The objective of this paper is to work out a strategy that is aimed at reducing the shipping costs on the West-East route in Indonesia. For this strategy, investigate whether it is useful to use the Port of Tenau Kupang as a transhipment port of the containers from the Port of Tanjung Perak to South-Eastern area of the country or not.

1.4 Research Topic Scope and Limitations of Research

In order to define the topic and research problem more clearly, we delimit the scope of this thesis as follows:

1. In this study, we analyse the routes defined by the Indonesian government in the sea toll road programme of 2016 and 2017, in particular all of the routes starting at the Port of Tanjung Perak. The main reason to choose this port as the port of origin for the routes to the Eastern regions of Indonesia is the fact that it serves as a gateway and distribution centre on the routes from the West to the East of Indonesia.
2. Following the master plan of sea toll road programme, Tanjung Perak port as a hub port is connected to six feeder ports i.e. Tanjung Emas, Banjarmasin, Sampit, Balikpapan, Samarinda and Tenau Kupang. In this paper, the port of Tenau Kupang is considered as a port pairing to Tanjung Perak port since this port is located in the Eastern region in Indonesia.
3. The aim of this study is to find an optimal route to minimise shipping costs of cargo distribution from the port of Tanjung Perak to South-East of Indonesia. Whether or not to involve the Tenau Kupang port as a transhipment port for the implementation of the current sea toll road programme will be the subject of this research.
4. Only containers that transport staple and essential goods are included in the analysis of this research.
5. The Indonesian government has stipulated the size of the ships, the annual frequency and the commission days per voyage (the number of days specified for ships sailing from the port of origin to the final port and back. We will follow this specification.

1.5 Thesis Structure

This thesis consists of five chapters.

Chapter 1 - Introduction

In this part of the study, we present an overview of the main topics that will be discussed. We also provide the main and sub-research questions.

Chapter 2 - Literature Review

This part consists of several theories to provide theoretical framework of our research. This chapter is divided into three parts. The first part is an explanation of MP3EI, design model that is used by the Indonesian government to create connectivity. In the second part, we present the description of the logistics system and the transportation system to provide an overview of the network used in this study. And in the last part, we elaborate on the theoretical framework of the total costs consists of shipping costs and the chartering concepts.

Chapter 3 - Research Methodology

In this chapter, we describe the method used in this study to work out an optimal route to minimise the shipping costs for each alternative routing. A mathematical model is developed to calculate shipping costs for each alternative route. Also, we describe the assumptions that underpin each of the three scenarios under the scheme of research methodology and data related to the methodological calculations.

Chapter 4 - Overview on the Sea Toll Road Programme in Indonesia

In this chapter, we provide a detailed description of the implementation of the sea toll road programme established in 2016 and the route changes made in 2017. Moreover, we also provide the profile of the Port of Tanjung Perak and Tenau Kupang as two main subjects in this study.

Chapter 5 - Results and Analysis

In this chapter, we answer the sub-research questions that help address the main research question of this thesis. Description of the shipping cost analysis based on three scenarios are also presented here. The first scenario reflects the condition of the sea toll road programme set in 2016, the second scenario is defined by the change to be programme made in 2017, and the third scenario includes the port of Tenau Kupang on each alternative route. At the end of this chapter, the comparison between the three scenarios is conducted in order to choose the route with the minimum shipping costs.

Chapter 6 - Conclusions and Recommendations

In this chapter, we make conclusions based on all the results of the analysis and provides recommendations that are expected to make a valuable contribution for further research and assist the Indonesian government in creating an effective and efficient route.

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Chapter 2 Literature Review

In this chapter, we present theoretical framework and government regulations as the foundation of this research. Section 2.1, provides an overview of the Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3EI) which is used as a reference by the Indonesian government to create the connectivity as a background to this study. The government of Indonesia requires logistics and transportation system design as a tool to realise connectivity, both locally and internationally. Hence, various theories and government regulations are discussed in Sections 2.2 and 2.3. In Section 2.4, we review the previous study conducted on this topic, to figure out how the network model works in order to minimise the total shipping costs based on the use of the mathematical model and operation research approach. Section 2.5, we present the theory on shipping costs, including operating expenses, voyage costs, and cargo handling costs and shipping charter. At the end of this chapter, we provide the description of staple goods and essential goods based on government regulation.

2.1 The Master plan for the Acceleration and Expansion of Indonesia's Economic Development (MP3EI)

The master plan for acceleration and expansion of Indonesia's economic development (MP3EI) is implemented to accelerate and strengthen economic development in accordance with the superiority and strategic potential of the region in six corridors (Simlitabmas, 2011). There are three main elements that are integrated as an effort to realise the MP3EI strategy.

1. Economic potential development of the region on six Indonesian Economic Corridors (EC) namely EC Sumatra, EC Java, EC Borneo, EC Sulawesi, EC Bali-Nusa and EC Papua-Maluku.
2. Strengthening domestic integration and globally connectivity.
3. Strengthening the capacity of human resources (HR) as well as national science and technology in supporting the key programme's development in every economic corridor (EC).

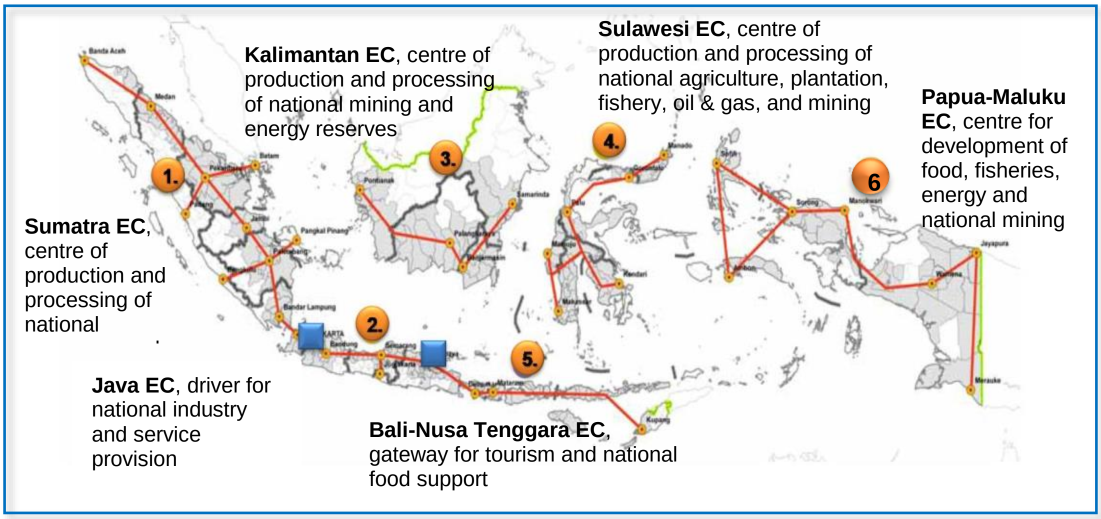

Figure 3. Six Economic Corridors in Indonesia
Source: Modified from the cabinet secretariat of the Republic of Indonesia, 2014

Increased connectivity of the six corridors is reflected in the four elements of national policy; National Logistic System, National Transportation System, regional development and information and communication technology (The cabinet secretariat of the Republic of Indonesia, 2014). The integration of these four key elements aims to achieve national connectivity objectives that are locally integrated and globally connected. Local integration is intended to integrate the existing connectivity system effectively and efficiently to support the mobilisation of goods, services on the territory of Indonesia. In order to develop locally integrated connectivity, there should be a transport network with transport nodes. Furthermore, to support connectivity integration of communication and information is required.

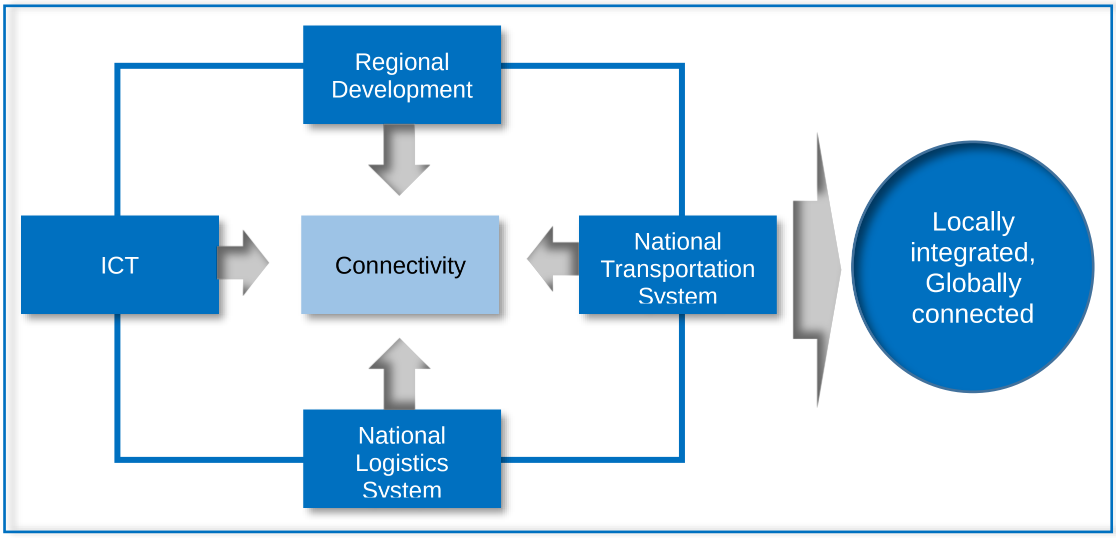

Figure 4. National Connectivity Framework
Source: modified from the cabinet secretariat of the Republic of Indonesia, 2014

In line with the MP3EI, the Indonesian government issued the blueprint of national logistic system development and national transportation system.

2.2 National Logistics System

The logistics system handles all the activities related to the delivery of goods or products from origin to destination. Origin point acts as a manufacturer because it serves as a supplier of goods, both as a producer and a distributor, and the destination point works as a consumer, either directly or indirectly.

Logistics management has a vital role in supporting the economy and prosperity of a country. Good logistics management helps the businesses to be competitive through cost efficiency which generates more value for the product or service. Furthermore, increasing competitiveness leads to improving the welfare of the community. In this regard, the World Bank has a special perspective on the logistics sector, with an emphasis on the costs and improvements to the quality of logistics and transportation systems that increase access to international markets, and thereby directly impact trade and income increment and can significantly reduce poverty. The World Bank is periodically conducting a survey of Logistics Performance Index (LPI) across 160 countries in the world. Logistics Performance Index is an assessment tool used to help countries identify the challenges and opportunities they face in logistics performance and is expected to improve their performance (World Bank, 2016).

Based on the logistics issues related to cargo distribution, the Indonesian government has formulated the blueprint of the national logistics system to manage and develop the logistics sector in Indonesia. According to the Presidential Decree Number 26/2012, the main role of the blueprint is to provide direction and guidance for the Indonesian government and the businesses in establishing an efficient and effective national logistics system. The strategic goal of this blueprint is the availability of an adequate and reliable transportation infrastructure that operates efficiently

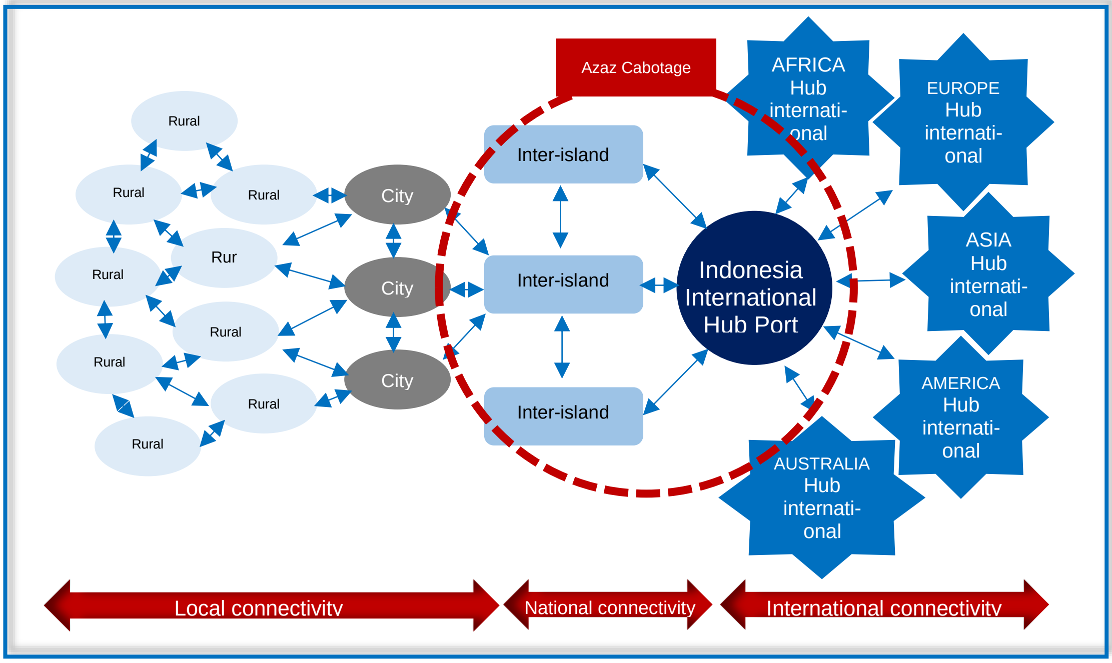

Figure 5. National Logistic System
Source: modified from Ministry of National Development Planning (BAPPENAS), 2015

The goal of maritime transportation development under the blueprint is to synchronise the international hub ports in the Eastern and Western regions of Indonesia as well as inter-islands transportation networks, in order to operate effectively and efficiently. This goal is achieved through the following programmes:

1. Global connectivity programme - creating export-import ports and international hub ports both in Eastern and Western regions of Indonesia.
2. Integrated inter-island connectivity programme which is based on building and revitalising hub ports and main ports in each province as well as developing port facilities and infrastructure.
3. Local connectivity programme which is aimed at developing shipping routes and scheduled short sea shipping and providing incentives to all the actors involved in providing the logistics services.
4. A programme on improving capacity and port services through establishing and upgrading capacity in several main ports as regional logistics centres.
5. Programme on full implementation of Azaz cabotage for domestic sea transportation, which is aimed at reducing the movement of the international vessel and to minimise the penetration of foreign products in Indonesia. The loading and unloading of export or import cargo is executed in the international hub ports and Indonesian flagged ships will dominate the distribution of cargo on the domestic shipping routes.

6. Programme on improving accessibility of sea freight in the underdeveloped and remote regions by optimising pioneering services, including short-sea shipping and encouraging the use of Ro-Ro vessels.
7. Programme on improving the number of fleets by developing domestic vessels

2.3 Transportation System

Transportation has an important role in the design of logistics system. The existence of a good transportation system has an impact on improving the logistics system. In addition, a good transportation system in logistics activities allows for increasing efficiency, reducing operating costs, and improving service quality. Improving the transportation system requires both public and private sectors. The support of a good transportation system in the logistics system will enhance the competitiveness of government and the companies. In Section 2.3.1, we discuss the differences between multi-port calling and hub-and-spoke network. Section 2.3.2 provides an analysis of the hub-and-feeder network in Indonesia under the Master Plan Sea Toll Road Programme that will be implemented in 2019.

2.3.1 Hub-and-Spoke vs. Multi-Port-Calling Network

Ronen (1983, 1993) and Christiansen, et al. (2004) stated that there are two main types of research in shipping service network design problem i.e. tramp shipping service network and liner shipping service network. Tramp shipping network deals with ship routing and vessels deployment for delivering bulk cargo without considering the H&S network operation. Because of this type of network, the cargo volume between the origin and the destination port is very big, and, therefore, cargo consolidation is not necessary on the hub port. The current studies on liner shipping service network can be classified into two categories – with and without the role of the hub port as a place where cargo is consolidated. In other words, there are two different design network alternatives on shipping liner network, namely Hub-and-Spoke (H&S) and Multi-Port-Calling (MPC).

Imai, et al. (2006) noted an interesting phenomenon - rapid growth in ship size leads to changes in the service network from multi-port-calling to the hub-and-spoke network. Over the past few years, there has been an unprecedented increase in the number of container ships serving the world's most densely packed maritime routes. This can be attributed to the fact that a more flexible and widespread form of cooperation has emerged in the maritime industry, 'The global alliances', which are so dominant on the main routes, have proven to be very successful in gaining the economies of scale achieved through the use of larger vessels. The hub-and-spoke (H&S) network entails using a mega-containership and the multi-port-calling system (MPC) is operated using smaller containerships (Imai, et al., 2009).

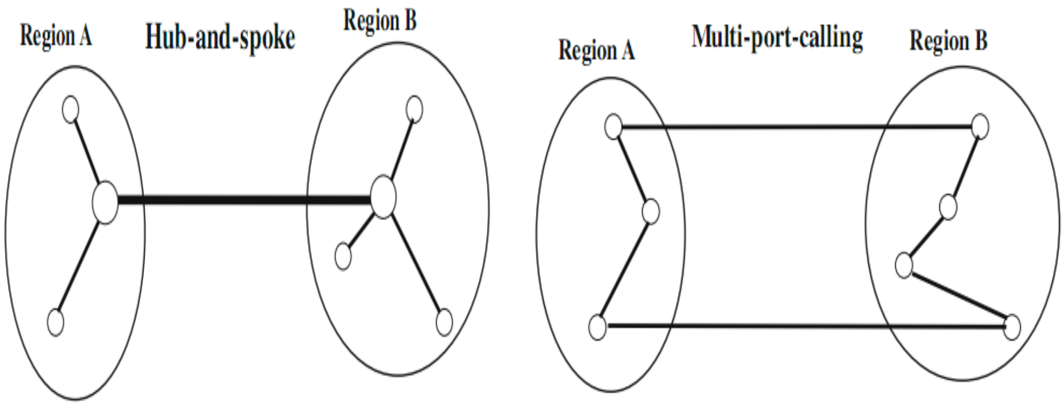

Figure 6. Service networks
Source: Imai, et al., 2009

A port might have a function of a regional port for one liner shipping operator or a function of a feeder port for another one (Notteboom & Rodrigue, 2008). Driven by economic factors, the port developed into two port types namely the hub port that serves the mother vessels, and the secondary port or commonly called the port 'spoke' (Mourao, et al., 2002). When the hub and spoke system was created, the feeder or land transportation mode moved the cargo to and from the hub port and used the port to consolidation transport flows. The low volume of goods transported between certain ports and the high fixed costs incurred by the vessels encouraged more intense use of this hub and spoke system (Mourao, et al., 2002). Mulder & Dekker (2014) made a distinction between the main services and the feeder services. The feeder services are used to ship the cargo from the cluster centre in one cluster to the other ports in the same cluster.

A hub-and-spoke network is a network pattern that has one or more ports that serve as a hub port in the destination area based on the geographical location and demand for shipping items (Hsu & Hsieh, 2007). Major ports are frequently selected as hub ports, and the other ports act as feeder ports or spoke ports. The cargo transported is consolidated at the port hub and then delivered by the larger vessels that provide inter-hub port services in both areas. Meanwhile, to provide services between port hubs and small ports small vessels (feeder vessels) are used. Figure 7 illustrates the fundamental hub-and-spoke maritime network. In their study, Hsu & Hsieh (2007) explained that each region has one or more hub ports (p3, p4, p5 and p6) and other ports act as feeder ports (p1 and p2). A container can be shipped directly from a feeder port in the region of origin to a hub port in the region of destination directly or have it transported through the hub port at the region of origin by routing the feeder line and then the main line.

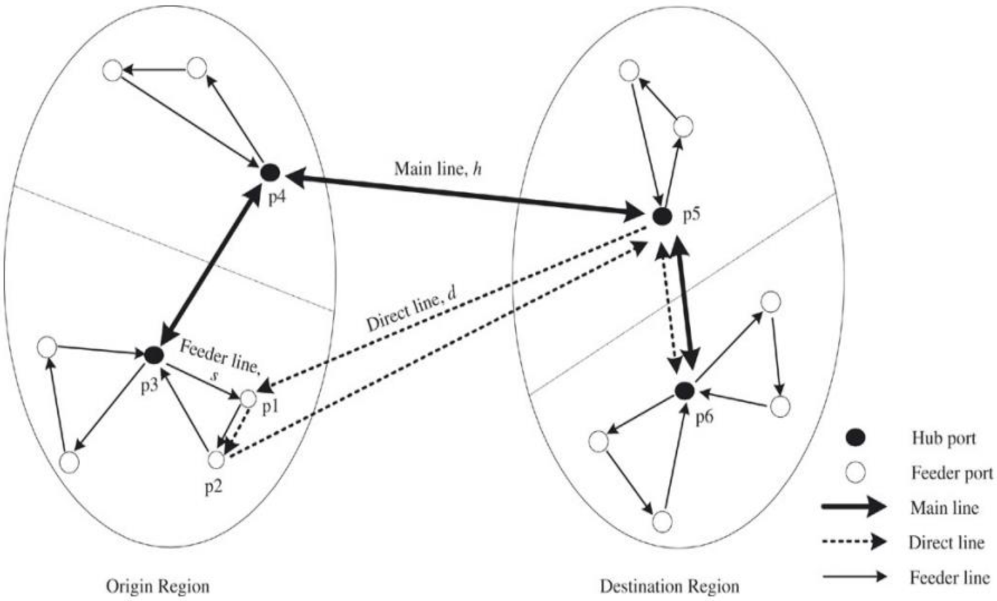

Figure 7. The fundamental hub and spoke maritime network
Source: Hsu & Hsieh, 2007

The connection between hub port and feeder port could use direct feeder shipping or a shuttle feeder services consisting of one feeder port or indirect feeder ships using a cyclic line bundling service that contains more than one feeder port (Polat, et al., 2014). The direct feeder shipping has an advantage in having the lowest transit time but requires smaller feeder containerships. In contrast, cycling feeder services offer the benefit of economies of scale but take a longer distance and subsequently generate longer transit times.

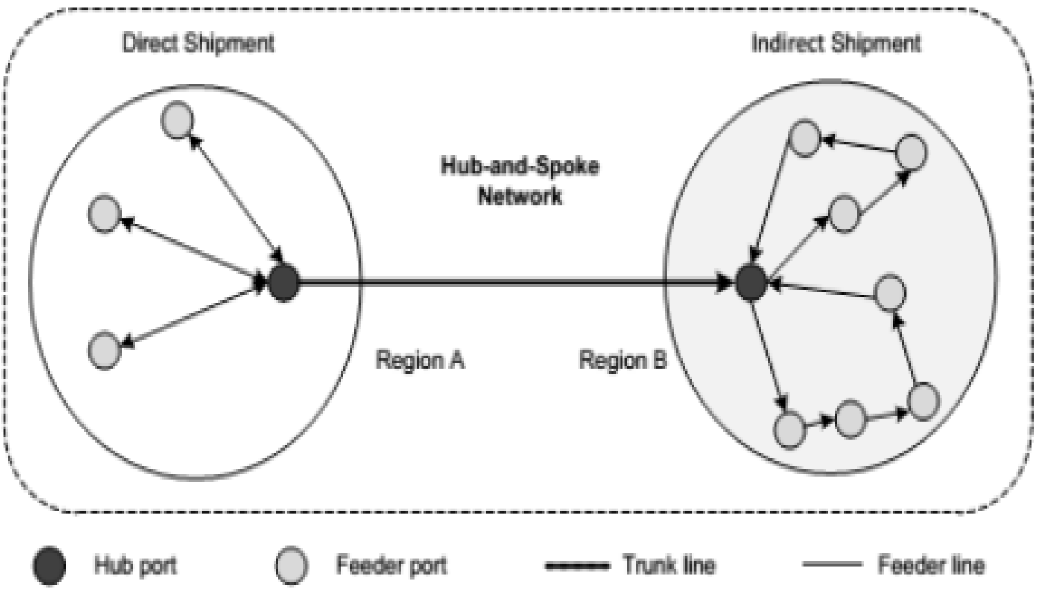

Figure 8. Feeder service network as a part of H&S network
Source: Polat, et al., 2014

Meng & Wang (2011) offer perspectives related to the network system changes from the MPC network to a combined H&S and MPC network resulting from increased ship size and shipment demand. The combined H&S and MPC network has characteristics of a conventional H&S network, larger vessels operate in the main line and feeder vessels serve the feeder line. The H&S network is used when container volume is not enough to justify a direct network, and thus, some containers have to be transhipped at hub ports.

2.3.2 Hub-and-Feeder Network in Indonesia

It can be concluded that there are two different service networks that can be applied in order to find out the best strategy for providing services. The Indonesian government considered employing the H&S model under the blueprint of the national logistics system in Indonesia. The government of Indonesia has formulated the design framework of the hub and feeder network with the objective to achieve connectivity and facilitate the logistics distribution. Refers to the national logistics system, distributing cargoes in the front area (international hub port) is connected to the inside area through the inter-island (domestic hub ports), and it is subsequently delivered to the feeder port and then continues to the sub-feeder port (Ministry of development planning, 2015). Moreover, the Indonesian government also developed vessel route which connects the two international hub ports, and this route passes through domestic hub ports from the Western to the Eastern regions of Indonesia. The Figure below illustrates the basic framework of the H&S model design in Indonesia.

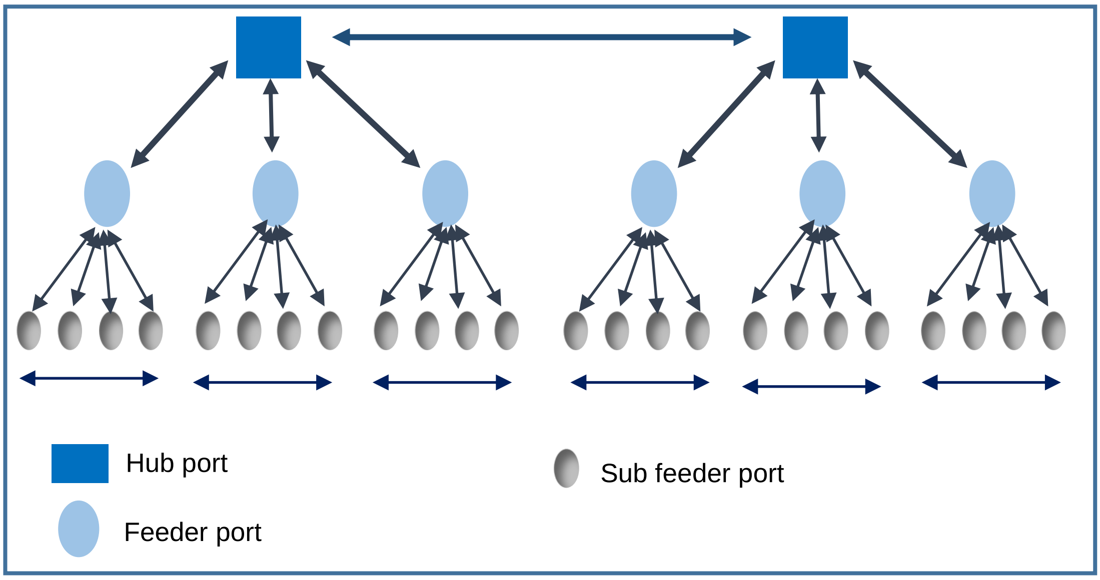

Figure 9. Integrated local and national connectivity
Source: Modified from Ministry of National Development Planning (BAPPENAS), 2015

According to Figure 9, the design of H&S model in Indonesia has been modified and the result of this modification is known as the Hub-and-Feeder model. This model allows bigger vessels sail from one hub port to another hub port and then connects hub port and feeder port using the feeder vessels. This model is slightly different from other theories on H&S model since the model in Indonesia also includes the sub-feeder ports located in the smaller regions. This design is based on the geographical situation in Indonesia.

2.4 Network Model

In this section we discuss previous studies conducted in this field, particularly, studies on the optimisation of the liner shipping routes. Review of previous studies is essential to figure out how the network model works in order to optimise the network with the help of the mathematical model and operation research approach. We consider to review these previous studies in this research paper since these are pre-reviewed and have been cited by a lot of others researchers. In Section 2.4.1, several references with respect to the optimal shipping routes creation are presented. The construction of MPC and H&S network are the main topics of discussion in Section 2.4.2. Theory related to pendulum service is introduced in Section 2.4.3.

2.4.1 Optimisation Method in Linear Network Design Problem

Mulder & Dekker (2014) have conducted the study using aggregation methods to solve the combined fleet-design, ship scheduling and cargo routing problems when looking at the limited capacity of ships in liner shipping. First, the ports are aggregated into port clusters in order to solve the problem of size. Initial route is developed and a linear programming formulation which is known as cargo routing problem is constructed to solve the cargo routing problem to be optimal. Second, they had to disaggregate again into individual ports after the results in clustered port were obtained. A distinction between main services and feeder services are introduced in their research. The feeder services are used to move the cargo from the centre of the cluster to the other ports in the cluster. Moreover, the centre of the cluster can be a part of main services and the other ports will be added to the main services network only if it is profitable. In this method, only intra-regional demand is taken into account. In their study, however, there is a possibility to add regional demand in the model, as the method will stay the same when regional demand is included. Finally, they developed ten scenarios with undertrained demand and compared them to the performance of the reference network and its profit levels.

Wardana (2014) developed two methods; Travelling Salesman Problem (TSP) and heuristics approach to create a service network for liner shipping in Indonesia. This research was conducted to study what impact the selected routes have on cargo allocation. The author used the nearest neighbouring algorithm as a solution method for the TSP model, to find out the fastest path in determining the next destination port after visiting the previous port. The heuristics approach was used to decide cargo allocation and to try to generate the highest profit levels from the selected routes. Profit generated by reducing the revenue and the costs. The author created the possible routes based on demand. The simulation of all possible routes that combined ship routing and cargo allocation was executed with the help of the Excel spreadsheet.

Van Rijn (2015) examined the design of a service network for liner shipping in Indonesia. This study constructs service networks consisting of different shipping routes, ship allocations, sailing speeds and cargo volume allocations. Two algorithms were developed in order to formulate the service network. The first algorithm used pendulum routes, and the second algorithm used randomly generated routes. The routes used in the route network of this study is based on the routes proposed by the Indonesian government.

Lazuardi (2015) analysed the connectivity between main port and international hub port in Indonesia. This study applied a heuristic approach combined with the use of the Feeder Network Design Problem (FNDP) and Multiple Commodities Problem in order to create the optimal route and cargo allocation by minimising the total transportation costs. There were two scenarios in this study, the first scenario analysed all the international containers of six main domestic ports, including Belawan, and the second scenario did not include the international container in Belawan. As a result of this study, two optimal routes for each scenario was suggested, consisting of a direct and indirect loop. The direct loop was defined as a direct connection between the hub and main domestic ports, while the indirect loop meant calling at multiple main domestic ports.

2.4.2 Construction of MPC and H&S Network in liner shipping network

Imai, et al. (2006) studied mega container vessels' viability by using a game theory model in competitive circumstances. In order to simplify the model, this study permitted each shipping company to have only two strategies, either by using mega container vessels or – alternatively – using smaller vessels. Service network structures in liner shipping routes were developed, then this study assumed that only two service networks were allowed: the hub-and-spoke (H&S) network for mega container vessels and multi-port-calling (MPC) for smaller vessels. The construction of H&S and MPC networks was chosen to minimise of origin and destination (O-D) traffic travel length weighted by shipment volumes. To make computations easier, the MPC network was constructed as "the travelling salesman" problem, while the H&S network was identified as "the minimum location" problem.

Hsu & Hsieh (2007) have formulated a two-objective optimisation model by minimising shipping costs and inventory costs to determine the optimal liner shipping routes, the size of vessels and sailing frequencies for container lines. Shipping costs can be distinguished into three categories; capital and operating costs, fuel costs and port charges. Inventory costs are associated with traffic volumes, the value of the cargo, and storage time length. In this study, only inventory cost related to shipping processes are considered and so are involving the waiting time and costs of shipping time. Firstly, this study uses an analytical method to formulate shipping and inventory costs. Then, Pareto optimal solutions are used to determine the two-objective model based on a trade-off between shipping and inventory costs. A fundamental hub-and-spoke network is taken into account in this study. Therefore, the objective optimisation model is not only used to determine optimal ship size and sailing frequencies but also decision-making processes on different scenarios of shipping routes.

Imai, et al. (2009) have examined two different alternatives of service networks for liner shipping routes, namely a multi-port-calling (MPC) network for conventional ship sizes (smaller ships) and a hub-and-spoke model for mega container ships. This study was conducted to refine the research that has been done before, where the design of liner shipping networks is taking into account container management problems including empty container repositioning. Two phases are performed to create a solution process, namely the service network design and container distribution. This research studies the MPC network as the minimisation of the total origin-destination traffic travel length weighted by the shipment volume by using a genetic algorithm (GA)-based heuristic. The MPC network does not consider a ship's capacity overutilization since it is not associated with fluctuations in demand. Also, the ship is not based on a specific port, therefore the carried cargoes are delivered to the ports in any calling sequence. The MPC construction is given as follows: set up the ports to be called and carried a number of the containers between the ports of origin and destination ports. This model has similar characteristics to the travelling salesman problem where one round route starting from an origin port and returning to this port after visiting all the ports with only one call. While the outline of the H&S network is constructed differently: there are two sets of calling ports and a number of containers is carried between the origin and destination ports. This model takes into account the existence of the hub ports and each feeder port in a region.

Meng & Wang (2011) conducted research to propose a medium-term liner shipping network design problem, referred to as a liner shipping service network, combining the H&S and MPC network operations and also empty container repositioning. The combination of H&S and MPC networks in liner shipping service networks has two main characteristics: 1) Container transhipment costs and handling times cannot be ignored because these costs are a substantial part of the operating costs; 2) Allowing the direct container shipment between any two ports including feeder ports. These two unique characteristics means that the combined H&S and MPC networks are significantly different from the conventional H&S operations networks.

2.4.3 Pendulum Network

According to Notteboom (2004), pendulum services are commonly used on the main east-west trading routes. The pendulum service relies on a hub port that serves as a turning point between the liner services of two different trades and is serviced by post-panamax vessels. The design of this kind of liner service has become popular in the high-volume international trade routes such as the US West coast-Far East- Europe trade. Consequently, in the last decade a new generation of loading centres along the east-west shipping lanes has been developed. These sites depend heavily on the flow of traffic generated by the interaction of places that are widely separated and stimulated by port location.

The pendulum service involves a regular schedule between port sequences that frequently serves by geographical proximity. Several ports along one coastal area are serviced and this process is repeated regularly (Lun & Browne, 2009). Chen & Zeng (2010) argued that container shipping networks can be distinguished into two types depending on their operating characteristics. The first is circular and the other is pendulum as shown in Figure 10. According to the Figure below, any pendulum route can be changed into a circular route as a basic form by inserting virtual port(s) in the backward direction and developing an adequate matrix for demand distributions.

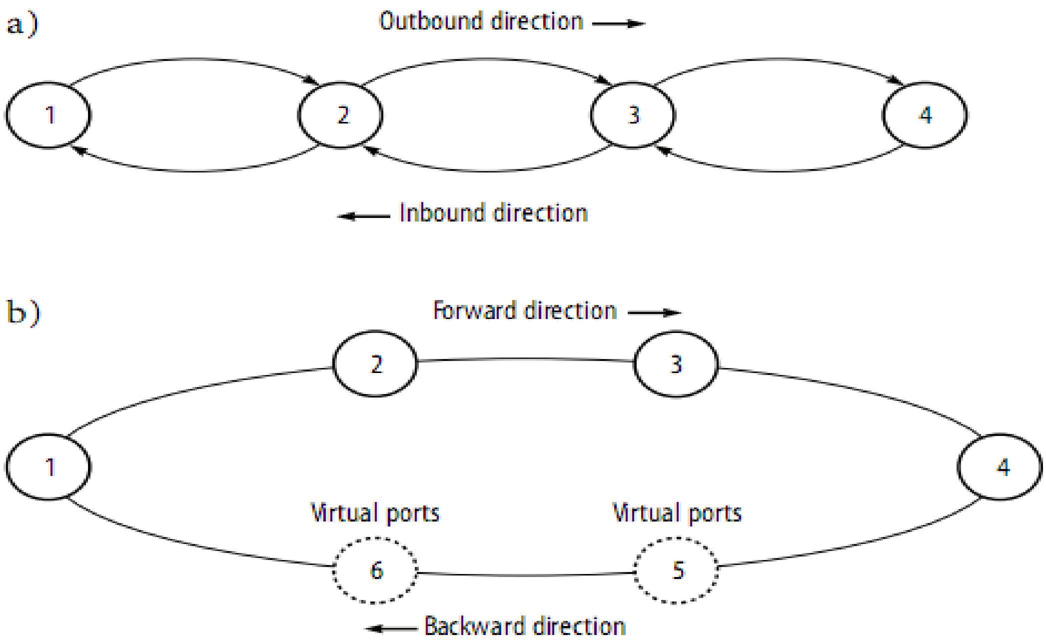

Figure 10. a) Pendulum route; b) Circular route
Source: Chen & Zeng, 2010

We can deduce that this study requires an analytical approach that probably combines with two or more methods to generate optimal solutions by minimising shipping costs. In this research, we develop two liner shipping network designs: the multi-port-calling (MPC) one, combined with pendulum services as followed by the sea toll road programme of 2016 and 2017 as stipulated by the Indonesian government. The other is the Hub-and-Spoke as a proposed network including the port of Tenau Kupang as a transhipment port. The result of these two networks will be compared in order to determine the optimal route that generates the lowest cost.

2.5 Transportation Costs

The ability of ship operations in terms of cargo distribution will affect the profitability and quality. Factors affecting operational performance include scheduling, ship routing, and ship size. Using larger vessels allows lower shipping costs per container as a result of economies of scale. In addition, the speed of the vessel and the productivity of loading and unloading containers is also a determinant of the costs to be incurred by the vessel.

2.5.1 Shipping Cost

In general, there are three basics factors combined in running a vessel. First, the cost of fuel consumption, the number of crew needed, and the condition of the vessel that is an indication for repair and maintenance requirements. Then, the cost of the purchase order, bunkers, wages, repairing costs and the interest rate. Third, administration costs and operational efficiency.

Stopford (2009) classifies shipping costs into five categories as follows:

1. Capital costs
   These costs depend on the way the ship has been financed (the form of equity or debt finance). In other word, capital costs include the cost calculation covering interest payments and returning the dividend depends on how the ship has been financed.

2. Operating costs
   Operating costs consist of the expenses related to the day-to-day running of the vessel and day-to-day repairs and maintenance (not major dry docking).

   a. Crew costs
      Crew costs or manning costs including basic salaries and wages, insurance, pensions, repatriation and victuals expenses. Manning costs depend on the size of the crew employed and employment policy adopted by the owner based on the ship's flag state.

   b. Stores and consumable
      These costs are categorised into two different items; general stores, including cabin stores and various items used on-board of the ships as well as lubricating oils as major costs.

   c. Repairs and maintenance
      Repair costs cover the standard requirement to maintain the vessel based on a company policy. While the maintenance costs cover the routine maintenance, including breakdowns and spares.

   d. Insurance
      Two-thirds of these costs cover the hull and machinery that insure the owner of the vessel from the physical loss or damage, and the other part covers the third party insurance which concerns the third party liability such as collision, cargo damage, death of crew, pollution, and other matters that can be covered in the open insurance market.

   e. General costs
      General costs include administrative and management charges, miscellaneous costs, owners' port charges and communication fees.

3. Periodic maintenance costs
   These costs include the cost of docking and special surveys. The cost level depends on the age and the condition of the ship. In order to maintain its seaworthiness, a ship shall be docking every two years, while the special survey should be conducted every four years.

4. Voyage costs
   These costs are built up of three basic variable costs that occur in a particular voyage, i.e. fuel costs, port charges and canal fees.

   1. Fuel costs
      Fuel consumption depends on the ship design, ship age, the design of the main and auxiliary engines, and hull condition as well as the speed level at which the ship is operated. Operation of the vessel at lower speed leads to fuel savings.

2. Port charges
   These costs can be divided into two categories: port dues and service charges. Port dues are charged to the vessel for general use of the port infrastructure, such as line handling fees, berth occupancy charges, wharf age charges and other provisions related to the basic port infrastructure. While, service charges including pilotage, tugging and cargo handling will be more discussed in the next section.

   Port charges can be categorised into the shipping charges and stevedoring charges. The shipping charges consist of pilotage, towage, and anchoring fees as well as berth occupancy charges. While, stevedore charge including loading and unloading fees, the use of equipment and stacking cost in the container yard (Hsu & Hsieh, 2007).

3. Canal fee
   Canal fees are paid on the use of a canal, where there are two canals in the world namely the Suez and Panama Canals. Because in this study we focus on discussing shipping costs in Indonesia, the canal fee element can safely be ignored.

5. Cargo-handling costs
   Cargo-handling costs consist of loading and discharging costs. These costs are a significant component in the total shipping cost. In general, the type of this cost depends on the type and size of the containers, whether they are empty or full and whether they are20' or 40' feet.

In order to make more detail, the shipping costs have been identified and linked as is shown in Figure 11.

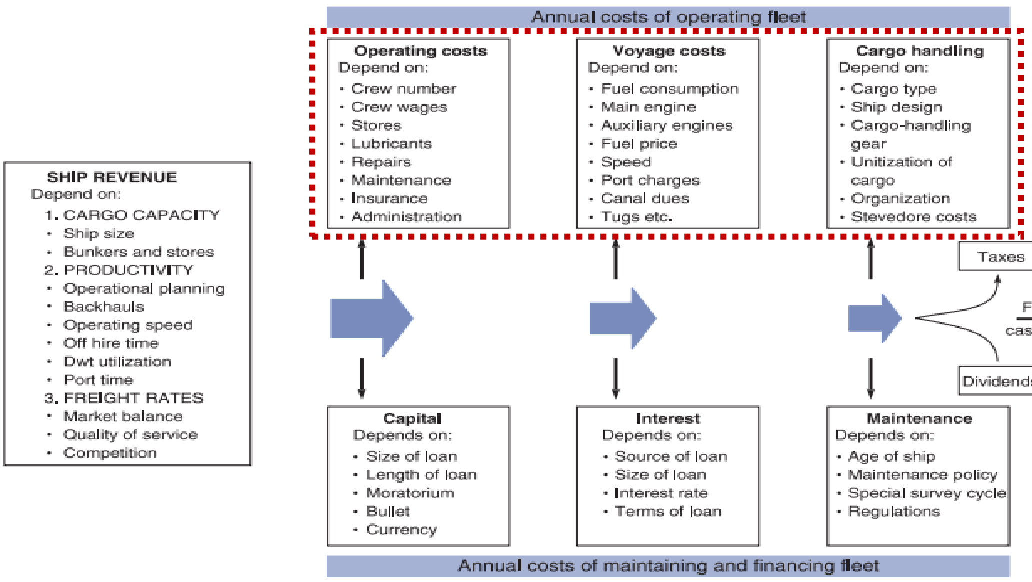

Figure 11. Shipping cash flow model
Source: Modified from Maritime Economics, third edition, Martin Stopford, 2009, p. 220

In this study, we decide to use the time charter method. As mentioned in the previous section, the ship-owner is obliged to pay all of the expenses related to the operational and capital costs excluding fuel costs, port dues and cargo handling fees. Therefore, the calculation of the shipping costs in this study is the sum of the operating costs based on the time charter rate, fuel consumption costs, port dues and cargo-handling fees.

2.5.2 Shipping Charter

Shipping companies might use their vessels or charter vessels in serving cargo distribution. According to Stopford (2009), there are three types of charter vessels that are commonly used; bareboat charters, time charters and voyage charters:

1. Bareboat charter
   A bareboat charter is an arrangement for chartering a ship where the charterer pays all the operating costs, voyage costs and costs related to cargo. Moreover, the charterer also takes both the operational and market risks.
2. Time charter
   A time charter is an arrangement for hiring a ship at a specified rate with a fixed daily or monthly payment. The ship-owner takes an operational risk in case the ship breaks down. While, the charterer takes a risk in terms of shipping market risk, the agreed rate must be paid regardless of market conditions. Moreover, the charterer pays fuel costs, port dues and port charges, stevedoring and other costs related to the cargo.
3. Voyage charter
   Under this arrangement, the ship-owner has an obligation to pay all the expenses excluding cargo handling and also is liable for operating the vessel including the planning and execution of the voyage. In this scheme, the ship-owner takes the operational and market risks. In other words, when there is no cargo, the ship breaks down or the vessel has to wait for cargo, the ship-owner will face losses.

In Table 1, we represent the division of expenses for different vessel hiring contracts

Remark	Voyage Charter	Time Charter	Bareboat Charter
Voyage Expenses	Ship-owner	Charterer	Charterer
Operational Expenses	Ship-owner	Ship-owner	Charterer
Capital Expenses	Ship-owner	Ship-owner	Ship-owner

Table 1. Division of expenses for different vessel hire contracts
Source: Lecture of Ship Finance by Pruyn, 2016

2.6 Staple and Essential Goods

According to Business Dictionary (2017), staple goods are "*consumer goods (such as bread, milk, paper, sugar) that are bought often and consumed routinely*", while "*some essential good types that are produced by business operators include food, water, gasoline and heating fuel, as well as residential building materials that can be used to construct homes for shelter*".

Sea toll road programme 2016 and 2017 are devoted to the distribution of staple and essential goods as stated in Presidential Decree No. 71 of 2015 on the stipulation and storage of staple and essential goods. In pursuance of this regulation, staple and essential goods consist of:

1. Staple goods
    a. Agricultural products
        1) Rice
        2) Soybeans
        3) Chili
        4) Shallot
    b. Industrial products
        1) Sugar
        2) Cooking oil
        3) Wheat flour
    c. Livestock and fishery products
        1) Beef
        2) Chicken meat
        3) Chicken eggs
        4) Fish
2. Essential goods
    a. Seeds are rice seed, corn, and soybean
    b. Fertiliser
    c. Heating fuel
    d. Plywood
    e. Cement
    f. Light steel

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Chapter 3 Research Methodology

A fundamental hub-and-spoke and a multi-port-calling network are taken into account in this study. Container shipping services are provided by the carrier between two regions separated by the ocean. Since the design of the hub-and-spoke model in Indonesia is slightly different from the common model introduced by several researchers in earlier work, we adapted the model by involving sub-feeder ports as part of the hub-and-spoke network. If the distribution of goods is conducted from hub to hub and then will be distributed to the feeder port, in this study we will analyse the distribution of goods from the hub port to the feeder port and then to the sub-feeder port. In that case the function of the feeder port in this study is one of a transhipment port. In section 3.1, a mathematical model for shipping cost functions is defined. Shipping costs consist of operating costs that are based on time charter rates, fuel consumption costs, port dues and cargo-handling fees on the route being served. Section 3.1.1 further determines shipping cost functions for multi-port-calling networks, followed by the hub-and-spoke network in section 3.1.2. The assumptions are explained in section 3.2 and followed by the research methodology scheme presented in this study in section 3.3. The last section will present the relevant data that is required in this study.

3.1 Shipping cost function

Based on Stopford (2009), shipping costs can be calculated as a sum of capital costs, operating costs, periodic maintenance costs, voyage costs and cargo handling costs. In this research, we consider that the ship is hired by using a time charter arrangement with the charter rate in Dollar per day (US$/day). Further, we change capital costs, operating costs and periodic maintenance costs by applying the time charter rate in unit dollars per day (US$/day), thus shipping costs is a sum of time charter rate, fuel costs, port dues and cargo handling costs as shown in the following formula:

$$C_S^m = \sum_i \left[\alpha_{it} + O_t W_i + F_{it} + D_i^m \left(\frac{O_t}{V_t} + \frac{F_t}{V_t}\right)\right] + \sum_i \sum_j \left[\left(\beta_i + \frac{O_t}{R_i}\right) P_{ij}\right] \qquad [1]$$

Subject to

$$\alpha_{it} = \sum_i Pl_{it} + To_{it} + L_{it} + B_{it}$$

Where:

m	route
i	port of origin on route m
j	port of destination on route m
t	type of ship
α_{it}	fixed portion of port i charge for a ship of type t (US$)
O_t	average daily charter rate for a ship of type t (US$/day)
W_i	time a ship spends on the arrival and departure process in port i (day)
F_{it}	fuel cost in port i by a ship of type t (US$)
D_i^m	shipping distance between port i and port i + 1 on route m (nautical mile)

V_t service speed for a ship of type t (knot)
F_t fuel cost at sea for a ship of type t (US$)
β_i average handling fee per TEU in port i (US$ per TEU)
R_i average gross handling rate in port i (TEU per day)
P_{ij} the number of containers shipped between port i and port j on route m (TEU)
Pl_{it} pilotage for a ship of type t (US$)
To_{it} towage for a ship of type t (US$)
L_{it} anchoring fee for a ship of type t (US$)
B_{it} berth occupancy charge for a ship of type t (US$)
G_i loading and unloading fee (US$/box)

The objective of the proposed model is to minimise shipping costs. The fixed component (Λ_t^m) and the variable shipping cost (ϕ_t^m) for ship type t on route m can further be denoted by simplifying the variables as:

$$\Lambda_t^m = \sum_i \left[\alpha_{it} + O_t W_i + F_{it} + D_i^m \left(\frac{O_t}{V_t} + \frac{F_t}{V_t}\right)\right] \quad [2]$$

$$\phi_t^m = \sum_i \sum_j \left[\left(G_i + \frac{\beta_{it}}{R_i} + \frac{O_t}{R_i}\right) P_{ij}\right] \quad [3]$$

Furthermore, the shipping cost equation can be simplified as

$$C_S^m = \Lambda_t^m + \phi_t^m \quad [4]$$

The shipping cost function as denoted in equation [1] and simplified in equation [4] is a basic formula to calculate the total shipping costs in our excel sheet. Moreover, we use unit cost (Cij) as the variable cost of one unit container (TEU). Unit cost for every route within arc (i, j) derived by dividing the total variable shipping cost (ϕ_t^m) by the number of containers carried from origin to destination (Pij). While, the fixed cost (Λ_t^m) dependent on the type of ship and route (Xij). Hence, we formulate the objective function [3] to determine the minimum shipping costs of distributing cargo on a certain route, as follows:

$$Min \sum_{i,j \in N} \sum_{c \in C} \sum_{d \in D} \left[P_{ij} * C_{ij}\right] + \sum_{i,j \in N} \Lambda_t^m * X_{ij} \quad [5]$$

3.1.1 Shipping Cost Functions for Multi-Port-Calling Network

In order to figure out the total shipping cost for a multi-port-calling network, we construct the formula that refers to equation [4] and substitutes the number of sailing frequencies on a certain route (f) per year.

$$C_S^d = \Lambda_t^m + \phi_t^m$$

$$= \mathrm{f}\,\Lambda_t^m + \phi_t^m \quad [6]$$

$$= f \textstyle\sum_{i \in N} \left[\alpha_{it} + O_t W_i + F_{it} + D_i^m \left(\frac{O_t}{V_t} + \frac{F_t}{V_t}\right)\right] + \sum_{i \in N} \sum_{j \in N} \left[\left(\beta_i + \frac{O_t}{R_i}\right) P_{ij}\right] \quad [7]$$

The objective function refers to equation [3] and substitute the number of sailing frequency (f), subject to:

Connectivity constraint

$$Xij \in \{0,1\} \quad [8]$$

$$\sum_{i \in N} X_{ij} \geq 1 \quad \forall j \in N \quad [9]$$

$$\sum_{j \in N} X_{ij} \geq 1 \quad \forall i \in N \quad [10]$$

Cargo allocation constraint:

$$\sum_{i \in N} P_{ij} = D_j \quad \forall j \in N \quad [11]$$

$$\sum_{j \in N} P_{ij} = S_i \quad \forall i \in N \quad [12]$$

$$P_{ij} \geq 0 \; and \; integer \; \forall i, j \in N \quad [13]$$

Ship capacity constraint

$$\sum_{i,j \in N} P_{ij} \leq \sum_{t \in T} U_t X_{ij} \quad [14]$$

Where:

Xij binary variable
1 = if ship sails from port i to port j using ship of type t
0 = otherwise

N all nodes on route m

D_j total demand of the container (TEU) at port j

S_i total supply of the container (TEU) from port i

U_t maximum TEU capacity of ship type t per voyage

We construct three constraints in order to gain the objective of this study. Firstly, we develop connectivity constraint, equation [8] depicts that ship sails from port i to port j (1) or not (0). Equations [9] and [10] indicate that the sum of travelling routes should be equal or more than 1, since this multi-port-calling model is used to capture the shipping costs in the implementation of the sea toll road programme of 2016 and 2017 where a vessel is allowed to visit port more than once in one route (pendulum service).

Due to the fact that the number of the container discharged at destination ports are from the port of Tanjung Perak as a port of origin, we formulate the equation [11] that illustrates that the number of containers discharged at the destination port should be equal to the total demand in this port. The similar way is applied to equation [12], the total number of containers loaded at the port of origin should be equal to the total supply in this port. The last constraint of cargo allocation is shown in equation [13], where the number of containers should be equal or more than zero and must be an integer. It means that the number of containers should have a positive value.

Ship capacity constraint delineates that the number of containers carried from the port of origin to the destination port should be less than or equal to the maximum ship capacity (TEU).

3.1.2 Shipping Cost Function for Hub-and-Spoke Network

In order to formulate the hub-and-spoke network, we consider combining the costs in two lines, i.e. main line (h) and feeder line (s). Moreover, the minimum shipping costs are derived from the minimum sailing frequency, indicating the use of the bigger vessel capacity. Since the number of containers carried on a ship cannot exceed its capacity on any route, the sailing frequency must be equal to the maximum network flow (Maxk). The minimum sailing frequency (f) can be formulated as:

$$f = f_t^{h-min} = \frac{max_k \sum_i \sum_j \delta_{ijk}^h Q_{ij}^h}{U_t} \qquad [15]$$

Where:

f_t^{h-min}	the minimum sailing frequency w.r.t. to a ship type t on the main line
max_k	maximum network flow
δ_{ijk}^h	the binary variable
	δ_{ijk}^h=1, if route from port i to j contains a link between port k and k+1
	δ_{ijk}^h=0, otherwise
Q_{ij}^h	Flow from port i to j on the main line per season (TEU)
U_t	Ship's capacity (TEU) given by the Indonesian government

Then the minimum shipping cost on the main line can be represented as $C_{S,t}^h$. Substituting formula [15] into formula [4] leads to the following equation

$$C_{S,t}^h = \frac{max_k \sum_i \sum_j \delta_{ijk}^h Q_{ij}^h}{U_t} \Lambda_t^m + \phi_t^m$$
$$= \frac{max_k \sum_i \sum_j \delta_{ijk}^h Q_{ij}^h}{U_t} \sum_{i \in N} \left[\alpha_{it} + O_t W_i + F_{it} + D_i^m \left(\frac{O_t}{V_t} + \frac{F_t}{V_t} \right) \right] + \sum_{i \in N} \sum_{j \in N} \left[\left(\beta_i + \frac{O_t}{R_i} \right) P_{ij} \right] \qquad [16]$$

We denote total shipping costs as TCs of the main line (h) and feeder line (s).

$$TC_s = C_{S,t}^h + C_{S,t}^s \qquad [17]$$

3.2 Assumption

In this section, we introduce several assumptions used in this research to simplify the calculation and derive the goal of this study. These assumptions can be explained as follows:

1. The demand and supply come from 16 domestic ports based on the average total container loading and unloading for each port over the last five years. The ports that are involved in the sea toll road programme of 2016 and 2017 include such ports as Tanjung Perak, Wanci, Namlea, Fak-Fak, Kaimana, Timika, Kalabahi, Saumlaki, Moa, Dobo, Merauke, Larantuka, Loweloba, Sabu, Rote and Waingapu.

2. We assume that demand and supply at the port of Moa and Sabu is equal to the port of Saumlaki since the total population is relatively the same. The reason behind this consideration is that these ports are small-scale ports and are not commercially operated. Before implementing the Sea Toll Road Programme of 2016, only passenger vessels and RoRo vessels came to these ports. Therefore, the report on the number of containers from Tanjung Perak to these ports and back do not capture this data.
3. The port of Tenau Kupang is proposed to be a transhipment port that can handle the total number of containers from the Port of Tanjung Perak before being deployed to the destination ports.
4. We assume that the terminal handling cost in non-commercial ports is equal to the nearest commercial port using the ship gear. Because there is no terminal operator that provides loading and unloading activities, several ports were identified as non-commercial ports (Dobo, Kaimana, Larantuka, Lewoleba, Moa, Namlea, Rote, Sabu, Saumlaki, Timika and Wanci). For these ports, the activities are directly handled by workers in the port under the supervision of the local port authority.
5. We consider using time charter vessels with the daily charter rate in Dollar per day (US$/day) to cover the capital costs, operating costs and periodic maintenance costs. Hence, shipping costs in this study is a sum of time charter rate, fuel costs, port dues and cargo handling costs.
6. The total shipping time per round voyage is a sum of the total time spent at sea and at the port. The total time at sea is based on the distance between the ports and the speed used. The total time at the port depends on the idle time and the time spent for container handling. The latter is based on handling productivity (TEU per day). In order to calculate the idle time at the port, we use the set target waiting times based on the port classification.
7. This study only takes into account the containers that carry staple and essential goods. We use the percentage based on Tanjung Perak report in order to capture the number of containers that contains this type of goods. The percentage derived by dividing the number of staple and essential goods by the total volume of cargo at the Port of Tanjung Perak. We use this approach as the data of the domestic containers at the port do not give information regarding the contents of the container.
8. We ignore the sailing frequency stipulated by the Indonesian government as stated in the government regulation. We apply this consideration since the number of frequency gained in this study as the result of fulfilment of all the containers demanded by the port of destination.

3.3 Research Methodology Scheme

Our research process consists of several steps that can be summarise in the following way:

1. Literature review is necessary to study and analyse the implementation of the Sea Toll Road Programme of 2016 and 2017 as well as the Master Plan of Sea Toll Road Programme. The Indonesian government issued the government regulation to regulate the implementation of this programme including the route, size of the ships, annual sailing frequency and the commission days per voyage. This step

aims to find out the routes connecting the port of Tanjung Perak as the port of origin in the East of the country and the destination ports. Furthermore, it also helps to identify whether the implementation of the Sea Toll Road Programme of 2016 and 2017 is in line with the Master Plan of Sea Toll Road Programme.

2. After the routes for this research are selected, we propose the port of Tenau Kupang as a feeder port that will serve as a transhipment port for the containers from Tanjung Perak to the South-East of Indonesia. Subsequently, we identify the market conditions of supply and demand by analysing the number of the containers loaded and unloaded at the designated ports.

3. Then we develop three scenarios, two of them being based on the Sea Toll Road Programme of 2016 and 2017, while the last scenario is based on the proposed network which assumes involving the port of Tenau Kupang as a port pairing of Tanjung Perak port that serves as a transhipment port.

    a. Scenario I based on the 2016 sea toll road programme

        1) Tanjung Perak – Wanci – Namlea – Fak-Fak – Kaimana – Timika – Kaimana – Fak-Fak – Namlea – Wanci – Tanjung Perak
        2) Tanjung Perak – Kalabahi – Moa – Saumlaki – Dobo – Merauke – Dobo – Saumlaki – Moa- Kalabahi – Tanjung Perak
        3) Tanjung Perak – Larantuka – Lewoleba – Rote – Sabu – Waingapu – Sabu – Rote – Lewoleba – Larantuka – Tanjung Perak

    b. Scenario II based on the 2017 sea toll road programme

        1) Tanjung Perak – Wanci – Namlea – Wanci – Namlea - Tanjung Perak
        2) Tanjung Perak – Fak-Fak – Kaimana – Timika – Kaimana – Fak-Fak – Tanjung Perak
        3) Tanjung Perak – Kalabahi – Moa – Saumlaki – Moa - Kalabahi – Tanjung Perak
        4) Tanjung Perak – Dobo – Merauke – Dobo –Tanjung Perak

    c. Scenario III is based on the proposed network to involve the port of Tenau Kupang as a transhipment port.

4. At the next step of the research we construct two fundamental networks, namely, the multi-port-calling (MPC) and the hub-and-spoke (H&S) networks. The scenario I and II apply multi-port-calling network and we do not need to run the solver since the routes have been stipulated by the Indonesian government. We build and run the mathematical model in excel sheet in order to gain the result of scenario III using hub-and-spoke network.
5. At this step, we calculate the total shipping costs per each route by using the equation [1]. The shipping costs are the sum of time charter rates, fuel costs, port charges and container handling costs. Moreover, we divide the shipping cost into two types of forms which are cost fixed cost and variable cost. Afterwards, we determine the objective function by minimising the total shipping costs.
6. At this step, we compare the results of each of the scenarios.
7. At the final step of the research, we draw conclusions and make recommendations the conclusion and recommendation.

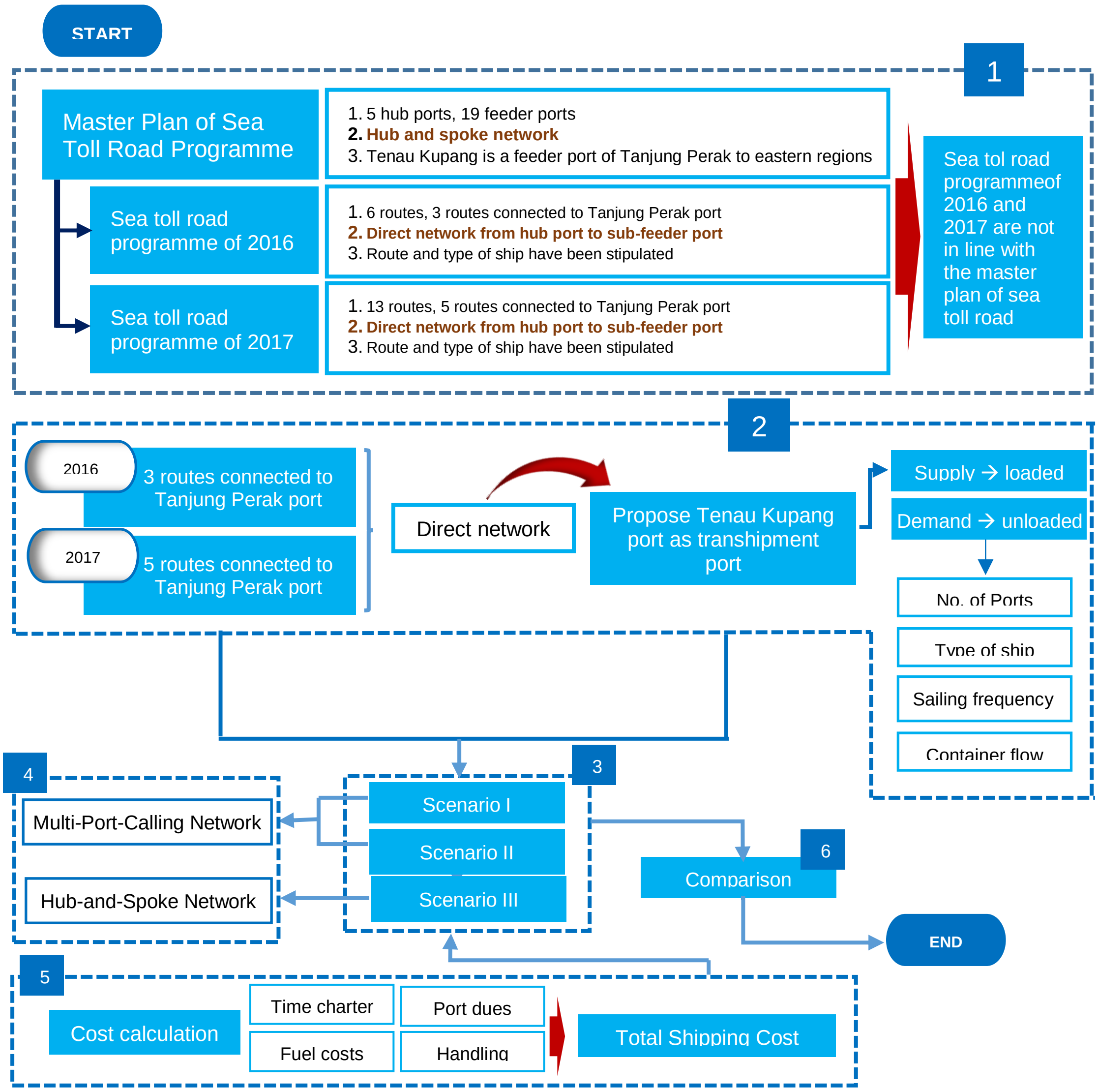


Figure 12. Research Methodology Scheme
Source: Author

3.4 Data

The following data are required as inputs in this research:

1. To analyse the implementation of the Sea Toll Road Programme of 2016 and 2017, the following data from the government regulation Number: AL.108/1/9/DJPL-17 is required:

    a. The routes
    b. The number of ports involved on the route
    c. The number of sailing frequency
    d. The maximum travel time
    e. The type of vessel and maximum capacity (TEU)

2. The demand and supply are reflected in the number of the containers loaded and unloaded at the ports is derived from the Tanjung Perak port report over the last five years.
3. To determine the components of total shipping costs, we obtain data from the Ministry of Transportation and Pelindo III corporation, the type of data is mentioned below:
    a. Port facilities
    b. Port classification
    c. Port operation performance
    d. Port dues
    e. Terminal handling charge
4. Additional data required are obtained from:
    a. The government Regulation(for the data on the distance between the ports in scenarios I and II);
    b. Websites http://www.searoutes.com and http://ports.com (for the data on the distance between the ports in scenario III);
    c. Indonesian Classification Agency (BKI register). The data necessary for the regression formula to determine the classification of the ship was collected from the list of specifications of container ships registered by this agency;
    d. The Maersk Broker 2015 (for the data on the time charter);
    e. Shell Indonesia (which provided information on the fuel price);
    f. Central statistical bureau of Indonesia;
    g. Ministry of National Development Planning

Chapter 4 Overview on the Sea Toll Road Programme in Indonesia

In this chapter, we briefly describe the implementation of the Sea Toll Road Programme including the ports, routes and the type of ships used to distribute the containers from the port of Tanjung Perak to the South-Eastern parts of Indonesia. Next to that, we also provide information on the container flows to or from the port involved in this programme with regards to the ports connected to Tanjung Perak port-Surabaya. The number of containers or the number of loading and unloading of the containers in this chapter reflects on the number of supply and demand in the region.

4.2 Sea toll road programme 2016

In 2016, the Indonesian government adopted a strategy defining six routes connecting the main ports with sub-feeder ports located on the small islands of the country. These routes started in early 2016 and were operated by PELNI, a state-owned enterprise. The six predefined routes mentioned in the Decree of the General of Sea Transportation Number: Al.108/7/8/DJPL-2015 were the following:

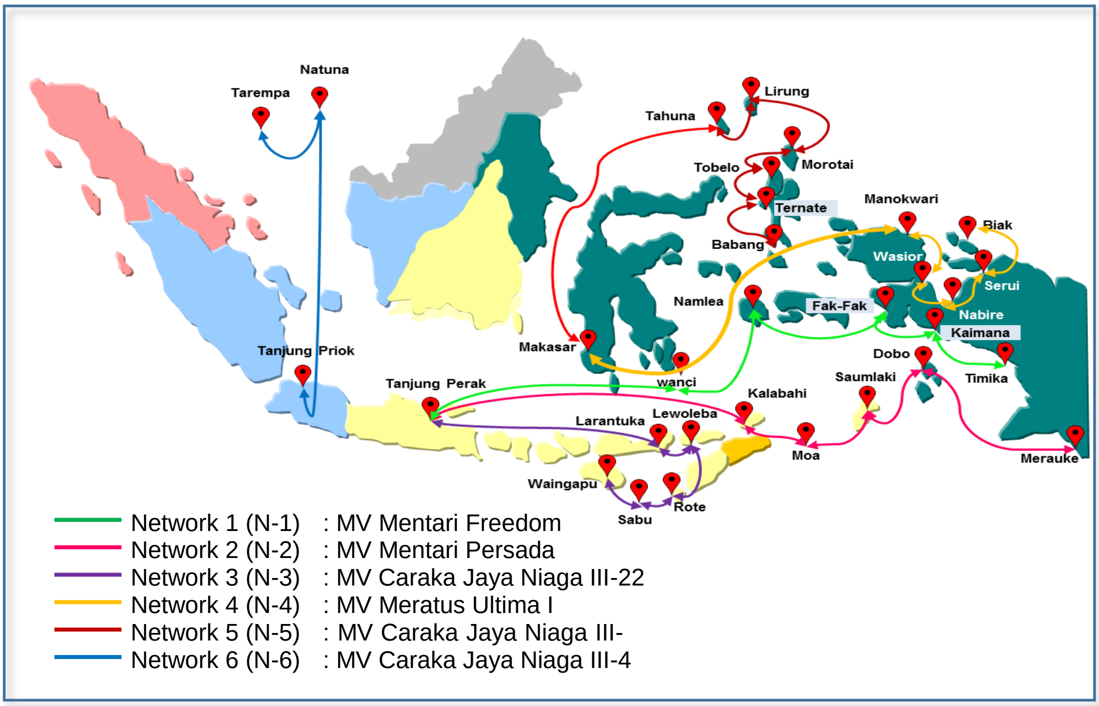


Figure 13. Sea toll road programme of 2016
Source: Modified from Ministry of Transportation, 2016

In the implementation of the programme, the Indonesian government also provided subsidies to PELNI to operate its vessels in servicing the predefined routes. The subsidy was given for one year as per the Ministry of Transportation Regulation No. 85 of 2016. The total amount of subsidies given by the government of Indonesia is presented in Table 2.

Code	Commission days per voyage	Number of voyage per year	Total (IDR)	Equal to ($)	The amount of Subsidy per voyage ($)
N-1	28	10	40,668,163,920	3,068,209	306,821
N-2	28	9	51,874,769,187	3,913,692	434,855
N-3	28	10	24,064,232,082	1,815,526	181,553
N-4	28	9	54,605,831,070	4,119,737	457,749
N-5	28	9	27,115,638,795	2,045,739	227,304
N-6	21	14	20,661,364,946	1,558,797	111,343
Total Subsidy			218,990,000,000	16,521,699	1,719,624

Table 2. Total subsidy is given by the Government of Indonesia
Source: Ministry of Transportation, 2016

Besides providing the subsidies, the Indonesian government also regulated tariffs for container distribution from or to the ports involved in this programme. This policy was only intended for container delivery by PELNI's vessels (Appendix 1). The number of sailing frequencies, types of ships, routes and the total of distances per each route are stipulated by the Indonesian government in the General Decree of Sea Transportation Number: Al.108/7/8/DJPL-2015.

Code	Routes							Total (N.miles)
N-1	Tg Perak	Wanci	Namlea	Fak-Fak	Kaimana	Timika		3,426
		Kaimana	Fak-Fak	Namlea	Wanci	Tg Perak		
N-2	Tg Perak	Kalabahi	Moa	Saumlaki	Dobo	Merauke		3,874
		Dobo	Saumlaki	Moa	Kalabahi	Tg Perak		
N-3	Tg Perak	Larantuka	Lewoleba	Rote	Sabu	Waingapu		2,078
		Sabu	Rote	Lewoleba	Larantuka	Tg Perak		
N-4	Tg Priok	Makasar	Manokwari	Wasior	Nabire	Serui	Biak	4,644
		Serui	Nabire	Wasior	Manokwari	Makasar	Tg Priok	
N-5	Makasar	Tahuna	Lirung	Morotai	Tobelo	Ternate	Babang	2,612
		Ternate	Tobelo	Morotai	Lirung	Tahuna	Makasar	
N-6	Tg Priok	Tarempa	Natuna	Tarempa	Tg Priok			1,400

Table 3. The routes of sea toll road programme 2016
Source: Modified from the decree of the General of Sea Transportation Number: Al.108/7/8/DJPL-2015

However, in this study, we only consider the routes starting from the port of Tanjung Perak, the main port and central distribution of cargo in the Western part of the country. Thus, we only take into account three routes, namely, N-1, N-2 and N-3. In order to serve the cargo distribution on each route, the Indonesian government defined the type of ships to be used in this programme. The name of the ships and its specifications can be explained in Appendix 2.

4.2 Sea toll road programme 2017

In the beginning of 2017, the Indonesian government decided to change the routes after evaluating the implementation of Sea Toll Road Programme in 2016. Several routes were added so the total number of the routes increased to 13. Four of the routes were a change from the previous route. The government found on the routes established in 2016, the ships had to sail over very long distances for a very long time so that had to change.

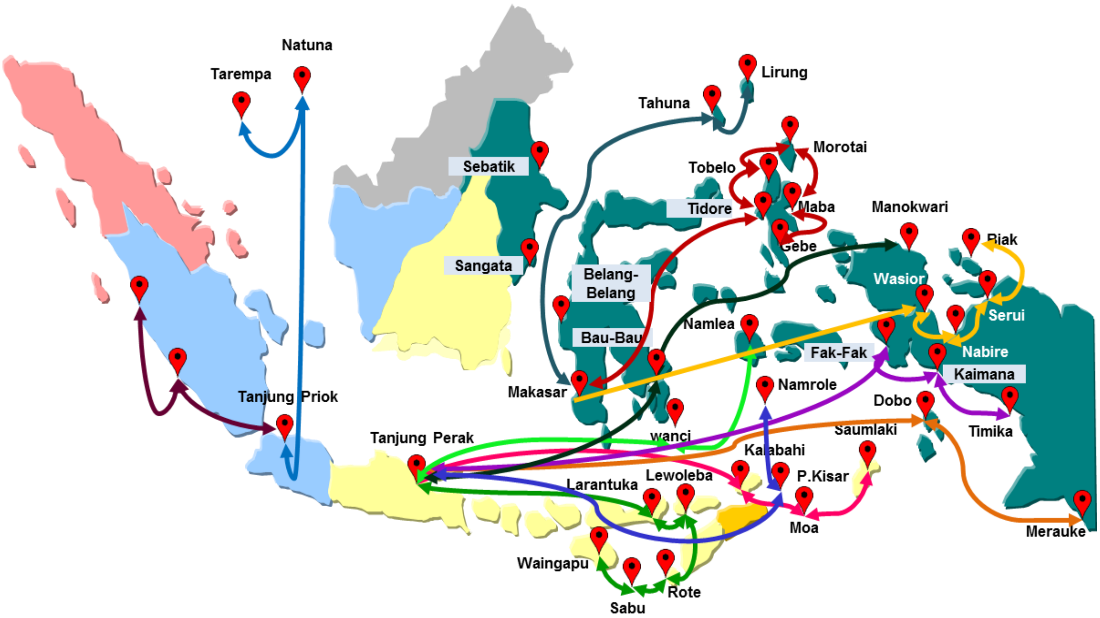


Figure 14. Sea toll road programme of 2017
Source: Modified from Ministry of Transportation, 2017

In 2017, the Indonesian government also stipulated the type of the ships, the route involving the main ports and sub-feeder ports, the sailing frequency and the maximum time required by a ship to sail. Besides the number of routes, the main item that distinguishes the programme from the previous year is that the Indonesian government allowed the private shipping companies to participate by serving some certain routes which cannot be handled by PELNI because they do not have the facilities. The government opened bidding process to assess the private shipping company that has capability to serve the certain routes (Ministry of Transportation, 2017). Table 4 below, we present the routes established by the government regulation number: AL.108/1/9/DJPL-17 of 2017.

Code	Routes								Total Nautical Miles (N.miles)
N-1	Tg Perak	Wanci	Namlea	Wanci	Tg Perak				1,980
N-2	Tg Perak	Kalabahi	Moa	Saumlaki	Moa	Kalabahi	Tg Perak		2,374
N-3	Tg Perak	Dompu	Maumere	Larantuka	Lewoleba	Rote	Sabu	Waingapu	2,150
		Sabu	Rote	Lewoleba	Larantuka	Maumere	Dompu	Tg Perak	
N-4	Tg Perak	Bau-Bau	Manokwari	Bau-Bau	Tg Perak				3,030
N-5	Makasar	Tahuna	Lirung	Tahuna	Makasar				1,760
N-6	Tg Priok	Tarempa	Natuna	Tarempa	Tg Priok				1,400
N-7	Tg Priok	Enggano	Mentawai	Enggano	Tg Priok				1,252
N-8	Tg Perak	Belang2	Sangata	Sebatik	Tg Perak				1,880
N-9	Tg Perak	Kisar	Namrole	Kisar	Tg Perak				2,404
N-10	Makasar	Tidore	Tobelo	Morotai	Maba	Gebe			2,652
		Maba	Morotai	Tobelo	Tidore	Makasar			
N-11	Tg Perak	Saumlaki	Dobo	Merauke	Dobo	Saumlaki	Tg Perak		3,864
N-12	Makasar	Wasior	Nabire	Serui	Biak				3,212
		Serui	Nabire	Wasior	Makasar				
N-13	Tg Perak	Fak-Fak	Kaimana	Timika	Kaimana	Fak-Fak	Tg Perak		3,408

Table 4. The routes of sea toll road programme 2017
Source: The decree of the General of Sea Transportation Number: AL.108/1/9/DJPL-17 of 2017

As mentioned above, in this research, we only take into account the routes starting from the port of Tanjung Perak. In 2017, there are eight routes to be evaluated. However, we only consider five routes, which are N-1, N-2, N-3, N-11 and N-13. The main thinking behind this consideration is that N-4 and N-9 are still in the bidding process, while N-8 is assigned to serve general cargo.

In addition, the PELNI serves N-3, N-11 and N-13 by using three vessels as they are used to serve the routes on the 2016 Sea Toll Road Programme. The MV Freedom is used for serving N-13, the MV Mentari Perdana is used to serve N-11 and the MV Caraka Jaya Niaga III-22 is used to serve the same route (N-3). Meanwhile, Mentari Sejati Perkasa, a private shipping company, has won the tender to serve N-1 and N-2 routes. The detailed information related to the ships used can be seen in Appendix 2.

4.3 Profile of Tanjung Perak Port

The port of Tanjung Perak is the second busiest port in Indonesia after the port of Tanjung Priok. The Tanjung Perak port is located in Surabaya - the capital of East Java. The biggest port of Indonesia, the port of Tanjung Priok is located in Jakarta. Due to its geographical location, the Tanjung Perak port is a well-known gateway and distribution centre in the East of the country. According to the Ministry of Transportation (2011), Tanjung Perak port is classified as the main class port under the management of Pelindo III Corporation.

The port of Tanjung Perak consists of the branch of Tanjung Perak and three subsidiaries namely Berlian Jasa Terminal Indonesia (BJTI Port), Terminal Petikemas Surabaya (TPS) and Lamong Bay Terminal.

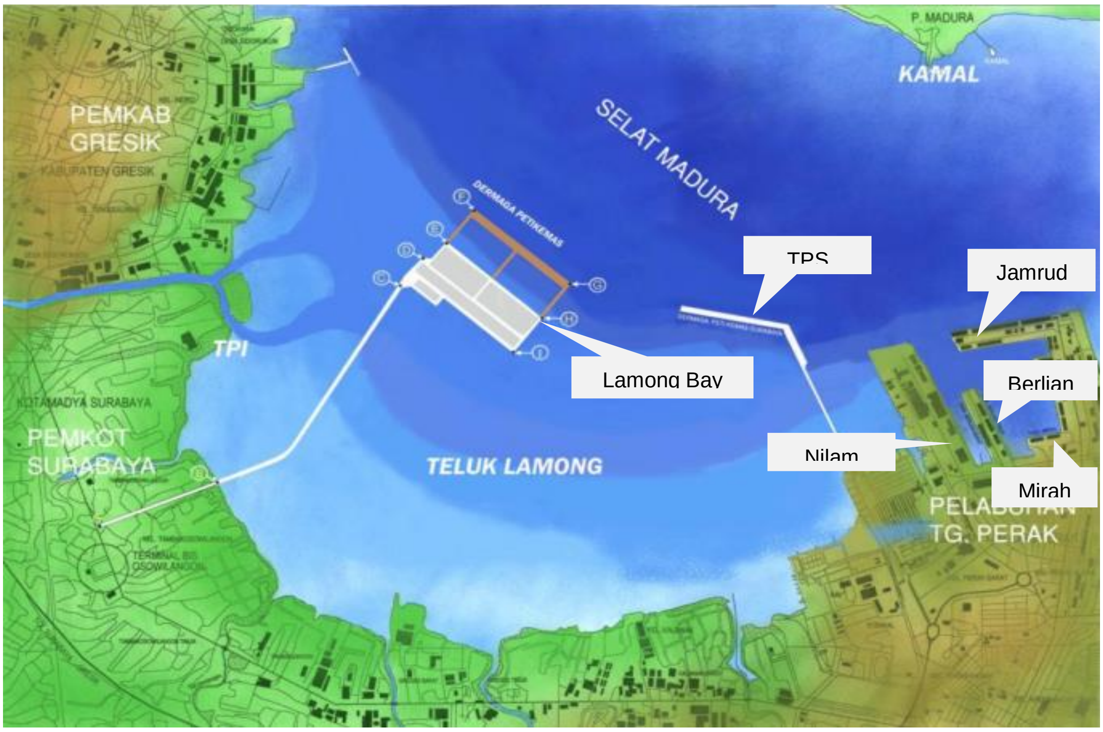


Figure 15. Lay out of Tanjung Perak port
Source: modified from Teluk Lamong Bay website, 2017

The following is the detailed information regarding each terminal in the port of Tanjung Perak:

1. Tanjung Perak branch

Tanjung Perak branch has three terminals: Jamrud Terminal, Mirah Terminal and Nilam Terminal. Referring to the circular letter number: SE.8/PJ.04/TPR-2013 about the arrangement of the terminal at the port of Tanjung Perak branch-Surabaya, the management of Pelindo III Corporation has specified each terminal as dedicated area for:

No	Name of Terminal	Kade Meter	Dedicated Area
1	Jamrud Terminal		
	a. North Jamrud	0 - 400 meter	Passanger and Cruise Terminal
		401 - 800 meter	International General Cargo
		801 - 1.200 meter	International Dry Bulk
	b. West Jamrud	0 - 210 meter	International Dry Bulk
	c. South Jamrud	0 - 210 meter	Domestic Dry Bulk
		211 - 800 meter	Domestic General Cargo
	d. Perak Kade	0 - 140 meter	RoRo Terminal
2	Mirah Terminal	0 - 324 meter	Domestic General Cargo
		550 - 650 meter	Off-shore and liquid bulk
		651 - 860 meter	RoRo Terminal
3	Nilam Terminal	60 - 330 meter	Multipurpose Terminal
		331 - 650 meter	Domestic Container Terminal
		650 - 930 meter	Liquid Bulk Terminal

Table 5. Dedicated terminal at the port of Tanjung Perak branch-Surabaya
Source: Pelindo III Corporation

The Tanjung Perak branch has adequate facilities to serve the loading and unloading of cargoes and containers. The summary of the Tanjung Perak branch facilities is presented in the following Table 6.

1	Length	320 meter	6	Container Crane	4 units
2	Width	15 meter	7	RTG	5 units
3	Depth	-8 m LWS	8	Reach Stacker	-
4	Container Yard	34,880 m2	9	Head Truck	12 units
5	Capacity	20,100 TEU	10	Chassis	12 units

Table 6. Facility of domestic container terminal at Tanjung Perak branch-Surabaya
Source: Pelindo III Corporation, 2017

2. Berlian Jasa Terminal Indonesia (BJTI Port)

The Berlian Jasa Terminal Indonesia is a subsidiary of the Pelindo III Corporation. The Berlian Terminal deals with domestic containers. The following Table is a summary of the facilities owned by the Berlian Terminal.

1	Length	1,620 meter	6	Harbour Mobile Crane	22 units
2	Width	15 meter	7	RTG	15 units
3	Depth	-9.5 m LWS	8	Reach Stacker	4 units
4	Container Yard	45,790 m2	9	Head Truck + Chassis	25 units
5	Capacity	26,300 TEU	10	Forklift	12 units

Table 7. Facility of Berlian terminal
Source: BJTI Port website, 2017

3. Terminal Petikemas Surabaya (TPS)

As well as the Berlian Jasa Terminal Indonesia, the Terminal Petikemas Surabaya is one of the subsidiaries of the Pelindo III Corporation, which is managed in cooperation with the DP World, the world-renowned terminal operator. The Terminal Petikemas Surabaya (TPS) handles the majority of international containers with the following facilities:

International Terminal			Equipment		
1	Length	1,000 meter	11	Container Crane	11 units
2	Width	50 meter	12	Head truck	80 units
3	Depth	-13 m LWS	13	Chassis	124 units
4	Container Yard	35 ha	14	RTG	28 units
5	Capacity	32,223 TEU	15	Reach Stacker	6 units
Domestic Terminal			16	Reefer Plug	909 units
6	Length	450 meter	17	Sky Stacker	3 units
7	Width	50 meter	18	Dolly System	58 units
8	Depth	-7.5 m LWS	19	Forklift Diesel	10 units
9	Container Yard	4.7 ha	20	Forklift Electric	8 units
10	Capacity	2,029 TEU	21	Trans lifter	7 units

Table 8. Facility of Terminal Petikemas Surabaya (TPS) Terminal
Source: Terminal Petikemas Surabaya website, 2017

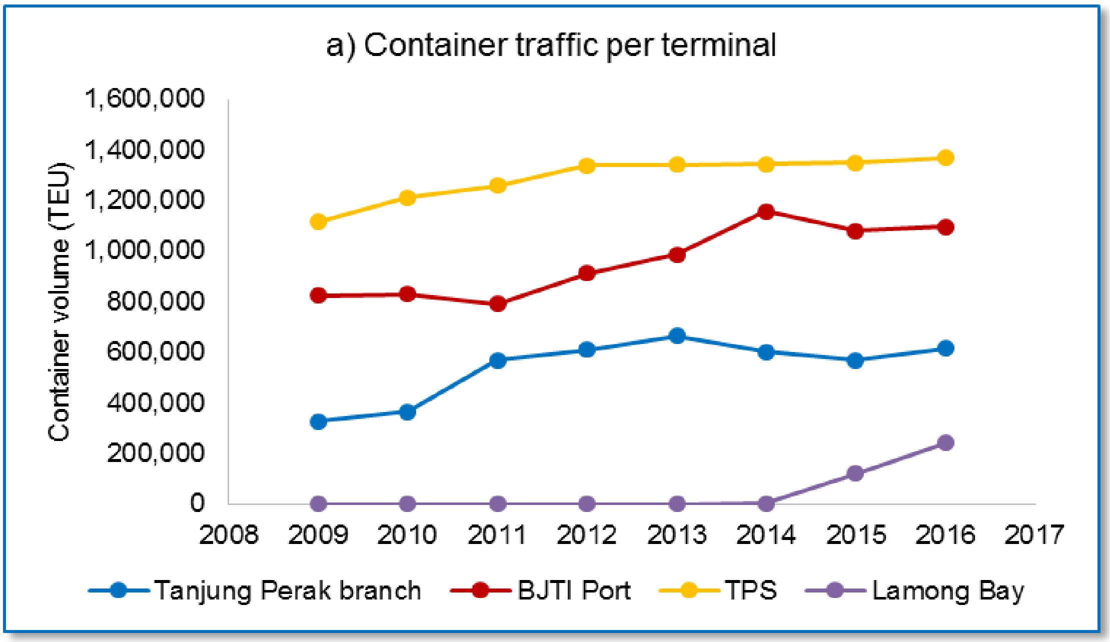
4. Terminal Lamong Bay

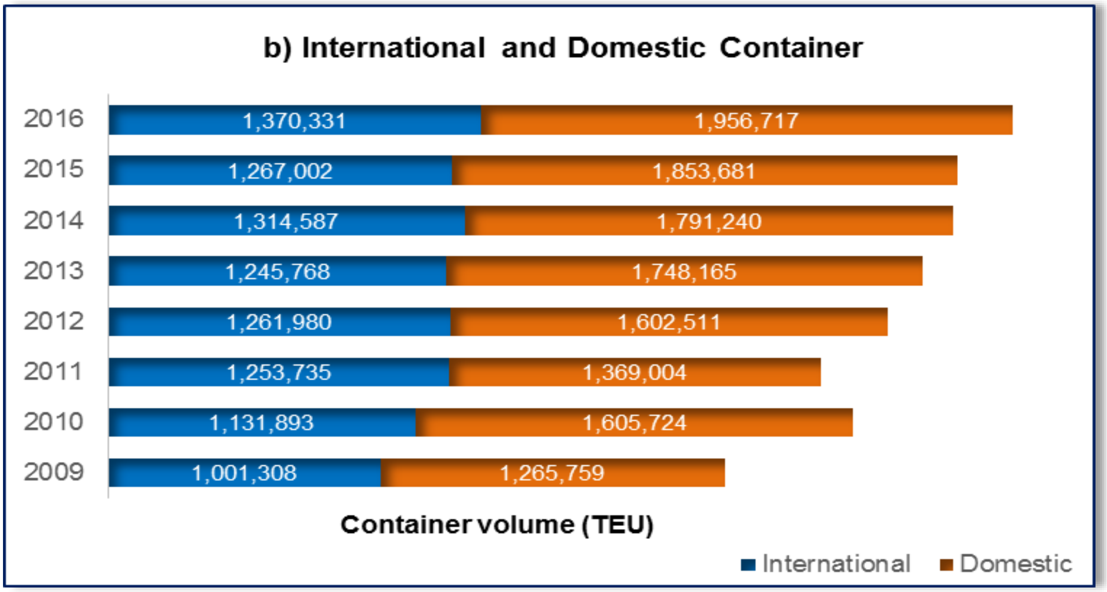
The Lamong Bay Terminal is the newest terminal that has just been built by the Terminal Teluk Lamong as a subsidiary of Pelindo III Corporation. The Lamong Bay Terminal started its operation in the beginning of 2015 and became the first green port in Indonesia (Lamong Bay Terminal, 2014). This Terminal is equipped with the modern equipment to support the increase in loading and unloading productivity as a solution to decrease the waiting time of the ships in the port of Tanjung Perak. Table 9 shows the complete range of facilities available in the terminal:

International Terminal			Equipment		
1	Length	500 meter	9	Straddle carrier	11 units
2	Width	50 meter	10	Automatic Stacking Crane	80 units
3	Depth	-14 m LWS	11	Ship to Shore	124 units
4	Capacity of CY	4,860 TEU	12	CTT	28 units
Domestic Terminal			13	Reach Stacker	6 units
5	Length	450 meter	14	Grab ship unloader	909 units
6	Width	30 meter			
7	Depth	-7.5 m LWS			
8	Capacity of CY	3,240 TEU			

Table 9. Facility of Lamong Bay Terminal
Source: Lamong Bay Terminal website, 2017

As the second busiest port in Indonesia, the port of Tanjung Perak has been able to handle the container flow over the last eight years. The detailed of its operation are specified in Figure 16 below:





Source: Annual report of Pelindo III Corporation, 2017
Figure 16. a) Container traffic per teminal b) International and Domestic container

4.4 Profile of Tenau Kupang Port

The port of Tenau Kupang is located in the East of Nusa Island. It is considered to be the main class port under the management of Pelindo III Corporation (Ministry of transportation Regulation, 2016). The Tenau Kupang port also manages three regional ports: Waingapu, Kalabahi and Ende/Ippi. Two of these ports, Waingapu and Kalabahi, are involved in the route of the Sea Toll Road Programme.

Figure 17. Layout of Tenau Kupang port
Source: Google earth, 2017

The Tenau Kupang port consists of four terminals: the Multiguna terminal, the Nusantara terminal, the Local terminal and the multipurpose terminal. In addition, the local port authority has just developed new berthing facility in the area of the port of Tenau Kupang with the length of 125 meter, and it is currently under approval from the Ministry of Transportation to be operated by Pelindo III Corporation. It means that the port of Tenau Kupang has an additional capacity to serve the loading and unloading activities. The Table 10 below depicts the facilities of the port of Tenau Kupang.

1	Length	237.45 meter	6	Container Crane	2 units
2	Width	45.75 meter	7	RTG	3 units
3	Depth	-12 m LWS	8	Reach Stacker	3 units
4	Container Yard	26,305 m2	9	Head Truck	8 units
5	Capacity	11,760 TEU	10	Chassis	8 units

Table 10. Facility of the port of Tenau Kupang
Source: Head Office of Pelindo III Corporation, 2017

The port of Tenau Kupang is the main port in the Eastern region of Indonesia as its container flows continues to grow over the past eight years:

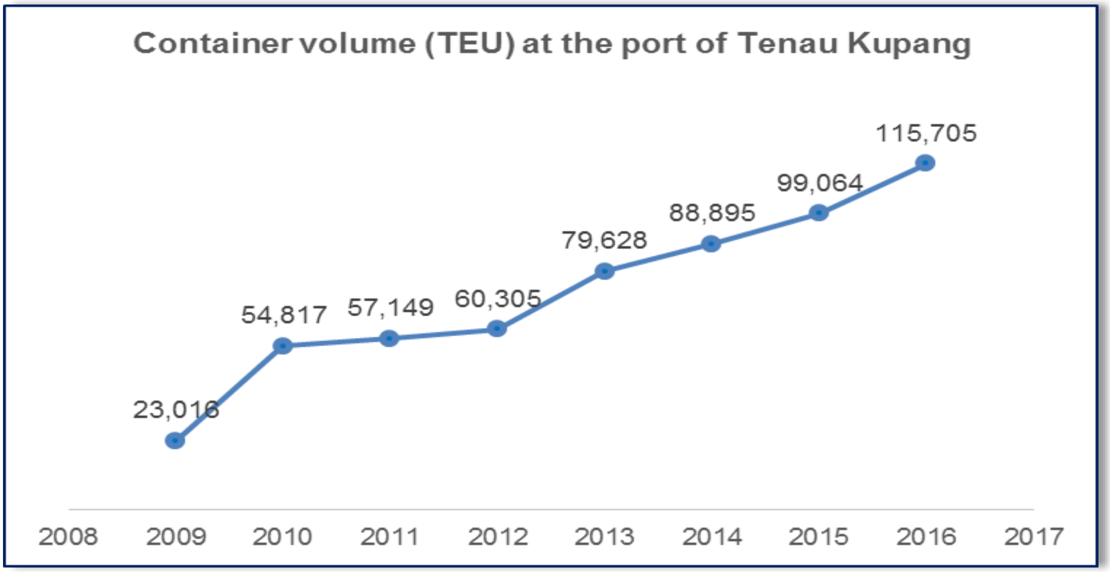


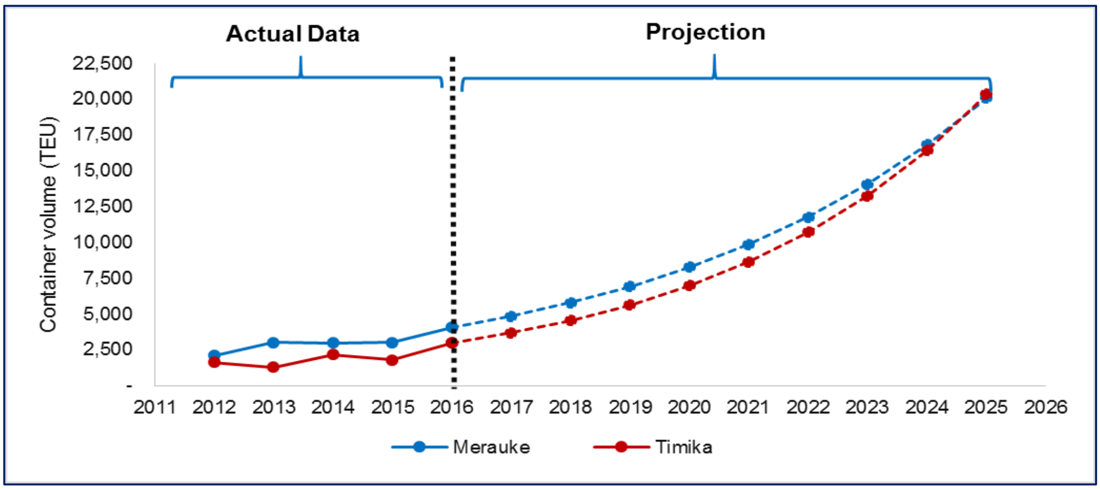
Figure 18. Container traffic at the port of Tenau Kupang
Source: Annual report of the port of Tenau Kupang, 2017

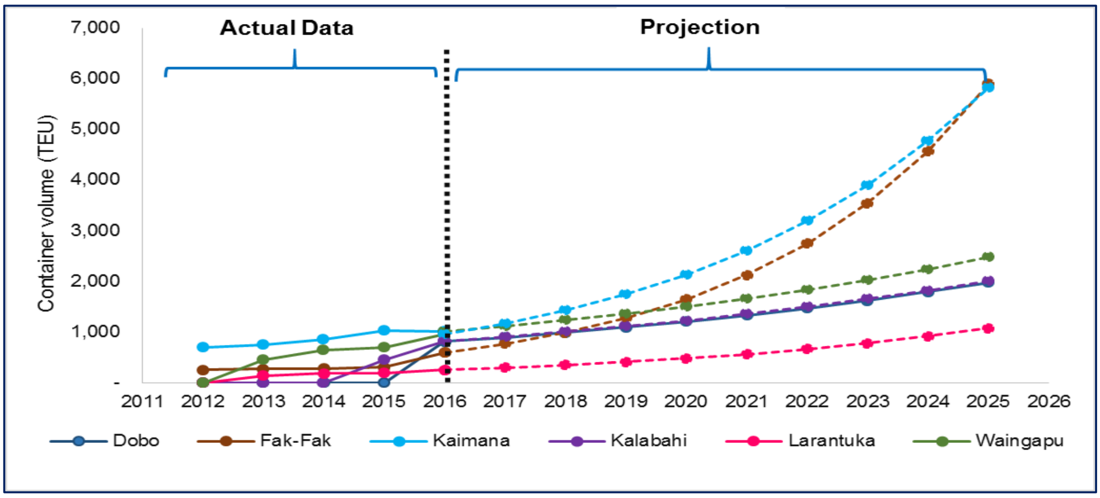
4.5 The Demand and Supply

Because the sea toll road programme master plan will be implemented until 2019, we projected the demand and supply of containers (containing staple goods) based on the historical data of container flows from the 2012 to 2016 period as can be seen in Appendix 1. However, we realize that this demand projection is a limitation since we project the result for 2019 by using the average growth per year over the last five years of the container flows containing staple goods and a historical trend is no guarantee for the future. Moreover, we also face some data constraints. The issues are the following:

1. The data are obtained from the Port of Tanjung Perak. We manually selected and analysed the database of origin and destination of the containers especially with regard to the ports involved in this programme.
2. The database for the domestic container flows at Tanjung Perak port does not provide cargo information regarding what is in each container. This information is necessary as we only take into account containers containing staple goods as stipulated by Government regulation 71/2015. To address the problem, we processed the data of non-containers in order to know the percentage of staple goods loaded and unloaded at the port of Tanjung Perak. We found that 29 percent of the cargo were classified as staple goods. We then used this finding to multiply it with the total container flows to or from the ports involved in this program.
3. Based on the data, some of the ports (such as Lewoleba, Namlea, Rote, Saumlaki, Sabu and Moa) have only recently provided the container loading and unloading activities for 2016. This was after implementing the sea toll road program 2016. Therefore, we could not calculate the average growth rates per year to conduct demand projections. Thus, we have assumed 10 percent of growth per year to these ports refers to the port of Kaimana which has the lowest of the demand growth per year.

The Figure 19 below illustrates the demand projection based on the data in 2012-2016. Due to a significant difference between the destination ports, we divide the result into three different graphs as follows:





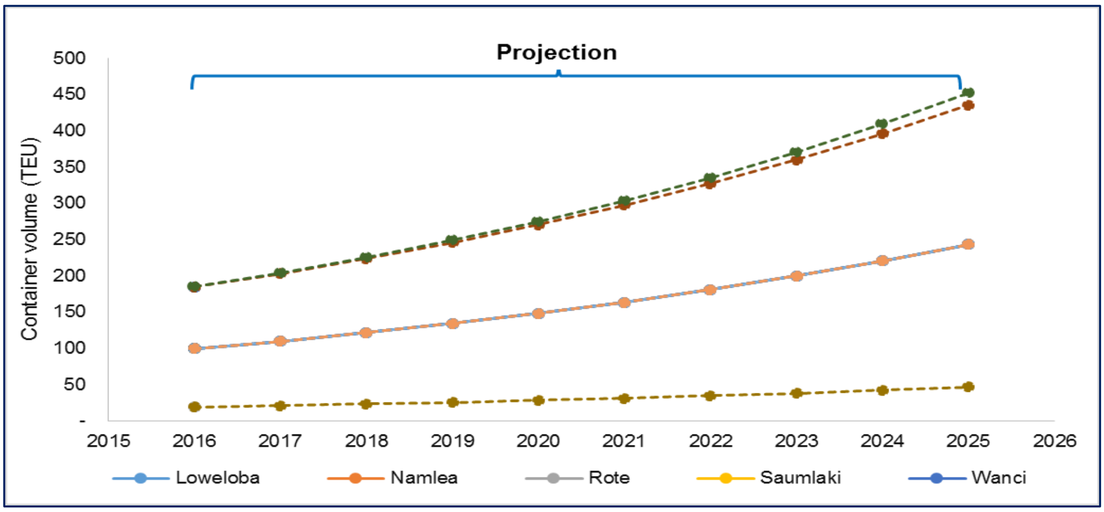


Figure 19. Projection of container flow by the port (TEU/year)
Source: Author

We assume that the number of containers loaded at the destination port represents the demand, while the containers unloaded reflects the supply. The result of this container flow projection in every selected port in this study will be applied on the model analysis in order to calculate the total shipping costs. In addition, the routes for the three scenarios have been stipulated. What we then do is to put the number of containers based on each route. In general, we consider the number of containers per month instead of per year which means we divide the annual number of containers (TEU per year) by 12 to get data at a monthly basis.

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Chapter 5 Data, Results and Analysis

In this Chapter, we present the results of our research and analyse them. First, we analyse the fixed (Λ_t^m) and variable costs (ϕ_t^m) per route in order to find out the total shipping costs based on the mathematical model mentioned in chapter 3. The fixed cost is associated with the type of ship used and the route, while the variable cost is related to the number of containers carried by the ship. We also calculate the number of sailing frequencies for a certain period by dividing the total number of containers demanded at the destination port and TEU capacity of the ship used on each route. Further, the total cost will be obtained by multiplying the number of sailing frequencies a year and the total costs (i.e. the sum of fixed and variable costs). We apply this basic calculation to three different scenarios. Scenario I and II are similar since these scenarios deploy multi-port-calling networks in which a ship sails from the hub port to the destination ports as per the sea toll road programmes of 2016 and 2017. Meanwhile, Scenario III uses a hub-and-spoke network where we propose the Port of Tenau Kupang as a transhipment port to be the linking pin between the hub port and the sub-feeder ports. After conducting the calculations, we evaluate the results per scenario in order to determine which route generates the minimum total shipping costs for Indonesia.

5.1 Total Shipping Cost Data

Total shipping costs are the sum of fixed (Λ_t^m) and variable costs (ϕ_t^m) multiplied by the number of sailing frequencies for a certain period. In this section, we will describe the data and assumptions used in the total shipping cost calculations, such as charter rates, fuel costs, port dues, distance and handling charges.

5.1.1 Distance

The distance between port of origin and destination port is one of the key inputs to determine total shipping costs. These data are provided by the Indonesian government as stated in the regulations concerning the implementation of the sea toll road program in 2016 and 2017. In addition, we also use an online distance calculator (http://www.searoutes.com and http://ports.com) to measure the distances between the Port of Tenau Kupang and its destination ports in nautical miles. We require the distance to find out the total sea time vessels travel by dividing the distance between the ports by the speed of the ship (both in nautical miles). Next, this output will determine the amount of the fuel cost and charter cost at the sea. The Table of the distance in the Appendix 4 presents the distance matrix amongst the ports that have been used in each of the scenarios.

5.1.2 Ship Specification

The container ship size is regulated by the Indonesian government to serve the container distribution on each route within the sea toll road program. We consider applying this type of ship in our calculation. Since we only take into account the routes starting from the Port of Tanjung Perak, we found that there are five routes involving 15 sub-feeder ports that can be evaluated in this study where one ship is employed on each route. Table 11 below shows the name and the characteristics of each vessel used in this programme.

Name of Vessel	DWT (Ton)	GT (Ton)	Capacity (20' Full) TEU	ME (HP)	AE (HP)	Vt (Knot)	Type of ship
MV Mentari Freedom	5,314	4,303	192	4,168	1,331	11	t1
MV Mentari Perdana	4,985	4,180	199	3,940	1,313	11	t2
MV Caraka Jaya N III-22	3,650	3,258	135	3,013	1,176	11	t3
MV Nusantara Pelangi	3,106	2,997	115	2,635	1,137	11	t4
MV Mentari Perkasa	6,207	4,258	200	4,788	1,324	11	t5

Table 11. The type of the ship used in the sea toll road programme
Source: Compiled by Author

Moreover, since in this study we propose a new route in Scenario III by involving the port of Tenau Kupang as a feeder port that serves as a transhipment hub connecting the main port (i.e. the port of Tanjung Perak) with the many sub-feeder ports, we need to determine the ship size used to carry the number of containers from Tanjung Perak port to the port of Tenau Kupang. To address with this problem, according to Maritime Technology course (Aalbers, 2016), we use a regression formula as can be seen in Appendix 5, where we can use the range of DWT to express the size of the ship including the gross tonnage (GT), TEU capacity, speed, engine power for Main Engine (ME) and Auxiliary Engine (AE) (. This calculation is based on the list of the ships and their specifications that already registered with the Indonesia Classification Bureau (BKI).

Type of Ship	Range of DWT			DWT (Ton)	Payload (TEUs)	GT (Ton)	ME (HP)	AE (HP)	Vt (knot)
ta		<	2,000	2,000	80	1,800	1,900	1,000	11
tb	2,000	-	3,000	3,000	160	2,700	2,600	1,100	11
tc	3,000	-	5,000	5,000	320	4,500	4,000	1,400	12
td	5,000	-	7,500	7,500	520	6,800	5,700	1,800	14
te	7,500	-	10,000	10,000	720	9,000	7,400	2,200	15
tf	10,001	-	12,500	12,500	920	11,300	9,200	2,500	15

Table 12. Ship specification by ship size
Source: Modified from Indonesia Classification Bureau (BKI)

We require the number of Gross Tonnage (GT) to calculate port dues including pilotage services, tugging services, anchoring fees and berth occupancy charges, while information on engine power is needed to figure out fuel consumption both at sea and in the port, allowing us to estimate fuel costs.

5.1.3 Ship Charter Rate

Basically, ship charter costs are used to replace operating costs, maintenance costs and capital costs. Ship charter rates obtained from Maersk Broker in 2015 provide the charter rates based on ship size. This charter rate covers capital, operating and periodic maintenance costs, excluding fuel costs, port dues and handling charges. Hence, in this study the total shipping costs are the sum of charter costs, fuel costs, port dues and container handling charges. The following Table 13 presents the time charter rate for a year based on the ship size from 200 until 5,199 TEU

Ship Size (TEU)	Charter Rate (USD/day)
200 - 399	1,900
400 - 649	4,969
650 - 899	5,594
900 - 1,299	7,800
1,300 - 1,999	9,609
2,000 - 2,999	9,834
3,000 - 3,949	11,608
3,950 - 5,199	14,364

Table 13. Time charter rate
Source: Maersk Broker, 2015

5.1.4 Fuel Cost

In our calculations, we divide the fuel consumption into two parts: fuel consumption at sea (Ft) which is influenced by the type of the ship used and the route, and fuel consumption at the port (Fit), which depends on the type of ship and the time at the port. Based on these results, we can calculate the fuel cost both at sea and at port by multiplying the amount of fuel consumed with the fuel price.

The type of ship used determines the type of main engine and auxiliary engine to calculate the amount of fuel consumption. We assume that using SFOC (Specific Fuel Oil Consumption) for a Main Engine (ME) is 0.22 Litter/HP.hour. For an Auxiliary Engine (AE) this is 0.293 Litter/HP.hour. Furthermore, we can calculate the amount of fuel consumed by multiplying the operating time (hours), the level of engine power (HP) and SPOC (Litter/HP. Hour).

Additionally, we assume that the ships use High Speed Diesel (HSD) as their specific fuel. According to the Shell Indonesia website, the price of HSD in July 2017 is IDR 9,300 per litter or equal to USD 0.70 per litter (1 USD equals IDR 13,255).

5.1.5 Port Dues

Basically, ports dues applied in Indonesia consist of pilotage, towage, anchoring fee and berth occupancy charges. Piloting and tugging services are offered, depending on whether the port is a mandatory pilotage zone or not. This provision is stipulated by the Indonesian government. Piloting services are paid based on movement and Gross Tonnage (GT) per ship as well as the operating time required to perform the service. Likewise, this provision applies to tugging services. The anchoring fee is a cost incurred due to the use of the anchoring pool. Meanwhile, berth occupancy charges are paid because of the use of berth capacity. This cost depends on Gross Tonnage (GT) per ship per day and berthing time. Berthing time is calculated by dividing the number of containers loaded or unloaded and crane productivity.

Table 14 below shows the anchoring fee, berthing occupancy charge, piloting and towage costs for each of the 17 ports in our study.

No	Name of Port	Port Class	Status	Mandato-ry Pilotage Zone	Anchoring fee (Per GT)	Berthing (Per GT/day)
1	Dobo	First Class	Non Commercial	No	0.007	0.006
2	Fak-Fak	Fisrt Class	Commercial	No	0.007	0.006
3	Kaimana	First Class	Non Commercial	No	0.007	0.006
4	Kalabahi	First Class	Commercial	No	0.006	0.004
5	Larantuka	First Class	Non Commercial	No	0.007	0.006
6	Lewoleba	Second Class	Non Commercial	No	0.006	0.005
7	Merauke	First Class	Commercial	Yes	0.007	0.007
8	Moa	Fisrt Class	Non Commercial	No	0.007	0.006
9	Namlea	First Class	Non Commercial	No	0.007	0.006
10	Rote	Third Class	Non Commercial	No	0.006	0.005
11	Sabu	Fisrt Class	Non Commercial	No	0.007	0.006
12	Saumlaki	First Class	Non Commercial	No	0.007	0.006
13	Tg Perak	Main Class	Commercial	Yes	0.100	0.131
14	Tenau Kupang	Main Class	Commercial	Yes	0.006	0.004
15	Timika	First Class	Non Commercial	No	0.007	0.006
16	Waingapu	Second Class	Commercial	No	0.006	0.004
17	Wanci	Second Class	Non Commercial	No	0.006	0.005

No	Name of Port	Mandatory Pilotage Zone	Pilot		Tug Boat	
			Fixed (per move)	Variable (per GT)	Fixed (per move)	Variable (per GT per hour)
1	Dobo	No	-	-	-	-
2	Fak-Fak	No	-	-	-	-
3	Kaimana	No	-	-	-	-
4	Kalabahi	No	-	-	-	-
5	Larantuka	No	-	-	-	-
6	Lewoleba	No	-	-	-	-
7	Merauke	Yes	4.936	0.003	24.142	0.000
8	Moa	No	-	-	-	-
9	Namlea	No	-	-	-	-
10	Rote	No	-	-	-	-
11	Sabu	No	-	-	-	-
12	Saumlaki	No	-	-	-	-
13	Tanjung Perak	Yes	45.000	0.030	30.000	0.005
14	Tenau Kupang	Yes	8.299	0.004	38.839	0.000
15	Timika	No	-	-	-	-
16	Waingapu	No	-	-	-	-
17	Wanci	No	-	-	-	-

Table 14. Port Dues
Source: Compiled by Author

5.1.6 Container Handling Charge

This sub chapter highlights the issue of container handling charges (CHC) of each port based on information obtained from the respective port's websites. In addition, we assume that handling fees for non-commercial ports is equal to handling fees for commercial ports, using shipping gear in the same region. Container handling charges are a combined package of stevedoring, lift on lift off (LOLO) and haulage. We also consider wharf charges for one unit (a container) in our calculations. Specifically, for handling large vessels in Scenario III, we also insert the loading and unloading equipment of container cranes into the equation and for both Tanjung Perak port and Tenau Kupang Port we take this into account.

No	Name of Port	Port Class	Status	Terminal Handling Charge	
				20' full	20' empty
1	Dobo	First Class	Non Commercial	41.70	24.19
2	Fak-Fak	Fisrt Class	Commercial	41.70	24.19
3	Kaimana	First Class	Non Commercial	41.70	24.19
4	Kalabahi	First Class	Commercial	27.46	7.32
5	Larantuka	First Class	Non Commercial	27.16	5.21
6	Lewoleba	Second Class	Non Commercial	27.16	5.21
7	Merauke	First Class	Commercial	41.70	24.19
8	Moa	Fisrt Class	Non Commercial	32.90	19.54
9	Namlea	First Class	Non Commercial	32.90	19.54
10	Rote	Third Class	Non Commercial	18.11	10.86
11	Sabu	Fisrt Class	Non Commercial	18.11	10.86
12	Saumlaki	First Class	Non Commercial	41.70	24.19
13	Tanjung Perak	Main Class	Commercial	15.84	8.24
14	Tenau Kupang	Main Class	Commercial	22.63	13.58
15	Timika	First Class	Non Commercial	41.70	24.19
16	Waingapu	Second Class	Commercial	27.91	3.77
17	Wanci	Second Class	Non Commercial	32.90	19.54

Table 15. Container Handling Charge
Source: Compiled by Author

5.1.7 Port operation

Port operation time can be described as the total time spent by the ship at port. Port operation times are the sum of berthing time and waiting time. To calculate berthing time, we require crane productivity, the number of cranes used and the number of containers loaded and unloaded at the port. While, waiting time is described as an idle time for a ship to reaching berth facilities. In general, the ship waits in an anchoring pool space provided by the port authority. The ship has to wait since the berthing facilities are, at that moment, being used by another ship or they have to wait for piloting or tugging service.

In addition, in Scenario I and II, we assume that the ships use the ship gear due to the size of the ship. While, in Scenario III, we use container cranes for loading or unloading activity. Moreover, we assume that the waiting time at the port of Tanjung Perak and the port of Tenau Kupang is four hours respectively, while other ports are assumed to have six hour waiting times, based on the port category.

Table 16 below informs us of the crane productivity (box per crane per hour) and idle time based on the port.

No	Name of Port	Port Class	B/C/H	Idle time (hour)
1	Dobo	First Class	5	6
2	Fak-Fak	Fisrt Class	12	6
3	Kaimana	First Class	5	6
4	Kalabahi	First Class	9	6
5	Larantuka	First Class	5	6
6	Lewoleba	Second Class	5	6
7	Merauke	First Class	12	6
8	Moa	Fisrt Class	5	6
9	Namlea	First Class	5	6
10	Rote	Third Class	5	6
11	Sabu	Fisrt Class	5	6
12	Saumlaki	First Class	5	6
13	Tanjung Perak	Main Class	15	4
14	Tenau Kupang	Main Class	14	4
15	Timika	First Class	5	6
16	Waingapu	Second Class	9	6
17	Wanci	Second Class	5	6

Table 16. Crane Productivity and Idle Time
Source: Compiled by Author

5.2 Results

This section describes the results of the model analysis used in this research paper. Calling to the previous explanation, we construct three scenarios where Scenario I and Scenario II use the multi-port-calling networks based on the implementation of the sea toll road program in 2016 and 2017, while Scenario III uses the hub-and-spoke network as described in the master plan of sea toll road program. The routes in Scenario I – sea toll road programme of 2016 and Scenario II – sea toll road programme of 2017 have been stipulated by the Indonesian government, so we follow these routes in order to calculate total shipping costs. Meanwhile, we build the routes in Scenario III by involving the port of Tenau Kupang as a transhipment port. As described before, the port of Tenau Kupang is set up as a feeder port and is connected with the main port (i.e. the Port of Tanjung Perak) according to the master plan of the sea toll road program (Ministry of development planning, 2015). Because the network in Indonesia recognises the main port, feeder ports and sub-feeder ports, Tenau Kupang port as a feeder port has the function of a transhipment port to connect the main port and the sub-feeder ports. We will compare the results of these three scenarios, and look at which one of the scenario generates the lowest total shipping costs.

In the implementation, all of the containers come from Tanjung Perak and will be distributed to the several destination ports involved on the routes in the different Scenarios. Likewise, containers from the destination ports will be carried back merely to the port of Tanjung Perak. This means that the vessel will visit all ports selected on the route. However, the container can merely be uploaded in the destination port.

Therefore, in order to simplify the calculation, we divide the costs into two different types of cost: fixed costs related to the type of ship used and the route, while variable costs related to the number of containers. The fixed costs cover all the ports visited by the ship (using connectivity between the ports), while the variable costs merely connect the port of Tanjung Perak and the destination port.

All scenarios constructed in this research paper use the same demand and supply data based on container flow projections in 2019. We divide the total demand and supply by 12 months as we would like to present the number of containers transported per voyage. If one ship is not allowed to carry all the containers demanded by the destination port on one route within a month due to constraints on the type of the ship used, we need more than one ship, whereby the total number of ships used should cover the total number of containers that needs to be transported. Next, we multiply the total number of ships used a month by 12 to find out the annual sailing frequencies.

A. Scenario I

We analyse three routes in the first scenario based on the implementation of the sea toll road programme 2016. In scenario I, we have three pendulum routes to be evaluated:

1. Tanjung Perak - Wanci - Namlea - Fak-Fak - Kaimana - Timika - Kaimana - Fak-Fak - Namlea - Wanci - Tanjung Perak
2. Tanjung Perak - Kalabahi - Moa - Saumlaki - Dobo - Merauke - Dobo - Saumlaki - Moa - Kalabahi - Tanjung Perak
3. Tanjung Perak - Larantuka - Loweloba - Rote - Sabu - Waingapu - Sabu - Rote - Lewoleba - Larantuka - Tanjung Perak

In order to get a more detailed explanation of our calculation, we will explain step by step by using network 1. These steps will also be applied on the other routes in this scenario as can be seen in Appendix 4. First, we have to capture the distance among the ports on this route as well as the type of the ship where we follow the Indonesian government. Network 1 is serviced by the type of ship with a capacity of 192 TEU. The distance travelled can be explained by the information presented in Table 17

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	700	990	1,316	1,498	1,713
WNC	700	-	290	616	798	1,013
NML	990	290	-	326	508	723
FAK	1,316	616	326	-	182	397
KMN	1,498	798	508	182	-	215
TMK	1,713	1,013	723	397	215	-

Table 17. Distance (in Nautical Mile)
Source: The decree of the General of Sea Transportation Number: Al.108/7/8/DJPL-2015

As explained before, we divided the cost into two different type of cost: fixed cost (USD) and unit cost (USD/TEU/Nmile) based on variable cost. Starting with the fixed cost, the following Table 18 presents the connectivity. First, we manually input 1 or 0 into the Table of connectivity (Xij). 1 (one) indicates that there is connectivity between a port and the next port. If there is no connectivity, we input 0. The connectivity is followed the routes as stipulated by the government of Indonesia.

O/D	TPK	WNC	NML	FAK	KMN	TMK	
TPK		1	0	0	0	0	1
WNC	1		1	0	0	0	2
NML	0	1		1	0	0	2
FAK	0	0	1		1	0	2
KMN	0	0	0	1		1	2
TMK	0	0	0	0	1		1
	1	2	2	2	2	1	

Table 18. Connectivity (Xij)
Source: Elaborated by Autor

The fixed costs (Λ_t^m) is based on the type of the ship used which is summarized in the following Table 19. We obtain this cost by applying the formula [2] in Chapter 3.

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	62,473.54	87,713.82	116,672.05	137,552.43	161,829.79
WNC	62,473.54	-	24,692.67	50,307.41	68,138.54	88,376.98
NML	87,713.82	24,692.67	-	27,370.18	43,355.71	63,085.94
FAK	116,672.05	50,307.41	27,370.18	-	18,680.47	36,404.60
KMN	137,552.43	68,138.54	43,355.71	18,680.47	-	20,683.22
TMK	161,829.79	88,376.98	63,085.94	36,404.60	20,683.22	-

Table 19. Fixed cost (USD)
Source: Author

Afterward, we multiply the Table of connectivity (Xij) and the Table of fixed cost (Λ_t^m). Furthermore, we will add this output with the variable cost. We obtain this cost by determining the number of container that will be loaded and unloaded at the ports involved on this route (∑Pij) and multiplying the number of containers with the unit cost (Cij) as described in Chapter 3 mainly in equation [5].

O/D	TPK	WNC	NML	FAK	KMN	TMK	
TPK	-	6	3	27	29	118	183
WNC	2	-	-	-	-	-	2
NML	1	-	-	-	-	-	1
FAK	3	-	-	-	-	-	3
KMN	2	-	-	-	-	-	2
TMK	6	-	-	-	-	-	6
	14	6	3	27	29	118	

Table 20. The number of container loaded and unloaded per voyage (Pij)
Source: Author

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	101.15	101.15	92.12	111.83	111.83
WNC	101.15	-	78.62	89.30	89.30	89.30
NML	101.15	78.62	-	89.30	89.30	89.30
FAK	92.12	89.30	89.30	-	89.30	89.30
KMN	111.83	89.30	89.30	89.30	-	89.30
TMK	111.83	89.30	89.30	89.30	89.30	-

Table 21. The Unit Cost (USD/TEU)
Source: Author

Further, total shipping cost derived by adding the fixed cost and variable cost. Moreover, we also calculate the time travel required for a ship to sail from the port of Tanjung Perak to the ports of destination and returns to the origin port. The total travel time is sum of the time at the sea (days) and the port that have been explained in the previous section. The result will be gained by multiply the following Table 22 and the Table of connectivity as can be seen in Table 23.

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	4	5	6	7	8
WNC	4	-	2	4	4	5
NML	5	2	-	3	3	4
FAK	6	4	3	-	2	3
KMN	7	4	3	2	-	2
TMK	8	5	4	3	2	-

Table 22. Time travel (days)
Source: Author

Moreover, we also determine the number of vessels are needed per month in order to generate the number of sailing frequencies per year. The result is one of the factors in determining the total shipping cost per route. As explained before, we divide the total demand and supply by 12 months as we would like to present the number of containers transported per voyage. If one ship is not allowed to carry all the containers demanded by the destination port on one route within a month due to constraints on the type of the ship used, we need more than one ship, whereby the total number of ships used should cover the total number of containers that needs to be transported. For example, the total containers demanded on the route N-1 is 722 TEU per month, where the total capacity of a ship used on this route is 192 TEU. Further, we divide the total containers demanded on one route by the total capacity of a ship used. We obtain that this route requires four ships. Moreover, we also consider the total travel time of one ship sailing from the origin port to the destination ports and back. As long as the total travel time less than one month, means that this route does not need additional vessel. The number of ships needed on one route per month can be explained by the information presented in Table 23.

In addition, we also calculate the utilization of vessel as one of the key factor in determining the effectiveness and efficiency of a vessel use. We calculate the utilization rate by dividing the total containers carried per voyage and the total capacity of a ship used. Table 23 informs us the utilization of vessel used to transport the container per route.

After calculating all of these networks in scenario I by applying those steps above, we generate the result as follows

The Route	Ship's Capacity (Teu)	Number of ships needed per month	Number of Sailing Frequency per year	Traveling time (days)	Utilizati-on of vessel	Total Shipping Cost per route
N-1	192	4	48	26	95%	$ 15,797,353
N-2	199	4	48	26	98%	$ 16,995,622
N-3	135	2	24	14	79%	$ 2,167,448
Total Shipping Cost						**$ 34,960,423**

Table 23. The result of Scenario I
Source: Author

B. Scenario II

Scenario II is constructed, based on the implementation of the sea toll road program 2017. The number of ports involved in this scenario is the same compared to Scenario I. However, the total networks in this scenario increases to five networks as Networks 1 and 2, that were used in Scenario I, are divided into two different networks, while the Network 3 remains the same as it was in Scenario I. The Indonesian government decided to change the routes since Networks 1 and 2 involved to many ports in one network. Scenario II therefore consists of the following five networks:

1. Tanjung Perak - Wanci - Namlea - Wanci - Tanjung Perak
2. Tanjung Perak - Fak-Fak - Kaimana - Timika - Kaimana - Fak-Fak - Tanjung Perak
3. Tanjung Perak - Kalabahi - Moa - Saumlaki - Moa - Kalabahi - Tanjung Perak
4. Tanjung Perak - Dobo - Merauke - Dobo -Tanjung Perak
5. Tanjung Perak - Larantuka - Loweloba - Rote - Sabu - Waingapu - Sabu - Rote - Lewoleba - Larantuka - Tanjung Perak

Our calculations follow the same methodological steps as under Scenario I. Table 24 shows the results of the total shipping cost in each network in Scenario II

The Route	Ship's Capacity (Teu)	Number of ships needed per month	Number of Sailing Frequency per year	Traveling time (days)	Utilizati-on of vessel	Total Shipping Cost per route
N-1	115	1	12	12	28%	$ 1,347,655
N-13	192	4	48	20	91%	$ 15,112,078
N-2	200	1	12	16	57%	$ 2,963,685
N-11	199	4	48	20	84%	$ 16,486,649
N-3	135	2	24	14	79%	$ 2,167,448
Total Shipping cost						**$ 38,077,514**

Table 24. The result of Scenario II
Source: Author

According to the result above, the level of vessel utilization on the route N-1 and N-2 are very low. Moreover, this ineffectiveness potentially leads to an increase in total shipping costs as we found that the total shipping cost in scenario II which reflects to the implementation of the sea toll road programme of 2017 has increased compared to the implementation in 2016. As mentioned before, the implementation of sea toll road programme in 2017 is a remedial step executed by the Indonesian government in improving the implementation of the previous programme.

C. Scenario III

We develop Scenario III on the basis of a hub-and-spoke network. As explained before, the Port of Tenau Kupang is part of this scenario. Since this port, as a feeder port to connect the port of Tanjung Perak to sub-feeder ports, it has a main function as a transhipment port. The calculations made are slightly different from those in Scenarios I and II, because in this Scenario we have to determine the type of ships used to carry containers from the port of Tanjung Perak to Tenau Kupang Port. Referring to Table 12, we select a ship with a capacity of 920 TEU. The main reason behind this selection is that this type of vessel is able to carry the number of containers demanded by the sub-feeder ports each month. We assume that this type of vessel is available.

Moreover, we have to multiply the container handling charges of loading and unloading at the port of Tenau Kupang by two. We assume that the stacking time for the container to be loaded and unloaded at the port of Tenau Kupang is five days. This means that there will be an additional ten days on a round time.

We construct 15 networks in this Scenario based on the number of sub-feeder ports selected in this study. The container will be carried from the port of Tanjung Perak and transhipped via the port of Tenau Kupang before being delivered to the sub-feeder ports. The use of a bigger vessel to transport the number of containers from Tanjung Perak to Tenau Kupang leads to the achievement of economies of scale. Our calculations show that the fixed costs and variable costs incurred on the route from Tanjung Perak to Tenau Kupang are $ 122,012.41 per voyage and $ 81.525 per TEU, respectively. These costs include the double container handling charge, stacking cost, double port dues and also the fuel cost. The calculation can be explained by the information presented in Appendix 3. These results will serve as inputs into the network calculations for this Scenario in a similar was we did in Scenarios I and II.

The Table 25 below depicts the result of the total shipping cost per network in scenario III

The Route	Name of the Port	Ship's Capacity (Teu)	Number of ships needed per month	Number of Sailing Frequency per year	Traveling time (days)	Utilizati-on of vessel	Total Shipping Cost per route
H&S 1	**Wanci**	**115**	**1**	**12**	**16**	**18%**	**$ 1,052,916**
H&S 2	Namlea	115	1	12	16	10%	$ 1,068,166
H&S 3	Fak-Fak	115	1	12	18	92%	$ 1,709,060
H&S 4	Kaimana	135	1	12	18	84%	$ 1,705,864
H&S 5	Timika	200	3	36	20	79%	$ 8,475,156
H&S 6	Saumlaki	115	1	12	16	10%	$ 1,075,838
H&S 7	Kalabahi	135	1	12	14	68%	$ 856,503
H&S 8	Moa	115	1	12	16	10%	$ 1,074,570
H&S 9	Dobo	115	1	12	16	88%	$ 1,306,072
H&S 10	Merauke	200	3	36	20	96%	$ 9,878,574
H&S 11	Larantuka	115	1	12	12	30%	$ 615,557
H&S 12	Lewoleba	115	1	12	12	17%	$ 558,138
H&S 13	Rote	115	1	12	12	2%	$ 511,451
H&S 14	Sabu	115	1	12	12	10%	$ 538,235
H&S 15	Waingapu	192	1	12	16	76%	$ 1,144,394
Total Shipping cost							**$ 31,570,494**

Table 25. The result of Scenario III
Source: Author

Based on the Table above, the calculation of Scenario III generates the lowest total shipping cost. However, since there are some ports with a low number of containers, we consider to create a hub-and-spoke network with indirect shipments. The main thinking behind this consideration is that we have to optimise the use of the vessel. We combine these ports in one route while the other ports which have enough demand remains the same using the direct hub-and-spoke, as follows:

1. Tanjung Perak – Tenau Kupang – Larantuka – Lewoleba – Wanci – Namlea – Wanci – Lewoleba – Larantuka – Tenau Kupang – Tanjung Perak (defined as H&S indirect 1)

2. Tanjung Perak – Tenau Kupang – Kalabahi – Moa – Saumlaki – Moa – Kalabahi – Tenau Kupang – Tanjung Perak (defined as H&S indirect 2)
3. Tanjung Perak – Tenau Kupang – Rote – Sabu – Waingapu – Sabu – Rote – Tenau Kupang – Tanjung Perak (defined as H&S indirect)

After changing the network by combining these ports that have low levels of container demand and that are close to each other, we generate the results presented in Table 26.

The Route	Name of the Port	Ship's Capacity (Teu)	Number of ships needed per month	Number of Sailing Frequency per year	Traveling time (days)	Utilizati-on of vessel	Total Shipping Cost per route
H&S Indirect 1		115	1	12	22	85%	$ 1,606,853
H&S Indirect 2		192	1	12	26	73%	$ 1,941,555
H&S Indirect 3		192	1	12	18	84%	$ 1,174,409
H&S 3	Fak-Fak	115	1	12	18	92%	$ 1,709,060
H&S 4	Kaimana	135	1	12	18	84%	$ 1,705,864
H&S 5	Timika	200	3	36	20	79%	$ 8,475,156
H&S 9	Dobo	115	1	12	16	88%	$ 1,306,072
H&S 10	Merauke	200	3	36	20	96%	$ 9,878,574
Total Shipping cost							**$ 27,797,543**

Table 26. The result of combining direct and indirect H&S network in Scenario III
Source: Author

We obtain that combining direct and direct hub-and-spoke network is more efficient to be applied in Scenario III.

5.3 Cost Comparison Analysis

After conducting an analysis based on three scenarios as described in the previous sections, this section turns to the results are comparing them with each other. In order to provide a good explanation and comparison between each scenario, all of the results are summarised in Table 27 and can be seen in Appendix 6.

No	Scenario	Average of Total Travel Time (days)	Average of the vessel utilization	Total Shipping cost
1	Scenario I	22	91%	$ 34,960,423
2	Scenario II	16	68%	$ 38,077,514
3	Scenario III			
	a) Direct	16	46%	$ 31,570,494
	b) Combining direct and indirect	20	85%	$ 27,797,543

Table 27. The comparison of each scenario
Source: Author

According to the Table 27 above, scenario II leads to the highest total shipping cost compared to scenario I and III. It is caused by the low vessel utilization. The ships have to sail per month and carry a low number of the containers. However, the number of sailing frequency in scenario II is less than scenario I, it makes sense since the number of the ports that should be visited by a ship on one route is less than scenario I.

Furthermore, Table 27 also indicates that applying hub-and-spoke network on delivering the container from the port of Tanjung Perak to the South-East of Indonesia can reduce the total shipping cost. We also combine the direct and indirect shipment on the basis hub-and-spoke network and the result is more efficient compared to the other results. Even though, the total round time increases compared to the direct hub-and-spoke network, results show that roundtrip travel time is shorter than scenario I.

This result therefore answers the main question of this study: the proposed network in which we involve the port of Tenau Kupang clearly contributes to reducing the total shipping costs of distributing a container from the western region of Indonesia (represented by the Port of Tanjung Perak) to the South-Eastern region of Indonesia.

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Chapter 6 Conclusion and Recommendation

6.1 Conclusion

Nowadays, the government of Indonesia is attempting to implement the design of a sea toll road program as an integrated system that uses the hub-and-feeder concept to reduce logistics costs and to lower the price disparity between the western and eastern regions of Indonesia. During 2015-2019, the Indonesian government focuses on developing 24 strategic ports involved in this program. However, several issues especially with regard to the higher logistic cost and price disparity need to be solved as soon as possible. Therefore, in 2016, the Indonesian government stipulated the six routes under the sea toll road program for 2016. These routes applied multi-port-calling networks, where a ship takes one month to sail from the port of Tanjung Perak to the port of selected in this programme.

In 2017, the Indonesian government changed the routes after evaluating the implementation of the sea toll road program in 2016. The number of the routes was increased to 13, where four of these routes resulted from a split-up of previous routes. As in 2016, the implementation of the sea toll road program in 2017 used a multi-port-calling network. Referring to the design of the sea toll road program that will be implemented by 2019, the network to be used in these programs is the hub-and-spoke network. A container will be transported from the main port to the feeder port before being further distributed to the sub-feeder ports. However, in the implementation of the sea toll road program in 2016 and 2017, the function of the feeder ports has been ignored since the container was directly distributed from the main port to the sub-feeder ports.

As explained above, we conduct this study in order to obtain an in- depth analysis of how and what best networks can be applied by the Indonesian government to distribute a container from the western regions to the South-Eastern parts of Indonesia. We take into account the routes starting from the port of Tanjung Perak (as the gateway and distribution centre) from the west to the east of Indonesia. We construct three scenarios. Scenario I consist of three networks based on the implementation of the sea toll road program in 2016. Scenario II consists of five networks based on the routes stipulated by the sea toll road program 2017. Finally, Scenario III also involves the Port of Tenau Kupang as a transhipment port. The main consideration behind this final Scenario is that the Port of Tenau Kupang is set up as a feeder port and is connected to the port of Tanjung Perak according to the master plan of the sea toll road program (BAPPENAS, 2015). Because the network in Indonesia recognizes the different nodes: main port, feeder port and sub-feeder port, Tenau Kupang port as a feeder port has a transhipment function to connect the main port and the sub-feeder ports.

After conducting the analysis, we obtain four results based on three scenarios where two of these results are generated by Scenario III. We construct 15 networks in Scenario III based on the number of the ports selected in this study. Since the network used in Scenario III is hub-and-spoke, there are some ports that face low demand and generate low ship utilization rates. Hence, we consider to combine these ports with the low demand in order to optimize the use of the ship.

Overall, scenario II generates the highest total shipping cost compared to scenarios I and III. The Indonesian government has already changed the routes and made the network operate over shorter distances. However, the low vessel utilization leads to higher costs for container distribution in Scenario II. In contrast, scenario I produces a high level of sailing frequencies compared to other scenarios. The reason for this is that the ship has a maximum capacity and should carry the container to several ports. While, combining direct and indirect hub-and-spoke network in Scenario III shows the best result of this study. The hub-and-spoke model allows the use of the bigger sized vessels for container demand from the port of Tanjung Perak to the port of Tenau Kupang to achieve economies of scale. So, the proposed model by involving the port of Tenau Kupang, contributes to reduce total shipping costs of container distribution from the western regions of Indonesia that are represented by the port of Tanjung Perak to South-Eastern part of Indonesia.

6.2 Recommendation

The result of this research can assist the Indonesian government in order to create an effective and efficient route in terms of distributing container from the West to East of Indonesia under the sea toll road programme.

Due to the limitation of this research, we suggest for the further research to consider other the main ports are located in Western regions of Indonesia as the port of origin, such as: the port of Belawan and Tanjung Priok. Moreover, other feeder ports as defined in the master plan of the sea toll road programme also can be taken into account.

Furthermore, we merely focus on the total shipping cost incurred for distributing containers from the port of origin to the destination port without considering the total logistics costs from the shipper to the buyer. As a suggestion, it will be better, if the future research also calculate receiving and delivery cost. It can provide more depth analysis and close to the real condition.

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Appendices

Appendix 1. The demand and Supply

This table merely presents the number of containers loaded and unloaded at the Port of Tanjung Perak especially with regard to the ports involved in this programme.

Name of the port	2012		2013		2014		2015		2016	
	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand
DOBO	-	-	-	-	-	-	-	-	756	2,788
FAK-FAK	203	869	224	908	220	951	120	1,029	254	2,046
KAIMANA	60	2,370	106	2,541	157	2,942	214	3,506	134	3,492
KALABAHI	-	-	-	-	-	-	-	1,520	326	2,835
LARANTUKA	-	-	194	465	145	627	140	638	207	856
LEWOLEBA	-	-	-	-	-	-	-	-	207	638
MERAUKE	1,236	7,284	1,358	10,442	1,622	10,351	2,055	10,414	2,770	14,022
NAMLEA	-	-	-	-	-	-	-	-	102	344
ROTE	-	-	-	-	-	-	-	-	12	66
SAUMLAKI	-	-	-	-	-	-	-	-	44	344
TIMIKA	824	5,645	694	4,451	1,054	7,481	1,022	6,210	865	10,268
WAINGAPU	-	-	302	1,546	270	2,184	508	2,378	544	3,300
WANCI	-	-	-	-	-	-	-	-	207	638
SABU	-	-	-	-	-	-	-	-	44	344
MOA	-	-	-	-	-	-	-	-	44	344

Table 28. Total number of containers in TEU (Full)

Name of the port	2012		2013		2014		2015		2016	
	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand	Supply	Demand
DOBO	-	-	-	-	-	-	-	-	219	807
FAK-FAK	59	252	65	263	64	275	35	298	74	592
KAIMANA	17	686	31	736	45	852	62	1,015	39	1,011
KALABAHI	-	-	-	-	-	-	-	440	94	821
LARANTUKA	-	-	56	135	42	182	41	185	60	248
LEWOLEBA	-	-	-	-	-	-	-	-	60	185
MERAUKE	358	2,109	393	3,024	470	2,997	595	3,015	802	4,060
NAMLEA	-	-	-	-	-	-	-	-	30	100
ROTE	-	-	-	-	-	-	-	-	3	19
SAUMLAKI	-	-	-	-	-	-	-	-	13	100
TIMIKA	239	1,635	201	1,289	305	2,166	296	1,798	250	2,973
WAINGAPU	-	-	87	448	78	632	147	689	158	956
WANCI	-	-	-	-	-	-	-	-	60	185
SABU	-	-	-	-	-	-	-	-	13	100
MOA	-	-	-	-	-	-	-	-	13	100

Table 29. Total number of containers contain of staple goods in TEU (Full)

Appendix 2. The Ships used

1. MV Freedom

No	Remark	Information	No	Remark	Information
1	Name of vessel	MV Freedom	7	TEU Capacity	192 20' full
2	Name of Operator	PELNI	8	GT	4,303
3	Name of the Owner	Mentari Sejati Perkasa	9	LOA	108
4	Type	Container vessel	10	DWT	5,314
5	Year of Built	1993	11	Number of Ship Gear	2
6	Speed	11	12	Owned or Charter	Charter

Source: Mentari Line website, 2017

2. MV Mentari Perdana

No	Remark	Information	No	Remark	Information
1	Name of vessel	MV Mentari Perdana	7	TEU Capacity	199 20' full
2	Name of Operator	PELNI	8	GT	4,180
3	Name of the Owner	Mentari Sejati Perkasa	9	LOA	115
4	Type	Container Vessel	10	DWT	4,985
5	Year of Built	1997	11	Number of Ship Gear	2
6	Speed	11	12	Owned or Charter	Charter

Source: Modified from Mentariline

Source: Mentari Line website, 2017

3. MV Caraka Jaya Niaga III-22

No	Remark	Information	No	Remark	Information
1	Name of vessel	MV Caraka Jaya Niaga III-22	7	TEU Capacity	115 20' full
2	Name of Operator	PELNI	8	GT	3,258
3	Name of the Owner	Mentari Sejati Perkasa	9	LOA	98
4	Type	Semi-Container Vessel	10	DWT	3,650
5	Year of Built	1993	11	Number of Ship Gear	2
6	Speed	11	12	Owned or Charter	Charter

Source: www.marinetraffic.com

Source: Maritime observer website, 2017

4. MV Nusantara Pelangi

No	Remark	Information	No	Remark	Information
1	Name of vessel	MV Nusantara Pelangi	7	TEU Capacity	115 20' full
2	Name of Operator	Mentari Sejati Perkasa	8	GT	2,997
3	Name of the Owner	-	9	LOA	97
4	Type	Container Vessel	10	DWT	3,106
5	Year of Built	2008	11	Number of Ship Gear	2
6	Speed	11	12	Owned or Charter	Charter

Source: Maritime Traffic website, 2017

Source: Tirto website, 2017

5. MV Mentari Perkasa

No	Remark	Information	No	Remark	Information
1	Name of vessel	MV Mentari Prakarsa	7	TEU Capacity	115 20' full
2	Name of Operator	Mentari Sejati Perkasa	8	GT	4,258
3	Name of the Owner	-	9	LOA	112
4	Type	Container Vessel	10	DWT	6,207
5	Year of Built	2008	11	Number of Ship Gear	2
6	Speed	11.8	12	Owned or Charter	Charter

Source: Modified from Mentariline

Source: Maritime Traffic website, 2017

Appendix 3. Fixed Cost and Unit Cost per each route

ROUTE	No of Teu	Capacity	Distance (Di) nm	Speed v	Sea Time (days)	Port time days	Fixed portion (αit)	Daily charter at port i (OtWi)	Ft USD	$D_i^m\left(\frac{O_t}{V_t}+\frac{F_t}{V_t}\right)$	$\sum_i\sum_j\left[\left(\beta_i+\frac{O_t}{R_i}\right)P_{ij}\right]$	Fixed Cost US$	Unit cost US$/Teu
TPK-WNC	100	192	700	11	3	0.71	1,212	2,873	41,085	17,304	10,115.36	62,473.54	101.15
TPK-NML	100	192	990	11	4	0.71	1,212	2,873	57,775	25,853	10,115.36	87,713.82	101.15
TPK-FAK	100	192	1,307	11	5	0.71	1,212	2,873	76,392	36,195	9,211.59	116,672.05	92.12
TPK-KMN	100	192	1,498	11	6	0.71	1,212	2,873	87,305	46,162	11,183.25	137,552.43	111.83
TPK-TMK	100	192	1,713	11	7	0.71	1,212	2,873	100,144	57,601	11,183.25	161,829.79	111.83
WNC-TPK	100	192	700	11	3	1.83	63	7,436	41,085	17,304	8,516.04	65,887.49	85.16
WNC-NML	100	192	290	11	1	0.79	40	3,211	16,691	4,751	7,862.03	24,692.67	78.62
WNC-FAK	100	192	616	11	2	0.79	40	3,211	35,949	11,108	8,929.92	50,307.41	89.30
WNC-KMN	100	192	798	11	3	0.79	40	3,211	46,862	18,026	8,929.92	68,138.54	89.30
WNC-TMK	100	192	1,013	11	4	0.79	40	3,211	59,059	26,067	8,929.92	88,376.98	89.30
NML-TPK	100	192	990	11	4	1.83	69	7,436	57,775	25,853	8,516.04	91,133.89	85.16
NML-WNC	100	192	290	11	1	0.79	42	3,211	16,691	4,751	7,862.03	24,695.40	78.62
NML-FAK	100	192	326	11	1	0.79	42	3,211	19,258	4,858	8,929.92	27,370.18	89.30
NML-KMN	100	192	508	11	2	0.79	42	3,211	29,530	10,573	8,929.92	43,355.71	89.30
NML-TMK	100	192	723	11	3	0.79	42	3,211	42,369	17,464	8,929.92	63,085.94	89.30
FAK-TPK	100	192	1,316	11	5	0.92	49	3,718	77,034	36,329	6,544.37	117,129.56	65.44
FAK-WNC	100	192	616	11	2	0.79	46	3,211	35,949	11,108	7,862.03	50,313.47	78.62
FAK-NML	100	192	326	11	1	0.79	46	3,211	19,258	4,858	7,862.03	27,373.51	78.62
FAK-KMN	100	192	182	11	1	0.79	46	3,211	10,913	4,511	8,929.92	18,680.47	89.30
FAK-TMK	100	192	397	11	2	0.79	46	3,211	23,110	10,038	8,929.92	36,404.60	89.30
KMN-TPK	100	192	1,498	11	6	1.83	69	7,436	87,305	46,162	8,516.04	140,972.50	85.16
KMN-WNC	100	192	798	11	3	0.79	42	3,211	46,862	18,026	7,862.03	68,141.28	78.62
KMN-NML	100	192	508	11	2	0.79	42	3,211	29,530	10,573	7,862.03	43,355.71	78.62
KMN-FAK	100	192	182	11	1	0.79	42	3,211	10,913	4,511	8,929.92	18,677.14	89.30
KMN-TMK	100	192	215	11	1	0.79	42	3,211	12,839	4,591	8,929.92	20,683.22	89.30
TMK-TPK	100	192	1,713	11	7	1.83	69	7,436	100,144	57,601	8,516.04	165,249.85	85.16
TMK-WNC	100	192	1,013	11	4	0.79	42	3,211	59,059	26,067	7,862.03	88,379.71	78.62
TMK-NML	100	192	723	11	3	0.79	42	3,211	42,369	17,464	7,862.03	63,085.94	78.62
TMK-FAK	100	192	397	11	2	0.79	42	3,211	23,110	10,038	8,929.92	36,401.28	89.30
TMK-KMN	100	192	215	11	1	0.79	42	3,211	12,839	4,591	8,929.92	20,683.22	89.30
TPK-KLB	100	199	731	11	3	0.71	1,185	2,957	40,051	17,528	8,136.97	61,720.34	81.37
TPK-MOA	100	199	963	11	4	0.71	1,185	2,957	53,401	25,596	10,246.47	83,138.48	102.46
TPK-SML	100	199	1,187	11	5	0.71	1,185	2,957	65,538	34,524	11,126.51	104,202.62	111.27

ROUTE	No of Teu	Capacity	Distance (Di) nm	Speed v	Sea Time (days)	Port time days	Fixed portion (αit)	Daily charter at port i (OtWi)	Ft USD	$D_i^m\left(\frac{O_t}{V_t}+\frac{F_t}{V_t}\right)$	$\sum_i\sum_j\left[\left(\beta_t+\frac{O_t}{R_i}\right)P_{ij}\right]$	Fixed Cost US$	Unit cost US$/Teu
TPK-DBO	100	199	1,427	11	5	0.71	1,185	2,957	78,888	37,305	11,314.37	120,334.23	113.14
TPK-MRK	100	199	1,937	11	7	0.71	1,185	2,957	106,802	60,369	9,009.96	171,312.16	90.10
KLB-TPK	100	199	731	11	3	1.17	40	4,870	40,051	17,528	7,101.23	62,488.73	71.01
KLB-MOA	100	199	232	11	1	0.79	33	3,304	12,743	4,705	7,927.58	20,785.93	79.28
KLB-SML	100	199	456	11	2	0.79	33	3,304	24,880	10,421	8,807.62	38,638.93	88.08
KLB-DBO	100	199	696	11	3	0.79	33	3,304	38,230	17,301	8,995.48	58,868.69	89.95
KLB-MRK	100	199	1,206	11	5	0.79	33	3,304	66,751	34,777	8,720.10	104,865.53	87.20
MOA-TPK	100	199	963	11	4	1.92	69	8,000	53,401	25,596	8,647.15	87,067.04	86.47
MOA-KLB	100	199	232	11	1	0.79	41	3,304	12,743	4,705	7,364.01	20,793.96	73.64
MOA-SML	100	199	224	11	1	0.79	41	3,304	12,137	4,680	8,807.62	20,161.85	88.08
MOA-DBO	100	199	464	11	2	0.79	41	3,304	25,487	10,472	8,995.48	39,304.36	89.95
MOA-MRK	100	199	974	11	4	0.79	41	3,304	54,008	25,697	8,720.10	83,050.88	87.20
SML-TPK	100	199	1,187	11	5	1.92	69	8,000	65,538	34,524	8,647.15	108,131.19	86.47
SML-KLB	100	199	456	11	2	0.79	41	3,304	24,880	10,421	7,364.01	38,646.96	73.64
SML-MOA	100	199	224	11	1	0.79	41	3,304	12,137	4,680	7,927.58	20,161.85	79.28
SML-DBO	100	199	240	11	1	0.79	41	3,304	13,350	4,730	8,995.48	21,426.08	89.95
SML-MRK	100	199	750	11	3	0.79	41	3,304	41,265	17,680	8,720.10	62,290.14	87.20
DBO-TPK	100	199	1,427	11	5	1.92	69	8,000	78,888	37,305	8,647.15	124,262.79	86.47
DBO-KLB	100	199	696	11	3	0.79	41	3,304	38,230	17,301	7,364.01	58,876.71	73.64
DBO-MOA	100	199	464	11	2	0.79	41	3,304	25,487	10,472	7,927.58	39,304.36	79.28
DBO-SML	100	199	240	11	1	0.79	41	3,304	13,350	4,730	8,807.62	21,426.08	88.08
DBO-MRK	100	199	510	11	2	0.79	41	3,304	27,914	10,674	8,720.10	41,933.96	87.20
MRK-TPK	100	199	1,937	11	7	0.96	196	4,000	106,802	60,369	6,618.12	171,366.94	66.18
MRK-KLB	100	199	1,206	11	5	0.79	191	3,304	66,751	34,777	7,364.01	105,023.52	73.64
MRK-MOA	100	199	974	11	4	0.79	191	3,304	54,008	25,697	7,927.58	83,200.83	79.28
MRK-SML	100	199	750	11	3	0.79	191	3,304	41,265	17,680	8,807.62	62,440.10	88.08
MRK-DBO	100	199	510	11	2	0.79	191	3,304	27,914	10,674	8,995.48	42,083.92	89.95
TPK-LRK	100	135	656	11	3	0.54	905	1,635	27,843	12,537	8,467.46	42,921.17	84.67
TPK-LWB	100	135	808	11	3	0.54	905	1,635	33,876	13,292	8,467.46	49,708.00	84.67
TPK-RTE	100	135	840	11	3	0.54	905	1,635	35,268	13,466	7,464.05	51,274.19	74.64
TPK-SBU	100	135	920	11	4	0.54	905	1,635	38,981	18,573	7,464.05	60,093.90	74.64
TPK-WGP	100	135	1,039	11	4	0.54	905	1,635	43,621	19,346	7,326.68	65,507.90	73.27
LRK-TPK	100	135	656	11	3	1.38	44	4,151	27,843	12,537	7,363.82	44,575.47	73.64
LRK-LWB	100	135	32	11	0	0.63	29	1,887	1,392	-	6,790.24	3,307.80	67.90
LRK-RTE	100	135	184	11	1	0.63	29	1,887	7,889	3,348	5,786.82	13,152.31	57.87
LRK-SBU	100	135	264	11	1	0.63	29	1,887	11,137	3,483	5,786.82	16,536.05	57.87
LRK-WGP	100	135	383	11	1	0.63	29	1,887	16,242	3,696	6,767.61	21,853.37	67.68
LWB-TPK	100	135	808	11	3	1.38	40	4,151	33,876	13,292	7,363.82	51,358.80	73.64

ROUTE	No of Teu	Capacity	Distance (Di) nm	Speed v	Sea Time (days)	Port time days	Fixed portion (αit)	Daily charter at port i (OtWi)	Ft USD	$D_i^m\left(\frac{O_t}{V_t}+\frac{F_t}{V_t}\right)$	$\sum_i\sum_j\left[\left(\beta_t+\frac{O_t}{R_i}\right)P_{ij}\right]$	Fixed Cost US$	Unit cost US$/Teu
LWB-LRK	100	135	32	11	0	0.63	27	1,887	1,392	-	6,790.24	3,306.14	67.90
LWB-RTE	100	135	32	11	0	0.63	27	1,887	1,392	-	5,786.82	3,306.14	57.87
LWB-SBU	100	135	112	11	0	0.63	27	1,887	4,641	-	5,786.82	6,554.54	57.87
LWB-WGP	100	135	231	11	1	0.63	27	1,887	9,745	3,425	6,767.61	15,084.22	67.68
RTE-TPK	100	135	840	11	3	1.38	37	4,151	35,268	13,466	7,363.82	52,921.48	73.64
RTE-LRK	100	135	184	11	1	0.63	25	1,887	7,889	3,348	6,790.24	13,148.99	67.90
RTE-LWB	100	135	32	11	0	0.63	25	1,887	1,392	-	6,790.24	3,304.49	67.90
RTE-SBU	100	135	80	11	0	0.63	25	1,887	3,248	-	5,786.82	5,160.71	57.87
RTE-WGP	100	135	199	11	1	0.63	25	1,887	8,353	3,367	6,767.61	13,632.38	67.68
SBU-TPK	100	135	920	11	4	1.38	44	4,151	38,981	18,573	7,363.82	61,748.20	73.64
SBU-LRK	100	135	264	11	1	0.63	29	1,887	11,137	3,483	6,790.24	16,536.05	67.90
SBU-LWB	100	135	112	11	0	0.63	29	1,887	4,641	-	6,790.24	6,556.20	67.90
SBU-RTE	100	135	80	11	0	0.63	29	1,887	3,248	-	5,786.82	5,164.03	57.87
SBU-WGP	100	135	119	11	0	0.63	29	1,887	5,105	-	6,767.61	7,020.26	67.68
WGP-TPK	100	135	1,029	11	4	0.88	27	2,642	43,621	19,346	6,245.67	65,636.14	62.46
WGP-LRK	100	135	383	11	1	0.63	23	1,887	16,242	3,696	6,790.24	21,848.06	67.90
WGP-LWB	100	135	231	11	1	0.63	23	1,887	9,745	3,425	6,790.24	15,080.56	67.90
WGP-RTE	100	135	199	11	1	0.63	23	1,887	8,353	3,367	5,786.82	13,630.38	57.87
WGP-SBU	100	135	119	11	0	0.63	23	1,887	5,105	-	5,786.82	7,014.94	57.87
TKP-WNC	100	115	463	11	2	0.50	247	1,312	17,045	6,666	9,128.08	25,270.32	91.28
TKP-NML	100	115	510	11	2	0.50	247	1,312	18,669	6,802	9,128.08	27,028.95	91.28
WNC-TKP	100	115	463	11	2	1.21	34	3,169	17,045	6,666	8,081.66	26,915.25	80.82
NML-TKP	100	115	510	11	2	1.21	37	3,169	18,669	6,802	8,081.66	28,676.72	80.82
TKP-FAK	100	115	863	11	3	0.50	247	1,312	31,655	11,826	8,920.90	45,039.98	89.21
TKP-KMN	100	135	681	11	3	0.58	252	1,761	28,772	12,653	10,643.83	43,437.58	106.44
TKP-TMK	100	200	909	11	3	0.75	267	3,143	61,207	20,224	11,969.31	84,841.72	119.69
FAK-TKP	100	115	863	11	3	0.67	29	1,749	31,655	11,826	6,806.59	45,259.30	68.07
KMN-TKP	100	135	681	11	3	1.38	44	4,151	28,772	12,653	8,529.52	45,619.59	85.30
TMK-TKP	100	200	909	11	3	1.92	71	8,033	61,207	20,224	9,854.99	89,534.91	98.55
TKP-KLB	100	135	138	11	1	0.58	252	1,761	6,033	3,270	7,894.22	11,315.72	78.94
TKP-MOA	100	115	516	11	2	0.50	247	1,312	19,074	6,836	9,128.08	27,468.61	91.28
TKP-SML	100	115	516	11	2	0.50	247	1,312	19,074	6,836	10,008.12	27,468.61	100.08
KLB-TKP	100	135	138	11	1	0.88	27	2,642	6,033	3,270	7,411.37	11,971.67	74.11
MOA-TKP	100	115	516	11	2	1.21	37	3,169	19,074	6,836	8,081.66	29,116.38	80.82
SML-TKP	100	115	516	11	2	1.21	37	3,169	19,074	6,836	8,081.66	29,116.38	80.82
TKP-DBO	100	115	516	11	2	0.50	247	1,312	19,074	6,836	10,195.97	27,468.61	101.96

ROUTE	No of Teu	Capacity	Distance (Di) nm	Speed v	Sea Time (days)	Port time days	Fixed portion (αit)	Daily charter at port i (OtWi)	Ft USD	$D_i^m\left(\frac{O_t}{V_t}+\frac{F_t}{V_t}\right)$	$\sum_i\sum_j\left[\left(\beta_i+\frac{O_t}{R_i}\right)P_{ij}\right]$	Fixed Cost US$	Unit cost US$/Teu
TKP-MRK	100	200	1,023	11	4	0.75	267	3,143	68,582	28,194	9,656.64	100,186.49	96.57
DBO-TKP	100	115	822	11	3	1.21	37	3,169	30,438	11,674	8,081.66	45,318.04	80.82
MRK-TKP	100	200	1,023	11	4	0.96	197	4,016	68,582	28,194	7,817.70	100,989.52	78.18
TKP-LRK	100	115	121	11	0	0.50	247	1,312	4,464	-	8,632.41	6,022.91	86.32
TKP-LWB	100	115	89	11	0	0.50	247	1,312	3,247	-	8,632.41	4,805.40	86.32
TKP-RTE	100	115	89	11	0	0.50	247	1,312	3,247	-	7,628.99	4,805.40	76.29
TKP-SBU	100	115	104	11	0	0.50	247	1,312	3,653	-	7,628.99	5,211.24	76.29
TKP-WGP	100	192	279	11	1	0.75	268	3,042	16,049	4,725	8,728.21	24,083.08	87.28
LRK-TKP	100	115	121	11	0	1.21	37	3,169	4,464	-	8,081.66	7,670.68	80.82
LWB-TKP	100	115	89	11	0	1.21	34	3,169	3,247	-	8,081.66	6,450.32	80.82
RTE-TKP	100	115	89	11	0	1.21	31	3,169	3,247	-	8,081.66	6,447.48	80.82
SBU-TKP	100	115	104	11	0	1.21	37	3,169	3,653	-	8,081.66	6,859.01	80.82
WGP-TKP	100	192	279	11	1	1.13	40	4,563	16,049	4,725	8,200.09	25,376.61	82.00

Detail Calculation of the total shipping cost from the port of Tanjung Perak to Tenau Kupang port

ROUTE	No of Teu	Distance (Di) nm	Speed v	Sea Time (days)	Port time (days) PO	Port time (days) PD	Total time (d)	Fixed portion (αit) PO	Fixed portion (αit) PD	Daily charter at port i (OtWi)	Ft USD	$D_i^m\left(\frac{O_t}{V_t}+\frac{F_t}{V_t}\right)$
TPK-TKP	800	795	15	2	3.63	3.71	10	2,670	358	93,833	75,099	28,627

ROUTE	PO (βi) USD	PD (βj) USD	Total handling fee (USD)	Total Ot/Ri USD	$\sum_i\sum_j\left[\left(\beta_i+\frac{O_t}{R_i}\right)P_{ij}\right]$	Fixed US$	Variable Cost US$/Teu
TPK-TKP	20.05	25.58	45.62	35.90	65,219.70	122,012.41	81.525

Appendix 4. The Total Shipping Cost Calculation

1. Scenario I

a. Network 1

Connectivity (Network 1)

Xij

O/D	TPK	WNC	NML	FAK	KMN	TMK	
TPK		1	0	0	0	0	1
WNC	1		1	0	0	0	2
NML	0	1		1	0	0	2
FAK	0	0	1		1	0	2
KMN	0	0	0	1		1	2
TMK	0	0	0	0	1		1
	1	2	2	2	2	1	

Cargo Allocation

Pij

O/D	TPK	WNC	NML	FAK	KMN	TMK	
TPK	-	6	3	27	29	118	183
WNC	2	-	-	-	-	-	2
NML	1	-	-	-	-	-	1
FAK	3	-	-	-	-	-	3
KMN	2	-	-	-	-	-	2
TMK	6	-	-	-	-	-	6
	14	6	3	27	29	118	

Ship capacity constraint

∑(t∈T) Ut = 192 TEU 95%

O/D	TPK	WNC	NML	FAK	KMN	TMK	
TPK	-	6	3	27	29	118	183
WNC	2	-	-	-	-	-	2
NML	1	-	-	-	-	-	1
FAK	3	-	-	-	-	-	3
KMN	2	-	-	-	-	-	2
TMK	6	-	-	-	-	-	6
	14	6	3	27	29	118	

Distance (Nm)

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	700	990	1,316	1,498	1,713
WNC	700	-	290	616	798	1,013
NML	990	290	-	326	508	723
FAK	1,316	616	326	-	182	397
KMN	1,498	798	508	182	-	215
TMK	1,713	1,013	723	397	215	-

Fixed Cost (USD)

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	62,473.54	87,713.82	116,672.05	137,552.43	161,829.79
WNC	62,473.54	-	24,692.67	50,307.41	68,138.54	88,376.98
NML	87,713.82	24,692.67	-	27,370.18	43,355.71	63,085.94
FAK	116,672.05	50,307.41	27,370.18	-	18,680.47	36,404.60
KMN	137,552.43	68,138.54	43,355.71	18,680.47	-	20,683.22

Variable Cost (USD/TEU/Nml)

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	101.15	101.15	92.12	111.83	111.83
WNC	101.15	-	78.62	89.30	89.30	89.30
NML	101.15	78.62	-	89.30	89.30	89.30
FAK	92.12	89.30	89.30	-	89.30	89.30
KMN	111.83	89.30	89.30	89.30	-	89.30
TMK	111.83	89.30	89.30	89.30	89.30	-

Time (days)

O/D	TPK	WNC	NML	FAK	KMN	TMK
TPK	-	4	5	6	7	8
WNC	4	-	2	4	4	5
NML	5	2	-	3	3	4
FAK	6	4	3	-	2	3
KMN	7	4	3	2	-	2
TMK	8	5	4	3	2	-

Objective Function

Total Cost per voyage	$	329,112	
Number of sailing frequency		48	calls/year
Total Cost per year	$	15,797,353	
Total travel time per voyage		26	days

b. Network 2

Connectivity (Network 2)

Xij

O/D	TPK	KLB	MOA	SML	DBO	MRK	
TPK	0	1	0	0	0	0	1
KLB	1	0	1	0	0	0	2
MOA	0	1		1	0	0	2
SML	0	0	1	0	1	0	2
DBO	0	0	0	1	0	1	2
MRK	0	0	0	0	1	0	1
	1	2	2	2	2	1	

Pij

O/D	TPK	KLB	MOA	SML	DBO	MRK	
TPK	-	23	3	3	23	144	196
KLB	3	-	-	-	-	-	3
MOA	1	-	-	-	-	-	1
SML	1	-	-	-	-	-	1
DBO	6	-	-	-	-	-	6
MRK	31	-	-	-	-	-	31
	42	23	3	3	23	144	

Ship capacity constraint

∑(t∈T) Ut = 199 TEU 98%

O/D	TPK	KLB	MOA	SML	DBO	MRK	
TPK	-	23	3	3	23	144	196
KLB	3	-	-	-	-	-	3
MOA	1	-	-	-	-	-	1
SML	1	-	-	-	-	-	1
DBO	6	-	-	-	-	-	6
MRK	31	-	-	-	-	-	31
	42	23	3	3	23	144	

Distance (Nm)

O/D	TPK	KLB	MOA	SML	DBO	MRK
TPK	-	731	963	1,187	1,427	1,937
KLB	731	-	232	456	696	1,206
MOA	963	232	-	224	464	974
SML	1,187	456	224	-	240	750
DBO	1,427	696	464	240	-	510
MRK	1,937	1,206	974	750	510	-

Fixed Cost (USD)

O/D	TPK	KLB	MOA	SML	DBO	MRK
TPK	-	61,720.34	83,138.48	104,202.62	120,334.23	171,312.16
KLB	61,720.34	-	20,785.93	38,638.93	58,868.69	104,865.53
MOA	83,138.48	20,785.93	-	20,161.85	39,304.36	83,050.88
SML	104,202.62	38,638.93	20,161.85	-	21,426.08	62,290.14
DBO	120,334.23	58,868.69	39,304.36	21,426.08	-	41,933.96
MRK	171,312.16	104,865.53	83,050.88	62,290.14	41,933.96	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	KLB	MOA	SML	DBO	MRK
TPK	-	81.37	102.46	111.27	113.14	90.10
KLB	81.37	-	79.28	88.08	89.95	87.20
MOA	102.46	79.28	-	88.08	89.95	87.20
SML	111.27	88.08	88.08	-	89.95	87.20
DBO	113.14	89.95	89.95	89.95	-	87.20
MRK	90.10	87.20	87.20	87.20	87.20	-

Time

O/D	TPK	KLB	MOA	SML	DBO	MRK
TPK	-	4	5	6	7	9
KLB	4	-	2	3	4	6
MOA	5	2	-	2	3	5
SML	6	3	2	-	2	4
DBO	7	4	3	2	-	3
MRK	9	6	5	4	3	-

Objective Function

Total Cost per voyage	$	354,075	
Number of sailing frequency		48	calls/year
Total Cost per year	$	16,995,622	
Total travel time per voyage		26	days

c. Network 3

Connectivity (Network 3)

Xij

O/D	TPK	LRK	LWB	RTE	SBU	WGP	
TPK	0	0	0	0	0	0	0
LRK	1	0	1	0	0	0	2
LWB	0	1	0	1	0	0	2
RTE	0	0	1	0	1	0	2
SBU	0	0	0	1	0	1	2
WGP	0	0	0	0	1	0	1
	1	1	2	2	2	1	

Cargo Allocation

Pij

O/D	TPK	LRK	LWB	RTE	SBU	WGP	
TPK	-	17	10	1	6	73	107
LRK	3	-	-	-	-	-	3
LWB	3	-	-	-	-	-	3
RTE	1	-	-	-	-	-	1
SBU	1	-	-	-	-	-	1
WGP	12	-	-	-	-	-	12
	20	17	10	1	6	73	

Ship capacity constraint

∑(t∈T) Ut = 135 TEU 79%

O/D	TPK	LRK	LWB	RTE	SBU	WGP	
TPK	-	17	10	1	6	73	107
LRK	3	-	-	-	-	-	3
LWB	3	-	-	-	-	-	3
RTE	1	-	-	-	-	-	1
SBU	1	-	-	-	-	-	1
WGP	12	-	-	-	-	-	12
	20	17	10	1	6	73	

Distance (Nm)

O/D	TPK	LRK	LWB	RTE	SBU	WGP
TPK	-	656	808	840	920	1,039
LRK	656	-	152	184	264	383
LWB	808	152	-	32	112	231
RTE	840	184	32	-	80	199
SBU	920	264	112	80	-	119
WGP	1,039	383	231	199	119	-

Fixed Cost (USD)

O/D	TPK	LRK	LWB	RTE	SBU	WGP
TPK	-	42,921.17	49,708.00	51,274.19	60,093.90	65,507.90
LRK	42,921.17	-	3,307.80	13,152.31	16,536.05	21,853.37
LWB	49,708.00	3,307.80	-	3,306.14	6,554.54	15,084.22
RTE	51,274.19	13,152.31	3,306.14	-	5,160.71	13,632.38
SBU	60,093.90	16,536.05	6,554.54	5,160.71	-	7,020.26
WGP	65,507.90	21,853.37	15,084.22	13,632.38	7,020.26	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	LRK	LWB	RTE	SBU	WGP
TPK	-	89.95	84.67	74.64	74.64	73.27
LRK	89.95	-	67.90	57.87	57.87	67.68
LWB	84.67	67.90	-	57.87	57.87	67.68
RTE	74.64	57.87	57.87	-	57.87	67.68
SBU	74.64	57.87	57.87	57.87	-	67.68
WGP	73.27	67.68	67.68	67.68	67.68	-

Time

O/D	TPK	LRK	LWB	RTE	SBU	WGP
TPK	-	4	4	4	5	5
LRK	4	-	1	2	2	3
LWB	4	1	-	1	2	2
RTE	4	2	1	-	1	2
SBU	5	2	2	1	-	2
WGP	5	3	2	2	2	-

Objective Function

Total Cost per voyage	$	90,310	
Number of sailing frequency		24	calls/year
Total Cost per year	$	2,167,448	
Total travel time per voyage		14	days

2. Scenario II (N-3 remains the same as in Scenenario I)

a. Network 1

Connectivity (Network 1)

Xij

O/D	TPK	WNC	NML	
TPK	-	1	-	1
WNC	1	-	1	2
NML	-	1	-	1
	1	2	1	

Cargo Allocation

Pij

O/D	TPK	WNC	NML	
TPK	-	21	11	32
WNC	6	-	-	6
NML	3	-	-	3
	9	21	11	

Ship capacity constraint

∑(t∈T) Ut = 115

O/D	TPK	WNC	NML	
TPK	-	21	11	32
WNC	6	-	-	6
NML	3	-	-	3
	9	21	11	

Distance (Nm)

O/D	TPK	WNC	NML
TPK	-	700	990
WNC	700	-	290
NML	990	290	-

Fixed Cost (USD)

O/D	TPK	WNC	NML
TPK	-	39,236	55,252
WNC	39,236	-	15,169
NML	55,252	15,169	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	WNC	NML
TPK	-	85.23	85.23
WNC	85.23	-	70.66
NML	85.23	70.66	-

Time (days)

O/D	TPK	WNC	NML
TPK	-	4	5
WNC	4	-	2
NML	5	2	-

Objective Function

Total Cost	$	112,305
Number of sailing frequency		12
Total Cost per year	$	1,347,655
Total travel time per voyage		12

b. Network 13

Connectivity (Network 13)

Xij

O/D	TPK	FAK	KMN	TMK	
TPK	-	1	-	-	1
FAK	1	-	1	-	2
KMN	-	1	-	1	2
TMK	-	-	1	-	1
	1	2	2	1	

Cargo Allocation

Pij

O/D	TPK	FAK	KMN	TMK	
TPK	-	27	29	118	174
FAK	3	-	-	-	3
KMN	2	-	-	-	2
TMK	6	-	-	-	6
	11	27	29	118	

Ship capacity constraint

∑(t∈T) Ut 192 TEU 91%

O/D	TPK	FAK	KMN	TMK	
TPK	-	27	29	118	174
FAK	3	-	-	-	3
KMN	2	-	-	-	2
TMK	6	-	-	-	6
	11	27	29	118	

Distance (Nm)

O/D	TPK	FAK	KMN	TMK
TPK	-	1,316	1,498	1,713
FAK	1,316	-	182	397
KMN	1,498	182	-	215
TMK	1,713	397	215	-

Fixed Cost (USD)

O/D	TPK	FAK	KMN	TMK
TPK	-	116,672	-	-
FAK	116,672	-	18,680	-
KMN	-	18,680	-	20,683
TMK	-	-	20,683	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	FAK	KMN	TMK
TPK	-	92.12	-	-
FAK	92.12	-	89.30	-
KMN	-	89.30	-	89.30
TMK	-	-	89.30	-

Time (days)

O/D	TPK	FAK	KMN	TMK
TPK	-	6	-	-
FAK	6	-	2	-
KMN	-	2	-	2
TMK	-	-	2	-

Objective Function

Total Cost	$	314,835	
Number of sailing frequency		48	calls/year
Total Cost per year	$	15,112,078	
Total travel time per voyage		20	days

c. Network 2

Connectivity (Network 2)

Xij

O/D	TPK	KLB	MOA	SML	
TPK	-	1	-	-	1
KLB	1	-	1	-	2
MOA	-	1	-	1	2
SML	-	-	1	-	1
	1	2	2	1	

Cargo Allocation

Pij

O/D	TPK	KLB	MOA	SML	
TPK	-	92	11	11	114
KLB	9	-	-	-	9
MOA	1	-	-	-	1
SML	1	-	-	-	1
	11	92	11	11	

Ship capacity constraint

∑(t∈T) Ut = 200 TEU 57%

O/D	TPK	KLB	MOA	SML	
TPK	-	92	11	11	114
KLB	9	-	-	-	9
MOA	1	-	-	-	1
SML	1	-	-	-	1
	11	92	11	11	

∑(c∈C)Pijc

O/D	TPK	KLB	MOA	SML
TPK	-	92	11	11
KLB	9	-	-	-
MOA	1	-	-	-
SML	1	-	-	-

Cost

Distance (Nm)

O/D	TPK	KLB	MOA	SML
TPK	-	731	963	1,187
KLB	731	-	232	456
MOA	963	232	-	224
SML	1,187	456	224	-

Fixed Cost (USD)

O/D	TPK	KLB	MOA	SML
TPK	-	71,499	96,645	121,362
KLB	71,499	-	23,674	44,488
MOA	96,645	23,674	-	22,914
SML	121,362	44,488	22,914	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	KLB	MOA	SML
TPK	-	81.50	102.65	111.45
KLB	81.50	-	79.37	88.17
MOA	102.65	79.37	-	88.17
SML	111.45	88.17	88.17	-

Time (days)

O/D	TPK	KLB	MOA	SML
TPK	-	4	5	6
KLB	4	-	2	3
MOA	5	2	-	2
SML	6	3	2	-

Objective Function

Total Cost	$	246,974	
Number of sailing frequency		12	calls/year
Total Cost per year	$	2,963,685	
Total travel time per voyage		16	days

d. Network 11

Xij

O/D	TPK	DBO	MRK	
TPK	-	1	-	1
DBO	1	-	1	2
MRK	-	1	-	1
	1	2	1	

Cargo Allocation

Pij

O/D	TPK	DBO	MRK	
TPK	-	23	144	167
DBO	5	-	-	5
MRK	31	-	-	31
	36	23	144	

Ship capacity constraint

∑(t∈T) Ut = 199 84%

O/D	TPK	DBO	MRK	
TPK	-	23	144	167
DBO	5	-	-	5
MRK	31	-	-	31
	36	23	144	

Distance (Nm)

O/D	TPK	DBO	MRK
TPK	-	1,427	1,937
DBO	1,427	-	510
MRK	1,937	510	-

Fixed Cost (USD)

O/D	TPK	DBO	MRK
TPK	-	120,334	171,312
DBO	120,334	-	41,934
MRK	171,312	41,934	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	DBO	MRK
TPK	-	113.14	90.10
DBO	113.14	-	87.20
MRK	90.10	87.20	-

Time (days)

O/D	TPK	DBO	MRK
TPK	-	7	9
DBO	7	-	3
MRK	9	3	-

Objective Function

Total Cost	$	343,472	
Number of sailing frequency		48	calls/year
Total Cost per year	$	16,486,649	
Total travel time per voyage		20	days

3. Scenario III

a. Direct Hub and Spoke

Connectivity Wanci

Xij

O/D	TPK	TKP	WNC	
TPK	-	1	-	1
TKP	1	-	1	2
WNC	-	1	-	1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	WNC	
TPK	-	21	-	21
TKP	6	-	21	27
WNC	-	6	-	6
	6	27	21	

Ship capacity constraint Occupancy

∑(t∈T) Ut = 115 18%

O/D	TPK	TKP	WNC	
TPK	-	21	-	21
TKP	6	-	21	27
WNC	-	6	-	6
	6	27	21	

Fixed Cost (USD)

O/D	TPK	TKP	WNC
TPK	-	16,268.3	62,473.5
TKP	16,268.3	-	25,270.3
WNC	62,473.5	25,270.3	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	WNC
TPK	-	81.525	101.154
TKP	81.525	-	91.281
WNC	101.154	91.281	-

Time (days)

O/D	TPK	TKP	WNC
TPK	-	5	4
TKP	5	-	3
WNC	4	3	-

Objective Function

Total Cost	$	87,743
Number of sailing frequency		12
Total Cost per year	$	1,052,916
Total travel time per voyage		16

Connectivity Namlea

Xij

O/D	TPK	TKP	NML	
TPK	-	1	-	1
TKP	1	-	1	
NML	-	1	-	1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	NML	
TPK	-	11	-	11
TKP	3	-	11	14
NML	-	3	-	3
	3	14	11	

Ship capacity constraint

∑(t∈T) Ut = 115 10%

O/D	TPK	TKP	NML	
TPK	-	11	-	11
TKP	3	-	11	14
NML	-	3	-	3
	3	14	11	

Fixed Cost (USD)

O/D	TPK	TKP	NML
TPK	-	16,268.3	87,713.8
TKP	16,268.3	-	27,029.0
NML	87,713.8	27,029.0	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	NML
TPK	-	81.525	101.154
TKP	81.525	-	91.281
NML	101.154	91.281	-

Time (days)

O/D	TPK	TKP	NML
TPK	-	5	5
TKP	5	-	3
NML	5	3	-

Objective Function

Total Cost	$	89,014
Number of sailing frequency		12
Total Cost per year	$	1,068,166
Total travel time per voyage		16

Connectivity Fak-Fak

Xij

O/D	TPK	TKP	FAK	
TPK	-	1	-	1
TKP	1	-	1	
FAK	-	1	-	1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	FAK	
TPK	-	106	-	106
TKP	10	-	106	116
FAK	-	10	-	10
	10	116	106	

Ship capacity constraint

∑(t∈T) Ut = 115 92%

O/D	TPK	TKP	FAK	
TPK	-	106	-	106
TKP	10	-	106	116
FAK	-	10	-	10
	10	116	106	

Fixed Cost (USD)

O/D	TPK	TKP	FAK
TPK	-	16,268.3	116,672.0
TKP	16,268.3	-	45,040.0
FAK	116,672.0	45,040.0	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	FAK
TPK	-	81.525	92.116
TKP	81.525	-	89.209
FAK	92.116	89.209	-

Time (days)

O/D	TPK	TKP	FAK
TPK	-	5	6
TKP	5	-	4
FAK	6	4	-

Objective Function

Total Cost	$	142,422
Number of sailing frequency		12
Total Cost per year	$	1,709,060
Total travel time per voyage		18

Connectivity Kaimana

Xij

O/D	TPK	TKP	KMN	
TPK	-	1	-	1
TKP	1	-	1	
KMN	-	1	-	1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	KMN	
TPK	-	114	-	114
TKP	7	-	114	121
KMN	-	7	-	7
	7	121	114	

Ship capacity constraint

$\sum(t \in T)$ Ut = 135 84%

O/D	TPK	TKP	KMN	
TPK	-	114	-	114
TKP	7	-	114	121
KMN	-	7	-	7
	7	121	114	

Fixed Cost (USD)

O/D	TPK	TKP	KMN
TPK	-	16,268.3	137,552.4
TKP	16,268.3	-	43,437.6
KMN	137,552.4	43,437.6	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	KMN
TPK	-	81.525	111.833
TKP	81.525	-	106.438
KMN	111.833	106.438	-

Time (days)

O/D	TPK	TKP	KMN
TPK	-	5	7
TKP	5	-	4
KMN	7	4	-

Objective Function

Total Cost	$	142,155
Number of sailing frequency		12
Total Cost per year	$	1,705,864
Total travel time per voyage		18

Connectivity Timika

Xij

O/D	TPK	TKP	TMK	
TPK	-	1		1
TKP	1		1	
TMK		1		1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	TMK	
TPK	-	157	-	157
TKP	8	-	157	165
TMK	-	8	-	8
	8	165	157	

∑(t∈T) Ut = 200 79%

O/D	TPK	TKP	TMK	
TPK	-	157	-	157
TKP	8	-	157	165
TMK	-	8	-	8
	8	165	157	

Fixed Cost (USD)

O/D	TPK	TKP	TMK
TPK	-	16,268.3	161,829.8
TKP	16,268.3	-	84,841.7
TMK	161,829.8	84,841.7	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	TMK
TPK	-	81.525	111.833
TKP	81.525	-	119.693
TMK	111.833	119.693	-

Time (days)

O/D	TPK	TKP	TMK
TPK	-	5	8
TKP	5	-	5
TMK	8	5	-

Objective Function

Total Cost	$	235,421
Number of sailing frequency		36
Total Cost per year	$	8,475,156
Total travel time per voyage		20

Connectivity Saumlaki

Xij

O/D	TPK	TKP	SML	
TPK	-	1		1
TKP	1		1	
SML		1		1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	SML	
TPK	-	11	-	11
TKP	1	-	11	12
SML	-	1	-	1
	1	12	11	

∑(t∈T) Ut = 115 10%

O/D	TPK	TKP	SML	
TPK	-	11	-	11
TKP	1	-	11	12
SML	-	1	-	1
	1	12	11	

Fixed Cost (USD)

O/D	TPK	TKP	SML
TPK	-	16,268.3	121,361.6
TKP	16,268.3	-	27,468.6
SML	121,361.6	27,468.6	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	SML
TPK	-	81.525	111.454
TKP	81.525	-	100.081
SML	111.454	100.081	-

Time (days)

O/D	TPK	TKP	SML
TPK	-	5	6
TKP	5	-	3
SML	6	3	-

Objective Function

Total Cost	$	89,653
Number of sailing frequency		12
Total Cost per year	$	1,075,838
Total travel time per voyage		16

Connectivity Kalabahi

Xij

O/D	TPK	TKP	KLB	
TPK	-	1		1
TKP	1		1	
KLB		1		1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	KLB	
TPK	-	92	-	92
TKP	9	-	92	101
KLB	-	9	-	9
	9	101	92	

∑(t∈T) Ut = 135 68%

O/D	TPK	TKP	KLB	
TPK	-	92	-	92
TKP	9	-	92	101
KLB	-	9	-	9
	9	101	92	

Fixed Cost (USD)

O/D	TPK	TKP	KLB
TPK	-	16,268.3	71,498.6
TKP	16,268.3	-	11,315.7
KLB	71,498.6	11,315.7	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	KLB
TPK	-	81.525	81.496
TKP	81.525	-	78.942
KLB	81.496	78.942	-

Time (days)

O/D	TPK	TKP	KLB
TPK	-	5	4
TKP	5	-	2
KLB	4	2	-

Objective Function

Total Cost	$	71,375
Number of sailing frequency		12
Total Cost per year	$	856,503
Total travel time per voyage		14

Connectivity Moa

Xij

O/D	TPK	TKP	MOA	
TPK	-	1		1
TKP	1		1	
MOA		1		1
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	MOA	
TPK	-	11	-	11
TKP	1	-	11	12
MOA	-	1	-	1
	1	12	11	

∑(t∈T) Ut = 115 10%

O/D	TPK	TKP	MOA	
TPK	-	11	-	11
TKP	1	-	11	12
MOA	-	1	-	1
	1	12	11	

Fixed Cost (USD)

O/D	TPK	TKP	MOA
TPK	-	16,268.3	96,645.2
TKP	16,268.3	-	27,468.6
MOA	96,645.2	27,468.6	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	MOA
TPK	-	81.525	102.654
TKP	81.525	-	91.281
MOA	102.654	91.281	-

Time (days)

O/D	TPK	TKP	MOA
TPK	-	5	5
TKP	5	-	3
MOA	5	3	-

Objective Function

Total Cost	$	89,548
Number of sailing frequency		12
Total Cost per year	$	1,074,570
Total travel time per voyage		16

Connectivity Dobo

Xij

O/D	TPK	TKP	DBO	
TPK	-	1	-	1
TKP	1	-	1	2
DBO	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	DBO	
TPK	-	101	-	101
TKP	21	-	91	112
DBO	-	21	-	21
	21	122	91	

∑(t∈T) Ut = 115 88%

O/D	TPK	TKP	DBO	
TPK	-	101	-	101
TKP	21	-	91	112
DBO	-	21	-	21
	21	122	91	

Fixed Cost (USD)

O/D	TPK	TKP	DBO
TPK	-	16,268.3	120,334.2
TKP	16,268.3	-	27,468.6
DBO	120,334.2	27,468.6	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	DBO
TPK	-	81.525	113.144
TKP	81.525	-	101.960
DBO	113.144	101.960	-

Time (days)

O/D	TPK	TKP	DBO
TPK	-	5	7
TKP	5	-	3
DBO	7	3	-

Objective Function

Total Cost	$	108,839
Number of sailing frequency		12
Total Cost per year	$	1,306,072
Total travel time per voyage		16

Connectivity Merauke

Xij

O/D	TPK	TKP	MRK	
TPK	-	1	-	1
TKP	1	-	1	2
MRK	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	MRK	
TPK	-	192	-	192
TKP	41	-	192	233
MRK	-	41	-	41
	41	233	192	

∑(t∈T) Ut = 200 96%

O/D	TPK	TKP	MRK	
TPK	-	192	-	192
TKP	41	-	192	233
MRK	-	41	-	41
	41	233	192	

Fixed Cost (USD)

O/D	TPK	TKP	MRK
TPK	-	16,268.3	171,312.2
TKP	16,268.3	-	100,186.5
MRK	171,312.2	100,186.5	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	MRK
TPK	-	81.525	90.100
TKP	81.525	-	96.566
MRK	90.100	96.566	-

Time (days)

O/D	TPK	TKP	MRK
TPK	-	5	9
TKP	5	-	5
MRK	9	5	-

Objective Function

Total Cost	$	274,405
Number of sailing frequency		36
Total Cost per year	$	9,878,574
Total travel time per voyage		20

Connectivity Larantuka

Xij

O/D	TPK	TKP	LRK	
TPK	-	1	-	1
TKP	1	-	1	2
LRK	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	LRK	
TPK	-	34	-	34
TKP	6	-	34	40
LRK	-	6	-	6
	6	40	34	

∑(t∈T) Ut = 115 30%

O/D	TPK	TKP	LRK	
TPK	-	34	-	34
TKP	6	-	34	40
LRK	-	6	-	6
	6	40	34	

Fixed Cost (USD)

O/D	TPK	TKP	LRK
TPK	-	16,268.3	42,921.2
TKP	16,268.3	-	6,022.9
LRK	42,921.2	6,022.9	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	LRK
TPK	-	81.525	84.675
TKP	81.525	-	86.324
LRK	84.675	86.324	-

Time (days)

O/D	TPK	TKP	LRK
TPK	-	5	4
TKP	5	-	1
LRK	4	1	-

Objective Function

Total Cost	$	51,296
Number of sailing frequency		12
Total Cost per year	$	615,557
Total travel time per voyage		12

Connectivity Lewoleba

Xij

O/D	TPK	TKP	LWB	
TPK	-	1	-	1
TKP	1	-	1	2
LWB	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1

O/D	TPK	TKP	LWB	
TPK	-	20	-	20
TKP	6	-	20	26
LWB	-	6	-	6
	6	26	20	

∑(t∈T) Ut = 115 17%

O/D	TPK	TKP	LWB	
TPK	-	20	-	20
TKP	6	-	20	26
LWB	-	6	-	6
	6	26	20	

Fixed Cost (USD)

O/D	TPK	TKP	LWB
TPK	-	16,268.3	49,708.0
TKP	16,268.3	-	4,805.4
LWB	49,708.0	4,805.4	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	LWB
TPK	-	81.525	84.675
TKP	81.525	-	86.324
LWB	84.675	86.324	-

Time (days)

O/D	TPK	TKP	LWB
TPK	-	5	4
TKP	5	-	1
LWB	4	1	-

Objective Function

Total Cost	$	46,512
Number of sailing frequency		12
Total Cost per year	$	558,138
Total travel time per voyage		12

Connectivity Rote

Xij

O/D	TPK	TKP	RTE	
TPK	-	1	-	1
TKP	1	-	1	2
RTE	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1

O/D	TPK	TKP	RTE	
TPK	-	2	-	2
TKP	1	-	2	3
RTE	-	1	-	1
	1	3	2	

∑(t∈T) Ut = 115 2%

O/D	TPK	TKP	RTE	
TPK	-	2	-	2
TKP	1	-	2	3
RTE	-	1	-	1
	1	3	2	

Fixed Cost (USD)

O/D	TPK	TKP	RTE
TPK	-	16,268.3	51,274.2
TKP	16,268.3	-	4,805.4
RTE	51,274.2	4,805.4	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	RTE
TPK	-	81.525	74.640
TKP	81.525	-	76.290
RTE	74.640	76.290	-

Time (days)

O/D	TPK	TKP	RTE
TPK	-	5	4
TKP	5	-	1
RTE	4	1	-

Objective Function

Total Cost	$	42,621
Number of sailing frequency		12
Total Cost per year	$	511,451
Total travel time per voyage		12

Connectivity Sabu

Xij

O/D	TPK	TKP	SBU	
TPK	-	1	-	1
TKP	1	-	1	2
SBU	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1

O/D	TPK	TKP	SBU	
TPK	-	11	-	11
TKP	1	-	11	12
SBU	-	1	-	1
	1	12	11	

∑(t∈T) Ut = 115 10%

O/D	TPK	TKP	SBU	
TPK	-	11	-	11
TKP	1	-	11	12
SBU	-	1	-	1
	1	12	11	

Fixed Cost (USD)

O/D	TPK	TKP	SBU
TPK	-	16,268.3	60,093.9
TKP	16,268.3	-	5,211.2
SBU	60,093.9	5,211.2	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	SBU
TPK	-	81.525	74.640
TKP	81.525	-	76.290
SBU	74.640	76.290	-

Time (days)

O/D	TPK	TKP	SBU
TPK	-	5	5
TKP	5	-	1
SBU	5	1	-

Objective Function

Total Cost	$	44,853
Number of sailing frequency		12
Total Cost per year	$	538,235
Total travel time per voyage		12

Connectivity Waingapu

Xij

O/D	TPK	TKP	WGP	
TPK	-	1	-	1
TKP	1	-	1	2
WGP	-	1	-	1
	1	2	1	
	1	2	1	

Cargo Allocation **Pij**

c_1

O/D	TPK	TKP	WGP	
TPK	-	145	-	145
TKP	23	-	145	168
WGP	-	23	-	23
	23	168	145	

∑(t∈T) Ut = 192 76%

O/D	TPK	TKP	WGP	
TPK	-	145	-	145
TKP	23	-	145	168
WGP	-	23	-	23
	23	168	145	

Fixed Cost (USD)

O/D	TPK	TKP	WGP
TPK	-	16,268.3	65,507.9
TKP	16,268.3	-	24,083.1
WGP	65,507.9	24,083.1	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	WGP
TPK	-	-	73.267
TKP	-	-	87.282
WGP	73.267	87.282	-

Time (days)

O/D	TPK	TKP	WGP
TPK	-	5	5
TKP	5	-	3
WGP	5	3	-

Objective Function

Total Cost	$	95,366
Number of sailing frequency		12
Total Cost per year	$	1,144,394
Total travel time per voyage		16

b. Indirect Hub and Spoke

1) H&S Indirect 1

Connectivity

Xij

O/D	TPK	TKP	LRT	LWB	WNC	NML	
TPK	-	1	-	-	-	-	1
TKP	1	-	1	-	-	-	2
LRT	-	1	-	1	-	-	2
LWB	-	-	1	-	1	-	2
WNC	-	-	-	1	-	1	2
NML	-	-	-	-	1	-	1
	1	2	2	2	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	LRT	LWB	WNC	NML	
TPK		98					98
TKP	21		34	25	25	14	119
LRT		6					6
LWB		6					6
WNC		6					6
NML		3					3
	21	119	34	25	25	14	

Ship capacity constraint

			Occupancy
∑(t∈T) Ut	=	115	85%

O/D	TPK	TKP	LRT	LWB	WNC	NML	
TPK	-	98	-	-	-	-	98
TKP	21	-	34	25	25	14	119
LRT	-	6	-	-	-	-	6
LWB	-	6	-	-	-	-	6
WNC	-	6	-	-	-	-	6
NML	-	3	-	-	-	-	3
	21	119	34	25	25	14	

Distance (Nm)

O/D	TPK	TKP	LRT	LWB	WNC	NML
TPK	-	795	656	691	700	990
TKP	795	-	121	89	463	510
LRT	656	121	-	32	342	389
LWB	691	89	32	-	374	421
WNC	700	463	342	374	-	290
NML	990	510	389	421	290	-

Fixed Cost (USD)

O/D	TPK	TKP	LRT	LWB	WNC	NML
TPK	-	16,268.32	42,921.17	49,708.00	62,473.54	87,713.82
TKP	16,268.32	-	6,022.91	4,805.40	25,270.32	27,028.95
LRT	42,921.17	6,022.91	-	3,307.80	16,536.05	21,853.37
LWB	49,708.00	4,805.40	3,307.80	-	6,554.54	15,084.22
WNC	62,473.54	25,270.32	16,536.05	6,554.54	-	24,692.67

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	LRT	LWB	WNC	NML
TPK	-	81.52	84.67	84.67	101.15	101.15
TKP	81.52	-	86.32	86.32	91.28	91.28
LRT	84.67	86.32	-	67.90	57.87	67.68
LWB	84.67	86.32	67.90	-	57.87	67.68
WNC	101.15	91.28	57.87	57.87	-	78.62

Time (days)

O/D	TPK	TKP	LRT	LWB	WNC	NML
TPK	-	5	4	4	4	5
TKP	5	-	1	1	3	3
LRT	4	1	-	1	2	3
LWB	4	1	1	-	2	2
WNC	4	3	2	2	-	2

Objective Function

Total Cost	$	133,904
Number of sailing frequency		12
Total Cost per year	$	1,606,853
Total travel time per voyage		22

2) H&S Indirect 2

Connectivity

Xij

O/D	TPK	TKP	KLB	MOA	SML	
TPK	-	1	-	-	-	1
TKP	1	-	1	-	-	2
KLB	-	1	-	1	-	2
MOA	-	-	1	-	1	2
SML				1		1
	1	2	2	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	KLB	MOA	SML	
TPK		140				140
TKP	11		112	14	14	151
KLB		9		-		9
MOA		1	-		-	1
SML		1		-		1
	11	151	112	14	14	

Ship capacity constraint

		Occupancy
$\sum(t \in T)$ Ut =	192	73%

O/D	TPK	TKP	KLB	MOA	SML	
TPK	-	140	-	-	-	140
TKP	11	-	112	14	14	151
KLB	-	9	-	-	-	9
MOA	-	1	-	-	-	1
SML	-	1	-	-	-	1
	11	151	112	14	14	

Distance (Nm)

O/D	TPK	TKP	KLB	MOA	SML
TPK	-	795	731	963	1,187
TKP	795	-	138	516	516
KLB	731	138	-	232	456
MOA	963	516	232	-	224
SML	1,187	516	456	224	-

Fixed Cost (USD)

O/D	TPK	TKP	KLB	MOA	SML
TPK	-	16,268.32	61,720.34	83,138.48	104,202.62
TKP	16,268.32	-	11,315.72	27,468.61	27,468.61
KLB	61,720.34	11,315.72	-	20,785.93	38,638.93
MOA	83,138.48	27,468.61	20,785.93	-	20,161.85
SML	104,202.62	27,468.61	38,638.93	20,161.85	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	KLB	MOA	SML
TPK	-	81.52	81.37	102.46	111.27
TKP	81.52	-	78.94	91.28	100.08
KLB	81.37	78.94	-	79.28	88.08
MOA	102.46	91.28	79.28	-	88.08
SML	111.27	100.08	88.08	88.08	-

Time (days)

O/D	TPK	TKP	KLB	MOA	SML
TPK	-	5	4	5	6
TKP	5	-	4	5	6
KLB	4	4	-	2	3
MOA	5	5	2	-	2
SML	6	6	3	2	-

Objective Function

Total Cost	$	161,796
Number of sailing frequency		12
Total Cost per year	$	1,941,555
Total travel time per voyage		26

3) H&S Indirect 3

Connectivity

Xij

O/D	TPK	TKP	RTE	SBU	WGP	
TPK	-	1	-	-	-	1
TKP	1	-	1	-	-	2
RTE	-	1	-	1	-	2
SBU	-	-	1	-	1	2
WGP				1		1
	1	2	2	2	1	

Cargo Allocation **Pij**

c_1 TPK

O/D	TPK	TKP	RTE	SBU	WGP	
TPK		162				162
TKP	25		3	14	145	187
RTE		1		-		1
SBU		1	-		-	1
WGP		23		-		23
	25	187	3	14	145	

Ship capacity constraint Occupancy

∑(t∈T) Ut = 192 84%

O/D	TPK	TKP	RTE	SBU	WGP	
TPK	-	162	-	-	-	162
TKP	25	-	3	14	145	187
RTE	-	1	-	-	-	1
SBU	-	1	-	-	-	1
WGP	-	23	-	-	-	23
	25	187	3	14	145	

Distance (Nm)

O/D	TPK	TKP	RTE	SBU	WGP
TPK	-	795	840	920	1,039
TKP	795	-	89	104	279
RTE	840	89	-	80	199
SBU	920	104	80	-	119
WGP	1,039	279	199	119	-

Fixed Cost (USD)

O/D	TPK	TKP	RTE	SBU	WGP
TPK	-	16,268.32	51,274.19	60,093.90	65,507.90
TKP	16,268.32	-	4,805.40	5,211.24	24,083.08
RTE	51,274.19	4,805.40	-	5,160.71	13,632.38
SBU	60,093.90	5,211.24	5,160.71	-	7,020.26
WGP	65,507.90	24,083.08	13,632.38	7,020.26	-

Variable Cost (USD/TEU/Nml)

O/D	TPK	TKP	RTE	SBU	WGP
TPK	-	81.52	74.64	74.64	73.27
TKP	81.52	-	76.29	76.29	87.28
RTE	74.64	76.29	-	57.87	67.68
SBU	74.64	76.29	57.87	-	67.68
WGP	73.27	87.28	67.68	67.68	-

Time (days)

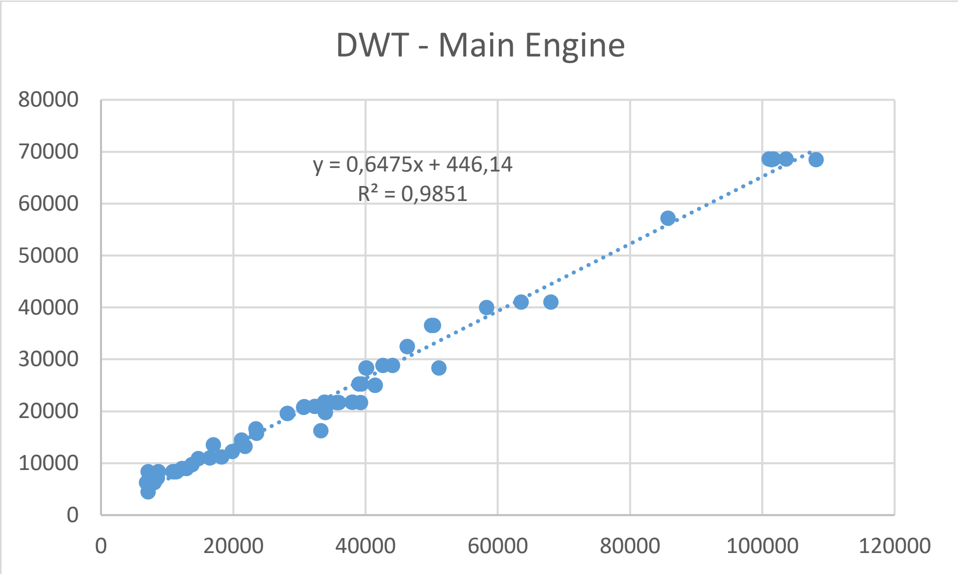
O/D	TPK	TKP	RTE	SBU	WGP
TPK	-	5	4	5	5
TKP	5	-	1	1	2
RTE	4	1	-	1	2
SBU	5	1	1	-	2
WGP	5	2	2	2	-

Objective Function

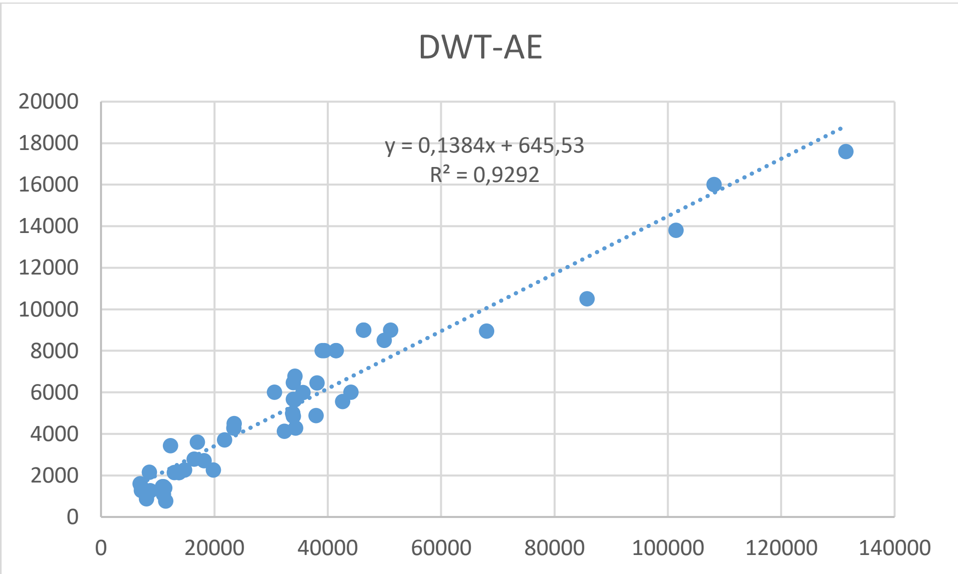
Total Cost	$	97,867
Number of sailing frequency		12
Total Cost per year	$	1,174,409
Total travel time per voyage		18

Appendix 5. Regression Formula

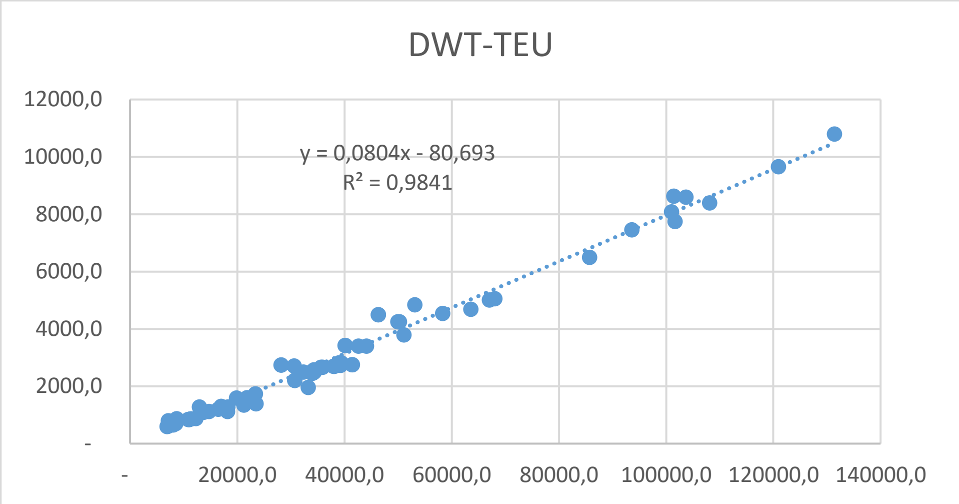
1. DWT – Main Engine (ME)



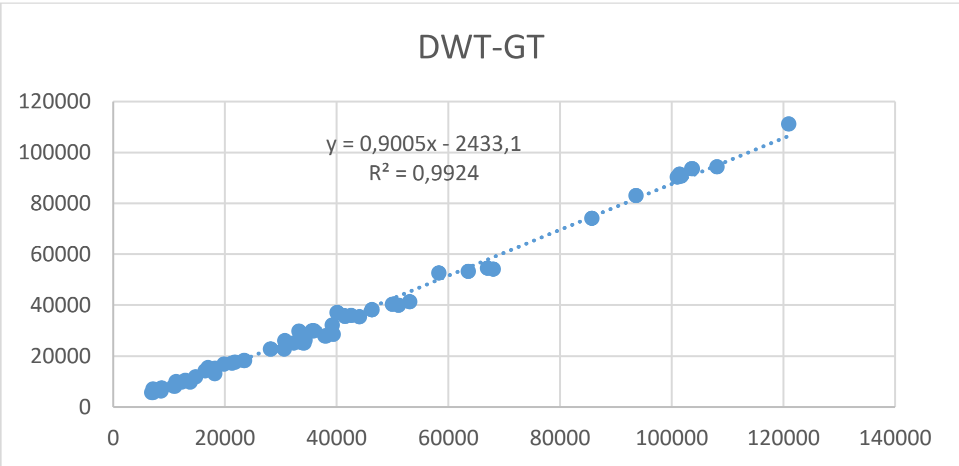
2. DWT – Auxaliary Engine (AE)



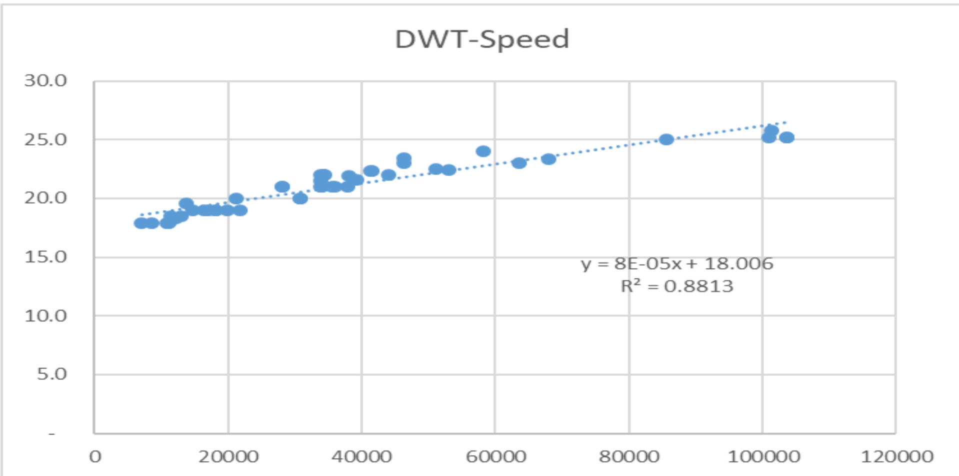
3. DWT - TEU



4. DWT – GT



5. DWT – Speed



Appendix 6. Cost Comparison

The Route	Name of the Port	Ship's Capacity (Teu)	Number of ships needed per month	Number of Sailing Frequency per year	Traveling time (days)	Utilizati-on of vessel	Total Shipping Cost per route
N-1		192	4	48	26	95%	$ 15,797,353
N-2		199	4	48	26	98%	$ 16,995,622
N-3		135	2	24	14	79%	$ 2,167,448
Total Shipping Cost							**$ 34,960,423**
N-1		115	1	12	12	28%	$ 1,347,655
N-13		192	4	48	20	91%	$ 15,112,078
N-2		200	1	12	16	57%	$ 2,963,685
N-11		199	4	48	20	84%	$ 16,486,649
N-3		135	2	24	14	79%	$ 2,167,448
Total Shipping cost							**$ 38,077,514**
H&S 1	**Wanci**	**115**	**1**	**12**	**16**	**18%**	**$ 1,052,916**
H&S 2	Namlea	115	1	12	16	10%	$ 1,068,166
H&S 3	Fak-Fak	115	1	12	18	92%	$ 1,709,060
H&S 4	Kaimana	135	1	12	18	84%	$ 1,705,864
H&S 5	Timika	200	3	36	20	79%	$ 8,475,156
H&S 6	Saumlaki	115	1	12	16	10%	$ 1,075,838
H&S 7	Kalabahi	135	1	12	14	68%	$ 856,503
H&S 8	Moa	115	1	12	16	10%	$ 1,074,570
H&S 9	Dobo	115	1	12	16	88%	$ 1,306,072
H&S 10	Merauke	200	3	36	20	96%	$ 9,878,574
H&S 11	Larantuka	115	1	12	12	30%	$ 615,557
H&S 12	Lewoleba	115	1	12	12	17%	$ 558,138
H&S 13	Rote	115	1	12	12	2%	$ 511,451
H&S 14	Sabu	115	1	12	12	10%	$ 538,235
H&S 15	Waingapu	192	1	12	16	76%	$ 1,144,394
Total Shipping cost							**$ 31,570,494**

The Route	Name of the Port	Ship's Capacity (Teu)	Number of ships needed	Number of Sailing Frequency per year	Traveling time (days)	Utilizati-on of vessel	Total Shipping Cost per route
H&S Indirect 1		115	1	12	22	85%	$ 1,606,853
H&S Indirect 2		192	1	12	26	73%	$ 1,941,555
H&S Indirect 3		192	1	12	18	84%	$ 1,174,409
H&S 3	Fak-Fak	115	1	12	18	92%	$ 1,709,060
H&S 4	Kaimana	135	1	12	18	84%	$ 1,705,864
H&S 5	Timika	200	3	36	20	79%	$ 8,475,156
H&S 9	Dobo	115	1	12	16	88%	$ 1,306,072
H&S 10	Merauke	200	3	36	20	96%	$ 9,878,574
Total Shipping cost							**$ 27,797,543**