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Analyzing the National Logistics System through Integrated and Efficient Logistics Networks: a Case Study of Container Shipping Connectivity in Indonesia

by

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Acknowledgments

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Abstract

Indonesia, as a maritime country should be able to integrate inter-island into a coherent whole and sovereign country. In order to face Indonesia government's plan with respect to the international hub ports issue, whereby Indonesia should have its own international hub port in the future, so that it no longer depends on neighbouring country ports. Hence, this study is required to analyse the connectivity between main domestic ports and international hub ports in Indonesia, according to the National Logistics System. We apply a heuristics approach by combining the Feeder Network Design Problem (FNDP) and Multiple Commodities Problem to create the optimum routes as well as to allocate the cargo by minimizing the total transportation costs.

Two scenarios are applied in the calculation due to the closer distance between Kuala Tanjung as one of the proposed international hub ports and Belawan as one of the main domestic ports. The first scenario, we analyse all international containers of six main domestic ports (with Belawan), while the second scenario does not consider the international containers in Belawan (without Belawan). It means that the second scenario only considers to the five remaining main domestic ports, excluding Belawan, because it is possible to deliver Belawan's international containers to Kuala Tanjung directly by using land transport or short-sea shipping.

As the results, we obtain two optimum routes for each scenario that consist of direct and indirect loop. A direct loop connects between hub and main domestic port directly, whereas an indirect loop calls at multiple main domestic ports. The results of the first scenario "with Belawan", one indirect loop (one integrated route) has the total shipping costs of USD 76.9 million by using the maximum ship capacity (Qt) within range 56,313 to 72,447 TEUs. Meanwhile, two indirect loops (west and east route) produce the lower total costs of USD 64.94 million by using the Qt at least of 72,448 TEUs. On the other hand, the results of the second scenario "without Belawan" are combined routes and two indirect routes. The combined routes consist of one direct route and one indirect route. It produces the total costs of USD 51.6 million by using the Qt is within range 56,313 – 80,446 TEUs. Meanwhile, two indirect routes gain the lower total costs of USD 50 million by using the value of Qt at least 80,447 TEUs. Overall, if the larger ship capacity used on these routes, then each route will have the fewer legs and shorter distances. Consequently, it will have the lower total shipping costs due to the fewer number of ships required to serve this kind of routes.

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List of Abbreviations

A	AE	Auxiliary Engine
B	BICT	Belawan International Container Terminal
	BLW	Belawan Port
	BNA	Banjarmasin Port
	BTG	Bitung Port
C	CHC	Container Handling Charges
	CSSOM	Container Shipping Scheme Optimization Method
	CY	Container Yard
D	DWT	Deadweight
F	FNDP	Feeder Network Design Problem
G	GT	Gross Tonnage
H	HMC	Harbour Mobile Crane
	HP	Horse Power
	HSD	High Speed Diesel
I	IPC	Indonesia Port Corporation
J	JICT	Jakarta International Container Terminal
K	KP3EI	Committee of Indonesia Development Expansion and Acceleration
	KTJ	Kuala Tanjung Port
L	LPGA	Linear Programming Genetic Algorithm
	LSNDP	Liner Shipping Network Design Problems
	LWS	Low Water Spring
M	ME	Main Engine
	MIP	Mixed Integer Programming
	MKS	Makassar Port
	MP3EI	Masterplan for Acceleration and Expansion of Indonesia Economic Development
	MTI	Multi Terminal Indonesia
N	Nm	Nautical miles
O	O/D	Origin-Destination
P	Pelindo	Pelabuhan Indonesia
R	RTG	Rubber Tyred Ganry Crane
S	SFOC	Specific Fuel Oil Consumption
	SISLOGNAS	Blueprint for Development of National Logistics System
	SRG	Sorong Port

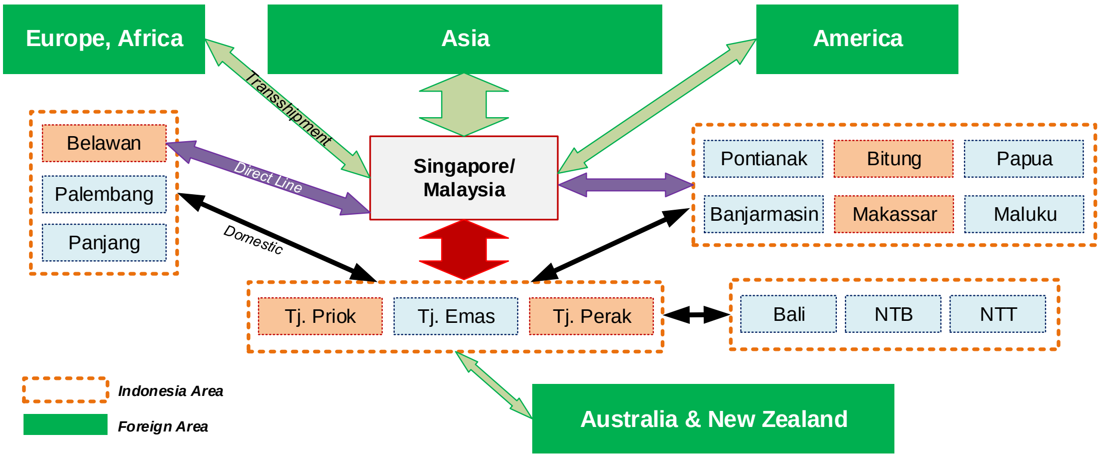
T	TEU	Twenty-Foot Equivalent Unit
	TPK	Tanjung Perak Port
	TPKB	Banjarmasin Container Terminal
	TPR	Tanjung Priok Port
	TPS	Surabaya Container Terminal
	TSP	Travelling Salesman Problem

1. Introduction

1.1. Problem Identification

Indonesia, as the world's largest archipelagic country, has more than 17.000 islands spread over a territory from west to east with the total coastal line of 81.000 km (Bahagia, et al., 2013). Under this geographical condition, the maritime transportation plays a critical role as a basic infrastructure for connecting inter-island economic activities. Therefore, the connectivity has been becoming an important factor in the maritime transportation sector, especially for driving a balance-trade throughout a territory of Indonesia.

Nowadays, Indonesia is depending on neighbouring countries with respect to the distribution of international trades. Based on the Logistics Report (2015), 90% of Indonesia's export and import commodities are transhipped through international hub ports in Singapore and Malaysia (Bahagia, et al., 2015). As shown in Figure 1, all of international cargo should firstly be transhipped on the international hub ports before they continued to distribute within domestic area. Furthermore, huge amount of international trades derive from Java region, where two biggest ports are located in this region, Port of Tanjung Priok (Jakarta) and Port of Tanjung Perak (Surabaya) (Statistics Indonesia, 2014). Because Port of Tanjung Perak is the main gateway of domestic-trade especially for eastern of Indonesia, so it is not surprising if it has numerous cargo to be transhipped and distributed to eastern area. Meanwhile, according to IPC (2014), Port of Tanjung Priok has certainly the largest amount of international cargo, because it is located on the capital city of Indonesia, which has many economic activities that can support surrounding trades. However, several shipping companies, which have cooperation with other countries, could transport their international cargo directly, i.e. from Port of Tanjung Perak - Surabaya to Darwin – Australia. It is allowed as long as there are availability of vessels and port facilities.



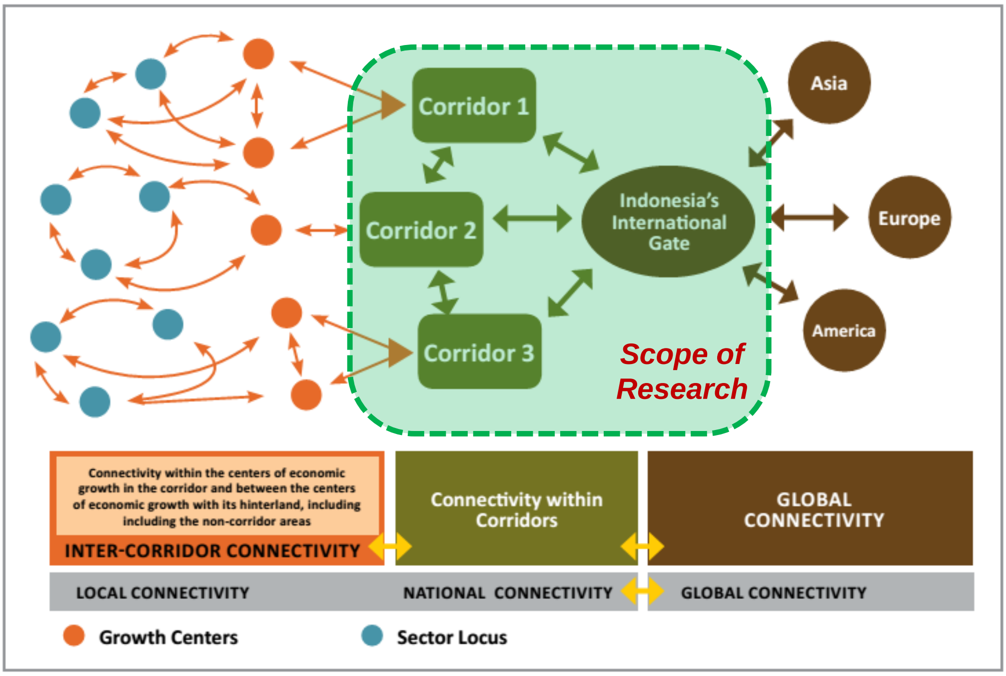
Source: Modified from National Logistics System, 2012

Figure 1 The Current International Container Connectivity

Moreover, one of dominant issues has been appearing that export commodities from east region of Indonesia should firstly be transported to the main domestic ports (Tanjung Priok or Tanjung Perak), before they continue to the final destination. In fact, the location of export cargo is closer to be reached directly to the destination countries (especially in Asia Pacific region) rather than should go first to either Tanjung Priok or

Tanjung Perak. Therefore, under the current condition of high transportation cost, it is difficult for local products to be competitive in the global market (Prasetyadi & Widianto, 2004).

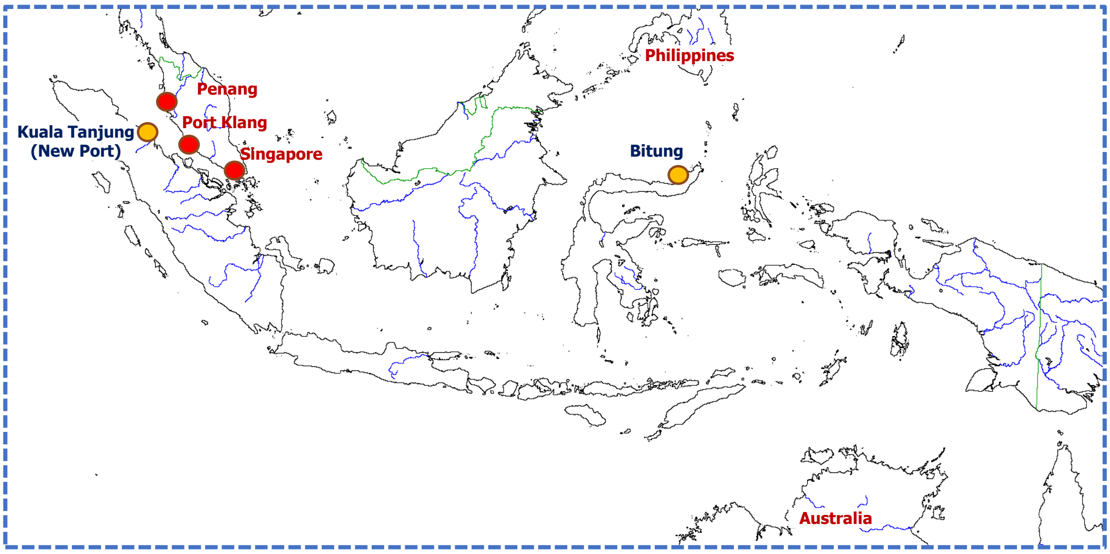
In order to minimize those impacts, so the Indonesia government through the Blueprint for Development of National Logistics System (Sislognas) creates a strategic role to develop the national logistics system as one of the infrastructures in building national competitiveness (KP3EI, 2012). In line with the Masterplan for Acceleration and Expansion of Indonesia Economic Development 2011-2025, the government formulated vision and mission under the blueprint to support the implementation of strategic role. One of its missions stated that Indonesia government along with stakeholders should create national logistics nodes and build the connectivity starting from rural, urban, inter-regional and inter-island to International hub port (Raza, 2013). It means that for the future logistics system in Indonesia should consider the international hub port issue. By having its own international hub port in the future, Indonesia no longer depends on neighbouring country ports, i.e. Singapore, in order to distribute international goods. Hence, it would be a driver for accelerating the economic development in Indonesia.



Source: Modified from National Connectivity Framework, MP3EI (2011)

Figure 2 National Connectivity Framework based on the MP3EI

Currently, the existing hub port that has dominantly been used by Indonesia to support its international trade is Port of Singapore. However, the Indonesia government would have a plan to build two international hub ports in the future as stated under the Sislognas' blueprint. Based on the KP3EI (Committee of Indonesia Development Expansion and Acceleration), two proposed international hub ports are Kuala Tanjung and Bitung that will serve the export and import cargo from western and eastern of Indonesia, respectively (see in Figure 3). The reason why Kuala Tanjung is choosen because for the west side, Sumatera Island is a gate of Indonesia from the worldwide market, thus it is important for the international hub port to be set in the east side of Sumatera, where Malacca Strait is located. On the other side of Indonesia, Bitung is selected as international hub port for east region of Indonesia, because the growth in eastern Indonesia tends to be higher than the western Indonesia due to abundant natural resources and closer access to the potential market especially in Asia Pacific region.



Source: Modified by Author from http://papuaweb.org/

Figure 3 The Location of Two Proposed International Hub Ports

As a maritime country, Indonesia should be capable of effectively and efficiently integrate inter-island into a coherent whole and sovereign country. In order to face Indonesia's plan with respect to the international future hub ports issue, this study is required to analyse the national logistics system through integrated and efficient logistics networks by creating the optimum connectivity for container shipping, between main domestic ports and international hub ports. Connectivity itself does not only mean the existence of routes in the certain logistics network, but also should consider to the availability and the number of vessels that can serve these routes. Meanwhile, the number of ports within a logistics network should be taken into account, because these ports should have sufficient facilities to handle both ship and container at the same time. Moreover, this study must also be in line with National Development Planning, which would be able to accelerate and expand the economic development in Indonesia by strengthening national connectivity. In other words, by implementing this research in the future, it would lead to balance-trade and improve regional economic potential for whole regions in Indonesia.

1.2. Research Question

After identified the problems, the main research question is formulated as follows:

"How to analyse the connectivity between main domestic ports and international hub ports in Indonesia, according to the National Logistics System?"

To answer the main research question properly, we divide it in three sub-research questions as follows:

1. How does the current Indonesian shipping transportation look like in practice?
2. How to create connectivity between main domestic ports and international hub ports in Indonesia for minimum costs?
3. What are the costs for creating connections between main domestic ports and international hub ports?

Generally, the main objective of this study is to analyse the National Logistics System especially through the container shipping connectivity by creating the optimum route from main domestic ports to international hub ports. This study also provides recommendations for the Indonesia government to build integrated and efficient logistics networks, especially from the container shipping connectivity point of view. Moreover, the following secondary objectives can be derived:

1. To analyze the current Indonesian shipping transportation in terms of container shipping connectivity.
2. To create connectivity between main domestic ports and international hub ports in Indonesia for minimum costs.
3. To determine the total costs as an impact of connections between main domestic ports and international hub ports.

1.3. Scope and Limitation of Research

In order to clarify the topic and make the problem more specific, the scope and limitation of research are defined as follows:

1. Only container export and import trades will be considered in the analysis. It means that we do not consider to domestic trades.

2. For the hinterland analysis will be focused on main domestic ports only. It means that the connectivity from rural to main domestic ports will not be analyzed.

3. This study aims to create optimal routes between main domestic ports and international hub ports. Thus, the analysis will be started from main domestic ports to international hub ports. However, the result merely provides the maximum ship capacity in every optimal route without considering the number of ship required to serve these routes.

4. Indonesia has 15 main domestic ports and this study only uses six main domestic ports; Belawan, Tanjung Priok, Tanjung Perak, Banjarmasin, Makassar and Sorong, because these ports are the representative of each region as well as data are available only for these main domestic ports.

1.4. Thesis Structure

The remaining of this study is organized as follows:

Chapter 2 provides the literature review, which gives an account of relevant previous studies related to this thesis. There are three parts in this chapter. The first part is National Logistics System in Indonesia. The second part is the network-planning concept especially to provide the overview about the useful method to obtain the new optimum route. The last part describes the theoretical approach of determining the total costs in term of shipping operational performance that including shipping costs and shipping charters concepts.

Chapter 3 depicts the method used to find out the new optimum routes from the main domestic ports to international hub ports and vice versa. Linear programming is used to develop the model and to calculate the minimum cost for each routing alternative. Moreover, the assumption, the description of two scenarios under the research methodology scheme and data related to the model calculation will be introduced in this chapter.

Chapter 4 identifies the existing Indonesian container shipping connectivity in the National Logistics System scheme, such as the overview on main domestic ports and two proposed international hub ports, the number of container ship currently served international containers, hinterland market analysis and demand projection.

Chapter 5 provides the answer of the remaining sub-research questions. This chapter also describes the shipping cost analysis, the results of routing analysis and the maximum ship capacity required based on two scenarios, with Belawan and without Belawan's international containers. In the end of this analysis, the comparison between two scenarios are conducted as the result in which route can obtain the minimum total shipping costs.

Chapter 6 is the last chapter that consists of conclusion and recommendation. All of the analysis results will be described on the conclusion part. Meanwhile, we provide recommendations for both the further study and the Indonesia government to build integrated and efficient logistics networks in term of the container shipping connectivity.

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2. Literature Review

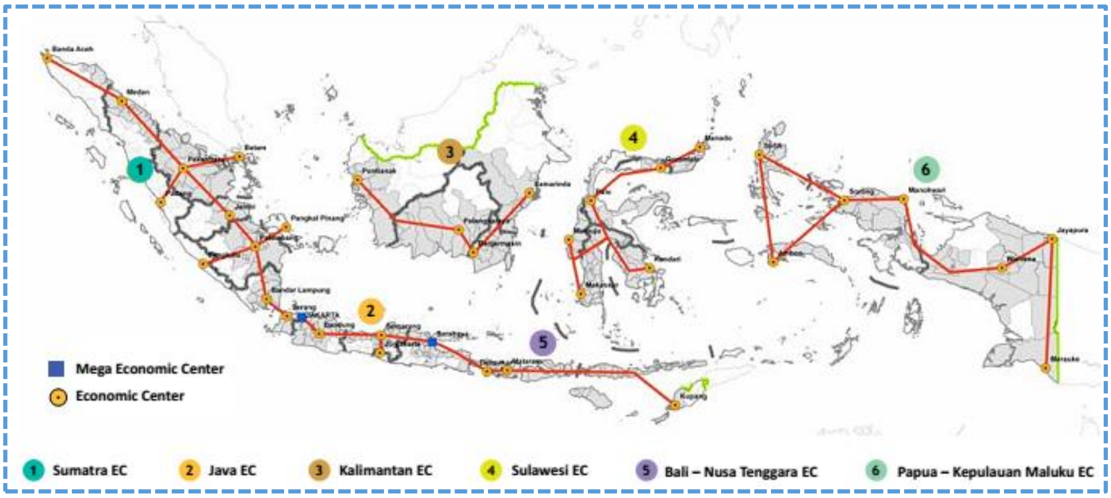
This chapter describes in more detail about the National Logistics System in Indonesia to provide the background of the topic, which is the most important thing for the future logistics system in Indonesia should be capable of handle the international trades by having own international hub port in the future. Thus, Indonesia would be independent in order to distribute international goods and no longer depends on the neighbouring countries. Following that, we explain network-planning models by reviewing the previous studies that related to the minimizing the total shipping costs in order to figure out how the network model in liner shipping works by implementing the operation research approach and mathematical formulation. In the last sub-chapter, we provide some basic theories about transportation costs including shipping costs and shipping charters to support the analysis on the National Logistics System through the container shipping connectivity by considering the minimum total transportation cost on the network model.

2.1. National Logistics System

National Logistics System is a concept of Indonesia government to support the implementation of the Masterplan for Acceleration and Expansion of Indonesia Economic Development (MP3EI) 2011 – 2025. The implementation strategy of MP3EI integrates three main elements:

1. *Developing the regional economic potential in six Indonesia Economic Corridors.*
2. *Strengthening national connectivity locally and internationally.*
3. *Strengthening human resources capacity and national science and technology to support the development of main programs in every economic corridor.*

(Coordinating Ministry For Economic Affairs, Republic of Indonesia, 2011, p. 28)



Source: Modified from MP3EI (2011)

Figure 4 Indonesia Six Economic Corridors

Underlining the concept of connectivity, the connectivity agenda has three main objectives: reducing regional disparities; accelerating poverty reduction; and enhancing competiveness. Meanwhile, these objectives could be achieved by reducing interisland shipping costs; lowering transport costs for rural citizens; upgrading access and enhancing efficiency of international ports. Therefore, the government formulated the vision and mission under the Sislognas' blueprint to develop the National Logistics System as one of the infrastructures in building national competitiveness. As mentioned on the mission that for the future logistics system, Indonesia should consider having its own international hub port.

According to the KP3EI (2012), Indonesia government planned to have two new international hub ports that will be located at Kuala Tanjung as the west hub port and at Bitung as the east hub port. The following figure shows the location of both international hub ports:

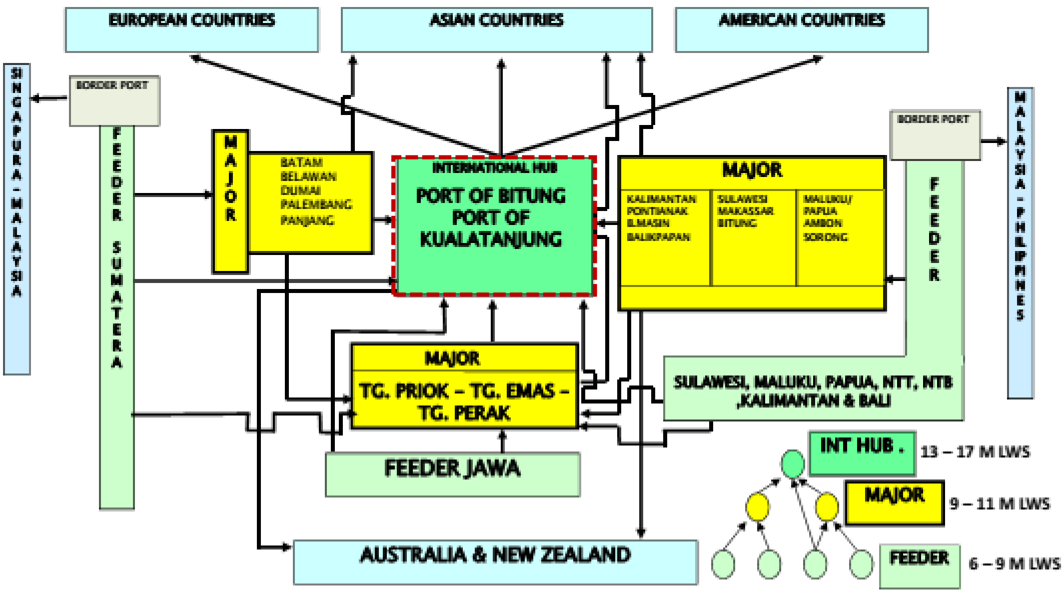
Source: Modified from Port Developments in Pelindo I (2014)

Figure 5 Strategic Action Plan for Facilitating Trade on the National Level

Sumatera is expected to be the national economy gate to the Europe, Africa, South Asia, East Asia, and Australia markets. Because, it produces the large value of palm oil, rubber, coal, shipping materials, and iron ore. Hence, one of the reasons Kuala Tanjung is selected to be the international hub port because it would be able to support the Sumatra Economic Corridor. Moreover, its location is strategic, which is in the east side of Sumatera.

On the other hand, the determination of Bitung as the international hub port by KP3EI is affected by the logistics dynamic in eastern of Indonesia, which is expected to grow exponentially. Northern Sulawesi itself has nearly all the assets and accessibilities to be the centre of global growth. Moreover, Bitung has close access to Malaysia, Korea, Japan, China, and Hong Kong markets, so it can be a potential location to be an engine of economic growth in this corridor.

However, two proposed international hub ports will have a huge impact on the connectivity of interisland so that it can actualize the balance-trade throughout a territory of Indonesia. If these hub ports will be implemented then Indonesia will be more independent in managing the distribution of goods, especially for international trade and will not depend on the Port of Singapore anymore. As shown in Figure 6, the international hub port has accessibility to connect the international cargo with other countries. Meanwhile, the main port (domestic hub port) has a role to collect the export cargo from the rural area by using feeder lines and then has to transport it to the international hub port. Conversely, from the international hub port, the import cargo should be distributed to the main port first, thus it has to be continued to the final destination by using feeder lines. Therefore, the role of main port is very important in this supply chain because it has to organize both domestic and international cargo simultaneously. The current condition, Indonesia has 15 major ports: Batam, Belawan, Dumai, Palembang, Panjang, Tanjung Priok, Tanjung Emas, Tanjung Perak, Pontianak, Banjarmasin, Balikpapan, Makassar, Bitung, Ambon dan Sorong, but only six major ports as domestic hub ports that can handle the international cargo, which are Belawan, Tanjung Priok, Tanjung Perak, Banjarmasin, Makassar dan Sorong (Ministry of Transportation, 2014).



Source: Modified from Port Developments in Pelindo I (2014)

Figure 6 Hierarchy of Port

2.2. Network-Planning Models

According to Ronen (1983, 1993) and Christiansen et al. (2004) who reviewed the literatures on ship routing stated there were only a few studies on the optimization of container shipping routes before 2000. However, since 2000, many researchers have started to conduct study on this field especially on the optimization of liner shipping routes. For instance, Notteboom and Vernimmen (2009) studied the optimization of liner services and shipping routes by focusing on the slot allocation on routes and the impact on the bunker costs. Moreover, Takano and Arai (2009) conducted the optimization of shipping routes by applying hub-and-spoke network concept. In their concepts, they had a fixed slot allocation plan that complied all demand in the ports, thus they used it into a ship routing model. Therefore, in this study, we particularly focus on the literature dealing with the creating optimum shipping routes by considering the impact of cargo slot allocation on routes.

2.2.1. Optimization Method in the Liner Shipping Routing

Yang, et al (2012) developed a new Container Shipping Scheme Optimization Method (CSSOM) to optimize the shipping route and the container slot allocation on vessels by considering the interactions between the container shipping scheme and the transport demand in the ports. A CSSOM itself was developed as a combination between a heuristic and the genetic algorithm. For the first process, they built a Mixed Integer Programming (MIP) model that can optimize the shipping route and the slot allocation simultaneously. Moreover, on the second process, they considered to the transport demand (from the port city and from inland cities and regions). It affected on the cargo flow behave when choosing a port of loading. Overall, because there was no efficient method to obtain the proper solution of the MIP model, thus they used the linear programming model by simplifying the MIP model (if the shipping route was given). Finally, they developed a Linear Programming Genetic Algorithm (LPGA) to create the population of the initial shipping routes and to calculate the maximum profit for each routing alternative (Yang, et al., 2012).

Mulder and Dekker (2013) have conducted the study about methods for strategic liner shipping network design. They combined fleet-design, ship-scheduling and cargo-routing problem by considering the limitation of ships' availability in order to find the most profitable route with different approaching levels. They constructed initial route networks and a linear programming formulation to solve the optimization on the cargo-routing (Mulder & Dekker, 2013).

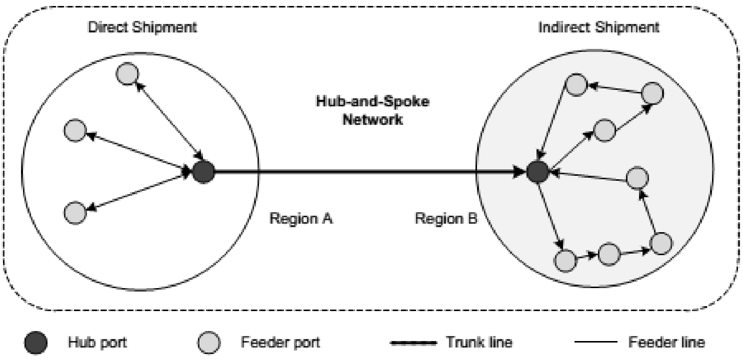
Wardhana (2014) has done another study about how the selected route has impact on the cargo allocation. The study combined two methods, Travelling Salesman Problem (TSP) and heuristics approach to create the network design. In order to find the fastest way to decide the next port after visiting one origin port, the author used the nearest neighbour algorithm as a solution method for the TSP model. Meanwhile, the heuristic was used to analyse the cargo allocation in order to find the highest profit from the selected route. The profit was determined by subtracting the revenue and the costs. The author set the possible route, which referred to the demand, and for the next routes were determined by the demand that has not been accommodated by the previous route. Overall, the heuristic was used iteratively until no more profitable route available. All calculation was made by excel spreadsheet that combined ship routing and cargo allocation by simulating all possible routes (Wardana, 2014).

It can be concluded that it requires an approach that probably combines two methods or even more to solve the ship routing problem. Because the problems in this thesis are not only to define the optimum domestic routes for international containers, but also we have to allocate these international containers, which have different total amount of export and import for each region in Indonesia. The key characteristic is that specific amounts of containers must be transported between each main domestic port and one of the international ports. It must be prevented that these are discharged or loaded on other main domestic ports. Therefore, we need to solve routing and cargo flows by combining two methods in this study, the feeder network design problem and multiple commodities problem.

2.2.2. Feeder Network Design Problem

In the global hub-and-spoke networks model of shipping lines particularly, there are two types of feeder shipping systems; direct and indirect feeder shipping. As shown in Figure 7, direct feeder shipping connects between hub and feeder port and indirect feeder shipping uses line-bundling loops, which are including more than one feeder port (Polat, et al., 2012).

A few studies have been conducted on the indirect feeder network design in order to minimize the total shipping cost. For instance, Mourao et al. (2001) applied an integer linear programming model for ship assignment on the current indirect feeder routes, Catalani (2009) determined one containership route in the Mediterranean area by proposing a cost-minimization based expert system model for sequencing and scheduling of feeder ports and Andersen (2010) used mathematical model to predefine solid indirect liner feeder networks. In addition, Yang & Chen (2010) has done the optimization of the combination of trunk and indirect feeder networks for a shipping company by applying a genetic algorithm approach. Generally, the authors developed their methods based on the heuristic approaches in order to solve the problems.



Source: O. Polat, H. Günther, O. Kulak (2014). The Containership Feeder Network Design Problem: The New Izmir Port as Hub in the Black Sea, Maritime Economics & Logistics, pp.348

Figure 7 Feeder Shipping Networks as Part of Hub-and-Spoke Network

In conclusion, the direct feeder shipping requires more feeders but lower transit time. It means that it will gain higher operational costs due to a huge number of feeder vessels used. On the other hand, indirect feeder shipping gives more advantages from the economies of scale point of view. Even though it reduces a number of feeder vessels but incurs longer distances and longer transit times. Therefore, by considering the number of main domestic ports and two proposed international hub ports to analyse the national logistics connectivity in Indonesia, so we apply the feeder network design to define the optimum shipping routes that can obtain the minimum total shipping cost.

2.2.3. Multiple Commodities Network Design Problem

In spite of a few studies about multiple commodities on Liner Shipping Network Design Problems (LSNDP), however Lee et al. (2006) developed a multi-commodity network flow model to evaluate the impact of container throughput in Asia's port by varying terminal handling charges and turnaround time. On the model development phase, the authors emphasized to minimize the total costs of transporting containers from port of origin to destination as well as to represent container flows within Asia and the interactions between Asia and the rest of the world.

In addition, Plum et al. (2012) have conducted study about the multi-commodity one-to-one pickup-and-delivery by using Traveling Salesman Problem with path duration limits in order to minimize operational costs and to obtain the best paying cargo under commercial constraints. They proposed a branch and cut and price as a solution method to guide the optimal deployment of ships by presenting an arc flow and a path flow model based on LSNDP (Plum, et al., 2012).

In this study, we consider multiple commodities problem because we need to differentiate cargo related to each individual domestic port. For instance, the number of export/import containers belong to Port of Belawan cannot be discharge at any other main domestic port. It means that every ship, which will serve optimum routes (direct or indirect loop), should carry multiple commodities from/to the main domestic ports. Every main domestic port has a role as a representative of its region to receive and deliver the international cargo, so the export and import cargo is strictly related to each port. We could accommodate it by solving the routing for multiple commodities.

2.3. Transportation Cost

The liner shipping has unique characteristics, which are type of operations is very dynamics and diversity in the majority of cost component. Profitable and quality of shipping will be determined by the operational performance. Meanwhile, scheduling, ship routing, and ship size are different factors, which influence operational performance of container shipping. Due to the larger service of liner shipping, it will allow to use the bigger vessel to serve the demand. Therefore, the economies of scale is being important for liner shipping. This concept suggests that a larger vessel will have cheaper cost compare to small vessel. However, other cost components might increase of total cost, for instance time spent in port due to the lower crane productivity and a huge number of cargo loaded/unloaded (McLean & Biles, 2008). Because, the longer time spent in port could rise not only the port handling charges and port dues, but also fuel cost at port.

2.3.1. Shipping Cost

Commonly, the operational performance of ship can be described by total revenue and total cost are gained. The total revenue is derived by multiplying the freight rate and the total transported cargo. Meanwhile, the total shipping cost is the function of both ship-operating costs and fixed costs. In general, ship-operating expenses can be grouped into four cost components (Stopford, 2009). Combined with fixed costs, this gives five components:

1. Capital cost
   Capital costs are fixed costs, they are counted by ship prices at the time of purchase or construction. Capital costs are included in the cost calculation to cover interest payments and return of capital depending on how the way the ship has been financed. Returning on capital value is reflected as an annual payment.

2. Maintenance cost
   A maintenance and repair costs cover all requirements to maintain a vessel according to the company policy and the standard of classification societies, these costs are divided into three categories as follows: classification survey, periodic maintenance and repair.

3. Operating cost
   Operating costs are incurred for the operational aspects of daily running ship. These costs consist of crew, stores, groceries, lubricating oil, insurance and administration. In some cases, maintenance costs are also entered into operating costs.

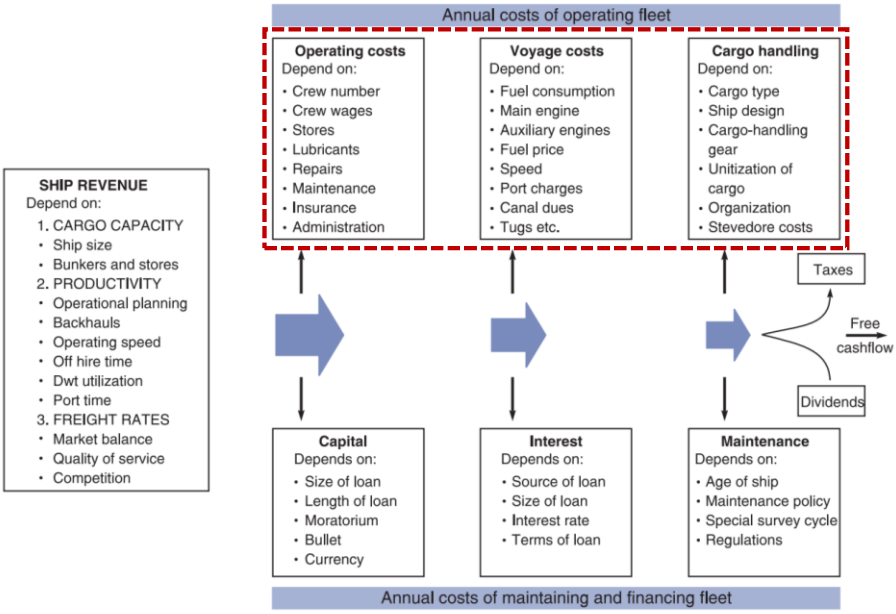
4. Voyage cost
   Voyage costs are variable costs incurred for the specific voyage. The components of these costs include fuel and port charges.

   a. Fuel cost
      Fuel consumption depends on several variables such as ship size, shape and condition of the ship hull, speed, weather (waves, currents, and winds), type and capacity of main engine and auxiliary engine and type of fuel. Therefore, fuel costs depend on the fuel prices and daily fuel consumption over the sea and port.

   b. Port dues
      Port dues are fees charged for using port facilities such as tugging, berthing, mooring, harbor pools and other facilities, which depend on the ship capacity and ship volume (gross tonnage and net tonnage). Berthing cost and penalty costs will be charged if a vessel overstaying of port schedule.

5. Cargo handling cost
   Cargo handling cost affects also on the shipping costs. These costs occur in port related with stevedore and container storage charges. Generally, storage charges are based on types of containers, empty or full-loaded containers and including container transshipment or not. Another cost is container cost, which lease containers fee per day (Gkonis & Psaraftis, 2009).

In more detail, the component cost of ship can be seen in the following figure:



Source: Modified from Maritime Economics, 3rd Edition, Martin Stopford, 2009, p. 220

Figure 8 Shipping Cash Flow Model

After explaining the cost components in shipping, thus we generally relate this concept with our methods used to solve the problem in this thesis. According to Polat et al. (2012), the FNDP requires both delivery and pick-up operations. In other words, the feeder vessel that has certain capacity should serve each feeder port for both operations. Each vessel departs from hub port by carrying the total amount of containers that must be delivered and then returns to the hub port by carrying the total amount of containers that must be picked-up. Thus, the following table shows the basic calculation of total costs by using the FNDP model:

Table 1 The Related Basic Cost Calculations

Parameter	***Basic formulation***
Total cost	Fixed cost + Variable cost
Fixed cost	No. of ship*(chartering + operating + administration cost)
Variable cost	No. of service*(bunker at sea + bunker at port + port charges)
No. of ship	(Voyage duration + lay-up duration) / service frequency
No. of service	Planning period / service frequency
Voyage duration	On sea duration + On port duration (feeder + hub)
Idle duration	No. of ship * service frequency – (voyage + lay-up duration)
Total ship duration	Voyage duration + lay-up duration + idle duration

Source: O. Polat, H. Günther, O. Kulak (2014). The Containership Feeder Network Design Problem: The New Izmir Port as Hub in the Black Sea, Maritime Economics & Logistics, pp.350

The feeder network design of shipping lines depends on "*the characteristics of feeder ships, characteristics of feeder ports, container demand and supply volumes of the ports and bunker costs as well as the operating/chartering/administration costs of the ships"* (Polat, et al., 2012, pp. 347-348). Moreover, according to the Hsu & Hsieh (2007), total shipping costs can be calculated as the sum of capital and operating costs, the fuel costs and the port charges (Hsu & Hsieh, 2007).

2.3.2. Shipping Charter

In the carriage of goods by sea, commonly we can use either our own vessels or charter vessels. In practice, there are three type of charters; bareboat charter, time charter and voyage charter. According to Stopford (2009), the description of these charters can be explained as follows:

1. Bareboat charter
   Bareboat charter is an arrangement for chartering a ship whereby this ship is in "empty" conditions. It means that the owner finances the vessel and receives a charter payment, while the operational of ship including voyage and cargo-related costs become the responsibility of the charterer. It seems like rent a car on vacation while driving it ourselves and we pay for fuel and insurance. In general, the duration of the charter is extremely long (over 10 years).

2. Time charter
   Under this arrangement, the charterer should cover the fuel costs, port charges and other cargo-related costs. Commonly, charterer uses time charter because the charter hire is specified as a fixed daily payment for the hire of the vessel, i.e. $5.000 per day. Regardless, the agreed daily hire rate is depending on the market conditions, so as a charterer should take into account the market risk while dealing with this type of charters. In other words, the charterer might face the market risk due to unpredictable of daily charter rate.
3. Voyage charter
   The charterer hires the ship for a particular voyage, from A to B, so that the freight rate is paid per unit of cargo transported, i.e. $20 per ton. Generally, under this arrangement, the owner should pay all the costs including operating costs, port costs and bunkers. Only for the cargo handling costs is not included under the owner's responsibility.

Furthermore, we consider to apply the time charter method for determining the fixed costs, because the rate is stated as a fixed daily payment for certain period. Moreover, under this charter already covers all costs, except for fuel costs and port charges, as explained on the description above. Hence, we calculate the total shipping costs as the sum of operating costs based on the time charter rate, port dues and cargo handling charges.
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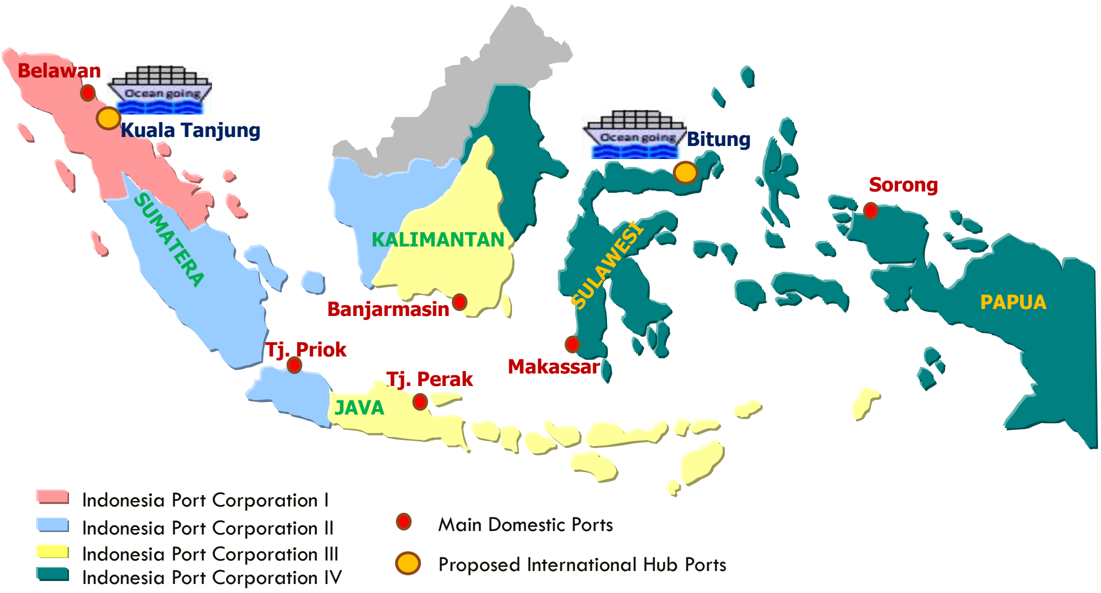
3. Research Methodology and Data

After describing the literatures about network-planning models, in this chapter we present the method and the data used. We decide to apply a heuristics approach by combining the FNDP and multiple commodities problem to create the optimum route as well as to allocate the cargo by minimizing the total transport costs. As shown in Figure 9, the scope of areas is started from main domestic hub ports to international hub ports and vice versa. There are six main domestic hub ports and two international hub ports. That is why the FNDP model fits to solve this problem, because for the certain container ship will perform simultaneously container pickups and deliveries between main domestic ports and international hub ports in order to minimize the total costs. Meanwhile, we consider the multiple commodities problem to allocate the number of international containers that belongs to each main domestic port in every region. Hence, we have introduced multiple commodity flows into our FNDP formulation.



Source: Modified from Indonesia Port Corporation III (2012)

Figure 9 The Scope of Hinterland Area in Indonesia for the FNDP Model

3.1. The FNDP Model for the Indonesian International Hub Port

Normally, the total costs can be calculated as the sum of capital cost, fuel cost, port dues and cargo handling charges. In this thesis, we assume that all ships served the route m are chartered by using time charter arrangement with charter rate in unit dollar per day (USD/day), thus we change the capital cost by applying charter rate in this cost calculation. The following formulation is used to determine the total costs:

$$Cm = \sum_{i\,\in N} \left[Ot\,Wi + Fit + dij\left(\frac{Ot}{Vt} + \frac{Ft}{Vt}\right)\right] + \sum_{i\in N}\sum_{j\in N}\left[Pi\,Wi + \left(Hi + \frac{Ot}{Ri}\right)(Pijc)\right]$$

Where:

Ot : Average daily charter rate for a ship of type t [USD/day]
Wi : Total waiting time a ship of type t spends in port i [day]
Fit : Fuel cost in port i by a ship of type t [USD]

dij : Shipping distance between port i and port j on route m [Nm]
Vt : Service speed for a ship of type t [knot]
Ft : Fuel cost at sea for a ship of type t [USD/day]
Pi : Port dues in port i [USD/day]
Hi : Cargo handling charges in port i [USD/TEU]
Ri : Crane productivity in port i [TEU/day]
$Pijc$: The number of container of commodity c transported along arc (i,j)∈N [TEU]

Afterwards, we obtain the total shipping cost for every route from port of origin (port i) to port of destination (j). In order to formulate the objective function of this study, we use unit cost of one container transported per nautical miles (Cij) based on total shipping cost for every route within arc (i,j) by the different distance (dij) and the number of containers transported (Pijc). Hence, we formulate the objective function to determine the minimum total transport costs of picking up and delivering all containers on the certain route, as follows:

$$Min \sum_{i,j \in N} \sum_{c \in C} Pijc * Cij * dij$$

Subject to:

Connectivity constraints:

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

$$\sum_{i \in N} Xij = 1 \quad \forall\ j \in N \quad [2]$$

$$\sum_{j \in N} Xij = 1 \quad \forall\ i \in N \quad [3]$$

Cargo allocation constraints:

$$\sum_{i \in N} Pijc = Dj \text{ for each } j \in N' \text{ and for } c = j \quad [4]$$

$$\sum_{j \in N} Pijc = Si \text{ for each } i \in N' \text{ and for } c = j \quad [5]$$

$$\sum_{i \in N} Pijc - \sum_{j \in N} Pijc = 0 \text{ for each } i,j \in N' \text{ and for } c \neq j \quad [6]$$

$$Pijc \geq 0 \text{ for each } i,j \in N' \quad [7]$$

Ship capacity constraint:

$$\sum_{c \in C} Pijc \leq \sum_{t \in T} Qt\ Xij \quad \forall\ i,j \in N \quad [8]$$

Where:
N : All nodes including main domestic ports and international hub ports
N' : The nodes only for main domestic ports
c : Container allocation in every main domestic port
C : All containers in main domestic ports
$Pijc$: The number of container of commodity c transported along arc (i,j)∈N [TEU]
Cij : Unit cost [USD/TEU.Nm]
dij : Total distance from port i to j [Nm]

Si : Total supply of TEU export container from port i
Dj : Total demand of TEU import container from port i
Qt : Maximum capacity of ship t per voyage [TEU]
Xij : The binary variable,
Xij = 1 if traveling directly from port i to j using ship of type t and
Xij = 0 if otherwise

To achieve the goal of this study, which defines the optimum route by minimizing the total transport costs, so we have three major constraints. Firstly, we consider about connectivity constraints, equation [1] specifies that ports i and j are directly connected by the route (1) or not (0). Equation [2] and [3] indicate the sum of traveling routes should be equal to 1 for each the port of origin (i) and port of destination (j), respectively. It ensures that only one port that can be in-and-out by certain route during traveling this arc (i,j).

Due to the different amount between export and import containers in every main domestic ports, so we apply the multiple commodities problem for the second constraints, which are cargo allocation constraints. These constraints can only be considered by main domestic ports (N'), where the commodity (container), which has already belonged to one main domestic port, cannot be mixed with other main domestic ports. Thus, we formulate the equation [4], which describes the number of import container in each main domestic port (i) should be equal to the total demand on the main domestic port itself. For instance, the demand in Port of Belawan are 30,000 TEU/week, so these containers should be equal to the number of import containers to be delivered in Port of Belawan. Meanwhile, the similar way we apply for constraint [5], the number of export container in each main domestic port (j) should be equal to the total supply on the main domestic port itself. We repeat these two constraints for the remaining domestic ports.

However, to ensure that we have the proper cargo allocation constraint for each main domestic port, we add the equation [6] that shows the number of containers goes-in into one port should be equal to the number of containers goes-out, excluding the number of container belongs to port itself. These containers belong to another domestic port and remain on the feeder ship during the visit of this container port. As an example, c1 is cargo allocation for Port of Belawan, we have the total demand (d1) are 30,000 TEU/week, and the total supply are 50,000 TEU/week. This constraint only underlines on the number of containers in all main domestic ports exclude the port where the cargo allocation computed (so in this example we exclude Port of Belawan). The sum of containers goes-in should be the same as the sum of containers goes-out. Furthermore, we do the same thing for the rest of main domestic ports.

The last constraint for cargo allocation constraints is equation [7], it depicts the number of containers for each commodity in every port is greater than and equal to zero. It means that we should have a positive value for the number of containers transported within arc (i,j) only for main domestic ports.

The third constraint is for ship capacity constraint. This constraint describes the restriction of total container shipped should be less than and equal to the total capacity of container ships. We use a constant number for the total ship capacity so that all of containers can be transported properly.

3.2. Assumption

In this sub-chapter, we describe several assumptions that can be used in order to simplify the model calculation. These assumptions mostly can be applied to determine the total transport costs. Therefore, they are explained as follows:

- The demand and supply of containers come from six main domestic ports based on the total number of import and export for each region, respectively. For instance, the total import in Kalimantan region represents the demand of Banjarmasin Port. However, we use proportion in the Java region, because there are two main domestic ports, Port of Tanjung Priok and Port of Tanjung Perak. It will be explain more detail in the chapter 4 under the hinterland market analysis section.

- Two proposed international hub ports, Kuala Tanjung and Bitung, are able to handle the total amount of containers from main domestic ports.

- The total shipping time per round voyage is sum of the total time at sea and in port. The total time at sea depends on the distance between ports and the speed of container ships. Meanwhile, the total time in ports is based on the waiting time in port and the total time spent for handling the containers. However, we assume the waiting time in every port is based on the port class categorization.

- There are unlimited container ships available to serve all possible routes, where all of container ships used in this calculation are under time charter method. Because this method already covers all the costs, so we only consider the additional cost of the fuel costs and cargo handling charges into the total costs.

3.3. Research Methodology Scheme

The following explanation depicts the stages of this thesis:

1. Identifying the current condition.
   Firstly, we identify the market condition by analyzing from both supply and demand sides. The supply side describes an overview about six main domestic ports and two proposed international hub ports as well as provides the ship specification including the number of ships and ship capacity. On the other hand, the demand side consists of the total international container volume per year (2008-2013) and per region. Secondly, we conduct the demand projection as a basic calculation to obtain the number of total volume of export and import container in the future so that we can estimate how large the ship capacity required to handle them.

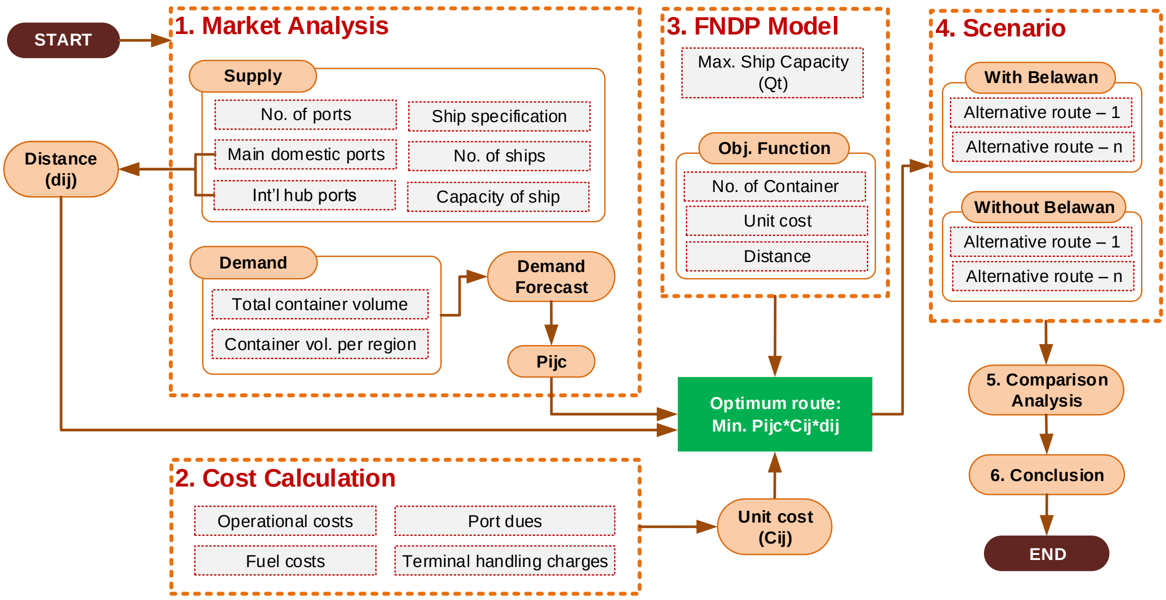
2. Determining the total shipping costs for each route by applying the formulation in Sub-chapter 3.1. In order to calculate the total costs, we firstly determine the operational costs, fuel costs, port dues and terminal handling charges. Moreover, we obtain the total costs by adding these costs. The total costs represent to the costs of every ship for one trip service (staring from port origin to destination). Afterwards, we calculate the unit cost (USD/TEU.Nm) that can be used in the model calculation.

3. Creating the FNDP model for the Indonesian International Hub Port by applying the FNDP formulation to obtain the optimum route by minimizing the total transport costs between main domestic ports and international hub ports. Moreover, we build and run the model by using Opensolver provided by Microsoft Excel.

4. Dividing the analysis becomes two scenarios. The first scenario determines all international containers of six main domestic ports (with Belawan). Meanwhile, the second scenario only considers to the five remaining main domestic ports, excluding Belawan, because Belawan has closer distance to Kuala Tanjung so it is possible to deliver Belawan's international containers to Kuala Tanjung directly by using land transport or short-sea shipping. It means that the second scenario does not consider the international containers in Belawan (without Belawan).

5. Conducting the comparison cost analysis in the end of this analysis to summarize in which route can obtain the minimum total transport costs based on the results of two scenarios.

6. Providing the conclusion and recommendation.



Source: Author

Figure 10 Research Methodology Scheme

3.4. Data

The following relevant data, which are required as inputs on the FNDP model:

A. To identify the current international container shipping services connectivity is required data from the Ministry of Transportation, as follows:
   a. Container shipping volume based on region.
   b. Number of container ships, which served international containers.
   c. Container ship capacity based on ship sizing.

B. To analyze the optimum route and to determine its total cost are required data from Shipping Companies and Terminal Operators in Indonesia. Type of data can be mentioned as below:
   a. Ship operational performance.
   b. Port facilities for international hub ports and main domestic ports.
   c. Port operational performance.

C. Additional data to determine the shipping cost are derived from website:
   a. Distance between ports is given by website (http:www.ports.com).
   b. Specification of container ships are based on the Indonesia Classification Agency (BKI Register).
   c. Time charter rate is set by the Maersk Broker 2015.
   d. Fuel price is provided by Shell Indonesia website.

4. Overview on the National Logistics System in Indonesia

In order to provide the better insight about the national logistics system in Indonesia through the current condition, thus, we briefly describe the profile of both main domestic ports and international hub ports as well as perform the number of available container ships that served the current international container volume. After describing the supply side, we look at the demand side by conducting the hinterland market analysis with regard to export-import container volumes in every port per region. Following that, we determine the demand projection based on the market analysis. Therefore, this chapter provides some argument and illustration with respect to the data input for the model calculation.

4.1. Profile of Main Domestic Ports

Indonesia has four port corporations under the Ministry of State-Owned Enterprise, namely Indonesia Port Corporation I, II, III and IV. These port corporations were established to organise the main commercial ports within region. Table 2 depicts the working areas of each IPC per province. In addition, the Ministry of Transportation has arranged the port class categorization for each port under IPC management in order to set port dues and cargo handling charges. The port class categorization consists of five categories; a main class, the first class, the second class, the third class, the fourth class and the working area class (The Ministry of Transportation, 2008). If the port is categorized as a main class, then this port can be described as a big port that has sufficient facilities to handle a huge number of various cargo. Meanwhile, the working area class indicates a small port that has lack of facilities and still need to be developed.

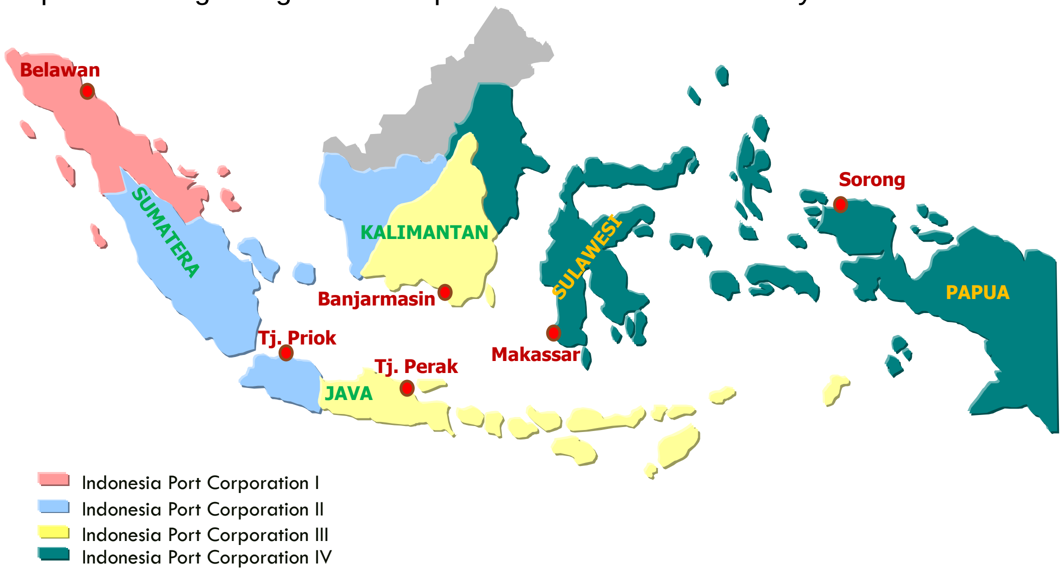
Table 2 The Working areas of IPC I - IV

Port Corporation	Working Areas per Province	Ports Administered
IPC I	Aceh, North Sumatera, Riau, Riau Islands	Belawan, Pekanbaru, Dumai, Tanjung Pinang, Lhokseumawe
IPC II	West Sumatera, Jambi, Bengkulu, Bangka-Belitung, South Sumatera, Lampung, Jakarta, Banten, West Kalimantan	Panjang, Palembang, Teluk Bayur, Pontianak, Cirebon, Jambi, Bengkulu, Banten, Pangkal Batam, Tanjung Pandan, Tanjung Priok
IPC III	Central Java, East Java, Central Kalimantan, South Kalimantan, Bali, West Nusa Tenggara, East Nusa Tenggara	Tanjung Emas, Tanjung Perak, Tanjung Wangi, Banjarmasin, Benoa, Kupang
IPC IV	East Kalimantan, South Sulawesi, South-East Sulawesi, North Sulawesi, Central Sulawesi, Maluku, North Maluku, West Papua, West Papua	Makassar, Bitung, Balikpapan, Samarinda, Ambon, Sorong, Biak, Jayapura

Source: Author based on the IPC I - IV

In the model analysis, we cover six main domestic ports in Indonesia under management of Indonesia Port Corporation I until IV (IPC I – IV). These main domestic ports spread from west to east region in Indonesia, such as Belawan (Sumatera), Tanjung Priok (Jakarta – Java), Tanjung Perak (Surabaya – Java), Banjarmasin (Kalimantan), Makassar (Sulawesi) and Sorong (Papua). Moreover, these ports have sufficient facilities to handle various cargo, including general cargo, dry and liquid bulk, container, etc.

However, in this study, because only export and import containers will be considered in the analysis, so we only take into account either the ports or container terminals that have facility to handle international trades. Hence, we briefly describe the characteristic of these ports, including location, class port categorization, port infrastructures and port facilities, as a basic illustration before determining port dues and port handling charges in each port used on the model analysis.



Source: Modified from Indonesia Port Corporation III (2012)

Figure 11 The Locations of Indonesia's Main Domestic Ports Covered in this Study

4.1.1. Belawan International Container Terminal (BICT)

BICT is located at Port of Belawan about 30 km from the central city of Medan, the capital city of North Sumatera Province. It is a container terminal operator under IPC I and is categorized as the first class port. Due to its geographical location, which has the depth of basin area of -8 to -10 meters LWS, it presents a significant advantage to shipping lines. Table 3 shows more detail about the terminal facilities in the BICT.

Furthermore, BICT serves mainly feeder ships for both international and domestic containers to Port Klang, Penang, Singapore and domestic ports. The main export commodities are agricultural industry products, such as: cocoa, coffee, rubber, etc. Meanwhile, the main import commodities are such as soybean, chemical, machinery part, etc. For domestic commodities are foodstuff and general cargo (BICT, 2013).

Table 3 Terminal Facilities in the BICT

Port Area	ha	30
Channel Length	Nm	13.5
International Berth		
Length	m	550
Width	m	31
Depth	m LWS	-10
Inetrnational Container Yard		
Total Land Area	m^2	158,464
Capacity	TEU	15,726

Equipment	Total	Capacity
Container Crane	11 unit	35 ton
RTG	22 unit	35 ton
Reach Stacker	10 unit	40 ton
HMC	2 unit	104 ton
Head Truck	55 unit	40 ton
Chasis Combo	56 unit	40 ton
Side Loader	3 unit	9 ton
Forklift	5 unit	15 ton

Source: Modified from BICT (2013)

4.1.2. Port of Tanjung Priok

Port of Tanjung Priok is the busiest port in Indonesia because it has a main function as a gateway of international and domestic trades (IPC II, 2012). It is located in the capital city of Indonesia, Jakarta, and is categorized as a main class port. In addition, it has generally two types of facilities, which are facilities serving conventional and international cargo handling activities. For the conventional facility, it is managed by IPC II, which has function to serve the cargo handling activities, such as general cargo, bulk and domestic container. Whereas, the international facility is dedicated to handle the export-import container handling activities and is organized by management under the Jakarta International Container Terminal (JICT), Koja Container Terminal, and Multi Terminal Indonesia (MTI) (The Ministry of Transportation, 2011). The following table summarises the international facilities in the Port of Tanjung Priok, including JICT, Koja and MTI.

Table 4 Summary of International Facilities in the Port of Tanjung Priok

Port Area	ha	1,064
Channel Length	km	0.014
International Berth		
Length	m	2,800
Total of Berth	unit	13
Depth	m LWS	-8.5 to -14
International Container Yard		
Total Land Area	ha	156.7
Total of CY	unit	3

Equipment		
Container Crane	unit	31
Transtainer	unit	94
Reach Stacker	unit	40
Head Truck	unit	123
Chasis Combo	unit	132
Side Loader	unit	2
Forklift	unit	20

Source: Summarized by Author

4.1.3. Port of Tanjung Perak

Java region has two biggest ports, Port of Tanjung Priok and Tanjung Perak (Ministry of Transportation, 2014). Port of Tanjung Perak is well-known as a gateway for eastern trade of Indonesia. It is located in the capital city of East Java, Surabaya and is categorized as a main class port under IPC III management. IPC III has conducted revitalization on the Surabaya West Access Channel, so it can be benefit to container ships because it provides the wider and the deeper channel. Therefore, after revitalizing the container ship can be passed through has specification as follows: 40.000 DWT, 260 m of length, -12.4 m of depth, and 3.000 TEUs of capacity (Surjanto, 2015).

Moreover, Port of Tanjung Perak has three container terminals namely Berlian, Nilam and Mirah. Berlian can handle both domestic and international containers, whereas the two remaining terminals are dedicated for the domestic containers (IPC III, 2012). Meanwhile, IPC III has two subsidiaries that focus on the international container terminals and are located in Surabaya as well. They are known as Surabaya Container Terminal (TPS) and Lamong Bay Terminal, which is the first green port in Indonesia (Lamong Bay Terminal, 2014). Thus, the summary of TPS and Lamong Bay Terminal facilities can be shown in the following table:

Table 5 Summary of Facilities in the Port of Tanjung Perak

Port Area	ha	1,574
Channel Length	Nm	25
International Berth		
Length	m	1,500
Width	m	100
Depth	m LWS	-14
Inetrnational Container Yard		
Total Land Area	m^2	60.9
Capacity	TEU	2,000,000

Equipment	Total	Capacity
Container Crane	11 unit 5 unit	35 ton 40 ton
RTG	33 unit	35 ton
Reach Stacker	6 unit	35 ton
HMC	1 unit	100 ton
Head Truck	75 unit	
Automated Stacking Crane	10 unit	40 ton
Automated Terminal Trailer	50 unit	
Straddle Carrier	5 unit	

Source: Summarized by Author

4.1.4. Port of Banjarmasin

Port of Banjarmasin is located in the capital city in South Kalimantan, Banjarmasin. It is categorized as the first class port under working area of IPC III. Moreover, it is the most important river port of Kalimantan because it has a role as a gateway to Central and South Kalimantan trades. This port consists of four terminals, Trisakti, Martapura Baru, Basirih, and Banjarmasin Container Terminal (TPKB). However, the Banjarmasin Container Terminal currently takes over the international trades through Kalimantan region. The following table depicts the facilities of TPKB, which is generally dedicated to export and import containers:

Table 6 The Facilities in the TPKB

Port Area	ha	12
Channel Length	m	6.1
Berth		
Length	m	505
Width	m	36
Depth	m LWS	-6.5
Container Yard		
Total Land Area	m^2	101,869
Capacity	TEU	332,044

Equipment	Total	Capacity
Container Crane	4 unit	40 ton
RTG	11 unit	40 ton
Reach Stacker	17 unit	40 ton
HMC	2 unit	
Head Truck and Chasis	63 unit	
Top Loader	1 unit	
Side Loader	1 unit	10 ton
Forklift	5 unit	5-28 ton

Source: Summarized by Author

4.1.5. Port of Makassar

Port of Makassar is one of biggest ports in eastern Indonesia. It is located in the capital city of South Sulawesi, Makassar, and is categorized as main class port of IPC IV. This port can handle various cargo and can serve both international and domestic trades. The dominant export commodities are rice, grains, cocoa, etc, while the main import commodities are sugar, flour, fertilizer, sparepart, etc. Moreover, Port of Makassar has four terminals, Soekarno, Hatta, Hasanuddin and Paotere, whereas only Hatta terminal that handles the containers (IPC IV, 2014).

Table 7 The Facilities in the Hatta Terminal

Port Area	ha	386.04
Channel Length	Nm	25
Max. Size	DWT	30,000
Hatta Berth		
Length	m	850
Width	m	30
Depth	m LWS	-12
Hatta Container Yard		
Total Land Area	m^2	114,416
Capacity	TEU	

Equipment	Total	Capacity
Container Crane	4 unit	
Transtainer	8 unit	
Reach Stacker	2 unit	45 ton
Head Truck	14 unit	
Chasis Combo	32 unit	
Top Loader	2 unit	36 ton
BottomLift	1 unit	15 ton
Forklift	10 unit	2 ton

Source: Summarized by Author

4.1.6. Port of Sorong

Port of Sorong is located in the North West of West Papua, Sorong, and is categorized as the first class port of IPC IV. It is relatively classified as a small port if we compare its facilities to other main domestic ports. Nevertheless, this port is the most important port for Papua region because it is a main gateway to serve both passenger and cargo that come from surrounding areas mainly from West Papua and Papua (Solossa, et al., 2013). Even though, this port has lack of facilities but under the government planning with respect to the port development program, it will be able to handle the increased container volumes by average of 11.5% per year in 2011 (IPC IV, 2014), in the medium term.

Table 8 The Facilities in the Port of Sorong

Port Area	ha	210
Channel Length	Nm	3.5
Berth		
Length	m	340
Width	m	22
Depth	m LWS	-11 to -13
Container Yard		
Total Land Area	m^2	20,030
Capacity	TEU	

Equipment	Total	Capacity
Shore Crane	5 unit	
Truck Loader Crane	1 unit	5 ton
HMC	1 unit	25 ton
Forklift	5 unit	5 -7 ton

Source: Summarized by Author

4.2. Profile of International Hub Ports

As we described on the National Logistics System sub-chapter, two proposed international hub ports have role to support the national connectivity network by connecting them to main domestic ports for international trades particularly. Before we conduct the analysis to create optimum routes between international hub ports and main domestic ports, we have to provide some descriptions about these international hub ports. Therefore, we briefly describe the characteristics as well as categorize the class port for both international hub ports.

4.2.1. Port of Kuala Tanjung

Port of Kuala Tanjung has been planned by government to be established as a strategic port on the Malacca Strait, which is known as the busiest strait in the world (Siagian, 2014). Moreover, it is also selected to be an international port that enhances the connectivity within Indonesia Economic Corridors (KP3EI, 2012). According to IPC I, a whole construction project of this port consists of four stages. The first and second construction stages would be completed in 2019, whereby the first stage is intended for the multipurpose terminal, container and bulk (Bisnis Indonesia, 2015).

In addition, this port would have the total port area of 19,070 Ha. It would be categorized as a main class port under the IPC I management. The distance from the capital city of North Sumatera, Medan, and from Port of Belawan are 85 km and 140 km, respectively (The Ministry of Transportation, 2012). The following table shows the facilities that would be set on this port:

Table 9 The Facilities in the Port of Kuala Tanjung

Berth		Short Term	Medium Term	Long Term
Length	m	-	9,400	15,050
Width	m	23		
Depth	m LWS	-12	-17	-17
Reclamation Area	Ha	-	820	1,330
Container Yard				
Total Land Area	Ha	43.5	863.5	1,373.5
Capacity	M. TEU	-	1.0	2.5

Equipment		Total	Remarks
Container Crane	unit	10	Post Panamax Size
Transtainer	unit	30	one over six

Port Area	Ha	19,070
Ship Capacity	TEU	18,270

Source: Summarized by Author

In the medium term, Kuala Tanjung will have the container yard capacity of 1 million TEUs, however it will increase to 2.5 million TEUs based on the long term planning. This capacity indicates the maximum container throughput can be handled by this port. Moreover, expansion and modernization of Kuala Tanjung would accommodate the ultra large container vessels (ULCC), which has a capacity around 18,270 TEUs. That is why this port has depth of at least -17 meters (Antara News, 2015).

Because Port of Kuala Tanjung is still under construction, so we assume this port would be able to handle all of containers come in-and-out. It means that there is no constraint for cargo allocation for this port because this port has unlimited capacity to be used as an international hub port.

4.2.2. Port of Bitung

Port of Bitung has been existing in the Sulawesi region and is categorized as the first class port under IPC IV management. It has several advantages, such as located in Indonesian Navigation Channel, provided suitable infrastructures and superstructures. Due to the increased container flows by an average of 5% per year (Prasetyadi & Widianto, 2004), so the government through IPC IV has a plan to develop this port by enhancing the infrastructures as well as adding the superstructures. The existing and future facilities in this port can be shown in Table 10 and Table 11, respectively.

Because of its position is in Indonesian Navigation Channel, which is closed to the Philippines and having a short distance to Europe and Asia Pacific, Port of Bitung has a fundamental factor to be an international hub port. According to IPC IV, the first stage of Bitung's port development planning would be finished in 2017, includes the container yard expansion area of 6.5 ha and the berth length extension of 500 meters. Moreover, the second stage would be implemented in 2018 to 2022 by increasing the container yard area of 46.8 ha in total and berth length of 250 meters (Bisnis Indonesia, 2015).

Table 10 The Existing Facilities In Port of Bitung

Channel		
Length	Nm	9
Width	m	600
Depth	m LWS	-12 to -15
Basin		
Total Area	Ha	4.5
Draught	m LWS	-7 to -15
Max. Ship Capacity	DWT	40,000
	TEU	3,000
Berth		
Length	m	130
No. of Berth	unit	2

Container Yard		
Total Land Area	m^2	44,000
Capacity	TEU	90,000
Equipment		
HMC	unit	2
Reach Stacker 48 ton	unit	2
Head Truck and Chassis	unit	1
Top Lifter	unit	1
Forklift	unit	13

Source: Summarized by Author

Table 11 The Development of Bitung Port in Short Term Operated up to 2015

Berth		
Length	m	750
No. of Berth	unit	3
Container Yard		
Total Land Area	Ha	46.8
Capacity	TEU	-

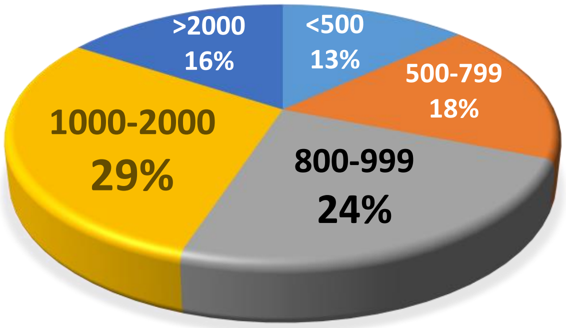
Equipment		
Container Crane	unit	1
Transtainer	unit	2
Head Truck	unit	4
Chassis	unit	8
Forklift 7 ton	unit	1

Source: Summarized by Author

4.3. Ship Size and Capacity

Currently, national shipping companies have not operated all of international container ships in Indonesia yet. However, they have been appointed as shipping agents, which have responsibility to manage overseas shipping activities during operated in Indonesia. This condition is in contrast with domestic trades, which have already used Indonesian-flagged vessels as well as have been operated by national shipping companies. According to statistics report from the Ministry of Transportation, the size of container ships for international trade in Indonesia is normally within range 500 to 2,000 TEUs. It is almost similar to the container ship size for domestic trade is between 300 and 1,000 TEUs.

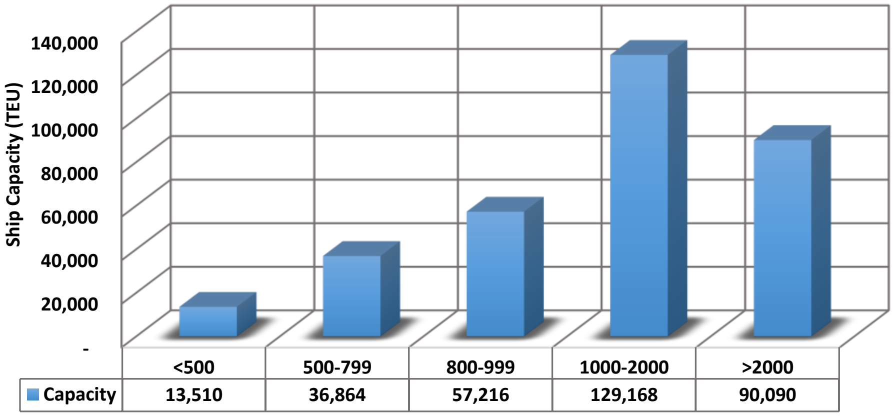
Based on the annual report of IPC I-IV in 2013, the total number of container ships that served international container was 267 units. Because these operated ships have various size, thus we classify them into five ranges, less than 500 TEUs (<500), within range 500-799 TEUs, 800-999 TEUs, 1,000-2,000 TEUs and greater than 2,000 TEUs (>2,000). Furthermore, the most widely international container ships operated was within size of 1,000-2,000 TEUs by 78 units (29%). Following that, the range of 800-999 TEUs by 64 units (24%), whereas the size of less than 500 TEUs is merely operated by 35 ships (13%). The proportion for each size range can be seen in Figure 12 as below:



Source: Modified from IPC I-IV Report in 2013

Figure 12 The Proportion of Total Container Ships by Range of Ship Size

In addition, the total capacity of international container ships in 2013 was 326,848 TEUs. The group range of 1,000-2,000 TEUs has the highest capacity by 129,168 TEUs or 40% of total capacity in 2013, while the group range of >500 TEUs has the lowest capacity by 13,510 TEUs or only 4% of total capacity. Due to lots of ports are being developed, it can reduce the number of small container size used for international trade within Indonesia region particularly. However, these type of containers can be useful only for some ports that have insufficient infrastructures and facilities. Moreover, we also present the total capacity of each size range based on the data in 2013, as follows:



Source: Modified from IPC I-IV Report in 2013

Figure 13 The Total Ship Capacity by Range of Ship Size

For more detail about the current ship size and capacity in Indonesia can be seen in Table 12 as below:

Table 12 The Summary of Total Container Ships and Capacity

Ship Size	Total	No.of Ship Proportion	Capacity	Average Capacity	Capacity Proportion
(TEU)	(unit)	(%)	(TEU)	(TEU)	(%)
< 500	35	13%	13,510	386	4%
500 - 799	48	18%	36,864	768	11%
800 - 999	64	24%	57,216	894	18%
1000 - 2000	78	29%	129,168	1,656	40%
> 2000	42	16%	90,090	2,145	28%
Total	**267**	**100%**	**326,848**	**5,849**	**100%**

Source: Modified from IPC I-IV Report in 2013

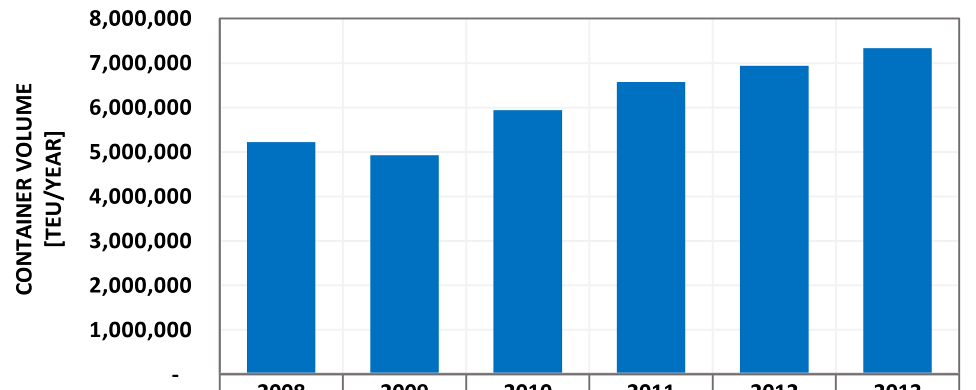
However, after reviewing the current international container shipping condition with respect to ship size and capacity, we assume there are unlimited container ships available that can serve the international container volume in the model analysis due to uncertainty demand in the future and unrealized international hub ports. Hence, we use a constant number to describe the maximum capacity of ship, which is denoted by Qt in the model.

4.4. Hinterland Market Analysis and Demand Projection

We analyse the hinterland demand based on the data of total international container volume in TEUs per year. Due to unfinished development of two international hub ports, meaning that we would face uncertainty demand in the future. Therefore, we also conduct the demand projection in order to provide the number of export and import containers for each main domestic port ($Pijc$) on the model analysis.

4.4.1. Hinterland Market Analysis

The hinterland market analysis is used to find out the demand of international containers in the Indonesia market. This demand is based on the historical data of the international container volume in 2008 to 2013. As shown in Figure 14, the container volume increased by an average 7.4% in every year. Even though, it dropped by 6% in 2009 due to international economic crisis, but the condition was back to normal in 2010.



	2008	2009	2010	2011	2012	2013
Total	5,220,108	4,925,757	5,937,029	6,571,928	6,942,194	7,334,739

Source: Modified from the Ministry of Transportation (2014)

Figure 14 The Total International Container Volume (in TEU/year)

Afterward, we firstly have to divide the Indonesia region into five regions with regard to the Indonesia Economic Corridor based on the MP3EI: Sumatera, Java, Kalimantan, Sulawesi and Rest of Indonesia (including Maluku, Bali, Nusa Tenggara and Papua) (see in Figure 15).

Source: Author

Figure 15 Zoning Region of Indonesia

The zoning area would be used to easily separate those containers in each main domestic port per region. Based on data from the Ministry of Transportation, we present the total international container volume in TEUs/ year per region, as follows:

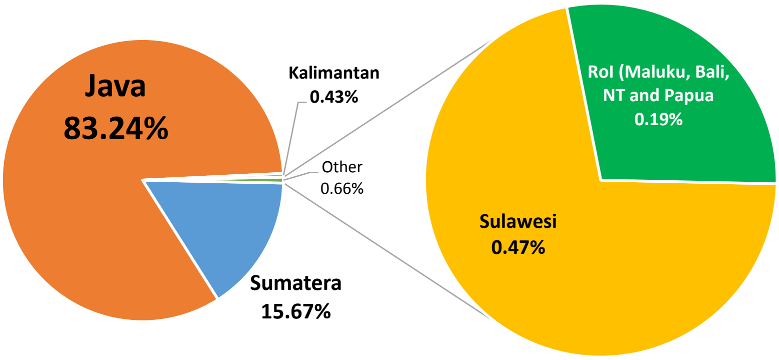
Table 13 The Total International Container Volume per Region (in TEUs per year)

Region	2008	2009	2010	2011	2012	2013
Sumatera	705,981	732,622	845,915	967,189	1,054,236	1,149,117
Java	4,463,730	4,147,608	5,032,435	5,537,990	5,814,890	6,105,634
Kalimantan	23,840	15,865	22,875	26,665	29,092	31,739
Sulawesi	18,868	20,893	25,126	28,534	31,387	34,526
RoI	7,689	8,769	10,678	11,550	12,590	13,723
Total	**5,220,108**	**4,925,757**	**5,937,029**	**6,571,928**	**6,942,194**	**7,334,739**

Source: Modified from the Ministry of Transportation (2014)

Generally, all of international container volumes grew significantly as shown in Table 13 above. Sumatera region increased by an average 10%, followed by Java (7%), Kalimantan (9%), Sulawesi (13%) and the Rest of Indonesia (12%). However, Java region dominated the international container volume in every year. It is not surprising because two biggest ports are located in Java and are able to handle numerous containers.

Moreover, we provide a proportion of the international container volumes by region in 2013 to present in which region that handled the largest international container volume. As a result, Java region reached 83.24% of total container volume. Following that, Sumatera by 15.67%, Sulawesi by 0.47%, Kalimantan by 0.43% and the Rest of Indonesia by 0.19%, which are including Maluku, Bali, Nusa Tenggara and Papua.



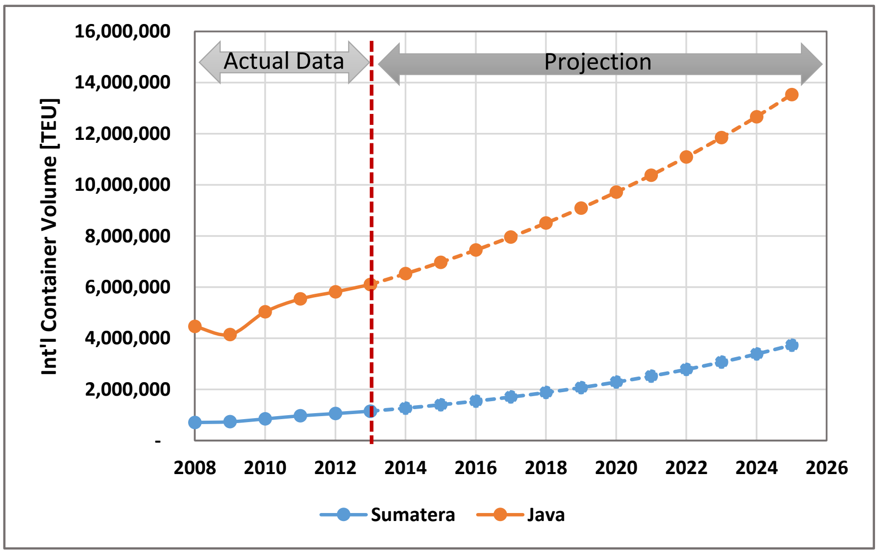
Source: Author based on the International Container Volume Data in 2013

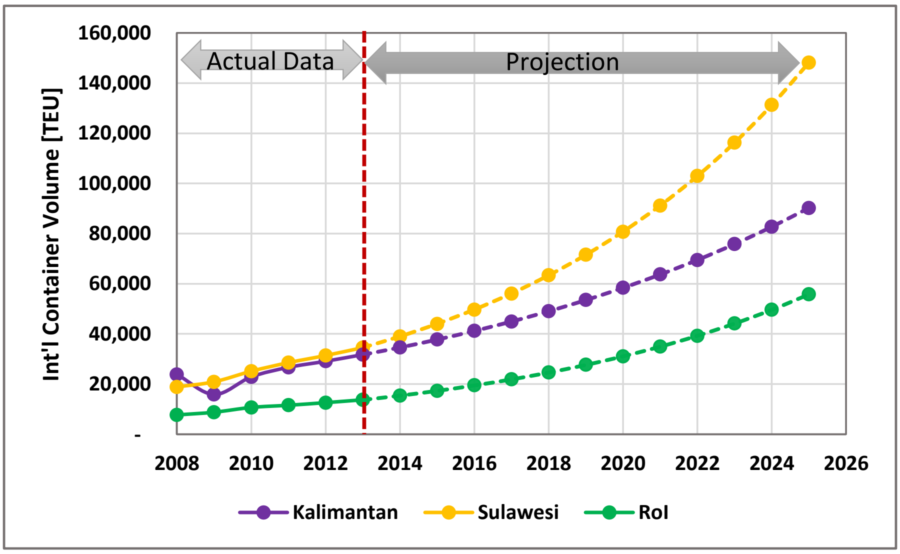
Figure 16 International Container Proportion by Region

4.4.2. Demand Projection

Because two proposed international hub ports would be implemented in up to 2020, so we conduct the demand projection from 2014 to 2025 based on the historical data of the international container volumes in 2008 to 2013. However, we understand that this demand projection has limitations that could not present properly the demand volume in the future because we estimate the results by using the average growth per year from the last six years data of international container volume.

Furthermore, in order to obtain the projection number for the next year, we use an average growth per year for every region, as explained before on the Hinterland Market Analysis section, which are 10% of Sumatera, 7% of Java, 9% of Kalimantan, 13% of Sulawesi and 12% of the Rest of Indonesia. Due to a huge number of international container volume in Java and Sumatera, so we separate the results by two graphs as shown in the following figure:





Source: Author

Figure 17 Projection Result of Total International Container Volume by Region (in TEU/year)

As a result, the total international container volume in 2015 and 2025 are 8.5 million TEUs and 17.5 million TEUs respectively, while Java remains the same as the largest region that would be able to handle 80% of total container volumes. Even though, two proposed international hub ports would be implemented in up to 2020, but in the model analysis, we use the demand projection in 2015 as data input for $Pijc$ to obtain the number of export and import containers in main domestic ports.

Furthermore, we assume that the total container volumes per region represent the international container throughput in every main domestic port in its region. For instance, Sumatera Region has the total international container volume in 2015 of 1.39 million TEUs, so this value would be represented as the total export and import containers in Belawan. This assumption is used by considering the hierarchy of port that all of international containers would be firstly transhipped in the main domestic ports before continuing to transport in the international hub ports.

According to the Indonesia Statistics, the proportion of export and import containers are 60% and 40%, respectively. Thus, we use these proportions to determine the number of export and import containers for every region. The result of this proportion can be seen in Table 14 below:

Table 14 The Number of Export and Import Container by Region in 2015 (TEUs)

Region	Export	Import
Sumatera	839,041	559,361
Java	4,183,194	2,788,796
Kalimantan	22,667	15,112
Sulawesi	26,410	17,607
RoI	10,401	6,934
Total	**5,081,715**	**3,387,810**

Source: Author

Furthermore, both export and import containers in Sumatera Region would automatically be the container throughput in Belawan and so on for other ports. However, we should consider for Java region because it consists of two biggest ports, Tanjung Priok and Tanjung Perak. Based on the IPC II and III (2013 and 2014), Tanjung Priok has the highest proportion of export and import containers, approximately 67% and 63%, respectively. Because these proportions are the average of the last two years and the trend of international trade tends to be higher in the future, so we round up the proportion of export and import containers in Tanjung Priok become 70% and 65%, respectively. Therefore, we assume to divide Java's export container to be 70% for Tanjung Priok and 30% for Tanjung Perak, whereas 65% of Java's import container belongs to Tanjung Priok and 35% for Tanjung Perak. Thus, the result of each proportion is shown in the following table:

Table 15 The Number of Export and Import Container by Port in 2015 (TEUs/year)

Main Domestic Port	Export	Import
Belawan	839,041	559,361
Tanjung Priok	2,928,236	1,812,718
Tanjung Perak	1,254,958	976,079
Banjarmasin	22,667	15,112
Makassar	26,410	17,607
Sorong	10,401	6,934

Source: Author

The result of export and import container in every main domestic port would be applied on the model analysis for determining the cargo allocation. In general, the network-shipping model determines the number of cargo in a week instead of a year, so we have to change these values from TEU per year to TEU per week by dividing 52 weeks.

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5. Results and Analysis

The results of routing analysis and the maximum ship capacity required based on two scenarios, with Belawan and without Belawan's international containers, will be explained in this chapter. However, we firstly analyse the total shipping cost for each route in order to obtain the unit cost that will be used in the FNDP model. Afterwards, we determine the optimum route by considering the number of containers transported (Pijc), unit cost (Cij) and distance between port of origin and destination (dij) in order to minimize the total shipping costs for each scenario. Meanwhile, we also evaluate each resulted route by changing the value of maximum ship capacity to obtain the optimum route, which has the lower total costs. In the end of this analysis, the comparison between two scenarios are conducted as the result in which route can obtain the minimum total shipping costs.

5.1. Shipping Cost Analysis

Total shipping costs are the sum of fixed costs and variable costs. By applying the formulation in Sub-chapter 3.1, thus we calculate the total shipping cost for each route. Afterwards, we would obtain the unit cost (Cij) in USD per TEU per nautical miles, that can be used in the model calculation. Firstly, we describe every assumption involved in the shipping cost calculation, i.e. charter rate, fuel price, cargo handling charges, etc.

5.1.1. Distance

One of the factors that relates to the model analysis and shipping cost calculation is distance between port of origin and destination (O-D). These data are provided by Sea Routes and Distance, which is online calculator to measure the shipping distance in nautical miles. The distance will be required to determine the total sea time. Meanwhile, the total sea time can be found by dividing the distance and speed of ship. Table 16 presents the distance matrix between two international hub ports and six main domestic ports, where the distance between international hub ports are automatically excluded. Because there is no direct connection to distribute cargo between international hub ports. This connectivity only have relation between international hub ports and main domestic ports as well as within main domestic ports itself.

Table 16 The Distance Matrix based on the Origin and Destination (in Nautical Miles)

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
BLW	49	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TPR	1,015	1,064	-	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TPE	1,439	1,488	438	-	[illegible]	[illegible]	[illegible]	[illegible]
BNA	1,381	1,430	614	328	-	[illegible]	[illegible]	[illegible]
MKS	1,659	1,708	806	520	353	-	[illegible]	[illegible]
SRN	2,758	2,807	2,102	1,816	1,577	1,375	-	[illegible]
BTG	2,298	2,347	1,517	1,231	992	790	585	-

Source: Sea Route & Distance, 2015 (http:www.ports.com)

5.1.2. Ship Specification

As described on the previous sub-chapter 4.3 about Ship Size and Capacity, the container ship size has been classified into five ranges. Moreover, we provide additional data such as Deadweight (DWT), Gross Tonnage (GT) and engine power for main engine (ME) and auxiliary engine (AE).

According to the Marine Technology course, DWT is the total weight of ship including payload, consumables and ballast, while GT is the capacity of closed-area in the ship that is conveyed in ton. Typically, DWT can also express the size of ship, especially for tanker, bulk carrier, etc. However, TEU is normally used in terms of container ship. We will use the number of GT to calculate the port dues, whereas engine power for determining the fuel consumption and fuel cost. The following table shows the ship specification based on the ship size range:

Table 17 Ship Specification by Ship Size

Ship Size	Average Speed	DWT	GT	ME	AE
(TEU)	(knot)	(Ton)	(Ton)	(HP)	(HP)
< 500	12	5,000	2,100	3,700	1,400
500 - 799	14	7,500	4,300	5,300	1,800
800 - 999	15	10,000	6,600	6,900	2,200
1000 - 2000	17	15,000	11,100	10,200	2,900
> 2000	18	30,000	24,600	19,900	5,100

Source: Indonesia Classification Agency (BKI Register)

5.1.3. Ship Charter Rate

Fixed costs can be described as the costs that cannot be influenced by the changes on route or the total amount of goods. Commonly, these costs take operating costs, periodic maintenance costs and capital costs into account. However, in this thesis, we replace those costs by applying time charter rate to compute the fixed costs. According to Maersk Broker in 2015, which provide the time charter rate by ship size, the bigger ship size, the higher charter rate will be gained. The following table shows the current time charter rate based on ship size from 400 TEUs to 5,200 TEUs.

Table 18 Time Charter Rate by Ship Size

Ship Size (TEU)	Charter Rate (USD/day)
400 - 649	4,969
650 - 899	5,594
900 - 1299	7,800
1300 - 1999	9,609
2000 - 2999	9,834
3000 - 3949	11,608
3950 - 5199	14,364

Source: Maersk Broker, 2015

These charter rates already cover all ship-operating costs, excluding fuel costs and cargo handling costs. Hence, we still have to calculate those costs in order to obtain the total shipping costs.

5.1.4. Fuel Cost

One of variable cost components is fuel cost, in which the value can change depending on the route and type of ship. Fuel cost can be calculated by multiplying the number of fuel consumptions and fuel price. Firstly, we have to compute the total fuel consumption of container ship. We assume the specific fuel oil consumption (SFOC) for main engine and auxiliary engine are 0.22 Liter/HP.hour and 0.293 Liter/HP.hour, respectively. By using the assumption of both SFOC for main engine and auxiliary engine, thus the total fuel consumptions (in Liter) will depend on the total operation time (hour) and engine power for both engines (HP).

In addition, we assume both engines use HSD (high speed diesel) as diesel fuels. According to Shell Indonesia, the price of HSD in 2015 is IDR 11,800 per liter, or equals to USD 0.87 per liter (1 USD = 13,500 IDR).

5.1.5. Port Dues and Handling Charges

Port dues and container handling charges are also including on the variable cost components. In general, port dues consist of piloting, tugging, and berthing costs. Piloting and tugging costs are costs for using piloting and tugging services within port area. Piloting costs can be paid by ship per move as well as depending on the GT per ship, whereas tugging cost is paid by call of ship. Meanwhile, berthing cost is cost incurred due to the use of berth. It depends on the GT of ship per day.

In addition, we determine port dues based on the port class categorization for each port origin and destination. As described on the sub-chapter 4.1 and 4.2, we summarize that Kuala Tanjung, Tanjung Priok, Tanjung Perak and Makassar are classified as main port class, while the remaining ports are categorized as the first port class. Table 19 depicts the piloting, tugging and berthing costs based on the port class categorization.

Table 19 Port Dues based on the Port Class Category

Port Class Category	Port dues (in USD)			
	Piloting		Tugging	Berthing
	ship/move (fixed)	GT/ship.move (variable)	ship/call	GT/day
Main	$11.11	$0.0022	$74.07	$0.0070
I	$8.89	$0.0019	$59.26	$0.0056
II	$7.41	$0.0015	$44.44	$0.0044
III	$5.56	$0.0015	$44.44	$0.0037
IV	$5.56	$0.0015	$44.44	$0.0037
WA	$5.56	$0.0015	$44.44	$0.0037

Source: The Standard of Port Operational Services Performance - Ministry of Transportation 2013

On the other hand, we provide the container handling charges (CHC) for each port based on the website of all IPCs. CHC rates differ in every port, except for ports in the same region. Because Kuala Tanjung does still not operate yet, we assume CHC in this port remains the same as Belawan, because they are located in the similar region, Sumatera. However, Bitung and Makassar have different rates, wherein Bitung is slightly higher than Makassar. It can be caused by the port class categorization, Bitung is classified as the first port class while Makassar is a main port class. The CHC for each port can be seen in the Table 20 below. It also shows that CHC rates in western are lower than eastern Indonesia.

Table 20 Container Handling Charges in USD per TEU

Port	Code	TEU
Kuala Tanjung	KTJ	$25.93
Belawan	BLW	$25.93
Tanjung Priok	TPR	$25.59
Tanjung Perak	TPE	$25.59
Banjarmasin	BNA	$27.43
Makassar	MKS	$29.63
Sorong	SRN	$30.74
Bitung	BTG	$32.59

Source: IPC I-IV (2013)

5.1.6. Port Operation

Port operation describes the total operation time of ship during staying at port. While total port time is sum of berthing time and idle time for each port of origin and destination. Berthing time depends on the container handling productivity, the number of cranes and the number of container loaded/unloaded. On the other side, idle time consists of waiting time and approaching time. Waiting time means a queue waiting time before berthing. Approaching time is a time when ship goes from the anchoring pool to the berth.

Table 21 presents the crane productivity and idle time based on the port class categorization. The higher crane productivity, the faster berthing time. However, it also depends on the number of cranes and the number of container transported in each port.

Table 21 Cargo Handling Productivity and Idle Time

Port Class Category	Cargo Handling Productivity		No. of Crane	Operational
	Loading	Unloading		Idle time
	TEU/Crane/hr	TEU/Crane/hr	Unit	Hour
Main	20	22	4	4
I	18	20	3	4
II	16	18	2	6
III	14	16	1	6
IV	12	14	1	6
WA	12	14	1	6

Source: The Standard of Port Operational Services Performance - Ministry of Transportation 2013

In conclusion, the total operation time of ship is sum of total sailing time and port time. While, the total sailing time is related to the distance between port and the speed of ship, as we explained on the first part of Shipping Cost Analysis section.

5.1.7. Unit Cost

In the current condition, only domestic container flows that are able to connect the main domestic ports. However, only for Tanjung Priok and Tanjung Perak have direct link to transport their international containers. Thus, for the remaining connectivity between main domestic ports, i.e. Belawan and Tanjung Priok, Tanjung Perak and Banjarmasin, etc, we use the connectivity of domestic container flows. Therefore, in order to calculate the total costs, we assume the total number of containers transported for each route has the value close to the ship capacity that serves its route. While, the ship capacity itself is based on the current size of container ships that serves domestic container flows. Because, there is no container ship that serve the Kuala Tanjung, we assume the total containers in this port remains the same as Belawan.

Moreover, these total costs represent to the costs of every ship for one trip service (staring from port origin to destination). The following table shows the assumption of total containers distributed per voyage in every route based on the ship capacity served the domestic container flows:

Table 22 Total Containers Transported per Voyage for Each Route (in TEU/voyage)

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	300	600	400	200	350	200	-
BLW	300	-	550	400	200	350	200	250
TPR	600	550	-	800	250	300	220	600
TPE	400	400	800	-	200	800	200	400
BNA	200	200	250	200	-	200	200	250
MKS	350	350	300	800	200	-	350	350
SRN	200	200	220	200	200	350	-	200
BTG	-	250	600	400	250	350	200	-

Source: Author

Afterwards, we determine the total cost by using all of assumptions that already explained before. Because the number of containers in each port differs by each other's, which has range of 200-800 TEUs, thus the ship specifications that serves every route are within range <500 TEU, 500 - 799 TEU and 800 - 999 TEU. Furthermore, in order to obtain the unit cost for each route, we divide the total costs in each route by the number of container transported and distance. As a result, the greater volume transported and the further distance travelled, the smaller unit costs will be gained.

Table 23 Unit Cost per Route (in USD/TEU.Nm)

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	1.81	0.24	0.25	0.37	0.27	0.34	-
BLW	1.81	-	0.26	0.25	0.37	0.28	0.34	0.28
TPR	0.24	0.26	-	0.38	0.38	0.30	0.32	0.22
TPE	0.25	0.25	0.38	-	0.57	0.35	0.35	0.27
BNA	0.37	0.37	0.38	0.57	-	0.56	0.36	0.40
MKS	0.27	0.28	0.30	0.35	0.56	-	0.29	0.34
SRN	0.34	0.34	0.32	0.35	0.36	0.29	-	0.47
BTG	-	0.28	0.22	0.27	0.40	0.34	0.47	-

Source: Author

5.2. Results of the FNDP Model for Indonesian International Hub Port

This sub-chapter presents the results of the FNDP Model for the Indonesian International Hub Port, which is defining connectivity between international hub ports and main domestic ports. Moreover, we build and run the model by using Opensolver provided by Microsoft Excel, wherein this model also provides the total costs for creating those connections, which produce the minimum total costs.

As described before, we have two scenarios to be analysed; with Belawan and without Belawan. The first scenario determines all international containers from six main domestic ports including Belawan, so the first scenario can be called as "with Belawan". Meanwhile, the second scenario refers to "without Belawan", because the closer distance between Belawan and Kuala Tanjung makes tendency to transport Belawan's international containers to Kuala Tanjung directly by using either land transport or short-sea shipping. It means that we merely consider the international containers from the remaining main domestic ports excluding Belawan.

5.2.1. Scenario 1: with Belawan

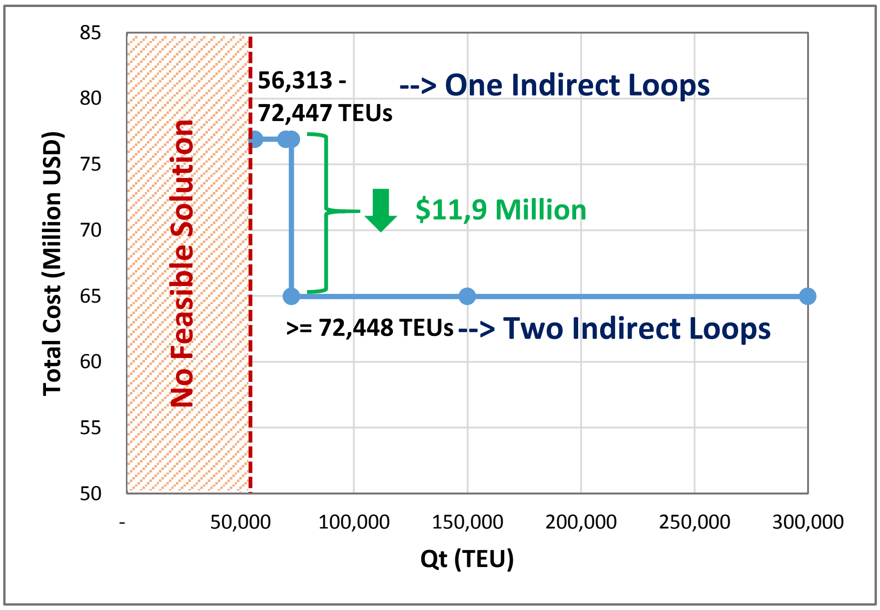
In the first scenario, we use data for total supply of export container and total demand of import container for all main domestic ports based on the demand projection in 2015. These data present the number of export and import container by each main domestic port in TEU per week. The following table depicts the number of export and import container by port in TEU per week, which are denoted by Si and Dj, respectively.

Table 24 Scenario 1: The Number of Export and Import Container by Port (in TEUs/week)

Main Domestic Port	Code	Export [Si]	Import [Dj]
Belawan	BLW	16,135	10,757
Tanjung Priok	TPR	56,312	34,860
Tanjung Perak	TPE	24,134	18,771
Banjarmasin	BNA	436	291
Makassar	MKS	508	339
Sorong	SRN	200	133

Source: Author

In the FNDP model, we apply a constant number to describe the maximum ship capacity per route (Qt), whereby the value should cover all of containers transported within this route. Hence, we set the value of Qt equals to 70,000 TEUs. Several experiments are carried out by changing the value of Qt and re-running the model. These experiments are based on the trial-and-error approach, we try iteratively to find the optimum Qt that has impact to the minimum total costs. As a result, we show it in the following graph:



Source: Author

Figure 18 The Relationship between Qt and TC for Scenario 1

As shown in Figure 18, if we change the value of Qt less than 56,313 TEUs, then the model will have no feasible solution because it cannot satisfy all of constraints, especially for ship capacity constraint. By using Qt = 56,313 TEUs, we obtain one integrated route that connects two international hub ports and six main domestic port, while resulting the total shipping costs of USD 76.9 million.

On the other hand, if we increase the Qt to 72,448 TEUs, then the result changes, which produces the lower total costs of USD 64.94 million and has two separated routes. Thus, for two separated routes can be referred as two indirect loops, which mean for every loop only connected to one international hub port. In addition, the total costs remain the same as USD 64.94 million even though we increase the Qt until 300,000 TEUs or even more. It can be concluded that the optimum value of Qt can be used to obtain the minimum total costs is 72,448 TEUs and the difference of total costs between two results is USD 11.9 million.

However, the total costs merely represent the operational transportation costs as an impact of these routes based on a unit TEU costs. These costs do not include the actual deployment of this capacity.

In addition, we explain more detail about the difference between one indirect loop and two indirect loops as follows:

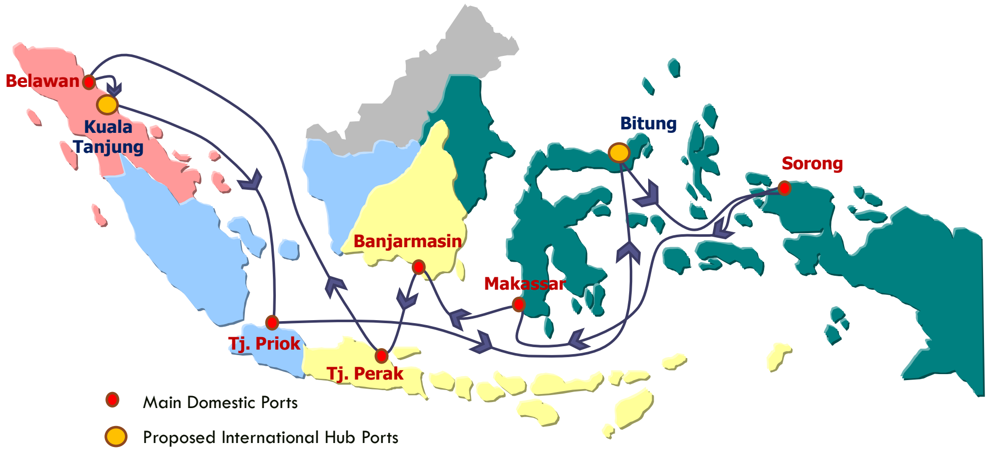
A. One Indirect Loop Analysis

After running the model by changing the constant Qt from 56,313 to 72,447 TEUs, we obtain one integrated route that we call as one indirect loop. The route is starting from Kuala Tanjung - Tanjung Priok – Bitung – Sorong – Makassar – Banjarmasin – Tanjung Perak – Belawan – Kuala Tanjung. The result of the model can be seen in the following table and figure:

Table 25 The Result of Optimum Route in One Indirect Loop

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	-	1	-	-	-	-	-
BLW	1	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	1
TPE	-	1	-	-	-	-	-	-
BNA	-	-	-	1	-	-	-	-
MKS	-	-	-	-	1	-	-	-
SRN	-	-	-	-	-	1	-	-
BTG	-	-	-	-	-	-	1	-

Source: Author



Source: Author

Figure 19 Optimum Route in One-Loop Connection

The starting point of this route always comes from international hub port, either Kuala Tanjung or Bitung. Because, hub port has a responsibility to collect and distribute the cargo from/to feeder port, in this case we use term main domestic port. In the one indirect loop, Kuala Tanjung becomes the start-and-end point of the ship to pick up-and-deliver of both export and import containers.

In order to achieve the goal for minimizing the total shipping costs in this route by using the maximum total capacity of container ships within range 56,313 to 72,447 TEUs, thus we get the cargo allocation for each main domestic port should be transported as shown in Table 26 to Table 27. The cargo allocation table presents the number of export and import containers remains on the ship before they are loaded and unloaded in the next port destination or final destination (international hub port).

As the result, the first main domestic port should be visited is Tanjung Priok because it has a huge number of export and import containers compare to other main domestic ports. Tanjung Priok has the weekly demand of import containers and the weekly supply of export containers of 34,860 TEUs and 56,312 TEUs, respectively. Hence, for cargo allocation in Tanjung Priok (see in Table 26), the feeder ship departs from Kuala Tanjung by carrying the import containers of 34,860 TEUs that should be discharged in Tanjung Priok. Meanwhile, this feeder ship also picks up the export containers of 56,312 TEUs to be transported to another international hub port, Bitung. In Bitung, Tanjung Priok's export containers are directly discharged. Meanwhile, the ship is also loaded by other import containers belong to the remaining domestic ports (Sorong, Makassar, Banjarmasin, Tanjung Perak and Belawan), because there are still available ship capacity to carry all import containers to next ports. It means that the ship from Bitung carries 30,290 TEUs in total.

Table 26 Cargo Allocation for Tanjung Priok (in TEU)

c2 TPR

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	34,860	-	-	-	-	-	34,860
BLW	-	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	56,312	56,312
TPE	-	-	-	-	-	-	-	-	-
BNA	-	-	-	-	-	-	-	-	-
MKS	-	-	-	-	-	-	-	-	-
SRN	-	-	-	-	-	-	-	-	-
BTG	-	-	-	-	-	-	-	-	-
d	-	-	34,860	-	-	-	-	56,312	

Source: Author

After loading in Bitung, the feeder ship goes to Sorong to unload the import containers of 133 TEUs, while loading 200 TEUs of export containers to be unloaded in Kuala Tanjung. It can be seen in the Table 27, the cargo allocation for Sorong, these export containers remain on the feeder ship until they will be unloaded in Kuala Tanjung. Therefore, the total number of containers on the ship is 30,357 TEUs, which contents of import containers for Makassar (339 TEUs), Banjarmasin (291 TEUs), Tanjung Perak (18,771 TEUs) and Belawan (10,757 TEUs) as well as export containers belong to Sorong (200 TEUs).

Table 27 Cargo Allocation for Sorong (in TEU)

c6 SRN

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	200	-	-	-	-	-	-	-	200
TPR	-	-	-	-	-	-	-	-	-
TPE	-	200	-	-	-	-	-	-	200
BNA	-	-	-	200	-	-	-	-	200
MKS	-	-	-	-	200	-	-	-	200
SRN	-	-	-	-	-	200	-	-	200
BTG	-	-	-	-	-	-	133	-	133
d	200	200	-	200	200	200	133	-	

Source: Author

By carrying of 30,357 TEUs, the next destination port is Makassar. Makassar has export containers of 508 TEUs that should be transported to Kuala Tanjung. These export containers remains on the ship until they will be unloaded in Kuala Tanjung. Meanwhile, this ship also carries the import containers belong to Makassar of 339 TEUs, which should be unloaded (see in Table 28 for cargo allocation in Makassar).

Thus, after loading and unloading container in Makassar, the ship goes to Banjarmasin by carrying the total containers of 30,526 TEU.

Table 28 Cargo Allocation for Makassar (in TEU)

c5 MKS

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	508	-	-	-	-	-	-	-	508
TPR	-	-	-	-	-	-	-	-	-
TPE	-	508	-	-	-	-	-	-	508
BNA	-	-	-	508	-	-	-	-	508
MKS	-	-	-	-	508	-	-	-	508
SRN	-	-	-	-	-	339	-	-	339
BTG	-	-	-	-	-	-	339	-	339
d	508	508	-	508	508	339	339	-	

Source: Author

After arriving in Barjamasin, 291 TEUs of import containers, which have been loaded in Bitung, should be discharge in Banjarmasin. At the same time, 436 TEUs of export container are loaded on the ship to be transported to the final destination, Kuala Tanjung. Thus, the ship that is still carrying the total containers of 30,672 TEUs goes to Tanjung Perak for the next destination port. The cargo allocation for Banjarmasin and Tanjung Perak can be seen in Table 29 and Table 30, respectively.

Table 29 Cargo Allocation for Banjarmasin (in TEU)

c4 BNA

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	436	-	-	-	-	-	-	-	436
TPR	-	-	-	-	-	-	-	-	-
TPE	-	436	-	-	-	-	-	-	436
BNA	-	-	-	436	-	-	-	-	436
MKS	-	-	-	-	291	-	-	-	291
SRN	-	-	-	-	-	291	-	-	291
BTG	-	-	-	-	-	-	291	-	291
d	436	436	-	436	291	291	291	-	

Source: Author

Tanjung Perak has 18,771 TEUs of import containers to be unloaded, whereas 24,134 TEus of export containers should be loaded and transported to Kuala Tanjung. These export containers remain on the ship until they are discharged in Kuala Tanjung. Hence, the total containers on the ship are 36,035 TEUs. By carrying these containers, the ship departs to Belawan.

Table 30 Cargo Allocation for Tanjung Perak (in TEU)

c3 TPE

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	24,134	-	-	-	-	-	-	-	24,134
TPR	-	-	-	-	-	-	-	-	-
TPE	-	24,134	-	-	-	-	-	-	24,134
BNA	-	-	-	18,771	-	-	-	-	18,771
MKS	-	-	-	-	18,771	-	-	-	18,771
SRN	-	-	-	-	-	18,771	-	-	18,771
BTG	-	-	-	-	-	-	18,771	-	18,771
d	24,134	24,134	-	18,771	18,771	18,771	18,771	-	

Source: Author

Belawan is the last domestic port visited in this route. Table 31 presents the cargo allocation for Belawan. This port has weekly demand of import containers of 10,757 TEUs, while the weekly supply of export containers is 16,135 TEUs. Hence, 10,757 TEUs of import containers and 16,135 TEUs of export containers should be unloaded and loaded, respectively, in this port. After loading and unloading, the ship comes back to the starting point, Kuala Tanjung, to discharge all containers remain on the ship of 41,413 TEUs. Afterwards, this ship will continue again to distribute all the international containers from international hub ports to main domestic ports within this route.

Table 31 Cargo Allocation for Belawan (in TEU)

c1 BLW

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	16,135	-	-	-	-	-	-	-	16,135
TPR	-	-	-	-	-	-	-	-	-
TPE	-	10,757	-	-	-	-	-	-	10,757
BNA	-	-	-	10,757	-	-	-	-	10,757
MKS	-	-	-	-	10,757	-	-	-	10,757
SRN	-	-	-	-	-	10,757	-	-	10,757
BTG	-	-	-	-	-	-	10,757	-	10,757
d	16,135	10,757	-	10,757	10,757	10,757	10,757	-	

Source: Author

For cargo allocation, the concept is similar to other ports, that all export containers from main domestic ports remain on the ship until they are discharged in Kuala Tanjung. However, only for Tanjung Priok has different concept, because Tanjung Priok is directly connected by both hub ports due to a huge number of containers. It affects on the cargo allocation of Tanjung Priok that never remain on the ship.

Table 32 Total Cargo Allocation in One-Loop Connection (in TEU)

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	-	34,860	-	-	-	-	-
BLW	41,413	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	56,312
TPE	-	36,035	-	-	-	-	-	-
BNA	-	-	-	30,672	-	-	-	-
MKS	-	-	-	-	30,526	-	-	-
SRN	-	-	-	-	-	30,357	-	-
BTG	-	-	-	-	-	-	30,290	-

Source: Author

The sum of cargo allocations in each main domestic port is referred to the total cargo transported in this route (one indirect loop). By multiplying this total cargo allocation (∑(c∈C) Pijc), unit cost (cij) and distance (dij), thus we gain the minimum total cost of USD 76.9 million within this route.

B. Two Indirect Loops Analysis

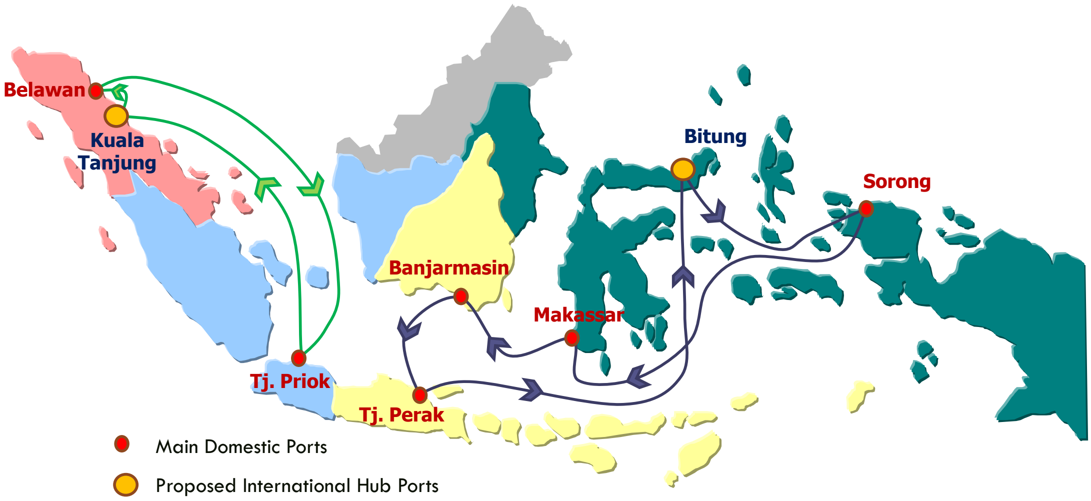
As stated before, by increasing the ship capacity (Qt) to 72,448 TEUs or even more, we get the result of two indirect loops. In this case, we have two routes that should be served by the ships, which have the minimum Qt of 72,448 TEUs for each route.

The first loop is referred to the west route because it connects to all main domestic ports in the west region of Indonesia. The west route is Kuala Tanjung – Belawan – Tanjung Priok – Kuala Tanjung. Moreover, the second loop is referred to the east route, which has the starting point from Bitung – Sorong – Makassar – Banjarmasin – Tanjung Perak – Bitung. It can be seen that for every loop only connected to one international hub port. We provide the route on the Indonesian map to be easily visualized (see in Figure 20 on page 49).

Table 33 The Result of Optimum Route in Two Indirect Loops

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	1	-	-	-	-	-	-
BLW	-	-	1	-	-	-	-	-
TPR	1	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	1
BNA	-	-	-	1	-	-	-	-
MKS	-	-	-	-	1	-	-	-
SRN	-	-	-	-	-	1	-	-
BTG	-	-	-	-	-	-	1	-

Source: Author



Source: Author

Figure 20 Optimum Routes in Two Indirect Loops

For west route, Kuala Tanjung becomes the start-and-end point of ship that has the minimum Qt of 72,448 TEUs. By having this number of Qt or even more, the cargo allocation for each domestic ports is only provided to Belawan and Tanjung Priok. The description regarding the cargo allocation for each domestic port is the same as the first result, which presents the number of export and import containers remains on the ship before they are loaded and unloaded in the next port of destination or the final destination (international hub port).

When the ship departs from Kuala Tanjung, it carries 45,617 TEUs of both import containers belong to Belawan and Tanjung Priok. Thus, it comes to Belawan to discharge 10,757 TEUs of import containers that have been loaded in Kuala Tanjung. Meanwhile, it is also loaded by 16,135 TEUs of export containers to be transported in Kuala Tanjung. These containers remains on the ship until they are unloaded in Kuala Tanjung. Afterwards, the ship goes to the Tanjung Priok by carrying 50,995 TEUs of total containers. In Tanjung Priok, 34,860 TEUs of import containers are discharges, while loading 56,312 TEUs of export containers to be transported to Kuala Tanjung. After loading and unloading, the ship goes back to the Kuala Tanjung for delivering 72,448 TEUs as the total of Belawan and Tanjung Priok's export containers. The cargo allocation for west route is presented on the following table:

Table 34 The Cargo Allocation for West Route (in TEU)

c1 BLW

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	10,757	-	-	-	-	-	-	10,757
BLW	-	-	16,135	-	-	-	-	-	16,135
TPR	16,135	-	-	-	-	-	-	-	16,135
TPE	-	-	-	-	-	-	-	-	-
BNA	-	-	-	-	-	-	-	-	-
MKS	-	-	-	-	-	-	-	-	-
SRN	-	-	-	-	-	-	-	-	-
BTG	-	-	-	-	-	-	-	-	-
d	16,135	10,757	16,135	-	-	-	-	-	

c2 TPR

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	34,860	-	-	-	-	-	-	34,860
BLW	-	-	34,860	-	-	-	-	-	34,860
TPR	56,312	-	-	-	-	-	-	-	56,312
TPE	-	-	-	-	-	-	-	-	-
BNA	-	-	-	-	-	-	-	-	-
MKS	-	-	-	-	-	-	-	-	-
SRN	-	-	-	-	-	-	-	-	-
BTG	-	-	-	-	-	-	-	-	-
d	56,312	34,860	34,860	-	-	-	-	-	

Source: Author

On the other hand, the cargo allocation for east route can be seen in Appendices II. In this route, Bitung becomes the start-and-end point of another ship that has the minimum Qt of 72,448 TEUs, to serve the east route. Cargo allocations in this route are for the remaining main domestic ports, such as Sorong, Makassar, Banjarmasin and Tanjung Perak. The terminology of cargo allocation is similar to the west route, so the ship can carry all international containers belong to each domestic port within this route in one round trip. Following that, the import containers should be discharged in every main domestic port, while loading the export containers that should be unloaded in the Bitung, as the end of point in this east route. The cargo allocation for east route is presented on the following table:

Table 35 Total Cargo Allocation in Two Indirect Loops (in TEU)

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	45,617	-	-	-	-	-	-
BLW	-	-	50,995	-	-	-	-	-
TPR	72,448	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	25,278
BNA	-	-	-	19,915	-	-	-	-
MKS	-	-	-	-	19,769	-	-	-
SRN	-	-	-	-	-	19,600	-	-
BTG	-	-	-	-	-	-	19,533	-

Source: Author

Table 35 shows total cargo allocation in two indirect loops in the unit measurement of TEU per week. By multiplying this total cargo allocation (∑(c∈C) Pijc), unit cost (cij) and distance (dij), thus we gain the minimum total cost of USD 64.96 million within these routes. Due to a bigger ship capacity on these routes, it leads on the fewer legs in every route. It means that every route has shorter distances and has short delivery times. Hence, two indirect loops provide the lower total costs as well.

5.2.2. Scenario 2: without Belawan

Two experiments were carried out to see the influence by changing the value of Qt. Afterwards, by considering a very close distance between Kuala Tanjung and Belawan, which is 49 Nm, so it is possible for Belawan's container volume to be directly transported either by land transport or by short-sea shipping to Kuala Tanjung.

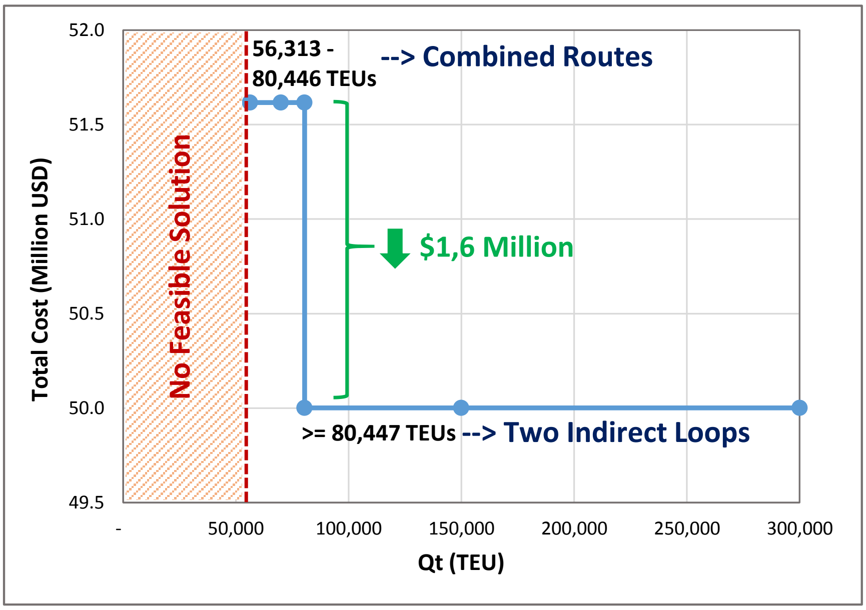
Therefore, we analyse the results of optimum routes excluding the number of export and import containers in Belawan. It means that there are only five remaining domestic ports that have international containers should be transported to international hub ports (see in Table 36).

Table 36 Scenario 2: The Number of Export and Import Container by Port (in TEUs/week)

Main Domestic Port	Code	Export [Si]	Import [Dj]
Tanjung Priok	TPR	56,312	34,860
Tanjung Perak	TPE	24,134	18,771
Banjarmasin	BNA	436	291
Makassar	MKS	508	339
Sorong	SRN	200	133

Source: Author

We also conduct some experiments by changing the value of Qt and re-running the model. By applying the trial-and-error approach, we obtain two results, if Qt is within range 56,313 – 80,446 TEUs, then we get one direct route and one indirect route with total costs of USD 51.6 million. If the Qt less than 56,313 TEUs, then the model does not find any feasible solution because it cannot adequate the ship capacity constraint or cannot fulfil all demand. However, if we rise the value of Qt to 80,447 TEUs or even more, we have two indirect routes with total costs of USD 50 million. The relationship between the changes of Qt and total cost (TC) can be seen in Figure 21.



Source: Author

Figure 21 The Relationship between Qt and TC for Scenario 2

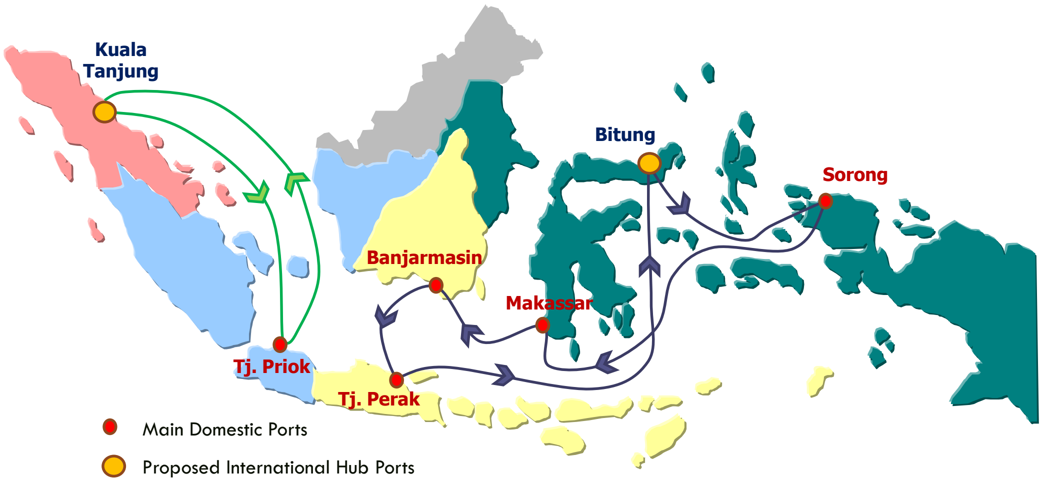
As shown in figure above, there is a slightly difference of total costs between two results by USD 1,6 million, because two results have a slightly difference of the total distance per each route. However, by having a larger ship capacity can obtain lower total costs. As described before, these costs only show the operational transportation costs and do not include the actual shipping costs based on the capacity deployment. Furthermore, we describe the results of optimum routes excluding the number of international containers in Belawan as follows:

A. Combined Direct and Indirect Route (without Belawan)

By applying the Qt within range 56,313 – 80,446 TEUs, the first result we obtained is the combination of direct and indirect route. The direct route is from Kuala Tanjung to Tanjung Priok, whereas another route is Bitung – Sorong – Makassar – Banjarmasin – Tanjung Perak – Bitung. The result of the model can be seen in the following table and figure:

Table 37 The Result of Combined Direct and Indirect Route (without Belawan)

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	1	-	-	-	-	-
TPR	1	-	-	-	-	-	-
TPE	-	-	-	-	-	-	1
BNA	-	-	1	-	-	-	-
MKS	-	-	-	1	-	-	-
SRN	-	-	-	-	1	-	-
BTG	-	-	-	-	-	1	-



Source: Author

Figure 22 Combined Direct and Indirect Route (without Belawan)

By having the direct route and maximum ship capacity of 56,313 – 80,446 TEUs for each route, it can give some benefits with respect to a huge number of container transported, shorter distances and a lower total operational time of ship. Even though, in this thesis, we do not compute the total operational of ship, it implies that the less cargo transported within this route, the more frequency of ship can be achieved.

Table 38 Total Cargo Allocation in TEU for Combined Routes (without Belawan)

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	34,860	-	-	-	-	-
TPR	56,312	-	-	-	-	-	-
TPE	-	-	-	-	-	-	25,278
BNA	-	-	19,915	-	-	-	-
MKS	-	-	-	19,769	-	-	-
SRN	-	-	-	-	19,600	-	-
BTG	-	-	-	-	-	19,533	-

Source: Author

Table 38 presents total cargo allocation for combined direct and indirect route. However, the cargo allocation for each main domestic port can be seen in Appendices III. For a direct route, the starting point is from Kuala Tanjung by carrying the import containers of 34,860 TEUs to be discharged in Tanjung Priok. Afterwards, 56,312 TEUs of export containers in Tanjung Priok should be loaded to the ship and then go back to Kuala Tanjung to unload those containers. Meanwhile, Bitung becomes the starting point for the indirect route. From Bitung, all import containers that belong to each main domestic port should be loaded, and then they will be distributed according to demand in each main domestic port. After discharging the import containers, the ships should carry the export containers from every main domestic port stopped to be discharged in the final destination, Bitung as the international hub port.

By multiplying this total cargo allocation, the similar unit cost as used for the previous analysis and the same distance, thus we obtain the minimum total cost of USD 51.6 million within this route.

B. Two Indirect Loops (without Belawan)

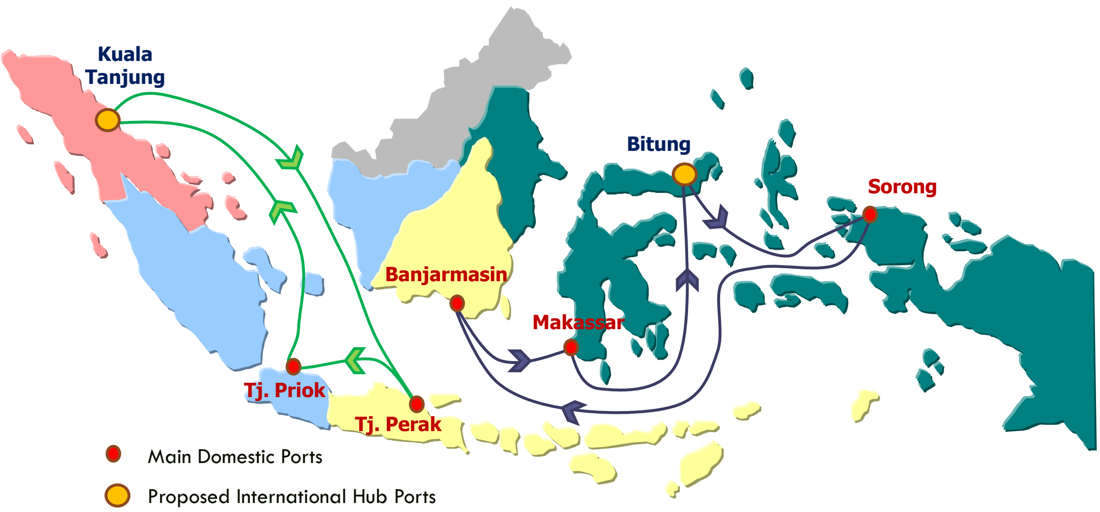
If we change the Qt to 80,447 TEUs or even more, then we have two indirect loops, which remain the same as two loops with Belawan; the west and east route. However, in this case, both main domestic ports in Java region involve in the west route instead of east route. Thus, the west route and east route can be showed as follows:

West route:	Kuala Tanjung – Tanjung Perak – Tanjung Priok – Kuala Tanjung
East route:	Bitung – Sorong – Banjarmasin – Makassar – Bitung

Table 39 The Result of Optimum Route in Two Indirect Loops (without Belawan)

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	-	1	-	-	-	-
TPR	1	-	-	-	-	-	-
TPE	-	1	-	-	-	-	-
BNA	-	-	-	-	1	-	-
MKS	-	-	-	-	-	-	1
SRN	-	-	-	1	-	-	-
BTG	-	-	-	-	-	1	-

Source: Author



Source: Author

Figure 23 The Optimum Route in Two Indirect Loops (without Belawan)

By increasing the value of Qt to 80,447 TEUs or even more, the west route can cover the international container volumes in Tanjung Perak as well. Following that, the east route merely handles the less number of international containers that belong to the Banjarmasin, Makassar and Sorong (see in Table 40). It indicates the lower total shipping costs gained of USD 50 million within this route due to the fewer ports visited, as a consequence it has shorter distances. In addition, the cargo allocation for each main domestic port can be shown in Appendices IV.

Table 40 Total Cargo Allocation in TEU for Two Indirect Loops (without Belawan)

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG
KTJ	-	-	53,631	-	-	-	-
TPR	80,446	-	-	-	-	-	-
TPE	-	58,994	-	-	-	-	-
BNA	-	-	-	-	975	-	-
MKS	-	-	-	-	-	-	1,144
SRN	-	-	-	829	-	-	-
BTG	-	-	-	-	-	763	-

Source: Author

As shown in the table above, even though the east route has the less number of container to be distributed, but the west route can handle efficiently a huge number of international containers from two biggest domestic ports due to the larger ship capacity provided in this route. By this kind of scenario, we can obtain the optimum ship capacity (Qt) of 80,447 TEUs within these routes by achieving the minimum total operational costs.

5.3. Cost Comparison Analysis

After creating the FNDP model to define the optimum routes between six main domestic ports and two proposed international hub ports, we firstly set the maximum ship capacity (Qt) as a constant number by 70,000 TEUs. This number is selected by considering the total container transported, so we assume the value of Qt should cover all the international containers in certain route. Afterwards, we change the value of Qt and re-run the model. We repeat it iteratively to find the optimum Qt that has impact to the minimum total shipping costs, for both scenarios; with Belawan and without Belawan. Hence, we obtain two optimum routes for each scenario, while one of these routes consists of direct and indirect loop. As we described on the concept of hub-and-spoke, a direct loop connects between hub and main domestic port directly, whereas an indirect loop calls at multiple ports.

Some analysis to obtain optimum routes were introduced in the previous sub-chapter. In this part, the results of those experiments are compared by each other. In order to provide a good comparison between several experiments, all results are summarized as follows:

Table 41 Cost Comparison

	With Belawan		Without Belawan	
	1 Indirect Loop	2 Indirect Loops	Combined Routes	2 Indirect Routes
Alternative Route	Kuala Tanjung - Tanjung Priok – Bitung – Sorong – Makassar – Banjarmasin – Tanjung Perak – Belawan – Kuala Tanjung	**West route:** Kuala Tanjung – Belawan – Tanjung Priok – Kuala Tanjung	**Direct route:** Kuala Tanjung – Tanjung Priok – Kuala Tanjung	**West route:** Kuala Tanjung – Tanjung Perak – Tanjung Priok – Kuala Tanjung
		East route: Bitung – Sorong – Makassar – Banjarmasin – Tanjung Perak – Bitung	**Indirect route:** Bitung – Sorong – Makassar – Banjarmasin – Tanjung Perak – Bitung	**East route:** Bitung – Sorong – Banjarmasin – Makassar – Bitung
dij	6,710 Nm	West route: 2,128 Nm	Direct route: 2,030 Nm	West route: 2,892 Nm
		East route: 3,872 Nm	Indirect route: 3,872 Nm	East route: 3,305 Nm
Qt	56,313 to 72,447	>= 72,448	56,313 – 80,446	>= 80,447
TC	76.9 million	64.94 million	51.6 million	50 million

dij: Total distance
Qt: The maximum ship capacity in certain route
TC: Total shipping cost

Source: Author

As shown in Table 41 above, if we compare the results of optimum routes by including Belawan, one indirect loop has higher total costs than two indirect loops. It is caused by the total ship capacity provided in one indirect loop is lower than two indirect loops. Moreover, as an impact of one integrated route, this route has the longest total distance. As an illustration, if there are two routes that are served by the similar size of ships, the route that has longer distance will produce the longer delivery time. In this case, it will require many ships to serve all demand in this route, so it will affect on the higher total shipping costs as well.

The similar thing happens in another experiment when we do not consider the number of international container in Belawan. The route, which has the larger ship capacity, can gain the lower total shipping costs. In addition, by having the direct route in the second scenario of combined routes, it can give a benefit with respect to the higher frequency of ship operated in this route due to the shortest distance. It can be concluded that in the second scenario, the fewer legs that appear in every route means that every route has shorter distances and has short delivery times. Hence, two indirect loops provide the lower total costs as well.

However, the total costs merely represent the operational transportation costs as an impact of these routes based on a unit TEU costs. These costs do not include the actual deployment of the ship capacity required in every route. In order to provide the actual costs for each route, we have to conduct another research, for instance ship assignment analysis to obtain the number of ships required, in which size and capacity and how many frequency of ship needed in the certain route. In this thesis, we focus on the costs for creating connections between main domestic ports and international hub ports, not to determine the actual shipping costs.

6. Conclusion and Recommendation

6.1. Conclusion

Currently, Indonesia is still depending on neighbouring countries with respect to the distribution of international trades. The ninety percent of Indonesia's export and import commodities are transhipped through international hub ports in Singapore and Malaysia. Moreover, export commodities from east region of Indonesia should firstly be transported to the main domestic port (Tanjung Priok or Tanjung Perak), before they continue to the final destination. In fact, the final destination has closer distance with the export commodities region. Therefore, in order to minimize those impacts, Indonesia government along with stakeholders create a strategic role to develop the national logistics system as stated on the vision and mission of the Sislognas' blueprint. Meanwhile, one of their missions is to create the connectivity from inter-island to International hub port. Thus, it can be underlined that for the future logistics system in Indonesia should be capable of handle the international trades by having own international hub port, so Indonesia no longer depends on neighbouring country ports, i.e. Singapore, in order to distribute international goods.

There are two proposed international hub ports based on the KP3EI, Kuala Tanjung and Bitung. Meanwhile, there are six main domestic ports as a representative for each region in Indonesia, Belawan (Sumatera), Tanjung Priok and Tanjung Perak (Java), Banjarmasin (Kalimantan), Makassar (Sulawesi) and Sorong (Rest of Indonesia, including Bali, Nusa Tenggara, Maluku and Papua). In this thesis, we face the main problem, which is to define the optimum connectivity between international hub ports and main domestic ports, according to the National Logistics System. Because the problems are not only to define the optimum domestic routes for international containers, but also we have to allocate these international containers, which have different total amount of export and import for each region in Indonesia. Therefore, we decide to apply a heuristics approach by combining the Feeder Network Design Problem (FNDP) and multiple commodities problem to solve the problems in this thesis. We create an analytical model based on both transportation network problems to create optimum routes by considering the minimum total transportation costs.

After conducting several experiment on the model analysis, we have four results based on two scenarios. The first scenario is namely "with Belawan", we apply all international containers from six main domestic ports into the FNDP model. As the results, by changing the value of maximum ship capacity (Qt), we have two resulted routes. By using Qt within range 56,313 to 72,447 TEUs, we obtain one integrated route that connects two international hub ports and six main domestic ports, while resulting the total shipping costs of USD 76.9 million. If we change the value of Qt less than 56,313 TEUs, then the model will have no feasible solution because it cannot satisfy all of constraints, especially for ship capacity constraint. On the other hand, if we increase the Qt to 72,448 TEUs or even more, then the result changes, which produces the lower total costs of USD 64.94 million and has two separated routes (west and east route).

The second scenario is called "without Belawan", when we do not consider the international containers in Belawan. Due to a closer distance between Belawan and Kuala Tanjung, which is merely 49 Nm, so we assume that all international containers from Belawan would directly be transported to Kuala Tanjung by using land transportation or by short-sea shipping. We evaluate the optimum route by changing the value of Qt, then we also obtain two optimum routes. As the results, if the Qt is within range 56,313 – 80,446 TEUs, then we obtain one direct route and one indirect route, which are called as combined routes with total costs of USD 51.6 million. If the Qt less than 56,313 TEUs, then the model does not provide the feasible solution because it cannot adequate the ship capacity constraint or cannot fulfil all demand. However, if we increase the value of Qt to 80,447 TEUs or even more, then we have two indirect routes (west and east route) with total costs of USD 50 million.

Overall, if the larger ship capacity used on these routes, then each route will have the fewer legs and shorter distances. It implies the fewer number of ships required to serve this route. Thus, it will affect on the lower total shipping costs as well. However, these costs do not include the actual deployment of the ship capacity required in every route. These costs merely represent the operational transportation costs based on a unit TEU costs as an impact of these routes.

6.2. Recommendation for Further Research

The results of this thesis can be recommended for the Indonesia government in order to build integrated and efficient logistics networks in terms of the international container shipping connectivity, between six main domestic ports and two proposed international hub ports.

For further research with regard to the limitations of this research, so we suggest to consider other main domestic ports that can be included in the model analysis. It can provide the results more specific and close to the real condition.

Furthermore, this thesis already provide the method to define optimum routes between international hub ports and main domestic ports. The results also include the optimum ship capacity and total costs in each route. Because, we focus on the costs for creating connections between main domestic ports and international hub ports, so we do not include the actual shipping costs in the model analysis. As a suggestion, it would be better, if the further research can determine ship assignment analysis for these routes resulted. Thus, it can provide more detail regarding how many ships required and total operational time of ships that will affect on the frequency of ships within this route as well. Afterwards, the total costs will be presented as the total actual transportation costs according to the ship deployment.

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Appendices

I. *Total International Container Volume Projection (in TEU/year)*

Table 42 Projection Result of Total International Container Volume by Region (in TEU/year)

Year	Sumatera	Java	Kalimantan	Sulawesi	RoI	Total
2014	1,267,647	6,524,448	34,628	38,984	15,424	7,881,130
2015	1,398,402	6,971,991	37,779	44,017	17,336	8,469,524
2016	1,542,645	7,450,232	41,217	49,700	19,485	9,103,279
2017	1,701,766	7,961,279	44,968	56,117	21,900	9,786,029
2018	1,877,300	8,507,380	49,060	63,363	24,615	10,521,717
2019	2,070,940	9,090,941	53,525	71,544	27,666	11,314,616
2020	2,284,553	9,714,531	58,396	80,781	31,096	12,169,358
2021	2,520,201	10,380,897	63,710	91,211	34,951	13,090,969
2022	2,780,155	11,092,971	69,508	102,987	39,283	14,084,905
2023	3,066,923	11,853,890	75,834	116,285	44,153	15,157,084
2024	3,383,270	12,667,004	82,735	131,298	49,626	16,313,934
2025	3,732,249	13,535,893	90,264	148,251	55,778	17,562,435

Source: Author

II. *Cargo Allocation for Scenario 1: Two Indirect Loops (in TEU/week)*

Table 43 Cargo Allocation for Scenario 1: East Route (in TEU

c6 SRN

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	-	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	200	200
BNA	-	-	-	200	-	-	-	-	200
MKS	-	-	-	-	200	-	-	-	200
SRN	-	-	-	-	-	200	-	-	200
BTG	-	-	-	-	-	-	133	-	133
d	-	-	-	200	200	200	133	200	

c5 MKS

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	-	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	508	508
BNA	-	-	-	508	-	-	-	-	508
MKS	-	-	-	-	508	-	-	-	508
SRN	-	-	-	-	-	339	-	-	339
BTG	-	-	-	-	-	-	339	-	339
d	-	-	-	508	508	339	339	508	

c4 BNA

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	-	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	436	436
BNA	-	-	-	436	-	-	-	-	436
MKS	-	-	-	-	291	-	-	-	291
SRN	-	-	-	-	-	291	-	-	291
BTG	-	-	-	-	-	-	291	-	291
d	-	-	-	436	291	291	291	436	

c3 TPE

O/D	KTJ	BLW	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-	-
BLW	-	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	24,134	24,134
BNA	-	-	-	18,771	-	-	-	-	18,771
MKS	-	-	-	-	18,771	-	-	-	18,771
SRN	-	-	-	-	-	18,771	-	-	18,771
BTG	-	-	-	-	-	-	18,771	-	18,771
d	-	-	-	18,771	18,771	18,771	18,771	24,134	

Source: Author

III. Cargo Allocation for Scenario 2: Combined Routes (in TEU/week)

Table 44 Cargo Allocation for Tanjung Priok in Scenario 2: Direct Route (in TEU)

c2 TPR

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	34,860	-	-	-	-	-	34,860
TPR	56,312	-	-	-	-	-	-	56,312
TPE	-	-	-	-	-	-	-	-
BNA	-	-	-	-	-	-	-	-
MKS	-	-	-	-	-	-	-	-
SRN	-	-	-	-	-	-	-	-
BTG	-	-	-	-	-	-	-	-
d	56,312	34,860	-	-	-	-	-	

Source: Author

Table 45 Cargo Allocation for Scenario 2: Indirect Route (in TEU)

c6 SRN

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	200	200
BNA	-	-	200	-	-	-	-	200
MKS	-	-	-	200	-	-	-	200
SRN	-	-	-	-	200	-	-	200
BTG	-	-	-	-	-	133	-	133
d	-	-	200	200	200	133	200	

c5 MKS

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	508	508
BNA	-	-	508	-	-	-	-	508
MKS	-	-	-	508	-	-	-	508
SRN	-	-	-	-	339	-	-	339
BTG	-	-	-	-	-	339	-	339
d	-	-	508	508	339	339	508	

c4 BNA

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	436	436
BNA	-	-	436	-	-	-	-	436
MKS	-	-	-	291	-	-	-	291
SRN	-	-	-	-	291	-	-	291
BTG	-	-	-	-	-	291	-	291
d	-	-	436	291	291	291	436	

c3 TPE

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	24,134	24,134
BNA	-	-	18,771	-	-	-	-	18,771
MKS	-	-	-	18,771	-	-	-	18,771
SRN	-	-	-	-	18,771	-	-	18,771
BTG	-	-	-	-	-	18,771	-	18,771
d	-	-	18,771	18,771	18,771	18,771	24,134	

Source: Author

IV. Cargo Allocation for Scenario 2: Two Indirect Routes (in TEU/week)

Table 46 Cargo Allocation for Scenario 2: West Route (in TEU)

c3 TPE

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	18,771	-	-	-	-	18,771
TPR	24,134	-	-	-	-	-	-	24,134
TPE	-	24,134	-	-	-	-	-	24,134
BNA	-	-	-	-	-	-	-	-
MKS	-	-	-	-	-	-	-	-
SRN	-	-	-	-	-	-	-	-
BTG	-	-	-	-	-	-	-	-
d	24,134	24,134	18,771	-	-	-	-	

c2 TPR

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	34,860	-	-	-	-	34,860
TPR	56,312	-	-	-	-	-	-	56,312
TPE	-	34,860	-	-	-	-	-	34,860
BNA	-	-	-	-	-	-	-	-
MKS	-	-	-	-	-	-	-	-
SRN	-	-	-	-	-	-	-	-
BTG	-	-	-	-	-	-	-	-
d	56,312	34,860	34,860	-	-	-	-	

Source: Author

Table 47 Cargo Allocation for Scenario 2: East Route (in TEU)

c6 SRN

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	-
BNA	-	-	-	-	200	-	-	200
MKS	-	-	-	-	-	-	200	200
SRN	-	-	-	200	-	-	-	200
BTG	-	-	-	-	-	133	-	133
d	-	-	-	200	200	133	200	

c4 BNA

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	-
BNA	-	-	-	-	436	-	-	436
MKS	-	-	-	-	-	-	436	436
SRN	-	-	-	291	-	-	-	291
BTG	-	-	-	-	-	291	-	291
d	-	-	-	291	436	291	436	

c5 MKS

O/D	KTJ	TPR	TPE	BNA	MKS	SRN	BTG	s
KTJ	-	-	-	-	-	-	-	-
TPR	-	-	-	-	-	-	-	-
TPE	-	-	-	-	-	-	-	-
BNA	-	-	-	-	339	-	-	339
MKS	-	-	-	-	-	-	508	508
SRN	-	-	-	339	-	-	-	339
BTG	-	-	-	-	-	339	-	339
d	-	-	-	339	339	339	508	

Source: Author

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