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Liner Shipping Network Design in Indonesia “Sea-Toll” Agenda: Tanjung Perak Corridor

by

Muchammad Arya Zamal

Acknowledgement

"A dream doesn't become reality through magic; it takes sweat, determination and hard work" – Colin.P.

A long journey to complete this research is started with finding a scholarship and end up with the thesis defence. In between, there is novel knowledge, life learned, and pleasant friendship.

To Prof. Dekker, my supervisor, with all your insightful discussion and knowledge, to all MEL lectures, with all your wisdoms, and for all MEL Class of 2018 with our engaging memories.

Untuk Papa, Ibu, Upi, dan Nana.

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Abstract

The Sea – Toll Agenda is one of the most ambitious initiatives of the Indonesian government to reduce the economic disparity between eastern and western regions in Indonesia. This program provides integrated logistics network for maritime sector in the form of subsidized liner shipping operation. However, after four years of implementation, this network is still underperforming, which concerns some operation issues, such as a high Round-Trip-Voyage (averagely 30 days per voyage). In addition, the budget for Sea – Toll operation is increasing around 45% each year because the government attempts to target more ports for this program. This thesis intends to offer a proposed network for the Sea – Toll Agenda to improve its performance in terms of vessel operation and total shipping cost.

The methodological approach is built based on the LSND (Liner Shipping Network Design) model to unravel the complex problem of establishing network into three decision levels, i.e., strategic, tactical, and operational. The k-means clustering algorithm accommodated our idea to group the set of port involved in the Sea – Toll Agenda into several clusters based on their distance. Then, a TSP (Travelling Salesman Problem) method is performed to yield the most efficient path to connect all ports and generate the Clustering Network. Some network options (Port Aggregation & Butterfly Hub) and scenarios (additional and backflow cargo) are developed from the Clustering Network to obtain the best-proposed network by comparing them with the current Sea – Toll Network in terms of operation planning and shipping cost performance.

Our thesis finds that the k-means clustering algorithm and the TSP model can generate a Clustering Network that has a lowest total distance (10,776 nm). However, the Butterfly Hub option offers the lowest total cost among others. This option can reduce about 50% of the total cost and save around 60% of the subsidy compared with the current Sea – Toll Network. Moreover, the proposed network can provide a better regularity (14 days round-trip-voyage) using half of the number of vessels operating on the Sea – Toll option.

The finding, obtained from the additional and backflow cargo scenarios, suggests that the government should consider to revoke the policy of goods limitation in Sea – Toll Agenda. Both scenarios are capable of improving the network by providing more subsidy saving (10% lower than proposed network) and a competitive unit cost per TEU (770 USD/TEU) compared to the cost from initial Sea – Toll Network (1,830 USD/TEU). A sensitivity analysis shows these results are quite robust to changes in the model parameters.

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Table of Contents

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List of Table

List of Figures

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List of Appendixes

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List of Abbreviations

Adonara (Terong)	TER	Saumlaki	SXK
Agats	AGA	Sebatik	SEB
Belang-Belang	BEL	Serui	ZRI
Biak	BIK	Tagulandang	TAG
Biaro	BIA	Tahuna	TAH
Buhias	BUH	Tanjung Perak	TJP
Dobo	DOB	Teba	TEB
Fak-fak	FKQ	Tidore	TID
Gebe	GEB	Timika	TMK
Kahakitang	KAH	Tobelo	TBO
Kaimana	KNG	Wanci	WAN
Kakorotan	KAK	Waren	WAR
Kalabahi	KBH	Wasior	WSR
Kisar (Wonreli)	KIS	Teluk Bayur	TBR
Larantuka	LKA	Nias Island	NIA
Lewoleba	LWE	Mentawai	MEN
Lirung	LIR	Enggano Island	ENG
Maba	MAB	Bengkulu	BKU
Makassar	MAK	Tanjung Priok	TPP
Marore	MAR	Tanjung Batu	TJT
Melonguane	MNA	Blinyu	BLI
Merauke	MKQ	Tarempa	TAR
Miangas	MIA	Natuna	NTX
Moa	MOA	Midai	MID
Morotai	OZI	Serasan	SRN
Nabire	NBX		
Namlea	NAM		
Namrole	NRE		
Nunukan	NNX		
Obi	OBI		
Oransbari	ORA		
Rote (Ba'a)	BAA		
Sabu (Biu)	BIU		
Sanana	SQN		
Sangata	SGQ		
Sarmi	ZRM		

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1. Introduction

Indonesia approximately consists of 15,000 islands in which seaborne trade plays an essential role to distribute the basic goods from the economic centres to all populated regions. However, 89.12% of the total industry is concentrated on Java Island (Shahab, 2015) which then leads to a price disparity between regions. Due to the logistical costs that is expensive, the farther the area from Java, and the higher the price will be.

Indonesian government has attempted to overcome the price disparity issue by launching nine priority agendas known as “Nawa Cita” (UNDP, 2015). The aim is to develop peripheral areas and reduce economic inequality by establishing and implementing an integrated maritime infrastructure network which was called “Sea-Toll” Agenda. One of the programs is setting up several liner shipping routes to distribute essential goods to some regions in Indonesia, particularly to the areas which are rarely visited by commercial shipping lines. Moreover, the government intends to provide a subsidy for some particular routes in order to reduce the cost of delivering specific goods to those place.

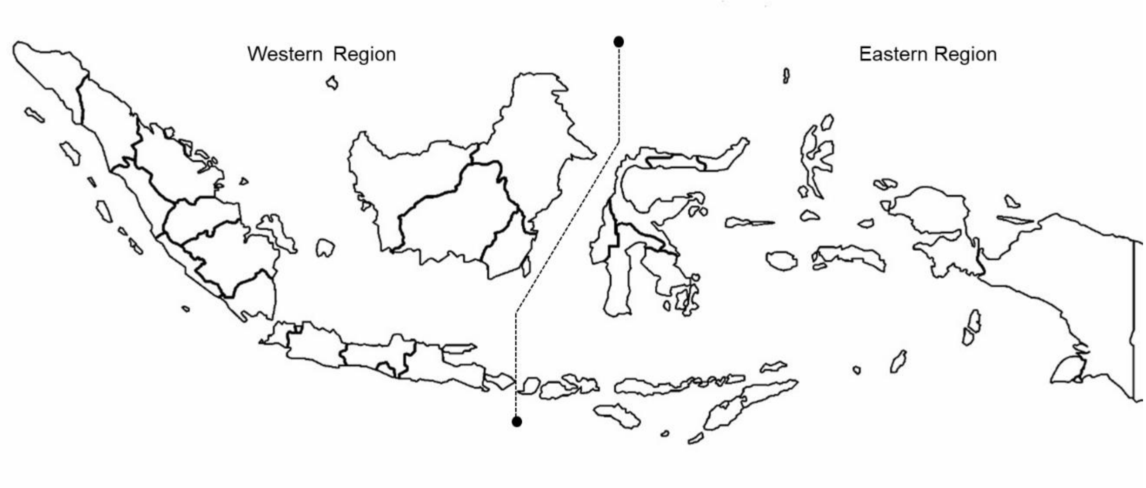

Figure 1 Division of the western and eastern Indonesia (Author illustration)

1.1 Problem Definition and Research Question

The Sea-Toll concept has already been discussed since 2012 which its original plan was connecting five main hub ports using a pendulum route from the western regions to the eastern regions (Transportation Directorate, 2015). Unfortunately, the program was formally launched in 2016 and the pendulum concept was transformed into several route networks, such as hub-and-feeder, circular, and short pendulum route. That happened because the number of ports, which are targeted in this program, increase every year.

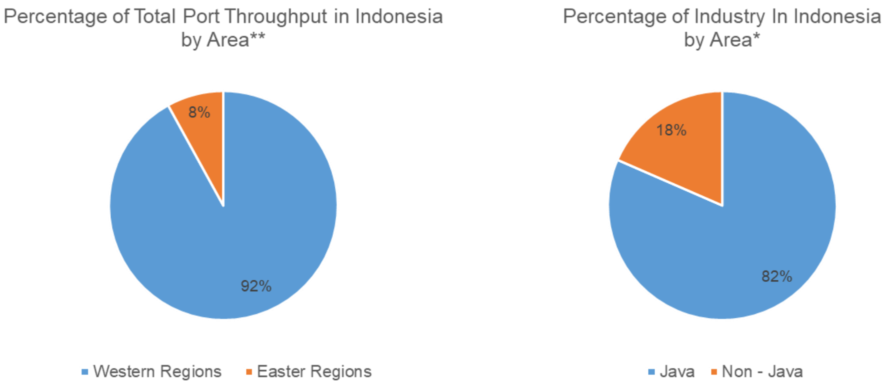

*Figure 2 Industry and Port Throughput Comparison in Indonesia (Source: National Statistics Bureau *2015, **2017)*

The alteration of the network was based on a yearly evaluation. The government had an agenda in maximizing the number of ports which are served by the Sea – Toll Program to expand the subsidized area for a less developed regions (eastern regions and outermost islands). However, the problem arising from such a policy was the length of Round-Trip-Voyage (RTV) because there are some additional ports that should be visited and the vessel should sail in a longer distance. Likewise, both supply and demand to a port destination were low considering a few populations and the small-scale of industry in that area. This condition triggers the government to arrange an efficient Sea – Toll network that can supress the total operation cost.

Table 1 Comparison of "Sea-Toll" Agenda (Author Compilation)

Parameters	**Before 2016**	**2016**	**2017**	**2018**
No. Hub/Main Ports	5	3	3	3
No. Feeder Ports	0	29	39	58
Network Design	Pendulum	Hub - Feeder	Hub - Feeder Circular	Pendulum Circular Hub - Feeder

Realizing the problem mentioned above, this paper attempts to answer the following research question ***"To what extent the Liner Shipping Network Design approach will improve the performance of Indonesia "Sea-Toll" Agenda in Tanjung Perak Corridor in terms of operation planning and total shipping cost?***

1.2 Objectives and Research Design

Accordingly, this thesis aims to provide a Sea – Toll network proposal to optimize current operation scheme plan concerning strategic level, tactical level, and operational level. Therefore, in the future, the network can sustain without any subsidies and the commercial shipping line can enter the route. To obtain such a network, several Sea – Toll contexts should be considered, such as keeping the RTV and fulfilling all demands although the demand is low and the port distance is far.

In this thesis, a proposed network will be established based on a set of ports that was determined by the latest Presidential Decree No. 70 the Year 2017 about Sea – Toll operation. To obtain the optimum network, the operation plan should be arranged. The fleet size and its type should be resolved because every vessel has its own specification, e.g., capacity, speed, and charter cost. Moreover, this thesis will examine the best schedule between once a week and two times a week for fulfilling demand in every port involved in Sea – Toll Agenda. Then, the shipping cost plays a role as performance parameter to evaluate each plan.

The LSND (Liner Shipping Network Design) model is used as a method to establish a proposed network because of its capability to achieve a comprehensive result. However, this paper will focus only on providing a conclusion for the Tanjung Perak corridor. It is because this port will serve for all eastern region ports. In addition, most of the problems come from that areas, e.g., long RTV, low supply/demand, and high operational cost. Afterward, this paper will compare the some options resulted from the model with the current scheme. Some alternative network methods, e.g., clustering network, port aggregation and butterfly route, which are expected to minimize the total shipping cost, will be introduced to optimize the network. Lastly, some possible scenarios, such as additional cargo for supply/demand, will be tested.

1.3 Thesis Structure

This thesis is structured into several chapters to answer the research question. First, we will explore academic frameworks in "Literature Review" as a basis to find a relevant issue associated with Indonesia shipping situation under Sea-Toll Agenda. This chapter will also discuss the development of LSND (Liner Shipping Design Network) model and its research finding. The operational and regulatory framework of Sea – Toll Agenda will be explained in Chapter 3 to introduce the context of the problem and its detail. Then, the steps to answer the research question, including its basic mathematical model, and scenario development will be revealed in the "Methodology" chapter.

The approach and calculation to obtain cargo flow estimation will be described in Chapter 5. We separate this chapter because some steps are applied to obtain the cargo flow. In the chapter "Calculation, Result, and Analysis" a whole computation will be described, the results will be drawn, and the reason behind the result will be criticized. Subsequently, the relevant findings from this thesis and the recommendations for the stakeholders will be presented in "Discussion" chapter. Finally, the summary, contribution, and possible future research will be presented in the "Conclusion" chapter.

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2. Literature Review

This chapter discusses a review of LSND (Liner Shipping Network Design) model, such as domains and current research findings. The report begins with an analysis of decision level in liner shipping to clarify the position LSND in the decision problem (Section 2.1). Then, an overview of LSND will be separated into liner shipping aspect (Section 2.2) and network design (Section 2.3) aspect because it consists of two area of studies. In addition, several papers regarding Sea – Toll Agenda in Indonesia are presented to obtain the insight from the result and possible contribution for this thesis (Section 2.4). By scrutinizing those aspects, this chapter will point out the relation between paper regarding LSND model and Sea – Toll Agenda context.

2.1 Decision Making Levels

Based on planning horizon, level of decision in liner shipping is often grouped as strategic, tactical and operational (Agarwal & Ergun, 2008). Strategic planning is the decision that will impact the company for a relatively long-term period (two to five years). However, a tactical plan will result in a shorter time horizon of 6 – 24 months and, based on the scope of it, operational planning is solved on a weekly or daily basis (Guericke, 2014).

However, in several publications, there are some differences in categorizing LSND in that decision level. Two most cited classification comes from Agarwal & Ergun (2008) and Meng et al. (2014). The comparison between the two papers shown in Figure 3 below.

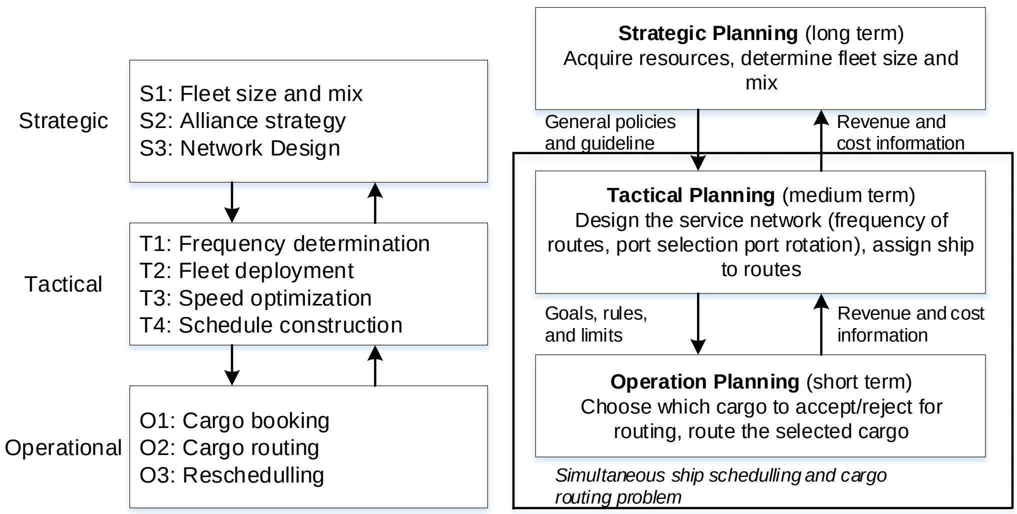

Figure 3 Decision Level Comparison between Meng et al (2014) - Left and Agarwal & Ergun (2008) - Right

Two papers view that LSND located in different decision-making level. The possible reason is that for some liner shipping company, entering the market in such a network can become a long investment because the arrangement will need some partnerships or should comply with some local regulations. On the other hand, when the company already establish the infrastructure, changing network can be considered as medium-term planning. However, there is an indication that LSND decision level could be at the intersection of a tactical and strategic level (Ameln & Fuglum, 2015).

Furthermore, there are several related issues in the decision level that can be solved together with LSND and compatible with this thesis. Fleet size selection, which is classified as a strategic issue, will impact liner shipping operator about 15 until 26 years because of the investment and vessel lifespan (Meng, Wang, Andersson, & Thun, 2014). Regional focus, or decision to enter the market, is categorized as long-term planning. If this problem is combined with the vessel planning (fleet and mix), the case is known as vessel routing problem. Based on the publications, there are some differences in determining the time horizon, from months until year's horizons. Distinct approaches implemented in each paper based on a context of problem and case studies.

Tactical planning problem attempts to answer derived problem from a strategic view namely, frequency, type vessel deployed in specific route (Alvarez, 2009), and fleet positioning - if it is possible to provide a service between two networks - (Tierney, Askelsdottir, Jensen, & Pisinger, 2014). Frequency and number vessel deployed are classified as a tactical problem which will be related to this paper.

Three activities are considered as operational planning decision level, i.e. determining which cargo will be delivered/rejected (Brouer, Alvarez, Plum, Pisinger, & Sigurd, 2014), revenue management, vessel schedule recovery, and stowage planning (Guericke, 2014). In the operational plan, this paper will study the condition of the Sea – Toll Agenda regarding cargo flow and demand fulfilment within the network.

Planning Performance Consideration

As a complement of planning horizon mentioned in the previous paragraph, there are several contexts that should be considered in planning network design for liner shipping, for instance business point of view, network, and infrastructure (Brouer, Alvarez, Plum, Pisinger, & Sigurd, 2014). This viewpoint adds some parameter performances in designing liner shipping, such as competitiveness, CO_2 emission, and service reliability.

In the business point of view, a service of liner shipping become an essential satisfactory index. A service can be defined as the time needed to perform a round-trip voyage at a given frequency known as Round Trip Voyage. Moreover, another time-related performance is transit time which is the duration required for cargo to deliver from origin to destination (Brouer, Alvarez, Plum, Pisinger, & Sigurd, 2014). The customer needs the certainty of the schedule so that their production planning can align with the distribution. Related with thesis topic, liner shipping service becomes a necessity to ensure the demand fulfilment in a designated area at the right time.

Concerning network, Brouer et al. (2014) argued that it should be competitive, efficient, and effective. Network competitiveness means that several routes possible to handle one pair of origin-destination. A few numbers of transhipments and low transit time is a requirement to conduct a competitive network. Moreover, better connection between main ports and feeder ports with a regular schedule is also a necessity of competitive network. Yet, the efficiency of network is also influenced by the infrastructure in the port, such as crane productivity. In addition, the effectivity of network is also closely connected with empty container repositioning.

Infrastructure is related with the cost structure optimization of all assets needed to establish the network. Study regarding shipping cost calculation has been done by Stopford (2009) and it becomes a basic model for obtaining shipping estimation cost in this thesis. However, some publications set some different method considering the context of the problem. In Adiliya (2017), she combined operation cost (OPEX) and capital cost in one chartering cost because, in her problem context, which was Sea – Toll Agenda, the vessel is chartered by time charter contract.

2.2 Liner Shipping Aspects

Based on some studies, several key aspects must be considered when establishing liner shipping routes. In this section we will figure out the problems, such as route structure, fleet composition, and frequency, etc., which will be implemented for the thesis.

Route Structure
Liner shipping service can be differentiated based on the port rotation type or route structure, viz.; Pendulum, Circular, and Butterfly. The visualization of each route can be seen in Figure 4. Pendulum route often calls more than two ports and it is usually classified as cargo without transshipment (Guericke, 2014). Butterfly route provides a service when at least one port is visited more than once (Ameln & Fuglum, 2015). In this thesis, we will use a definition from Reindhart and Pisinger (2011) which stated that butterfly route only has one port to visit twice. In addition, they also take into account transshipment cost on the route which will be assumed in this thesis. Compare with a circular route, butterfly structure allows the additional capacity on a single leg and potentially decrease transit time (Plum, Pisinger, & Sigurd, 2013).

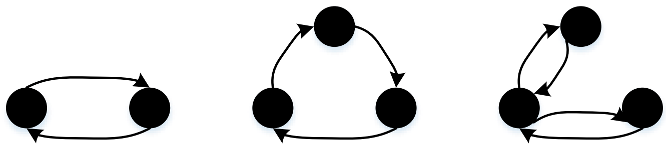

Figure 4 Route Types (Pendulum - Circular – Butterfly)

In this thesis, a circular and butterfly route will become a focus because the regulation rigidly limit the goods and the initial assumption is no backhaul demand. Moreover, the definition of the pendulum route in Sea – Toll Agenda can be included for more than two ports (Adiliya, 2017). However, for some routes, there is no point to doing pendulum route because the demand does not exist.

Fleet Composition
This aspect is related with the arrangement of ship deployed in one route. Homogenous fleet defined as the vessel which is similar in capacity, and cost structure (Ameln & Fuglum, 2015). Sambracos et al. (2004) conducted the study assuming this condition for feeder ship route in the Aegean Sea. The vessel travelled from one depot to 12 ports destination and set minimum cost as the objective by optimizing fuel consumption and port charges.

However, this thesis will apply heterogeneous fleet with different ship types in one network. The vessel set is the vessel available for Sea – Toll Agenda which owned by State Owned Company or Private Company. Basic calculation from Agarwal and Ergun (2008) using heterogeneous fleet arrangement and cost structure calculation of vessel from Adiliya (2017) will be implemented in this work.

Frequency Requirement
Regular schedule is an obligation in operating liner shipping activity. Global liner shipping companies usually perform weekly shipping service (Christiansen & Nygreen, 1998). Based on that finding, some publications perform a weekly frequency as a necessity of the mathematical models, such as Agarwal and Ergun (2008), Christiansen & Nygreen (1998), and Fagerholt (1999). However, ignoring weekly demand became a weakness in those studies. In this thesis, the demand will be estimated and the cost will be compared between once a week and once in two weeks frequency.

Repositioning of Empty Containers
Huge imbalance in the trade leads to another challenge faced by liner shipping. After loading-unloading activities, the empty container needs to reposition which involving significant cost. A study by Agarwal and Ergun (2008) found that a reduction in equipment and repositioning cost in the amount of 10%, potentially increase profitability by 30%-50%. This study allowed flexibility for empty repositioning. However, in this thesis, the assumption from Cheung and Chen (1998) will be considered; empty container will move in a given network. It is because in the Sea – Toll Agenda, after unloading, the container directly will be loaded again. The port has an obligation to provide a warehouse which will become a place to store all goods.

Sailing Speed and Fuel Consumption
Research finding from Mersin, et al (2017), which related to total operation cost in maritime transport, is stated that sailing speed has the power of three relations with bunkering consumption. The daily bunker consumption has a conformity with bunker cost which is usually shares a highest operational cost in total maritime cost operation (Meng, Wang, Andersson, & Thun, 2014).

Another issue in sailing speed is slow steaming which is known as a method to decrease operation cost by reducing the vessel speed from its maximum speed. Amln & Fuglum (2015) cited from CNSS (2013) stated that slow steaming was a win-win-win solution. This method balanced the value for people, profit, and planet. However, there is still a doubt whether the slow steaming method will sustain or not.

Most studies in Liner Shipping Network Design determined vessel speed at the beginning (Meng, Wang, Andersson, & Thun, 2014). This assumption leads to a limitation of research for slow steaming impact in designing liner shipping networks, such as studies from Fageholt (1999), Christiansen & Nygreen (1998), and Agarwal & Ergun (2008). However, the study by Alvarez (2009) considered the difference of speed for each type of ship. The research saw a container ship has a different range of operation region and market.

Considering Sea – Toll Agenda goal, this thesis assumes that the vessel should keep the RTV, therefore, sailing speed can be optimized and slow steaming can be recognized to as long as the vessel can reach the port at the right time.

Transit Time
As mentioned in Section 2.1 , transit time was a competitive parameter for liner shipping. The study by Notteboom (2006) found that some commodities were time sensitive, such as fashion and electronic device. This condition triggers the shippers

to choose liner shipping companies who are providing short transit time. However, there is a trade-off in achieving competitive transit time because the vessel should be operated at high speed and consume more fuel (Brouer, Alvarez, Plum, Pisinger, & Sigurd, 2014). Therefore, it is necessary not to neglect transit time as a constraint in network establishment.

Transshipment and Transshipment Cost
For consolidation and deconsolidation purpose in liner shipping operation, transshipment is considered. Usually, liner shipping could not reach a distant port because of an operational issue (lack of demand or high shipping cost). However, the shipping company use an intermediate destination, then, combine a shipment with the smaller vessel, so it called as consolidation (Ameln & Fuglum, 2015).

Some studies often included transshipment in their model because the operation frequently occurs, however, they did not consider the transshipment cost, such as in Agarwal & Ergun (2008). Paper from Reinhardt & Pisinger (2011) presented a comprehensive solution included transshipment cost and gave an opinion that transshipment cost should not be ignored in establishing a network. Furthermore, they recognized internal transshipment cost which was a transshipment within the similar route.

Transshipment activity will be incorporated in finding the solution for Sea – Toll proposed network. However, the transshipment cost at the beginning will be ignored because the data regarding transhipment cost is not available. The further discussion of transshipment cost will be presented on sensitivity analysis.

2.3 Network Design Problem

Network Design Problem is categorized as a combinatorial problem. The objective is solving the optimal subgraph which satisfies particular connectivity constraint (Korte & Vygen, 2006). In the same paper, formal definition of Network Design Problem presented in Table 2 below.

Table 2 Network Design Problem: A Formal Definition (Korte & Vygen, 2006)

Instance	An undirected graph G with weights $c: E(G) \rightarrow \mathbf{R}_+$, and a connectivity requirement $r_{xy} \in \mathbf{Z}_+$ for each (unordered) pair of vertices x,y
Task	Find a minimum weigh spanning subgraph H of G such that for each x, y there are at lieast r_{xy} edge-disjoint path from x to y

This network design was proven as NP – complete problem by Johnson et al. (1978). However, Agarwal and Ergun (2008) argued for LSND that the problem was NP – hard. It is because the polynomial – time algorithm possibly will not generate an optimal solution.

Application of network design have already presented in several transportation problems, such as in bus rapid transit route (Schmid, 2014) and aircraft routing and airline fleet assignment (Barnhart, et al., 1998). However, concerning maritime transport Meng et al. (2014) argued that the problem was more challenging than other transport system considering the operational complexity. For example, in the airline system, the flight usually one or two legs, but a liner shipping service route can possess 10 – 20 legs (Ameln & Fuglum, 2015).

Liner Shipping - Network Design
An initial approach to obtain the result for LSND in liner container shipping operation was a combination between enumeration and optimisation model from Heaver and Uyeno (1987). They enumerated all possible routes, then, chose the optimal ship route which complied with the problem context. Enumeration method for defining ship route and ship deployed in each continued by Fagerholt (1999) but in a more specific case, such as feeder network establishment. Moreover, the model is extended for determining a heterogeneous fleet with the assumption of cost structure, vessel speed, and capacity (Fagerholt, 2004)

The exact solution for LSND, as stated by Agarwal & Ergun (2008) that LSND Problem was a NP – hard, was solved by Reinhardt and Pisinger (2011) who have developed the solution using Branch and Cut algorithm to construct a network for 15 ports. The result was also included transshipment cost and heterogeneous fleet consideration.

The model in this thesis will follow an initiative in designing a liner shipping network from Koning (2018). The author used K – Means Clustering algorithm to group the port based on distance, then connects all ports using a basic model of TSP (Travelling Salesman Problem). We found that this method suitable for the problem context considering the compatibility of large coverage area between her study (Europe – Asia) and this thesis (eastern and western regions of Indonesia).

2.4 Sea – Toll Research Initiatives

Sea – Toll Agenda will be comprehensively discussed in section three. In this subsection, only research initiatives will be presented.

Sea – Toll Program officially introduced in 2014, therefore, an academic study regarding this initiative start around that year. However, there were several studies specifically reviewed the liner shipping network in Indonesia. Meijer (2015) and Rijn (2015) studied about container shipping network design for some major ports in Indonesia. Mulder and Dekker (2016) presented both cost and operational comparison between a hub and spoke, circular, butterfly, and pendulum route structure to connect six major ports in Indonesia. The result was a hub and spoke route provided lower cost if transhipment cost was not considered, however, when transshipment cost was assumed, the butterfly route became a comparable option.

Considering research in specific Sea – Toll Agenda, a study from Zamal (2017) tried to give a proposed tactical and operational planning for Sea – Toll assuming the route structure was a pendulum. The idea was separating five central hubs port into two pendulum routes considering the imbalance of trade between the east and west region. Setiawan (2018) continued the study by connecting the main hub to the neighbouring feeder ports using as Vehicle Routing Problem (VRP). However, both studies did not consider the specific regulation and operation context in Sea – Toll Agenda, such as goods transported, type of vessel, and RTV target. Furthermore, the network still not implemented the newest policy (see Table 1).

2.5 Chapter Summary

To conclude, all research regarding LSND have a goal to obtain a better shipping line objective which is a company profit. However, there is not a rigid method how to accomplish the goal. It is because the result can be approached by considering several different aspects and the constraint of the problem often different. Therefore, understanding the context and modelling the problem become an important issue.

This research aims to give a view and an alternative approach to find a better network specifically for liner shipping design in Indonesia “Sea-Toll” Agenda. This thesis will provide an insight on how to establish network using K – Means Clustering Algorithm to classify the port, TSP (Travelling Salesman Problem) for route generation and enumeration algorithm to optimize the network.

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3. “Sea – Toll” Agenda: A Subsidized Liner Shipping Initiative

In order to adjust the price of basic need within the country, the government establishes one strategic program in maritime logistics sector which is called “Sea – Toll “Agenda. The other crucial goals of the program are intending to ensure goods distribution and growing the trade of indigenous product from a remote region by setting subsidized liner shipping operation (Ministry of Trade Republic of Indonesia, 2014). Thus, the primary role of liner shipping was to deliver the goods and fulfil the demand for nearby population regularly to prevent a shortage. To implement the program, there are three entities involved; the government (Ministry Trade and Ministry Transportation) as the regulator, Pelindo as port operator, and Shipping Lines as vessel operator.

Stakeholders
As a regulator, the government also play a role to stipulate operational issues related to the implementation of Sea – Toll. In 2018, the government set an obligatory-visit port and its route, goods that can be shipped using Sea – Toll vessel, and freight rate in each route. Moreover, the government provided two scheme of subsidies; transport cost-based and container-based.

PT Pelabuhan Indonesia I – IV (Pelindo), as a state-owned company in port development and operation, assigned to provide a free port dues charge every Sea – Toll vessel. However, they still obtain income from port service activity (mooring, berthing, and piloting), terminal handling charge. Moreover, Pelindo had an obligation to accommodate a warehouse, known as “Rumah Kita” to store goods after the demolition process in a container yard. Nonetheless, this thesis only considers port-to-port delivery as a scope of research.

Shipping line has a role in operating their vessel in the Sea – Toll route. Currently, there are five companies become operator in 12 routes (three routes still in tender process); two state-owned company (PELNI and ASDP) and three commercial shipping line (Mentari, Meratus, and Temas). All elected shipping line will obtain a subsidy to operate the vessel. However, the freight rate should follow the government rule.

Port Involved
Some ports are chosen based on distance from an urban region, price index in a nearby area and regularity visitation by commercial shipping line. Because the program intends to reduce the price disparity, therefore, ports with some characteristics; high price index, remote or far from the main city, and rarely visit by commercial shipping, are chosen. Figure 5 below shows a set of the port in Sea-Toll Agenda, the port code can be seen on List of Abbreviations.

Figure 5 Port Involved in Sea- Toll Agenda
(Own illustration using ArcGIS)

Current Route
Furthermore, the government also sets the route and the price to deliver the container from origin port to destination port. Since implemented in 2016, the route was evaluated and changed every year. The last arrangement for 2018 is including 15 routes which are involved all seaports mentioned and several types of network. The summary of each route is presnted in Table 3 and overall network, route and its type can be seen in Figure 6.

Table 3 Current Sea - Toll Route (CNBC, 2018)

Route	Port Visited	Network*	Operator
T-1	Teluk Bayur – Pulau Nias – Mentawai – Pulau Enggano – Bengkulu	Pendulum	PT ASDP
T-2	Tanjung Priok – Tanjung Batu – Blinyu – Tarempa – Natuna – Midai – Serasan – Tanjung Priok	Circular	PT Pelni
T-3	Tanjung Perak – Belang-Belang – Sangatta – Nunukan – Pulau Sebatik – Tanjung Perak	Circular	PT ASDP
T-4 Hub	Tanjung Perak – Makassar – Tahuna	Pendulum	PT Pelni
T-4 Feeder	Tahuna – Kahakitang – Buhias – Tagulandang – Biaro – Lirung – Melonguane – Kakorotan – Miangas – Marore – Tahuna	Circular	PT Pelni
T-5 Hub	Tanjung Perak – Makassar – Tobelo – Tanjung Perak	Circular	In Tender
T-5 Feeder	Tobelo – Maba – Gebe – Obi – Sanana – Tobelo	Circular	In Tender
T-6	Tanjung Perak – Tidore – Morotai	Pendulum	PT Pelni
T-7	Tanjung Perak – Wanci – Namlea – Tanjung Perak	Circular	Mentari Line

Route	Port Visited	Network*	Operator
T-8 Hub	Tanjung Perak – Biak – Tanjung Perak	Circular	In Tender
T-8 Feeder	Biak – Oransbari – Waren – Teba – Sarmi – Biak	Circular	In Tender
T-9	Tanjung Perak – Nabire – Serui – Wasior – Tanjung Perak	Circular	Temas Line
T-10	Tanjung Perak – Fak-Fak – Kaimana – Tanjung Perak	Circular	In Tender
T-11	Tanjung Perak – Timika – Agats – Merauke – Tanjung Perak	Circular	Temas Line
T-12	Tanjung Perak – Saumlaki – Dobo – Tanjung Perak	Circular	Meratus Line
T-13	Tanjung Perak – Kalabahi – Moa – Rote – Sabu	Pendulum	PT Pelni
T-14	Tanjung Perak – Loweleba – Adonara - Larantuka	Pendulum	PT Pelni
T-15	Tanjung Perak – Kisar – Namrole – Tanjung Perak	Circular	PT Pelni

Figure 6 shows location and connection between ports involved in Sea – Toll Agenda 2018 in X and Y coordinate. The coordinate is based on distance in kilometer unit and connected in different colour per the route. Circular route is shown as a continuous line from the origin port and back to similar port, i.e. A – B – C – A. However, pendulum route will end in destination port and back to origin port by visiting all ports, i.e. A – B – C – B – A.

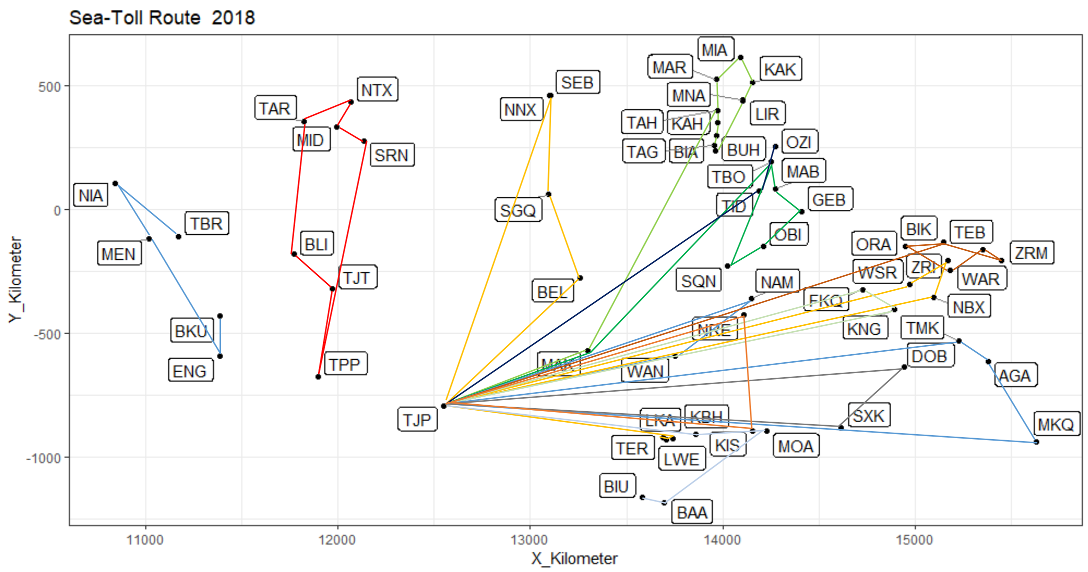

Figure 6 Sea - Toll Route 2018
(Author Illustration using R Studio)

Goods Transported

Aside of route, the government strictly regulated type goods can be transported using Sea – Toll service. The reason was that the government attempted to give the subsidy only to primary needs. Other goods which were not considered in the document of Presidential Decree number 71 the year 2015 was prohibited to use the vessel in the Sea – Toll route. Table 4 below shows a list of cargo from the document mentioned.

Table 4 List Goods for "Sea-Toll" Agenda

Regulated Goods for Sea – Toll Agenda	
Rice	Fertilizer
Soybeans	Kerosene
Chili	Plywood
Shallot	Cement
Sugar	Construction Steel
Cooking Oil	
Wheat Flour	
Beef	
Chicken Meat	
Chicken Eggs	
Fish	
Seeds (rice, corn, and soybean)	

In implementation 2016, about 60% of cargo transported in Sea-Toll Agenda was nondurable goods such as rice, sugar, and wheat flour (Directorate General of Sea Transportation, 2017). Although the programme provided a reefer container, the government still attempted to organize regular shipping because the goods were the primary need which will influence the market price if there was a shortage. In addition, they wanted to ensure all needs fulfilled in every region.

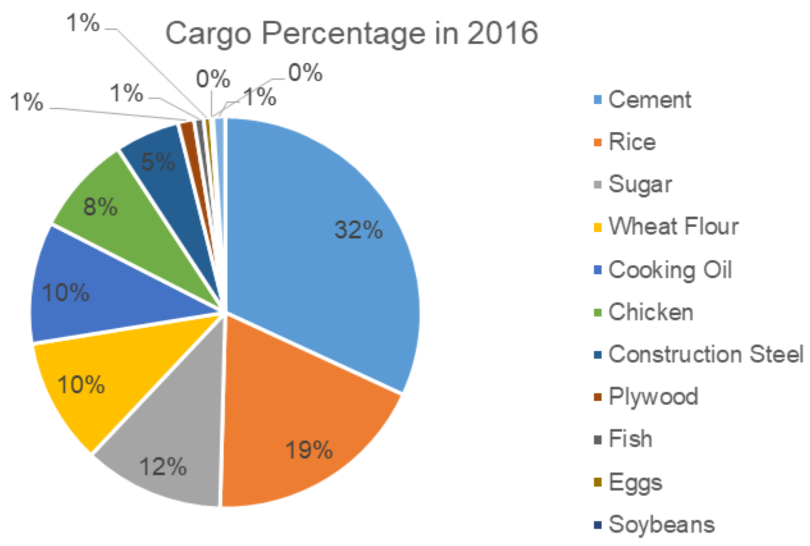

Figure 7 Cargo Percentage in "Sea-Toll" Implementation 2016
Adopted from (Directorate General of Sea Transportation, 2017)

Demand

Limitation of goods transported will impact the demand for Sea – Toll operation in every region. Therefore, a relevant estimation should be applied to predict the demand. This prediction will influence the planning for vessel size as well as frequency for satisfying the government target (100% goods transported). However, the cargo flow data for each route could not be obtained because the route mostly change every year.

Round Trip Voyage Issue
In 2016 implementation, “regularity” or Round Trip Voyage became an issue because a vessel can spend about a month in one voyage. It is because of the distance between the port and the poor performance of the non-commercial port.

Table 5 Average Round-Trip-Voyage in 2016 Sea - Toll Implementation (Directorate General of Sea Transportation, 2017)

Route	Port Visited	Total Voyage	Average Round-Trip-Voyage (Days)
T1	Tanjung Perak - Wanci - Namlea - Fak-fak - Kaimana – Timika	9	37.75
T2	Tanjung Perak - Kalabahi - Moa - Saumlaki - Dobo – Merauke	6	52.00
T3	Tanjung Perak - Larantuka - Lewoleba - Rote - Sabu - Biu – Waingapu	9	36.38
T4	Tanjung Priok – Makassar - Manokwari - Wasior - Nabire - Serui – Biak	8	30.71
T5	Makassar - Tahuna - Lirung - Morotai - Tobelo - Ternate – Babang	6	43.40
T6	Tanjung - Priok - Tarempa - Natuna	16	22.20

Freight Rate and Subsidy Scheme
The subsidy for mentioned goods is given by subtracting total transport cost per voyage with total revenue from shipping rate in on the route. Moreover, the government set the price for shipping rate in Ministry of Transportation Decree number 29 the year 2018. In the document, the government mentioned all possible route and its price per container whether dry container, reefer or general cargo (see in Appendix 14). The price is lower than commercial shipping rate to every destination. Therefore, the shipping line who won the tender for this program will not get any losses. It is because the government will cover all the difference between transport cost and revenue.

Another scheme of subsidy is based on container transported. The idea came up realizing that in one voyage the load factor was deficient. However, this thesis will use the first scheme of subsidy considering limitation goods transported that regulated by the government. This regulation causes shipping line could not take other demand, so the government should compensate the constraint.

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4. Methodology

This chapter aims to elaborate on every approach, i.e., concept, algorithm and mathematical model, to establish the proposed network for Sea-Toll Agenda. Moreover, the advantage and drawback of each method will be presented. The idea of new alternative network is classifying the port in some clusters based on the distance, then choosing one port as a hub in every cluster. The hub port plays a role as a connector for remaining feeder ports in that cluster. Subsequently, some options and scenarios will be developed to observe the change of performance in terms of total shipping cost.

Research framework will be depicted in Section 4.1 as a guide for overall research activity. Then, Liner Shipping Design method is described in Section 4.2 to disclose the domain and the scope of the problem. Subsequently, three optimization approaches to achieve an objective of this paper will be discussed, viz.; K Means Clustering (Subsection 4.2.1), Travelling Salesman Problem (Subsection 4.2.2), and shipping cost estimation model (Section 4.3). Every method will be explained concerning the reason for choosing the model, basic mathematical model and some limitations considering problem modelling. In addition, Section 4.3 will explain our approach to estimate the cargo flow for calculating the strategic and tactical planning. Some options and scenarios will be clarified in Section 4.5 regarding variable modified consistent with the research question. At the end of the section, we will portray the data set required to build the model including sources to obtain the data (Section 4.6).

4.1 Research Framework

To obtain the proposed network for Sea – Toll Agenda, this paper will conduct quantitative research realizing all approaches involve mathematical computations. All input data collected from the secondary sources, such as from government digital documents, yearly shipping company reports, and several journals. Moreover, if the data cannot be found, some assumptions and estimations are applied. Then, the data will be processed and the result will be compared with some scenarios.

Some calculation steps will be performed to obtain the final objective. Figure 8 below shows activity from understanding problem context until achieving a desirable result.

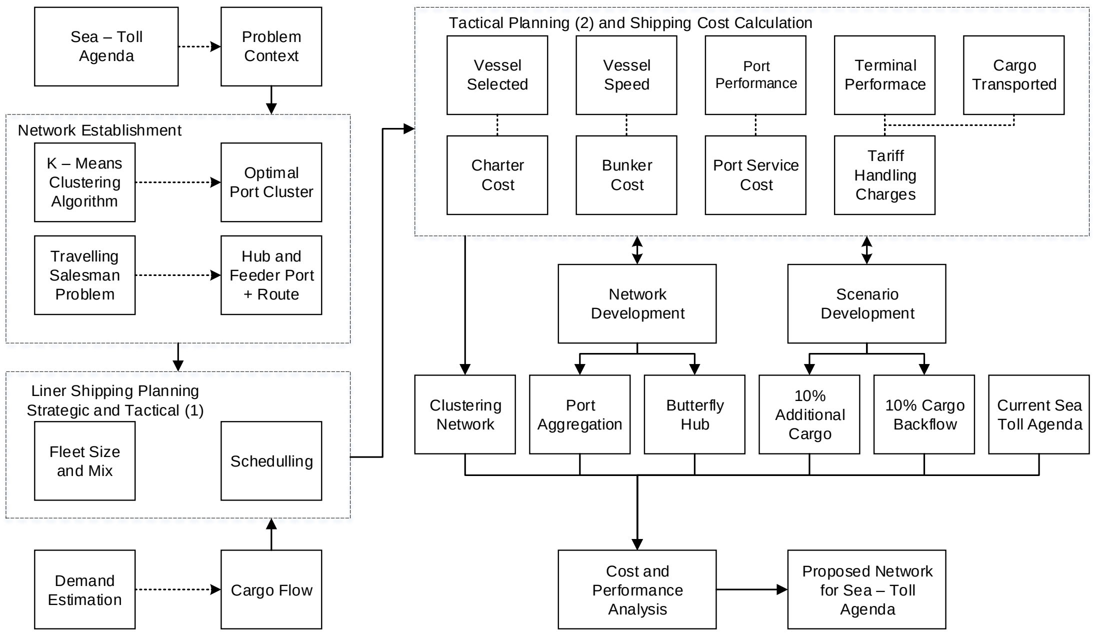

Figure 8 Research Framework

The paper begins with the study regarding Sea – Toll Agenda context which can be reviewed in Chapter 3. All findings from the observation is used as input for initial network establishment, such as port involved, goods transported and freight rate scheme. Aside, a set of data, i.e. port location data, is needed for determining an initial distance between ports. Moreover, demand estimation is calculated as the result of a lack of data from some non-commercial ports. This estimation is used for estimating cargo flow between regions.

Once the network is established, liner shipping planning for each strategic, tactical, and operational level is begun to calculate. This activity will reveal clustering network operation and cost which will be compared with other network options and scenarios. The cost and operation performance for those new possible networks will be assessed by the similar method. Lastly, all networks will be analysed to obtain the research objectives.

4.2 Domain of Liner Shipping Network Design

LSND (Liner Shipping Design Network) Problem intends to solve one level of decisions in liner shipping operation, which is the strategic level. This result will define one or more liner services that offered to the customer (Guericke, 2014). However, the outcome can influence whole decision levels. There are three different problem levels considering the planning horizons which has been mentioned in Section 2.1.

To obtain the research objective, namely proposed network of Sea – Toll Agenda 2018, there are some domains that will be answered by the concept of Liner Shipping Network Design. Each problem will have different mathematical models and approaches to solve.

4.2.1 Network Design: K – Means Clustering Algorithm

This subsection will explain the basic concept and calculation of the k-means clustering algorithm. K-means clustering aims to solve the distance problem of Sea – Toll Agenda that make the network is underperformed. The idea of this step is to divide 49 ports involved in the Sea – Toll Agenda into several clusters based on their distance. K-means algorithm is used to generate proposed port clusters for Sea – Toll Agenda. The reason for using this method because some advantages, such as simple, highly flexible and efficient (Seif, 2018). Working with only 49 ports location is not categorized as a complex data set. Therefore, a flexible algorithm is suitable to modify the data to align with the problem context. Because of that reason, k means algorithm is chosen.

Definition
K – Means clustering is one of unsupervised machine learning algorithm which has an aim to give a partition to the data set. Then, the data set is categorized into a set of *k* groups or *k* clusters, which *k* is the number of the predetermined groups. Every object classified in on one group based on their similarities. The output of this algorithm is two, which are

1. The middle point for each cluster, known as the centroid. This data related with the mean point of the object in the group.
2. To which clusters the data incorporated (data label)

K-means clustering algorithm has an idea to obtain the cluster by minimizing total intra-cluster variation or total within-cluster variation (WSS). The standard form of the k-means clustering algorithm defines the sum squared of distance between objects and its centroid as the within-cluster variation. The formula of within-cluster variation in each cluster is shown below.

$$W(C_k) = \sum_{x_i \epsilon C_k} (x_i - \mu_k)^2 \quad (1)$$

Where x_i is defined as a data point belonging to the cluster C_k and μ_k is defined as the mean value of the points incorporated with the cluster of C_k. The objective of k-means clustering is to minimize the sum of squares distance of each object x_i to assigned centroid μ_k.

Total within-cluster variation is calculated using the formula below.

$$tot.withiness = \sum_{k=1}^{k} W(C_k) = \sum_{k=1}^{k} \sum_{x_i \epsilon C_k} (x_i - \mu_k)^2 \quad (2)$$

This value indicates the compactness of the clustering and it needs to be minimized. Another parameter that usually evaluated for k-means clustering are between sum-square and explained variance in dataset/percentage variance explained. Between clusters sum-square shows the variation between clusters, meanwhile percentage variance explained depicts total variance of the data set explained by k-means clustering.

$$Between\ Cluster\ Sum\ Square = \ n \sum_{\mu_k \epsilon C_k} (\mu_k - \mu_t)^2 \qquad (3)$$

Where μ_k is every cluster means and μ_t is grand mean, and *n* is total number of objects in every cluster *k*. Moreover, total variance (usually the value is percentage) formula is presented below

$$Percentagae\ explained\ variance\ in\ data\ set = \frac{total.ss}{between.ss} \qquad (4)$$

Total sum square or (total ss) is obtained by adding the value of between cluster sum square (Equation 3) with total within sum square (Equation 2).

Clustering Distance Measures

From the previous paragraph, distance data is needed to perform the k-means clustering computation. Some approaches are already introduced to find the distance value. The distance calculation will influence the result and shape of clustering because it will define the similarity between objects. This thesis uses Euclidean distance as the formula to calculate the distance. It is because another option, such as Manhattan distance is relatively not suitable and may have more bias than actual shipping distance. Manhattan distance sees a distance between two points in a strict horizontal and/or vertical path which will make total distance possible higher than actual distance.

The equation below is used to calculate the distance using the Euclidian method.

$$d_{euc}(x,y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2} \qquad (5)$$

Where variable *x* and *y* are indicate the two vectors of length *n*.

Steps and Algorithm

To obtain the output of clustering, some steps should be done. The general overview can be seen in Figure 9 below.

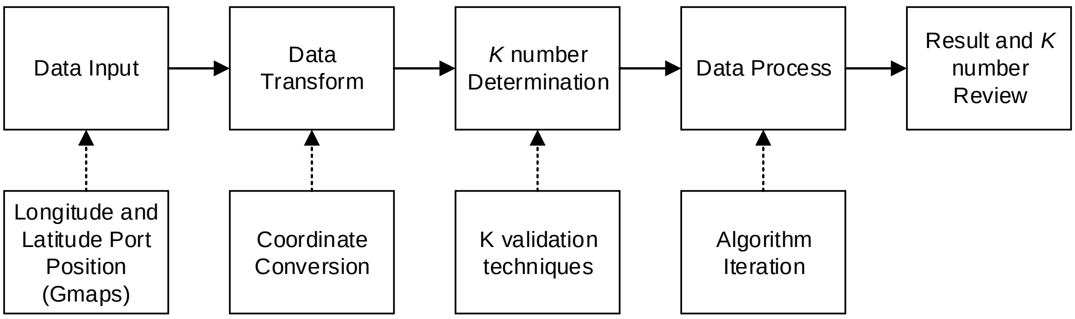

Figure 9 Generating K - Means Clustering Result

a. Data Input and Transformation

Input data for this thesis come from the port location. The data available in several sources on internet, but this thesis used data from google map to determine the location of the port in forms of longitude and latitude. It is because some ports location data are not available in one similar source.

Then, k-means clustering needs a feature of similarities to group the port data. The distance between ports become the feature because this thesis intends to minimize the cost and voyage cost contribute highly in total cost. Therefore, longitude and latitude inputs need to be converted to distance unit (kilometer). The conversion is done using help from converter website in whoi.edu. All the result and validation of the conversion will be presented in Chapter 6.

b. Techniques to Determine *K* numbers

After all data is collected, the number of *k* should be determined. There are several techniques to obtain *k* number, but each approach uses a different concept of calculation. So, in this thesis, some techniques are considered

1. Elbow Method

The calculation objective of k means clustering algorithm is minimized total intra-cluster variation or total within-cluster sum square (WSS):

$$minimize\left(\sum_{k=1}^{k} W(C_k)\right) \quad (6)$$

Given that C_k is the number of k cluster and within-cluster sum square is indicated by $W(C_k)$. The elbow method will look at the total WSS as a function of the number of clusters (Ambara K. , 2017). The validation using elbow method can be done by several steps

a. Calculate the clustering algorithm using different *k* value, i.e. from 1 - 10
b. Compute the WSS for every value of *k*
c. Draw the graph using the value of WSS and the value of *k* to see the plot.
d. The appropriate number of clusters shown of a bend (knee)

The example of the elbow method and the number *k* suggest can be seen in Figure 10 below.

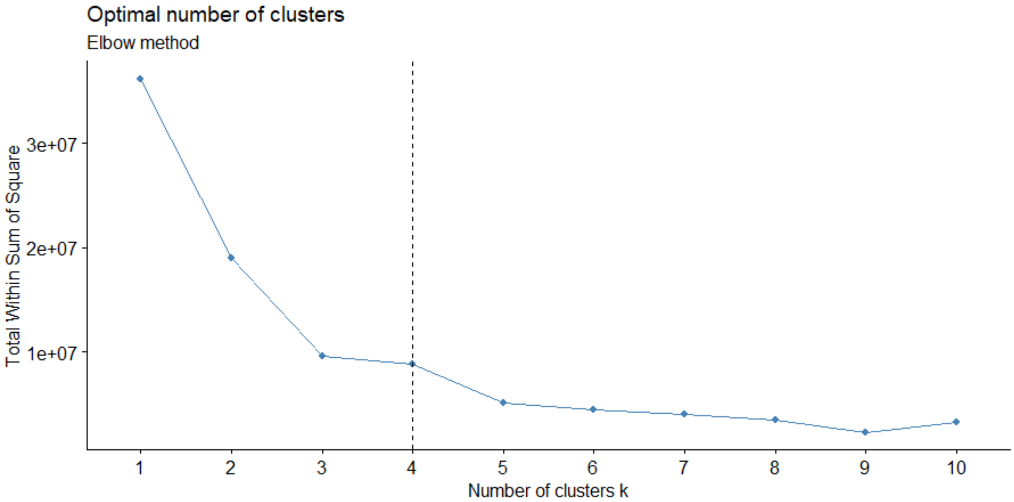

Figure 10 Example of Elbow Method Result

2. Silhouette Method

Different with elbow method, the silhouette method finds the suggested *k* number based on data cohesion within the cluster compared to other clusters. The mathematical model behind silhouette method can be seen in the equation below.

$$s(i) = \frac{b(i) - a(i)}{\max\{a(i), b\{i\})} \quad (7)$$

Let *i* is defined as datum and *a(i)* is the average distance between *i* and other data in the similar cluster. Therefore, whether datum *i* is suitable or not its cluster can be seen from the value of *a(i)*. The interpretation is the smaller the value, the better the assignment. The variable *b(i)* defined as the lowest average distance of *i* to all points in any other clusters of which *i* is not a member. The neighbouring cluster is the cluster with the lowest average dissimilarity (Wikipedia, 2018).

Silhouette coefficient or *s(i)* has a value between -1 and +1. If the value near +1, it indicates the sample has a distance from the closest cluster. However, 0 means that the sample is near or on the decision boundary between two nearest clusters and negative values suggested that the sample determined in the wrong cluster. Similar to elbow method, the result of the silhouette method can be observed in the graph (Figure 11).

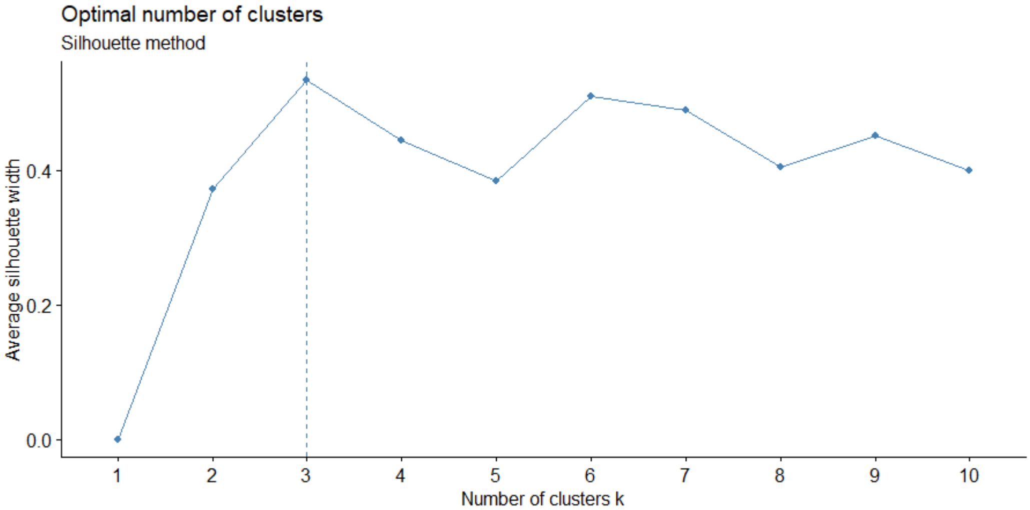

Figure 11 Example of Silhouette Method Result

3. Multi Indicator Method

This method is a form of package in R Studio containing 30 different criteria to determine the optimal number of clusters. The package is known as `NbClust` which will provide a result of clustering number based on majority rule.

```
NbClust(data = NULL, diss = NULL, distance = "euclidean",
min.nc = 2, max.nc = 15,method = NULL, index = "all",
alphaBeale = 0.1)
```

Table 6 Command Explanation (Charrad, Ghazzali, Boiteau, & Niknafs, 2014)

Command	**Explanation**
`data`	Matrix or dataset.
`diss`	Dissimilarity matrix to be used. By default,`diss=NULL`, but if it is replaced by a dissimilarity matrix, distance should be "NULL".
`distance`	The distance measure to be used to compute the dissimilarity matrix. This must be one of: "euclidean", "maximum", "manhattan", "canberra", "binary", "minkowski" or "NULL". By default, distance="euclidean". If the distance is "NULL", the dissimilarity matrix (diss) should be given by the user. If distance is not "NULL", the dissimilarity matrix should be "NULL".
`min.nc`	minimal number of clusters, between 1 and (number of objects - 1)
`max.nc`	Maximal number of clusters, between 2 and (number of objects - 1), greater or equal to min.nc. By default, max.nc=15.
`method`	The cluster analysis method to be used. This should be one of: "ward.D", "ward.D2", "single", "complete", "average", "mcquitty", "median", "centroid", "kmeans".
`index`	The index to be calculated. This should be one of : "kl", "ch", "hartigan", "ccc", "scott", "marriot", "trcovw", "tracew", "friedman", "rubin", "cindex", "db", "silhouette", "duda", "pseudot2", "beale", "ratkowsky", "ball", "ptbiserial", "gap", "frey", "mcclain", "gamma", "gplus", "tau", "dunn", "hubert", "sdindex", "dindex", "sdbw", "all" (all indices except GAP, Gamma, Gplus and Tau), "alllong" (all indices with Gap, Gamma, Gplus and Tau included).
`alphaBeale`	Significance value for Beale's index.

We choose this approach to see the result for majority indicator regarding the suitable number of *k* for port set data. However, we will not dive into one by one explanation of 30 indicators because the main point of this approach is for comparison to determine *k* number.

c. Data Process (K – Means Algorithm)

After determining the number of *k,* this numbers become an input for k – means data process. Every number of *k* is assigned to the calculation to obtain the result. Based on Ambara (2017) the computation consists of two iteration steps. The algorithm starts with determining initial centroid for each *k* cluster. The centroid can be generated randomly of obtained from dataset. Then, the following steps are

1. **Data assignment step**

   Based on the Euclidian distance, each data will be assigned to the closest centroid (Equation 5).

2. **Centroid update step**

   After assignment step, new mean value or the centroid data will be recalculated for each cluster. Then, every object will be checked whether it can be assigned to other clusters.

   The algorithm will be looped until there are some criteria met, i.e. the sum of distance is minimized (Equation 2) and the data point is not changed. This iteration guarantee a convergence result, but not a global optimum. Using a random centroid as an initial step might generate a better result.

d. *K N*umber Evaluation

The last step is reviewing data for each *k* result. As mentioned in the beginning, that k-means clustering is a type of unsupervised learning, the final decision to determine *k* will be based on qualitative judgement. In this thesis, some consideration will take into account to assess each *k* result, such as the geographical possibility for sailing.

The drawback using *k* means clustering in Sea – Toll context is the proximity of port calculated by Euclidean distance. The distance between ports will follow sailing route and usually not a straight line. Therefore, some detour schemes should be considered to recalculate the port distance.

4.2.2 Routing Problem: Travelling Salesman Problem

After getting the number of port clusters, this method will connect every port within the cluster. In the Sea – Toll Agenda, there is an obligation to visit all ports. Moreover, the cost for travel in the transport industry closely related to distance. Therefore Travelling Salesmen Problem (TSP) chosen as the method to solve the routing problem within a cluster and between clusters (hub connection). It is because this method has an objective to minimize the total distance of travelling.

Mathematically, TSP can be modelled in the following equation.

$$min \sum_i \sum_j c_{ij} x_{ij} \tag{8}$$

$$s.t \sum_j x_{ij} = s_i \text{ for each origin } i \tag{9}$$

$$\sum_i x_{ij} = d_j \text{ for each destination } j \tag{10}$$

$$x_{ij} \geq 0, \text{for all } i \text{ and } j \tag{11}$$

The objective of the model (8) is to minimize total cost *c* of transporting goods *x* from origin *i* to destination *j*. Constraint (9) shows that total goods transported should equal to supply from all origin. It means that there is an obligation to transport all goods. Constraint (10) implies that every demand in each destination should be fulfilled. Last constraint (11) is for ensuring non-negativity result.

However, in this thesis, the TSP method will be implemented using heuristic “2 – Optimum” approach. The idea is to compare the cost between 2 – adjacent tour, then choose the lower cost than the current tour. In this problem, the “cost” refers to the distance. If the lower cost is found, then it replaces the current tour. The iteration continues until there is no better solution.

Several advantages of using a heuristic approach are easy to understand, provide a quick solution, and there are some available software to help solve this problem. However, compare with the optimization, this approach may not give an optimal solution. If the software or coding package provides a sophisticated heuristic method, the drawback can be avoided.

Flowchart of using TSP model to obtain the routing result can be seen in Figure 12 below.

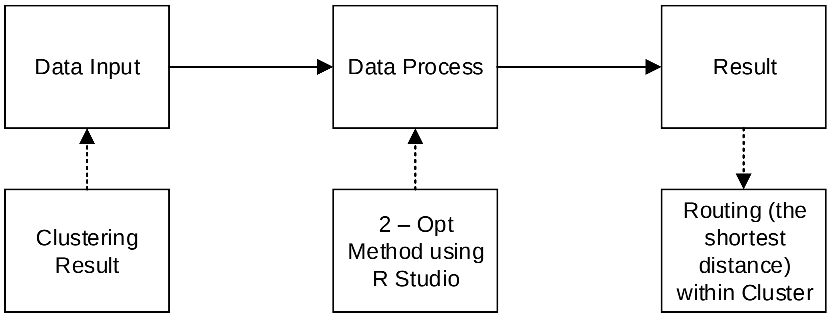

Figure 12 Flowchart Using TSP

4.2.3 Vessel Scheduling

Other domains of liner shipping decision which will be influenced by LSND are strategic and tactical planning. Ship scheduling problem will be solved after network design is established by using k-means and TSP method. This issue will be related to frequency, vessel speed optimization, and vessel deployed. In this thesis, ship scheduling problem is to determine whether the vessel should keep a regularity once a week or once in two weeks to obtain the goal from the government. To do so, a comparison between decisions will be analysed.

Figure 13 below shows the flowchart in determining schedule for vessel in Sea – Toll Agenda.

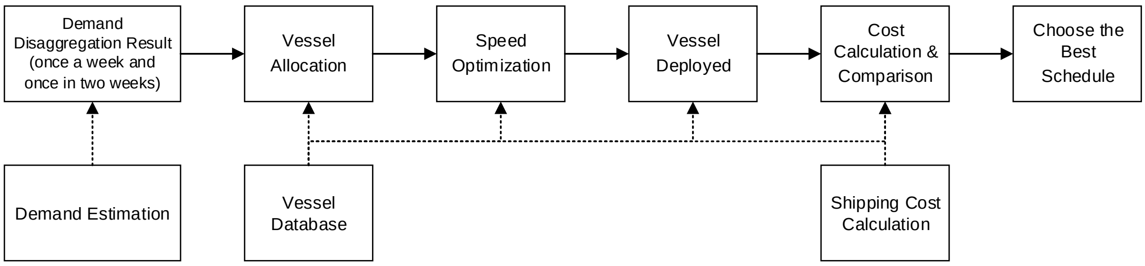

Figure 13 Choosing a Best Schedule

The schedule for the vessel will be determined by the amount of cargo transported. In once a week schedule, the vessel should transport cargo for one week demand to all ports visited. Likewise, in another scheme, once in two weeks demand, the cargo will be doubled. Then, for every scheduling scheme, the vessel type allocated and the number of ships deployed will be different because of the amount of cargo. Finally, for each schedule, the total cost will be calculated. This calculation will consider speed optimization to maintain once a week or once in two weeks schedule. However, if the speed to maintain the schedule is higher than the vessel maximum speed, more vessels will be deployed.

4.2.4 Vessel Allocation Problem

This domain attempts to determine which vessel should be allocated to a specific route. This decision will influence the total cost because every vessel has own charter cost and capacity.

To determine the best vessel, manual enumeration procedure is applied. The objective of this problem is to maximize vessel utilization and minimize potential bunker cost. Moreover, this thesis provides 60 type of vessels available operated by the private or state-owned company in Indonesia. The sample of ship particular data presented in Table 7 below. For the complete data can be found in Appendix 1.

Table 7 Sample Ship Particular Data

ID	***Type***	***Name***	***Size (TEU)***	***Dwt (Ton)***	***GT (Ton)***	***Speed (kn)***	***Cons (Ton/Day)***	***k***
1	Container	KM Kendhaga Nusantara	100	2,194	2,000	8.0	4.0	0.00781
2	MPP	KM Caraka Jaya Niaga III - 32	118	3,650	3,257	8.5	5.0	0.00814
…	…	…	…	…	…	…	….	…
60	Container	Armada Permata	714	12,723	9,048	15.0	23.0	0.00681

Ship particular data not only provides the size and capacity for the vessel but also speed, fuel consumption and *k* value. In the data set, speed is recognized as the design speed of the vessel. We construct the constraint that the speed should not exceed that design speed. Consumption (Ton/Day) in the data shows the fuel consumption in design speed. Because this study intends to find the optimum speed to maintain the schedule, *k* value is calculated using the following formula.

$$k\ value\ = \left(\frac{Cons}{Design\ Speed}\right)^{\varphi} \tag{12}$$

Where φ is defined as a coefficient based on the type of vessel. Wang and Meng (2012) stated that the value for container vessel is 3.

The following is the steps to select the vessel;

1. Calculate the suggested vessel capacity by dividing the route capacity by 70%. This percentage is given from International Maritime Organization (IMO) which regulate the load factor of the vessel.
2. Assign the vessel by comparing its capacity with the calculation result in (1). Choose the vessel which possesses the most capacity for the suggested reference.
3. If there are some vessels with similar capacity, choose the vessel with lower bunker consumption constant value (*k*).

Furthermore, in one route, more than one vessels can be allocated to fulfil the demand based on schedule. Number vessel *s* allocated in one route *r* (n_r^s) will be calculated by following formula

$$n_r^s = \left(\frac{T_r^v}{T_r^t}\right) \tag{13}$$

Where T_r^t is a target time in one round-trip voyage in route *r*, from origin port and back to the initial port and T_r^v is actual time for one round-trip voyage in route *r* after speed optimization. So, if the actual round-trip voyage exceeds the time needed to fulfil demand (target time), then the route requires more than a vessel to maintain the RTV.

4.2.5 Vessel Speed Optimization

This problem domain intends to obtain the optimum speed to meet the schedule or Round Trip Voyage (RTV) target (T_t). Thus, the value of T_r^t is predetermined based on the selection of schedule. RTV target time consists of total port service time T_r^p, total sailing time T_r^s, and total terminal handling time T_r^h in route *r*.

$$T_r^t = T_r^s + T_r^p + T_r^h \quad (14)$$

Sailing time is the time needed for the vessel to sail from origin port to destination port after all activities in port is completed. Port service time is the time required after vessel arrives, but before loading/unloading the cargo, so the vessel can berth safely in the terminal. This value is given for this thesis. Cargo handling time is determined by the amount of cargo that load/unload in the port and the productivity of crane. Therefore, the only parameter that can be optimized to meet the RTV target is sailing time.

In a simple equation, optimum speed *v* vessel *s* in route *r* (s_r^v) can be obtained with the following equation.

$$s_r^v = \frac{d_r}{T_r^t - T_r^p - T_r^h} \quad (15)$$

Optimum speed *v* vessel *s* route *r* is the result of a division of total distance between ports with total sailing time target T_r^s which is obtained from subtraction of RTV target T_r^t with total port service time T_r^p and total port handling time T_r^h. G*oal seek* feature in MS Excel is used to solve every speed optimization problem in each route.

Total port service time in each route (T_r^p) is calculated by summing up port service time in every port *h* where the port *h* is visited in of route *r* ($T_h^p,\ where\ h\ \in\ r$). Total service time in every port is given and it can be obtained in Appendix 3.

$$T_r^p = \sum_{h \in r} T_h^p \quad (16)$$

Similarly, total port handling time in each route (T_r^h) is computed by adding terminal handling time in every port *h* where the port *h* is visited in of route *r* ($T_h^h,\ where\ h\ \in\ r$)

$$T_r^h = \sum_{h \in r} T_h^h \quad (17)$$

Meanwhile, the value of terminal handling time in every pot T_h^h is not given. The following is the formula for obtaining the terminal handling time in each port destination ($T_{h_2}^h$)

$$T_{h_2}^h = 2 * \frac{\left(x_{h_1 h_2}^{od} + x_{h_1 h_2}^{ot}\right)}{(e_{h_2}^p * e_{h_2}^n)} \quad (18)$$

Total terminal handling time in the port destination ($T_{h_2}^{h}$) is calculated by dividing total cargo unloaded/loaded in the port with total crane productivity. The cargo, which directly delivered the destination port, is depicted by $x_{h_1 h_2}^{od}$. The notation $x_{h_1 h_2}^{ot}$ is presented the container which will be transhipped to another port. Total crane productivity is the result of the multiplication of crane productivity in port destination $e_{h_2}^{p}$ with the amount of crane $e_{h_2}^{n}$. The value of crane productivity can be found in Appendix 5, **while the number of cranes operated for Sea – Toll is assumed two cranes for every port**. Lastly, we multiply the result by two because **we assume that empty cargo directly loaded back to the vessel for cargo repositioning purpose.**

4.3 Cargo Flow Estimation

Recall from Figure 13, operational and tactical plan, such as scheduling, allocation, and speed, optimization needs reliable information for actual condition. Cargo flow data is one essential data required to perform the planning. However, there is a limitation to find the data for the Sea – Toll context. The following are some reasons behind the cargo flow data limitation;

1. Cargo, which is transported using Sea – Toll program, is not completely available for every port because the regulation always changes every year (Table 1). Thus the cargo flow estimation cannot be performed using regression.
2. Some ports are the non-commercial port (Appendix 3), so the port throughput data for all ports is difficult to find by online. Non-commercial port means the port is not operated for business reason. Thus, there is no obligation to share the data to the public.
3. By regulation, there is a limitation of goods transported using this programme. Usually, throughput data in every port is not provided information regarding the detail of the container.

Based on those limitations, this thesis attempts to construct own approach to obtain cargo demand data for every port. However, there is an assumption that in the initial network, **Tanjung Perak and Makassar will become port that provides the cargo. The rest of the ports only receive the cargo and trade between ports is not assessed in this thesis.** Figure 14 below shows the input and the step to obtain the cargo demand estimation for each port.

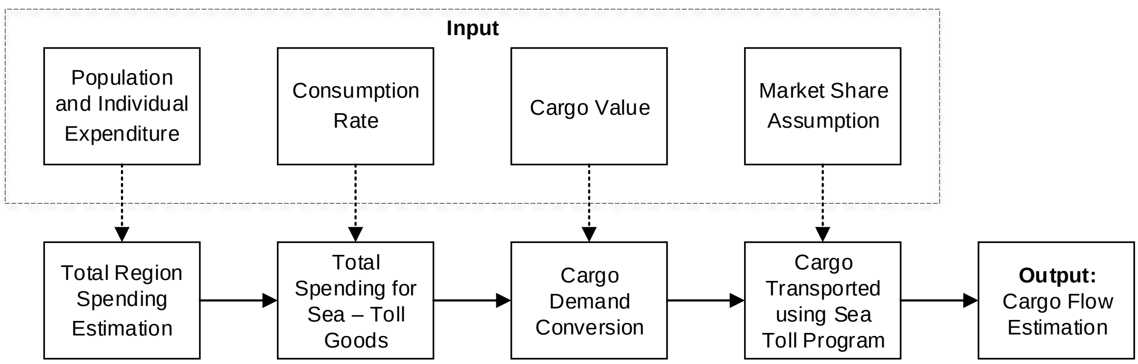

Figure 14 Calculation Approach for Cargo Estimation

4.3.1 Total Region Spending Estimation

Demand for goods in every region is related to the spending of all population in on that area. We calculate the total expenditure to know the total trade value in one region. We assume that the port will provide the service for the nearby neighbourhood. Total population calculated by following formula.

$$Total\ Monthly\ Spending = Population\ x\ Average\ Daily\ Expenditure\ x\ 30 \qquad (19)$$

Total spending (USD/Month) is the monthly expense of total population in one region. Therefore, this variable is the multiplication of population, daily spending and number of days in a month (30). Population is the total number of citizens living in region nearby port. The data is compiled from National Statistics Bureau. Average daily spending (USD/Day) is the mean of individual expense in particular region. This data obtained from personal expenditure in World Bank database (see Table 13). Moreover, the database provide the individual spending every category of income and residence (rural or urban)

4.3.2 Total Trade Value for Sea – Toll Goods

After obtaining total spending in the region, we will estimate how much trade value that spends on Sea-Toll goods. Recall from Table 4, the goods that delivered using the programme only food and basic needs (general goods). This formula below is presented the calculation.

$$Total\ Trade\ Value = Total\ Spending\ x\ (\%\ Spending\ for\ Food\ \&General\ Goods\ ) \qquad (20)$$

Total trade value (USD/month) is the total value of money that spend on Sea – Toll goods. The percentage of spending denotes the average proportion for food and general goods consumption which is provided by maritime trade for all population in one region. The percentage value obtained from World Bank data regarding consumption rate (see Table 15)

4.3.3 Trade Value Conversion

This calculation intends to convert trade value (USD/month) to become cargo demand (TEU/month). Approach from Ma (2016) is applied to perform this conversion. In her thesis, she converted trade value in the maritime trade from the currency unit (USD) to tonnage (Ton) by estimating the value of goods per ton. Adopting from the study, the formula below shows the cargo conversion

$$Cargo\ Demand = \frac{Total\ Trade\ Value}{Value\ of\ Goods * 21.6} \qquad (21)$$

Cargo demand is the total container in TEU which is needed to be fulfilled for each port involved in the Sea – Toll Agenda per month. To obtain cargo demand (TEU/month), total trade value (USD/month) is divided by the value of demand (USD/ton) times 21.6. Value of goods denotes the average value of combination goods per ton. We use a weighted average to obtain the value for Sea – Toll goods per ton. The constant value of 21.6 presents conversion value from ton to TEU (**assuming 1 TEU = 21.6 Ton**), so the cargo demand unit will be in TEU/month.

4.3.4 Effective Cargo Demand for Sea – Toll Agenda

Finally, we estimate effective cargo demand for Sea – Toll agenda. Realizing that some shipping lines already operated in some ports, this calculation attempts to find an estimation of actual demand in every port which should be fulfilled by Sea – Toll service.

$$Effective\ Cargo\ Demand = Cargo\ Demand * Market\ Share \qquad (22)$$

Effective cargo demand is defined as total container should be transported (TEU) per month after considering the current shipping line operator. This variable is the result of multiplication cargo demand (TEU/Month) and market share (%). Market share data is obtained from own compilation by collecting shipping line company data from website and news that already operated in each port. Then, we assume the percentage of market share from the number of the shipping lines. Table 8 below shows the assumption

Table 8 Market Share Assumption

Number of Competitor	Market Share Assumption
1	40%
2	20%
3	15%
4	10%

The number of competitor presents how many shipping lines that already operated in a particular port and provide the basic goods. Market share assumption for each number of the competitor is based on author assumption.

4.4 Shipping Cost Estimation

Shipping cost is calculated as a parameter for network performance. Based on Stopford (2009), basic shipping cost model is an addition of operating cost, voyage cost, cargo handling cost and capital cost. Operating cost is the charge for make the vessel ready to sail consisting of crew wage, stores, lubricants, repair, maintenance, insurance, and administration. The voyage cost is the expense when the ship is sailing. The cost depends on the fuel consumption, main engine, auxiliary engine, fuel price, speed and all port charges. Moreover, cargo handling cost is the cost to move the container from the ship to the container yard. It is influenced by the cargo type, ship layout, etc. Lastly, capital cost closely related with capital repayment and interest of the vessel.

However, in this thesis, the total shipping cost calculation consists of four cost elements, which are port cost, terminal handling charge, bunker cost, and charter cost. The adaptation is because of the different scheme in operation. For instance, in the Sea – Toll Agenda, the vessel is already available from shipping line operator. Most of the shipping operator uses chartering scheme, which includes all operation cost to finance their ship. Therefore, operating cost and capital cost is merged become charter cost.

Furthermore, the voyage cost will be separated become port cost and bunker cost. The reason is to facilitate the analysis of cost structure. Port cost covers all service required in port, such as mooring, berthing, etc. Bunker cost will calculate fuel needed for sailing which is including time spent in the sea and idle time in the port. All of this cost components will be described in the next subsection.

Before shipping cost estimation is described, table below shows notation for sets used in the formula.

Table 9 Sets Notation

Notation	Explanation
$\boldsymbol{n} \in \boldsymbol{N}$	Set of Network
$\boldsymbol{h} \in \boldsymbol{H}$	Set of Port
$\boldsymbol{r} \in \boldsymbol{R}$	Set of Route
$\boldsymbol{s} \in \boldsymbol{S}$	Set of Vessel

Shipping cost estimation is formulated by the following formula.

$$c_n^{tot} = c_n^b + c_n^h + c_n^p + c_n^c \text{ , } for\ every\ n \epsilon N \qquad (23)$$

Total cost in each network *n* (USD/Year) denotes in c_n^{tot}. The value is the result of addition all cost component considered in every network, which are total bunker cost c_n^b, total handling costc_n^h, total port service costc_n^p, and total chartering costc_n^c.

4.4.1 Port Service Cost

This section will contain the formula to calculate service cost in Indonesia context. Total port service cost in each network *n*, c_n^p in a year is an addition of pilotage fee p_h^f, tug fee t_h^f, anchoring fee a_h^f and berthing fee b_h^f in each port for every network. Then, the result is multiplied by total number of voyage n_v in one year. In this calculation we will ignore port dues fee because in the Sea – Toll context, the vessel will be not charged. Some ports have an obligatory pilot and tug and the other is not. All the data for port charges can be seen in appendixes. The formulation for total port cost per year can be seen in following formula.

$$c_n^p = \left(\sum_{\boldsymbol{h} \in \boldsymbol{H}} (b_h^f + a_h^f + p_h^f + t_h^f) \right) * n_v \text{ , } for\ every\ n \epsilon N \qquad (24)$$

Number of voyage in a year n_v calculated by dividing total days in a year T_y (assumed 365 days) with total Round-Trip-Voyage time in one cluster T_v, then multiplied by number of vessel n_s

$$n_v = \left(\frac{T_y}{T_v} \right) * n_s \qquad (25)$$

From Sudjaka (2018), Table below shows the port charge component and the calculation for each port

Table 10 Port Charge Component (Adopted from Sudjaka, 2018)

Port Charge Component	**Calculation Equation (For Each Port)**
Berthing Fees	$Berthing\ Fees = Tariff\ \times Ship\ GT \times No.of\ 24\ Hours\ at\ Berth$
Anchoring Fees	$Mooring\ Fees = Tariff\ \times Ship\ GT$
Pilotage (Primary)	$Primary\ Pilotage = Tariff \times 2\ Movements$
Pilotage (Additional)	$Additional\ Pilotage = Tariff \times Ship\ GT$
Tug (Primary)	$Primary\ Tug = Tariff \times 2\ Movements$
Tug (Additional)	$Additional\ Tug = Tariff \times Ship\ GT$

4.4.2 Terminal Handling Charge

This section will contain the formula for calculating terminal handling charge. Terminal handling cost consists of handling charge for full container and empty container. The data regarding the each charge can be seen in Appendix 4.

$$\boldsymbol{c_n^h} = \left(\sum_{\boldsymbol{h} \in \boldsymbol{H}} (\boldsymbol{c_h^f} + \boldsymbol{c_h^e}) * x_h^d\right) * n_v, for\ every\ n \in N \qquad (26)$$

Cost of terminal handling charge per year (USD/year) in network *n* is the total fee for (un)loading full container (TEU) and fee for (un)loading empty container (USD/TEU) in a year for every port. This thesis assumes that in each port, the terminal will move full container in same amount of empty container.

4.4.3 Bunker Cost

This section will contain the formula to obtain bunker cost per round trip and per year. Bunker cost per round trip is the total cost from the origin port and back to the initial port.

$$c_n^b = \left(\sum_{s \in \boldsymbol{S}} \sum_{r \in R} f_{rs}^c * p^f\right) * n_v\ for\ every\ n \in N \qquad (27)$$

Total bunker cost per year in *n* network (USD/year) is total fuel consumption (ton) for every vessel *s* assigned in route *r* multiplied by price fuel p^f (USD/Ton). Then the result is multiplied by total voyage in a year.

$$f_{rs}^c = T_v * s_v * (s_k)^3, \qquad for\ every\ r \in R\ and\ s \in S \qquad (28)$$

Fuel consumption (tonnes) in every vessel *s* assigned in route *r* calculated by multiplying optimum vessel speed *s* (knot) with the power of three of ship *k* value (constant). Then, the result is called *ship fuel consumption per day* (tonnes/day). This result is multiplied by total time needed T_v (day) to sail in one round-trip.

Furthermore, the fuel price is predetermined from the data collection. The fuel for vessel (MFO) price in obtained from official website of Indonesia state-owned oil company (Pertamina). The website provides the information for fuel price in rupiah per litre. However, the bunker consumption data from ship particular in USD/ton. Therefore we convert the currency, then transform the unit, from litre to tonnage. Given that 1 ton of MFO = 1,100 litre MFO.

Table 11 Selected Fuel Price

Period	***MFO Price***		
	Rupiah/litre	**USD/liter**	**USD/ton**
1-14 January 2018	7,700	0.54	590
15-31 January 2018	7,750	0.54	594
1-14 February 2018	7,850	0.55	602
15-28 February 2018	7,850	0.55	602
1-14 March 2018	7,500	0.52	575
15-31 March 2018	7,500	0.52	575
1-14 April 2018	7,850	0.55	602
15-30 April 2018	8,050	0.56	617
1-14 May 2018	8,500	0.59	652
15-31 May 2018	8,950	0.62	686
1-14 June 2018	9,900	0.69	759
15-30 June 2018	9,750	0.68	747
1-14 July 2018	9,650	0.67	740
15-30 July 2018	9,150	0.64	701
Selected Fuel Price		**0.69**	**759**

4.4.4 Charter Cost

This section will contain formula to calculate charter cost

$$c_n^c = \left(\sum_{s \in \boldsymbol{S}} \sum_{r \in R} c_{rs}^r * n_r^s \right) * \; T_y \tag{29}$$

Total charter cost in a year (USD/Year) is the total charter rate for every vessel *s* assigned in route *r* (USD/Day) times the number of vessel *s* in route *r* (unit). Then the result is multiplied by total days *Ty* in a year (365 days). The charter rate data can for each vessel can be obtained in Appendix 1.

4.4.5 Revenue and Subsidy

Based on Ministry of Transport Decree number 22 the year 2018 about profit and cost component for subsidized activity in cargo delivery in ocean stated that subsidy calculated in two ways. Either the difference between revenue in one route with its operational cost or difference between commercial shipping rates with the tariff set by the government. In this thesis, we will use the first term of subsidy which is the difference between total operational costs with the revenue based on a tariff set by the government.

The revenue in network *n* is calculated by accumulating all freight rate from port origin to port destination $f_{\boldsymbol{h_1},\boldsymbol{h_2}}^r$, with total cargo transported from given origin to destination port in a year $x_{h_1 h_2}$.

$$r_n = \sum_{h_1 \in H} \sum_{h_1 \in H} f^r_{h_1,h_2} * x_{h_1 h_2} \quad (30)$$

Therefore, the subsidy for the network *n* in a year is the difference between revenue r_n and total cost c_n^{tot} in network *n*.

$$Sb_n = r_n - c_n^{tot} \quad (31)$$

4.5 Options and Scenarios

Some network options are developed to improve the performance of the network established by the clustering method. It is because the clustering approach and the TSP method might produce a suboptimal output. Then, all options will be compared with the current Sea – Toll network operation. Some options that will be considered are the clustering network which established from k – mean clustering and TSP model, port aggregation model, and butterfly route. The following are the detail explanation of each network option for comparison.

1. Sea – Toll Agenda Current Network
   This network is based on the current operation of Sea – Toll Agenda as a basis of comparison. The network form and the route can be seen in Figure 6, Chapter 3.

2. Clustering Network (Circular)
   This network is the clustering network resulting from the implementation K – Means clustering algorithm and the TSP model. Further explanation and the steps to generate the network will be explained in Chapter 6.

3. Clustering Network with Port Aggregation
   After establishing the clustering network, some considerations are taking into account, such as cargo flow estimation to the port destination. In this network, we will ignore some ports which have a demand less than ten containers a month. Then, we assume there will be another service using local shipping line to the port destination.

4. Clustering Network with Butterfly Hub Route
   The new option is developed to see the difference if the route that is connecting main hub port is separated into two routes. The butterfly route structure will be established as a combination of previous option (port aggregation). The option is shown in Sub Section 6.3.1.4.

Furthermore, after analysing the difference between some network structures, we intend to investigate more issues. The scenario is to observe the impact if the government change the regulation regarding the regulated goods. We consider two additional scenarios related to extra cargo flow which are;

5. 10% Additional Goods Transported (Scenario 1)
   This scenario will observe the change of the network if there is 10% additional cargo from the origin port flow to the destination port. We will consider this scenario as **Scenario 1.**

6. 10% Additional Goods Transported + 10% Backflow Goods Transported (Scenario 2)
   After adding 10% additional cargo, this scenario will see the impact if there is a growth in 10% backflow cargo from each port to the origin port (Tanjung Perak). This scenario will be considered as **Scenario 2.**

4.6 Data

To run the model and obtain the result, some data are required as an input. This section will present the data and its source. As discussed in subsection Cargo Flow Estimation4.3, some data will be estimated as because of a limitation to finding a reliable source, such as cargo flow value. Therefore, some proxies are applied to predict the real data. Table 12 below provides the list of data and its source.

Table 12 Data and Sources

Data	***Source***
Sea – Toll Agenda regulatory framework	Trade Law Number 7 about Market Integration, Ministry of Trade, Republic of Indonesia
Sea – Toll Agenda operational plan	Ministry of Transportation Regulation regarding Cost and Revenue Component for Subsidy Activity in Maritime Transport.
Port Location	Google Maps
Ship Particular	Clarkson Market Intelligent
Cargo Flow in Sea – Toll Agenda	Directorate of Maritime Transport Report 2017, Ministry of Transportation Republic of Indonesia
Population	Indonesia National Statistics Bureau
Average Daily Expenditure	World Bank , Global Consumption Database
Consumption rate	World Bank , Global Consumption Database
Price of Sea – Toll Goods	Early Warning System Ministry of Trade Republic of Indonesia
Shipping Line Service	Each Shipping Line Website
Berthing Fees	Adopted from Adiliya (2017)
Anchoring Free	Adopted from Adiliya (2017)
Pilotage Fees	Adopted from Adiliya (2017)
Tug Fees	Adopted from Adiliya (2017)
Terminal Handling Charge	Adopted from Adiliya (2017)
Fuel Price	Fuel Price Information Website (Pertamina)
Charter Cost	Adopted from Adiliya (2017)
Freight Rate for Sea – Toll Network	Ministry of Transport Regulation regarding Public Service Obligation

4.7 Chapter Summary

This chapter portrays the whole steps to obtain the research objective from the general point of view in Research Design Section until the data required to perform the calculation. The idea of establishing the network for the proposed Sea – Toll network is by separating the ports into several clusters. Therefore, some ports with similarities will be grouped. K-means clustering is the method to solve the clustering problem by dividing the port based on distance. Then, the connections within the cluster and between the groups will be answered by TSP model. Subsequently, the other domains of liner planning, such as scheduling, vessel allocation problem and speed optimization will be solved by manual enumeration and software aid, in this case, is Microsoft Excel goal seek.

This chapter has described the approach to solve the limitation of cargo flow data which is required to perform the calculation for strategic and tactical planning. We estimate the cargo flow by calculating the consumption rate in each region nearby the port. Then, the consumption rate is converted to Sea – Toll Goods trade value which is provided by maritime transport. Using the approach by Ma (2016), we transform the trade value in currency unit to cargo demand value in TEU unit. Finally, the effective container demand is obtained by multiplying the cargo demand with market share in every port destination.

Subsequently, shipping cost is used as a parameter to compare the performance of the network. This thesis will consider four shipping cost components which are port service cost, terminal handling charge, bunker cost, and charter cost. Revenue and subsidy become additional parameter when the result is discussed in the government point of view.

We introduce four network options and two scenarios whose performance will be compared. Sea Toll Network is the current network that is implemented in the Sea – Toll Agenda 2018. The clustering network is the network resulted from k-means clustering and TSP model. The development of a clustering network generated two other options, i.e., Port Aggregation and Butterfly Hub. This thesis also attempts to observe the conditions when the container demand is increased. Scenario 1 will investigate the impact of 10% additional cargo flow to the network, while Scenario 2 will observe further effect if cargo backflow is grown by 10% from each port destinations. Finally, all required data is portrayed as the necessity to run the calculation and to generate the result for every options and scenarios.

5. Cargo Flow Estimation

Due to data limitation, as discussed in Section 4.3, this chapter strives to calculate the cargo estimation demand for each port in the Sea – Toll Agenda as an input for LSND model. Recall from Figure 14; there are four calculation steps to obtain the effective container demand. However, we will add one section to validate the result with available data which is cargo transported in the Sea – Toll Agenda 2016.

In Section 5.1, the calculation for obtaining total monthly spending in every region is presented. Then, the total trade value for all Sea – Toll goods is calculated in Section 5.2. The result of trade value calculation, which is in the currency unit, will be converted in Section 5.3 to become container flow value in TEU unit. Then, we calibrate the container flow in Section 5.4 considering the current shipping line actor to obtain the effective cargo demand for each port. Finally, the result will be validated in Section 5.5 by comparing the effective cargo demand with actual cargo flow in Sea – Toll Agenda 2016.

5.1 Total Region Spending Calculation

Total region spending is calculated using population and average daily spending (Table 13) as input. Equation 19 is dedicated for this computation purpose. We assume that one port will serve one region nearby.

Table 13 Spending Category (World Bank, 2018)

Category	***Average Daily Spending ($/Day)***	***Rural (%Population)***	***Urban (%Population)***
Lowest	1.5	84%	53%
Low	5.7	19%	43%
Middle	15.7	2%	4%
Higher	50.0	0%	0%

The rural population is used as the calculation for all population except nearby Tanjung Perak and Makassar regions. It is because both regions are considered as an urban region. The following is the calculation example for total monthly spending for Port of Agats (AGA).

$$Total\ Monthly\ Spending\ for\ AGA = 90{,}316 x\ (\ 1.5 * 0.84 + 5.7 * 0.19 + 15.7 * 0.2) x\ 30$$

$$Total\ Monthly\ Spending\ for\ AGA = \$\ 7{,}049{,}655$$

The sample of total spending per month for every region nearby the port can be seen in Table 14 below. For the completed calculation result can be seen in Appendix 6.

Table 14 Sample of Total Monthly Spending Calculation Result

No	***Port ID***	***Population Nearby***	***Average Daily Spending (USD/day)***	***Total Monthly Spending (USD/month)***
1	AGA	90,316	234,988	7,049,655
2	BIK	156,023	405,948	12,178,443
3	DBO	93,722	243,850	7,315,512
..	…	…	…	…

5.2 Total Trade Value for Sea – Toll Goods Calculation

Total spending for Sea – Toll goods, which is essential demand provided by maritime transport per month, or Total Trade Value is calculated based on Equation 20. Previous output (total spending per month) become an input for this calculation. Then it will be multiplied by consumption rate (Table 15)

Table 15 Consumption Rate (World Bank, 2018)

Consumption Rate	***National Percentage***	***Adjustment****
Food and Beverage	49%	23%
Housing	12%	12%
Others	10%	5%
Energy	6%	2%

We use adjustment percentage because the population in one region possibly fulfill their demand without using maritime transport. So, the adjustment is an assumption of consumption rate in one region provided by maritime transport. The value of adjustment rate is an assumption based on the possibility if the region capable of self-sufficient.

For example, we set the adjustment rate for food consumption is 23%. It means that 60% of the total consumption of food comes from the maritime trade. The reason is most region only feasible to produce some particular goods efficiently. In the housing sector, we set 100% products is sourced from maritime trade because most of the factories are accumulated in Java. “Others” goods category is assumed 50% come from the trade. It is because we expect some potential source comes self-sufficiency. The last is energy, we assume that 40% of energy needs come from shipping activities because some region still considers firewood as an energy source.

Table 16 Sample Result for Trade Value Calculation

No	***Port ID***	***Total Trade Value – Food (USD/Month)***	***Total Trade Value – General (USD/Month)***	***Total Trade Value (USD/Month)***
1	AGA	2,072,598	1,367,633	3,440,232
2	BIK	3,580,462	2,362,618	5,943,080
3	DBO	2,150,760	1,419,209	3,569,970
…	…	…	…	…

Table 16 above presents the sample result of trade value per month for Sea – Toll goods and transported by the maritime leg. We separate the trade value for food and general category (housing, energy, and “others”) because in the next calculation we will convert trade value to the container flow. In this problem, we assume that all food cargo will be transported using reefer container and general cargo will be transported using a dry container. For the complete result, the table can be obtained in Appendix 7. The following is an example of the calculation to yield the result as depicted above.

$$Total\ Trade\ Value\ for\ AGA = 7{,}049{,}655\ x\ (\ 0.20 +\ 0.12 + 0.05 + 0.02)$$

$$Total\ Trade\ Value\ for\ AGA(food) = 7{,}049{,}655\ x\ 0.20 = 2{,}072{,}598$$

$$Total\ Trade\ Value\ for\ AGA(general\ good) = 7{,}049{,}655\ x\ (0.12 + 0.05 + 0.02) = 1{,}367{,}633$$

$$Total\ Trade\ Value\ for\ AGA = 2{,}072{,}598 + 1{,}367{,}633 = 3{,}440{,}232$$

5.3 Calculation of Trade Conversion

In this subsection, trade value will be converted from the currency unit to TEU using Equation 21. Yet, the value of goods per ton is needed to perform the calculation. The value is calculated using the weighted average where the data for the proportion of goods obtained from the previous Sea – Toll Agenda report (Figure 7). In the calculation, we will separate between the food & beverage category and general goods. It is because the different type of goods will lead the difference container usage (reefer or dry). The list of the goods, price per kg and the weighted average is depicted below.

Table 17 Food Category - Weighted Average (Own Compilation)

Goods	Price (Rp/Kg)	Price (USD/Kg)	Weighted Average
Rice	12,000	0.83	30.16%
Soybeans	7,000	0.49	0.18%
Chilli	60,000	4.17	0.00%
Shallot	7,000	0.49	0.13%
Sugar	13,000	0.90	18.86%
Cooking Oil	11,000	0.76	16.41%
Wheat Flour	9,000	0.63	12.21%
Beef	120,000	8.34	4.23%
Chicken Meat	36,000	2.50	15.56%
Chicken Eggs	26,000	1.81	0.97%
Fish	35,000	2.43	1.29%
Value of Goods - Food (USD/kg)			1.42
Value of Goods (USD/ton)			1,417

Table 18 General Goods Category - Weighted Average (Own Compilation)

Goods	Price (Rp/Kg)	Price (USD/Kg)	Weighted Average
Fertiliser	2,000	0.14	5%
Kerosene	10,000	0.70	5%
Plywood	80,000	5.56	20%
Cement	2,000	0.14	50%
Light Steel	16,000	1.11	20%
Value of Goods – General (USD/kg)			1.45
Value of Goods – General (USD/ton)			1.456

As depicted form the table, we collect the market price data for each Sea – Toll goods per kilogram (assuming that 1 USD = 14,350 Rupiah). The data are obtained from early warning system in Ministry of Trade database (for foods) and online market price (for general goods category). From the calculation above, the value of goods per ton is **1417 USD/Ton and 1456 USD/Ton** for food and general goods, respectively. Subsequently, the cargo demand conversion can be generated using Equation 21. The following is the example of calculation for Port of Agats (AGA)

$$Cargo\ Demand\ (food) for\ AGA = \frac{2{,}072{,}598}{1417 * 21.6} \approx 68\ TEUs$$

$$Cargo\ Demand\ (general\ goods) for\ AGA = \frac{1{,}367{,}633}{1456 * 21.6} \approx 44\ TEUs$$

$$Total\ Cargo\ Demand\ for\ AGA = 68 + 44 = 112\ TEUs$$

We rounded up the result to accommodate the LCL container. The sample result of cargo demand conversion can be seen in the table below. The complete result can be obtained in Appendix 8.

Table 19 Cargo Demand Estimation Sample Result

No	Port ID	Cargo Demand - Food (TEU/Month)	Cargo Demand - General (TEU/Month)	Total Cargo Demand (TEU/Month)
1	AGA	68	44	112
2	BIK	118	76	194
3	DBO	71	46	117
…	…	…		…

5.4 Effective Cargo Demand Calculation

Effective cargo demand is calculated using Equation 22 and the data for market share assumption can be obtained in Table 8. Then, the result will be rounded up. The following is the calculation example for Port of Agats (AGA).

$$Effective\ Cargo\ Demand\ for\ AGA = 112 * 40\% \approx 45\ TEUs$$

The table below presents the sample result for effective cargo in every port. The complete result can be obtained in Appendix 9.

Table 20 Effective Cargo Demand Sample Result

No	Port ID	Competitor	Market Share (%)	Total Effective Cargo Demand (TEU/Month)
1	AGA	1	40%	45
2	BIK	2	20%	39
3	DBO	1	40%	47
…	…			…

5.5 Validation

The final step is comparing the estimation with actual cargo recorded in Sea – Toll Agenda. The last cargo flow data was 2016 in 22 ports. Thus, we compare between the 22 ports available with the estimation. The comparison portrays in Figure 15 below.

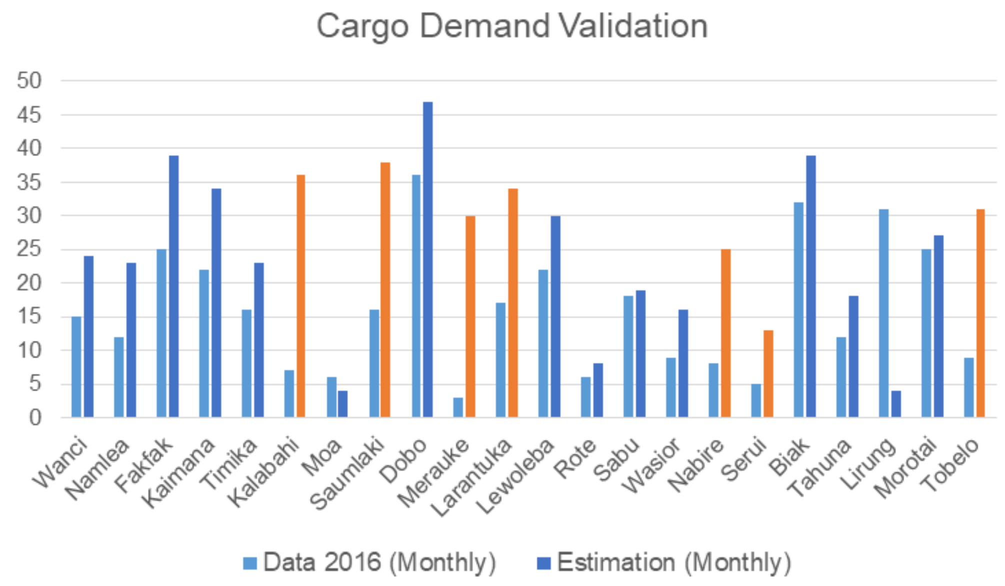

Figure 15 Cargo Demand Validation
**Data 2016 Obtained from (Directorate General of Sea Transportation, 2017)*

Seven out of 22 ports reveal the difference of more than 100%. Meanwhile, for the rest ports, the cargo demand deviation is around 25%. In addition, the difference in the number of the container is not significant, around 10 containers. The deviation possibly happens because of the demand fluctuation or the container already shipped by the existing shipping liners. Therefore, the result can become a basis that the approach is acceptable. For the next calculation, we use the result of cargo demand estimation for calculating the vessel operation planning. Recall from the assumption in Section 4.3, **the cargo demand means the number of cargo that needed to fulfil from Tanjung Perak or Makassar. Therefore, there is no demand for both two ports.**

Based on the Directorate General of Sea Transportation, if Makassar and Tanjung Perak are involved in one route, the proportion of supply is 25% from Tanjung Perak and 75% from Makassar. We assume that Tanjung Perak will provide the container to the nearest port. Later, Makassar will fulfill the demand to the rest.

5.6 Chapter Summary

In this chapter, the effective cargo demand for every port has been calculated by using our own approach. The summary of cargo demand estimation in Chapter 5 is based on port locations which is displayed in the map below.

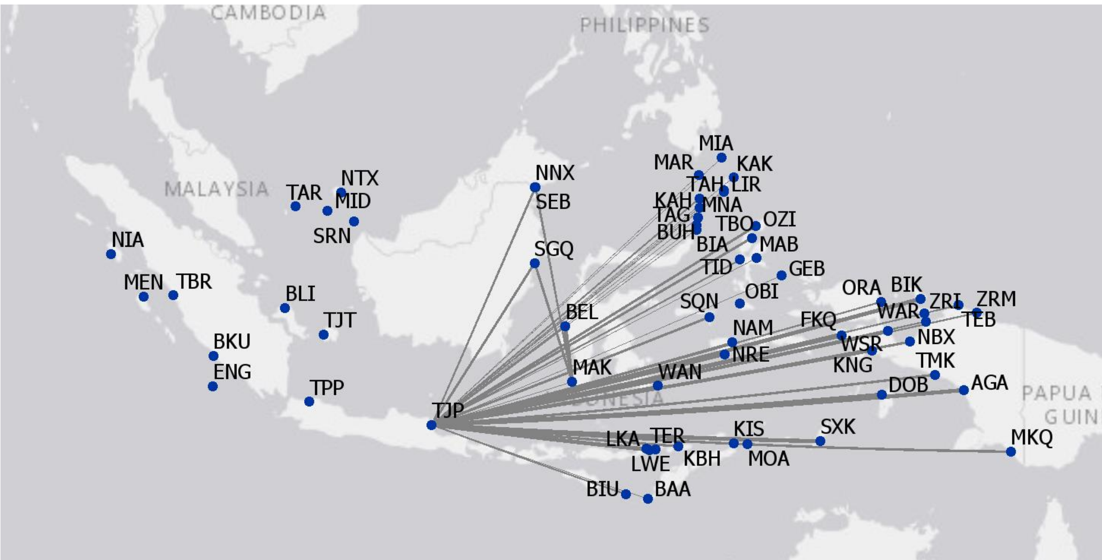

Figure 16 Cargo Demand based on Port Location

Figure 16 shows the distribution of cargo demand based on port location. The visualization is done by using ArcGIS software. The input data are port location (in longitude and latitude unit) and cargo estimation result from this chapter. The line size depicts the amount of demand for every port and its source (TJP and MAK). The thicker the line, the higher the cargo demand. Belang-belang (BEL) possesses the highest monthly cargo demand. It is reasonable because the port serves one populated region in the west of Sulawesi. However, most of the port in the North of Sulawesi relatively own a low cargo demand than other ports (indicated thinner line).

Most ports in the North of Sulawesi consist of the noncommercial port that become hinterland access for some small islands in North Sulawesi archipelago regions. Although the population is quite modest, the government tries to establish the commercial shipping connection to those regions. It is to ensure the demand fulfilment in those regions and to minimize the price disparity due to shortage and logistical cost.

6. Calculation, Result, and Analysis

This chapter will show the steps to process the data, which are port clustering, routing within the cluster and between clusters, liner shipping strategic and operational planning, and the shipping cost calculation results. Then the result for every calculation will be presented and analysed. The analysis part will discuss and reveal some reasons and phenomena behind the outcome.

In the beginning, the clustering of ports to establish the network design will be performed using k – means clustering algorithm in Section 6.1. This calculation will be followed with connecting feeder port the within cluster using the TSP model (Section 6.2). Afterward, vessel operation planning both for strategic and tactical will be computed in Section 6.3. In this chapter, network options and scenarios will also be introduced based on the result of Section 6.2 and 6.1. Finally, in shipping cost calculation (6.4), the financial performance for all options and scenarios will be calculated and compared. The analysis for every result will be presented in every section.

6.1 K – Means Clustering Algorithm

The location of 49 ports involved in this scope of the thesis is scattered in the eastern region of Indonesia. Providing a direct route will be not considered. It is because the policy will yield a super capital intensive considering the low demand and long distance journey. Therefore, the k-means clustering algorithm is performed to separate the ports based on their distance.

The output of k-means clustering algorithm is the clusters with an incorporated port set. This section will portray the calculation steps to obtain that result. Firstly, initial plotting will be done in Subsection 6.1.1 to observe the port location whether it can be clustered manually. Then, the number of k will be determined in Subsection 6.1.2. We will calculate the best number of k using three techniques, i.e. Elbow Method, Silhouette Method, and Multi-Indicator Method. Subsequently, the algorithm will be performed and the result will be visualized in Subsection 6.1.3 by using the result from the previous subsection. The most feasible clustering result will be analysed in Subsection 6.1.4 and then, the decision will be made. Subsection 0 is dedicated for hub selection process for every cluster. The comparison between potential hub ports with high demand and closest distance will be examined. To recall the steps, network establishments using K – Means clustering can be seen in Figure 7 (Sections 3).

6.1.1 Initial Plotting

For the beginning, we plot all port involved in thesis scope to see the initial pattern. To do so, we need port location data for 49 ports involved. The data is extracted from latitude and longitude location in google maps; then it is converted to kilometer unit. The conversion is done by using conversion tools online in whoi.edu (see bibliography). The example of port data location and conversion can be seen in Table 21 below.

Table 21 Conversion Example

Name of Port	ID	Longitude (Degree)	Latitude (Degree)	Converted	X (Kilometer)	Y (Kilometer)
Belang-Belang	BEL	-2.488900	119.101800	whoi.edu	13258.4957	-275.1908
Biak	BIK	-1.185340	136.076247		15148.1031	-131.0598
Dobo	DOB	-5.755148	134.214030		14940.7998	-636.3308

Initial plotting has been done using R studio. *Ggplot2* package is used to code and to draw the initial plotting. The map below portrays the location of the port in X and Y axis. The distance is in kilometer unit because the unit already converted from degree (latitude and longitude) to kilometers. The dot points represent the port location in the map, while the label denotes the port ID. All the port ID can be seen in the List of Abbreviations.

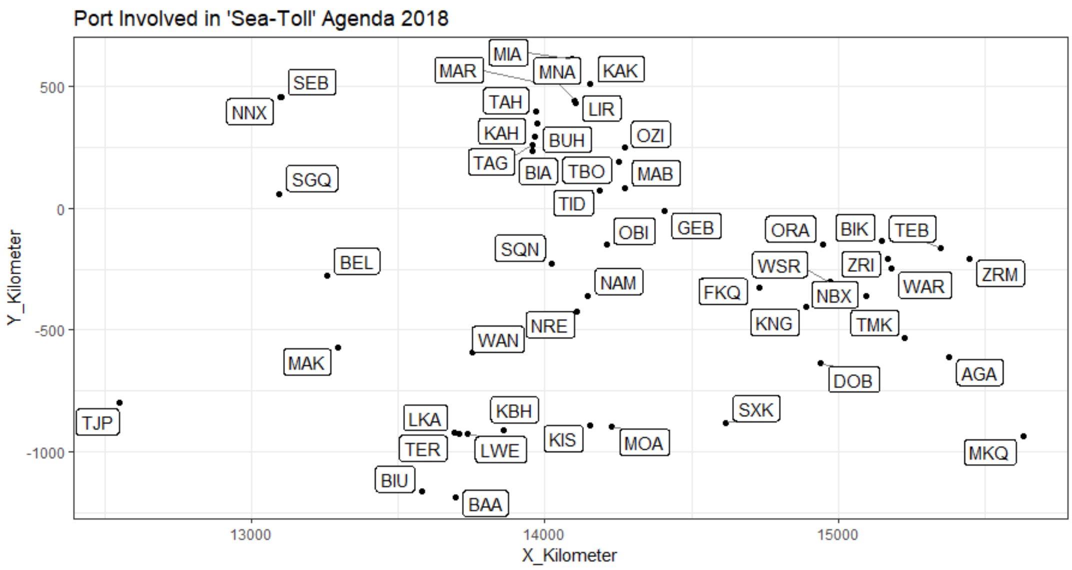

Figure 17 Initial Plotting of Selected Port

6.1.2 K Number Determination

From the initial plotting (Figure 17), there is not clearly seen how to cluster the port because the location is scattered. Then, the next step is determining the number of *k* or how many clusters needed to group all ports.

As mention in Chapter 4, methodology, there are three techniques to determine the number of *k*, namely; Elbow method, silhouette method, and multi-indicator approach.

a. Elbow Method

To obtain number of *k* using elbow method, port location data, which is already converted to distance unit, is became an input. R studio software is used to generate the result of elbow method because this software provides a function called `fviz_nbclust`. The function contains some commands to generate the *k* number, such as using elbow method, silhouette method, and gap statistics. Furthermore, `geom_vline` function is used for showing the result to a sophisticated graph. The result of elbow method using R Studio can be seen in Figure 18 below.

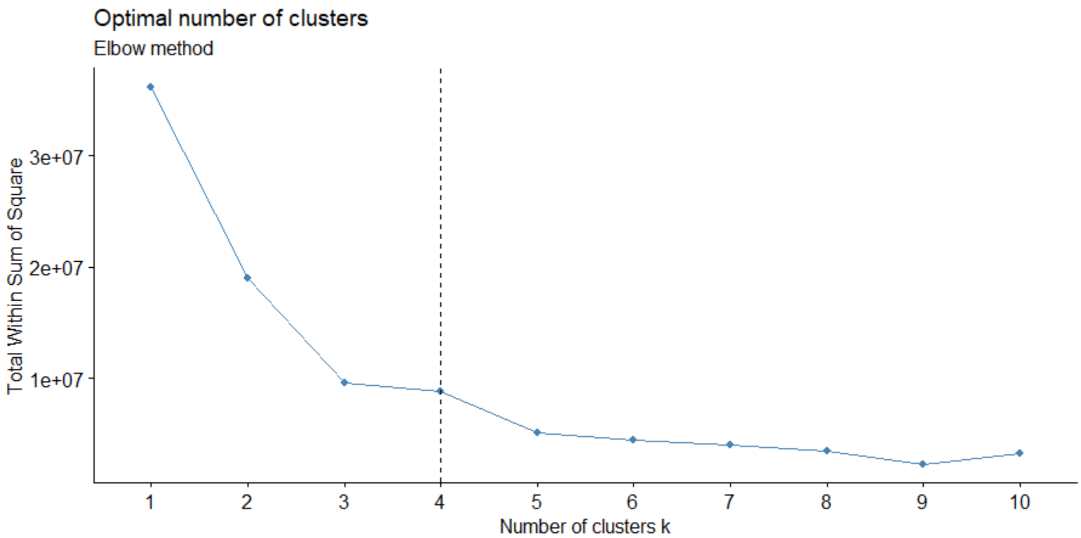

Figure 18 Optimal K number using Elbow Method

This method suggests to separate the port in **four clusters**. It means that when the port separated in four clusters, it will result in sufficient distance between ports within clusters. However, from the graph, we can also choose **three** and **five** for the number of clusters *k*. The definition to find the number of *k* is based on "*knee"* on the graph. We can infer that three or five also as a potential choice.

b. Silhouette Method

Similar with elbow method, this method requires the port location data in distance unit as an input. In addition, R Studio plays a role as the tool to process the data. The "`fviz_nbclust`" function is used to generate the calculation output of *k* number using silhouette method command. Afterward, the step is showing the calculation result using `geom_vline` function which can be seen in Figure 19.

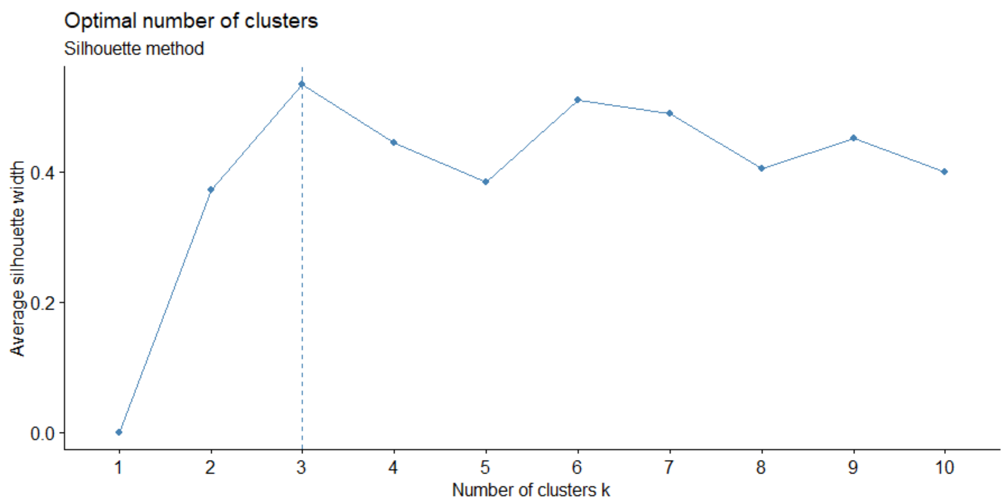

Figure 19 Optimal K number using Elbow Method

This method recommends to separate the set of ports in **three** clusters. The difference with elbow method is in the calculation approach. The optimal *k* number using silhouette indicates that three clusters will make the distance between clusters is close to each other than other solution.

c. Multi indicator approach

Multi indicator approach is generated using R Studio with NbClust package as the command. As mentioned in Subsection 4.3.1 regarding the command in this package, there are 30 indicators to calculate number of cluster *k*. The input for this package are port locations and the number of clusters. We set minimum number of cluster is zero and maximum number of cluster is 10. Afterward, the graph is generated by using "fviz_nbclust" function which can be seen in Figure 16 below.

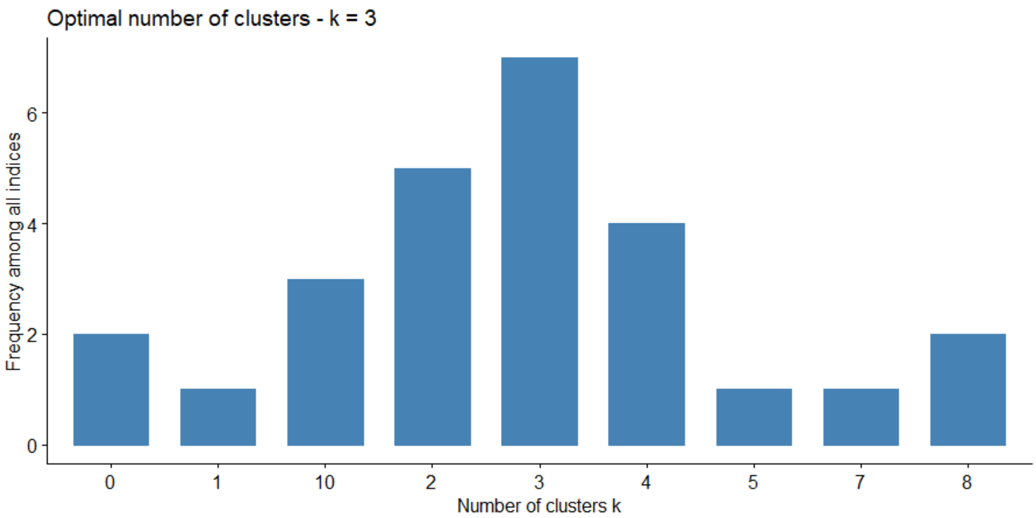

Figure 20 Optimal K number using Multi Indicator Approach

From rule of majority, **three clusters** is the better solution by using multi indicator approach. However, almost each number of *k* is suggested by at least one indicator. This result leads us to conclude that there is no "best" answer to define the number of *k*. Every indicator or method has own calculation which will lead to a different result in clustering the data.

Nevertheless, based on three techniques, **three** and **four** clusters are become the most likely number of *k.* Therefore, we try to visualize suggested *k* numbers to decide the number of clusters for this problem.

6.1.3 Clustering and Visualization

This subsection will describe how to generate the result of clustering and visualize the result. The basic calculation of clustering, after knowing the number of *k*, can be reviewed in Chapter Methodology, Subsections 4.2.1. We will generate the clustering using three and four clusters, then the result will be analyzed based on some considerations related to sailing operation, such as geographical condition and sailing route possibility.

The input data of the clustering algorithm are port location, which already obtained from the previous subsection in distance unit and number of *k*. The calculation and visualization are performed using R Studio. In addition, the software needs to install the package called “factor extra” to run the calculation.

The function to perform the calculation is called “`hkmeans`” where we should input the port location and the number of k. Afterward, function “`fviz_cluster`” is used to reveal the visualization of clustering. The result of clustering are within cluster sum square, between sum square, and total sum square. Those steps are utilized for generating the result both for three and four clusters which the result can be seen in Figure 21 below.

a. Three Clusters Visualization

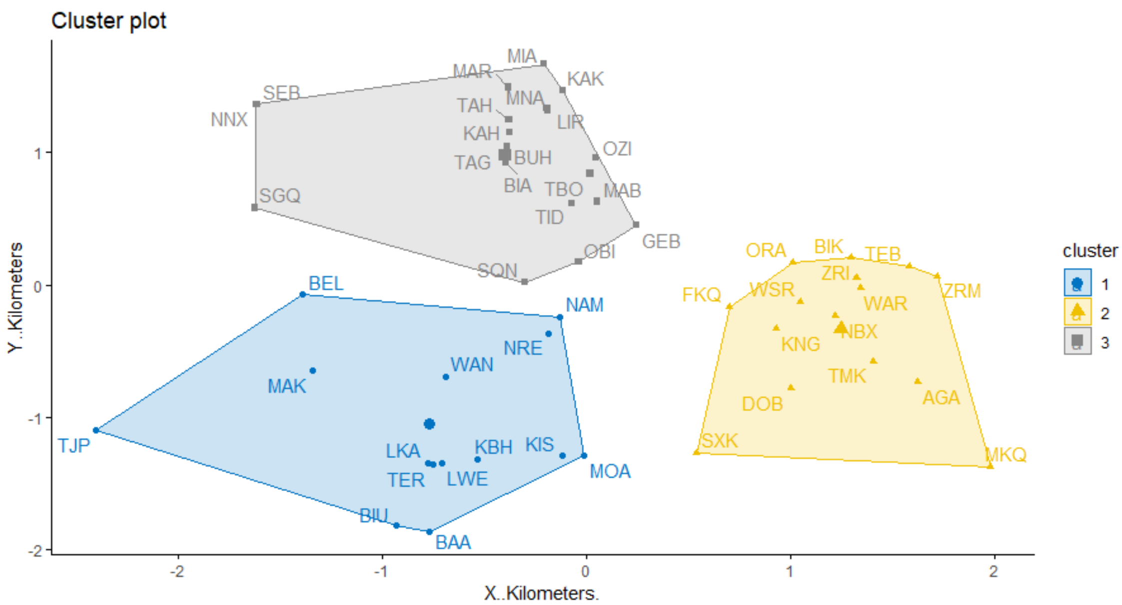

Figure 21 Three Cluster Port

Visualization for three clusters of the port is depicted in the figure above. Similar with map from initial plotting, X and Y coordinate is a distance in kilometer unit. Cluster 1 consists of 14 ports which are consisted of South Sulawesi, Nusa Tenggara, and Southern of Maluku. The centroid, depicted with bigger the blue dot, is leaning towards the port in Nusa Tenggara because more ports are accumulated in that region. This is an indication that the distribution of the distance between ports is not balanced. It can be seen from Table 22 that within-sum square of this clustering is quite high. The implication for the operation is the sailing time in one cluster may have a high difference between some ports.

However, Cluster 2, which shown in the yellow shaded area, has another issue. In terms of region, this cluster grouped 15 ports around Papua Island, but, the clustering does not consider the land between the Northern Coast of Papua and the Southern Coast of Papua. It is because of the limitation of Euclidean distance approach which is used in k means clustering algorithm calculation. The original distance between ports in Northern Papua and in the Southern part can be doubled or tripled because the vessel should sail along the coast.

The problem in Cluster 3, group of 20 ports, is similar to Cluster 1 which is one-sided accumulation of ports. WSS of this cluster has the highest value because the distribution of ports are unbalanced. The implication in the operation is the longer sailing time when the vessel should go to the port on the other side of the centroid. Another consequence is if the vessel tries to keep the RTV in a weekly schedule or once in two weeks schedule. There is a possibility that the vessel set a high speed. This condition will lead to a high bunker consumption which will not become a good decision for total network cost.

Table 22 Clustering with k = 3 Calculation Summary

	Number of Ports	*Within SS*	*Total Within SS*	*Between SS*	*Percentage Variance Explained*
Cluster 1	14	3,630,791	9,557,540	26,627,804	73.6%
Cluster 2	15	1,989,640			
Cluster 3	20	3,937,109			

To conclude, clustering using 3 groups of the port is good in a regional point of view. However, in operation context, it is quite not a considerable choice. The port should keep close with each other or the deviation of distance is not high which can be indicated from the location of the centroid. The calculation summary of k = 3 can be seen in Table above. All calculation formula is referred to Section 4.2.1

b. Four Clusters Visualization

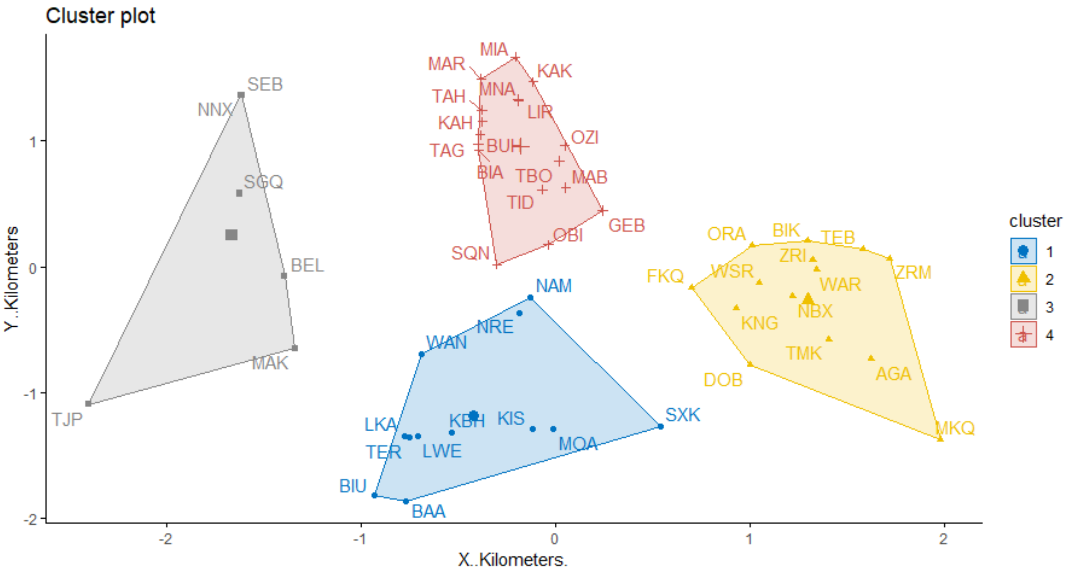

Figure 22 Four Cluster Port

Clustering with *k* = 4 generates the group of the port as shown in Figure 22 above. Cluster 1 (blue shaded area) merges 12 ports in Nusa Tenggara and some ports in South of Maluku. The distribution of the port is better than clustering using *k* = 3. It is because the value of WSS in every cluster is decreasing.

Cluster 2 groups 14 ports in Papua in one cluster. Regionally, this clustering is better because of the local government coordination issue. However, from the operational point of view, this condition will lead to another problem. The vessel will sail in a long distance because the actual distance is doubled. As discussed in the previous clustering section, there is a land between ports located in northern and southern Papua. Therefore, the vessel should make a detour to sail from the southern part (Port of FKG, WSR, KNG, TMK, AGA, and MKQ) to the northern part (Port of ORA, NBX, BIK, ZRI, WAR, TEB, and ZRM).

Cluster 3 consists of the lowest number of pots (6 ports). They are located in Java, Sulawesi, and Borneo. The clustering is reasonable because the distance between ports is quite high. Moreover, this clustering is grouped the “outlier” ports from the previous clustering.

Cluster 4 grouped 17 ports located in Northern Sulawesi and Northern of Maluku. This cluster consists of outermost port with relatively close to each other. This condition can be seen from the value of WSS for Cluster 4 which possesses the lowest value.

Table 23 Four Clustering Summary

	Number of Ports	*Within SS*	*Total Within SS*	*Between SS*	*Percentage Variance Explained*
Cluster 1	12	1,763,562	6,196,987	29,988,357	82.9%
Cluster 2	14	1,480,241			
Cluster 3	6	1,743,340			
Cluster 4	17	1,209,844			

c. Clustering Evaluation

After evaluating and plotting the number of *k* suggested by three techniques, clustering using k = 4 is considered as the best choice. However, there is a limitation from k-means clustering algorithm because of Euclidian distance measurement. Both clustering suggests that all ports in Papua should be one cluster. From the operation point of view, the actual sailing distance will be higher than estimated if Euclidian distance measurement is applied. Thus, we decide to separate Cluster 2 into two different clusters which will group port around South Coast Papua and North Coast Papua, The next subsection will calculate k-means clustering using determined port.

6.1.4 Feasible Cluster

As mentioned in the previous subsection, 5 clusters with the predetermined port is chosen as a selected feasible cluster. As a comparison, we will also present the result of 5 clustering using optimization of k-means algorithm. The steps to obtain the result for both clusterings is similar to the description in Subsection 6.1.3. The difference is in the predetermined port clustering, the set of port is given based on clustering *k = 4*, but Cluster 2 (Papua Region) is separated. The result of clustering k = 5 using k – means clustering algorithm is presented below.

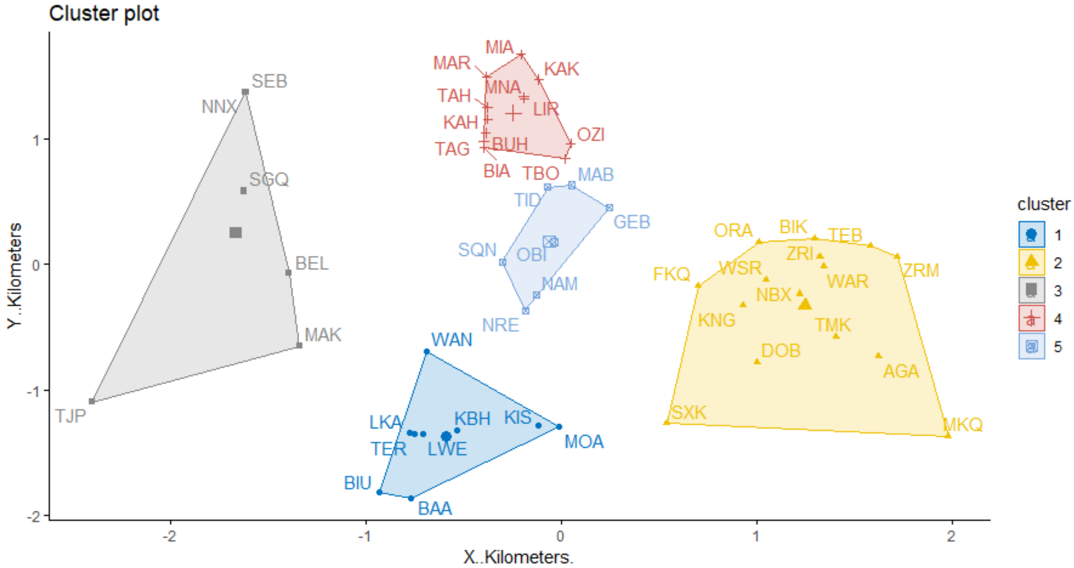

Figure 23 Clustering K = 5 using K-means Algorithm

The problem of clustering using k = 3 and k = 4 is still not solved if we choose k = 5. This is a shred of evidence that there is a high possibility that k-means clustering algorithm still groups all ports in Papua into one cluster. Based on parameter calculation, total within sum square (WSS) is lower than clustering using k = 4. However, the change is relatively not significant. That calculation result is the reason why the elbow method does not consider k = 5 as the selected number of k. The summary of clustering can be seen in the table below.

Table 24 Summary Clustering K = 5 using K-Means Algorithm

	Number of Ports	*Within SS*	*Total Within SS*	*Between SS*	*Percentage Variance Explained*
Cluster 1	9	630,374	5,049,292	31,136,052	86%
Cluster 2	15	1,989,639			
Cluster 3	6	1,743,339			
Cluster 4	12	343,478			
Cluster 5	7	342,459			

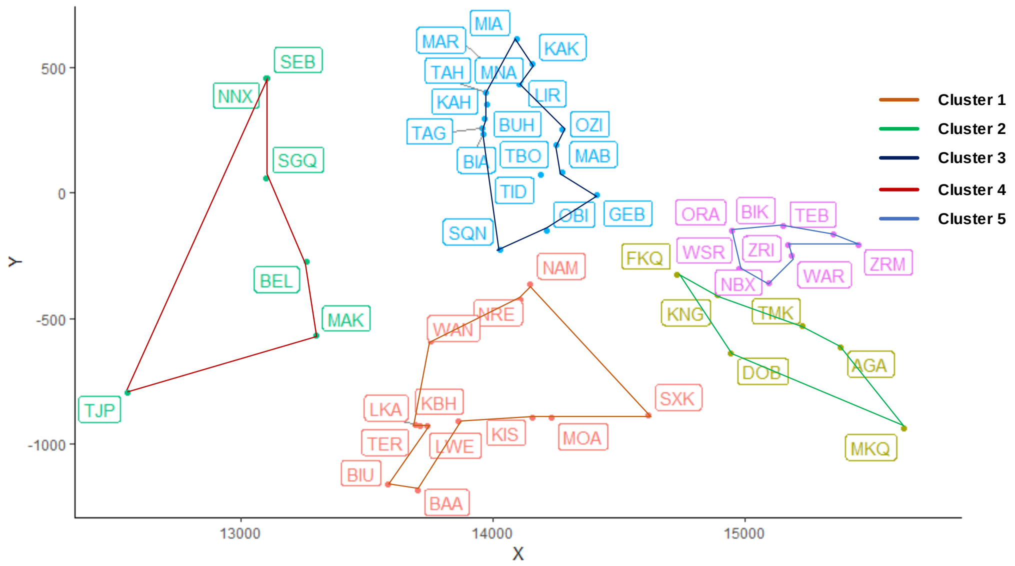

Figure 24 Selected Cluster, K = 5

Using predetermined port, the figure above presents the visualization of selected cluster using k=5. Comparing with previous clustering, this clustering generated lower value of WSS. It is reasonable because the last cluster is separated Cluster 2 without considering the other cluster. Thus, the percentage of variance explained by k-means clustering is lower than the comparison. However, this clustering already recognizes actual geographical constraint which will benefit the next step. In addition, the total sum square between clusters also lower than the comparison. It is indicated that there is a possibility the distance between hub ports every cluster will be lower. Summary for selected clustering can be seen in Table 25 below.

Table 25 Summary Selected Clustering K = 5

	Number of Ports	*Within SS*	*Total Within SS*	*Between SS*	*Percentage Variance Explained*
Cluster 1	12	1,763,562	5,764,903	27,469,065	82.26%
Cluster 2	6	802,620			
Cluster 3	6	1,743,340			
Cluster 4	17	1,209,844			
Cluster 5	8	245,537			

To conclude, from this subsection, we already obtain the set of cluster of ports and its incorporated members. Table 26 below presented all assigned ports to every cluster.

Table 26 Port and Its Cluster (Full Version in Appendix 10)

No	Name of Port	Clusters
1	Agats	1
2	Dobo	1
3	Fak-fak	1
	…	
47	Sarmi	5
48	Serui	5

No	Name of Port	Clusters
49	Teba	5

6.1.5 Selecting Hub Port in Every Cluster

After obtaining the feasible clusters, the next step is assigning the hub port to each cluster. This hub port has a role in providing a connection from the origin port (Tanjung Perak) to every cluster. In the real case of Sea – Toll, this hub port can become a center of distribution to feeder ports in every cluster. Moreover, the transshipment is done in the hub port to transfer the container to feeder ports.

The problem is, there are several parameters in determining the hub port in one region. Some studies concerning in finding a hub in set of ports has been conducted by (Zheng, Fu, & Kuang, 2017), (Wilmsmeier & Notteboom, 2011), and (Sun & Zheng, 2016). Those papers mentioned some considerations in selecting a hub. The volume of demand become a prominent factor because it decides market for the port and revenue in running the business. Another parameter is the cost of the network. It means that the port that will be selected as hub should minimize total cost to optimize the profit. The study from Sun & Zheng (2016) take into account the cost of voyage, handling, and chartering. However, Wilmsmeier & Notteboom (2011) saw that the determinant factor of selecting hub port should be based on the port performance itself, such as hinterland access, infrastructure & superstructure, and cost. In this discussion, only demand flow and total shipping cost will take into account in deciding hub port.

In order to obtain the cargo flow between ports, demand estimation data will be used. The calculation and the result of cargo flow can be seen in Section 5.6 for every port. Moreover, to obtain the cost estimation between potential hub ports, we used Euclidean distance data from k-means clustering calculation for estimating the distance and other cost data for every port obtained from data section (Section 4.6)

Approach to select hub ports in every cluster

The goal of this step is to find the potential hub port combination in every cluster, which has the closest distance, to become a hub port for the Sea – Toll Agenda. The distance becomes the parameter because from three cost components (chartering, bunkering, and terminal handling cost) only distance will be closely related with the total cost. Terminal handling cost will be calculated after obtaining bunkering cost, as well as chartering cost. The problem is there are five clusters and every cluster possess about seven until ten ports. To find the nearest distance and construct a combination of port, it will take a relatively long time both in calculation or building a model for a code. Therefore, we try to arrange an approach, even though this approach will not necessarily generate the optimum hub.

1. Choose possible hub-ports

From the last visualization (Figure 24), the hub ports candidate will be evaluated based on distance. It means every port will be examined from the closeness between ports in the different cluster. Moreover, the distance between ports within cluster should become a consideration because the hub will provide a service for all feeder ports. Therefore, choose at least one hub port for every cluster and at least two for some clusters as a candidate to become hub port. The selection will be based on the average distance of the port with the rest of the ports in the scope of thesis. Then the possible result will be evaluated. The evaluation will be done because the combination of port, which has lowest average distance, do not guarantee owning a shortest hub route.

The distance between all ports (49 x 49) is obtained by using the “tspmeta” package in R Studio. The package will provide the calculation by using the Euclidian method. Table 27 shows the sample result for Cluster 1. The complete result can be found in Appendix 2.

Table 27 Average Port Distance Cluster 1

Cluster	Name of Port	Average Distance Between Ports (km)
1	Agats (AGA)	1,315
1	Dobo (DBO)	1,051
1	Fak-fak (FKQ)	885
1	Kaimana (KNG)	957
1	Merauke (MKQ)	1,643
1	Timika (TMK)	1,179

Based on the criteria mentioned above and the calculation of port distance, the table below presents some possible hub ports candidates in every cluster.

Table 28 Possible Hub Ports

Cluster	Name of Port
C1	Fak-fak (FKQ)
C2	Wanci (WAN)
C2	Namlea (NAM)
C2	Namrole (NRE)
C3	Sanana (SQN)
C3	Obi (OBI)
C3	Gebe (GEB)
C4	Tanjung Perak (TJP)
C5	Oransbari (ORA)

In Cluster 4, we only choose Tanjung Perak because, in this thesis, we only consider Tanjung Perak to become the origin port which will provide goods for all ports. Fak-fak and Oransbari are the only port chosen for Cluster 1 and 4. It is because both ports are obviously the nearest port to other clusters among other ports. To reach the ports in Cluster 5, the vessel should visit Oransbari first. In Cluster 1, Dobo can be considered as a port which has a closeness with Saumlaki. However, Saumlaki cannot be classified as a possible hub port candidate in Cluster 2 because the distance to reach Cluster 1 and 3 is relatively higher than Wanci, Namlea, and Namrole.

Both in cluster three and four, we choose three possible hub ports because they are close to each other in terms of distance. Therefore, the next step is to evaluate all possible routes and the distance for every route.

2. Evaluate all possible route and its distance

There are nine possible combinations of hub ports for in this network concerning of distance. In addition, we also add one possible route which connected all hub ports with the high demand in every cluster. Table 29 below shows ports with the highest demand in every cluster. The complete table can be seen in Appendix 10.

Table 29 Port with the Highest Demand in Every Cluster

Name of Port	Monthly Demand (TEU//Month)
Tanjung Perak	-
Saumlaki	38
Tobelo	31
Biak	39
Dobo	47

Then, we calculate the total minimum distance for each possibility by using Travelling Salesman Problem (TSP). R Studio is used to calculate the distance. Input data for this step is the port location data, so the distance output will be on the Euclidean distance measure. Because the input data still in the kilometer distance unit, from this section afterward, we will convert all distance from kilometer to nautical mile (nm) for calculation reason. We assume that **1 km = 0.54 nm**.

TSP packaged in R Studio is used to run the command and the “2 – opt” method will become the approach to obtain the result. The explanation of both methods can be seen in Subsection 4.2.1. Finally, we show the monthly demand to see the cargo flow for every port.

Table 30 Distance Calculation for Every Hub Possibilities.

Summary	Port Combination	Distance (km)	Distance (nm)	Total Demand to All Ports (TEU/Month)
1	TJP-WAN-SQN-FKQ-ORA	5018.39	2709.76	110
2	TJP-NAM-SQN-FKQ-ORA	5024.53	2713.04	109
3	TJP-NRE-SQN-FKQ-ORA	5020.94	2711.09	110
4	TJP-WAN-OBI-FKQ-ORA	5031.06	2716.56	105
5	TJP-NAM-OBI-FKQ-ORA	5037.20	2719.87	104
6	TJP-NRE-OBI-FKQ-ORA	5029.61	2715.76	107
7	TJP-WAN-GEB-FKQ-ORA	5087.19	2746.86	84
8	TJP-NAM-GEB-FKQ-ORA	5093.32	2750.18	83
9	TJP-NRE-GEB-FKQ-ORA	5085.74	2746.08	90
10	TJP- TBO - SXK - DBO- BIK	5941.56	3208.20	150

From the table above we can see that Summary 1 provides the combination with lowest total distance, but in terms of cargo flow within the hub is not as high as Summary 10. However, Summary 10, which is the combination of the high demand port, possesses a high total distance to reach all ports. There is a tradeoff between high demand port and low total distance port. Yet, the total demand between ports are quite low, only 40 TEUs in a month. The revenue and cost difference will be shown in the next evaluation. Summary 1 and Summary 10 is chosen to be evaluated because both of them are the combination which has the highest value in each parameter (distance and cargo demand)

3. Evaluate shipping cost

In this step, we will compare shipping cost estimation between Summary 1 and Summary 10. This step follows all formula in Sections 4.3 to obtain total cost and revenue in every route. We assume both route use Mentari Perdana vessel and should provide service once in two weeks. The shipping cost summary can be seen in the table below

Table 31 Shipping Cost Evaluation between Summary 1 & 10

Parameters	***Route***		
	Unit	**Summary 1**	**Summary 10**
RTV	Days	14	14
Speed	Knot	9.23	11.07
Total Distance	Nm	2,709.5	3,208.20
Cargo Flow	TEU/Voy	65	79
Bunker Cost	USD/Voy	39,628	68,431
Port Service Cost	USD/Voy	1,030	957
Terminal Handling Charge (THC)	USD/Voy	5,470	6,876
Charter Cost	USD/Voy	69,566	69,579
Total Cost	USD/Voy	115,693	145,843
Total Revenue	USD/Voy	26,970	32,879
Subsidy	USD/Voy	88,723	112,964

From Table 31, Summary 10, which is indicated by the high demand hub, has a high bunker cost because the vessel travels over a long distance. Although the revenue is higher than another summary, this route still needs more subsidy than the route with low distance voyage if the program wants to keep the once in two week's schedule. The result leads to a conclusion that if the difference in demand is not significant, the distance between ports should be a consideration.

Hub port selected

After a calculation and discussion in selecting hub port, the port with the shortest distance among all is chosen as the hub port. The distance calculation result and the port combination can be seen Table 30. From the approach that established in the previous paragraph and shipping cost calculation (Table 31), **the selected hub port are; Tanjung Perak, Wanci, Sanana, Fak-fak, and Oransbari.**

6.2 Travelling Salesman Problem: Routing

Recall from Section 6.1, currently, the clustering for port already established (Figure 24) and hub port already selected (Subsection 0). This section has an output to establish the path between ports using those data as input. To build a whole network, the route to connect every port should be determined. Travelling Salesman Problem (TSP) is performed in order to solve this routing problem. This result of the calculation will connect all objects (port) within the cluster and hub ports between clusters. Basic calculation and idea of TSP can be reviewed in Subsection 4.2.2.

Several steps should be undertaken to obtain the final results which are routing between ports and its distance. Both hub and feeder routing are using similar steps. Therefore, the following steps for doing the routing problem is applicable for all routes.

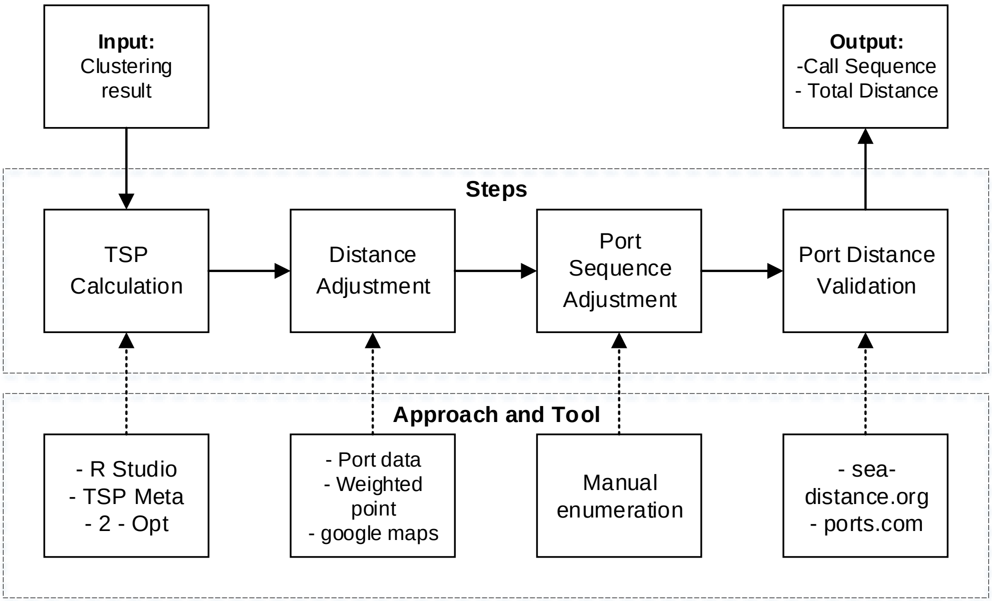

Figure 25 Routing Step

TSP calculation will be done by using R Studio and "TSP meta" package. The result of TSP will be evaluated because the distance still in Euclidian measurement. The possibility of a detour and actual sailing distance are considered in estimating the actual distance. Three approaches are implemented to obtain the distance between ports, such as collecting data from the internet or government document, weighted point, and google maps. Then, there is a possibility that a better port sequence is discovered. So, a manual enumeration is performed to find a better route which can be minimized the distance. Then, the final port distance will be compared with other data, i.e., sea-distance.org and ports.com

6.2.1 TSP Calculation and Route Visualization

R studio is used to perform the calculation. Beforehand, "tspmeta" package should be installed to do the computation. This package contains several heuristic methods to obtain the result of TSP, these are 'nearest_insertion', 'farthest_insertion', 'cheapest_insertion', 'arbitrary_insertion', 'nearest neighbor (nn)', 'repetitive_nn', and '2-opt'. In the first attempt, we try all methods to find the best result in terms of distance. The table below shows the result of total distance in kilometer for every cluster.

Table 32 Total Distance (kilometer) Summary for Every Cluster using All Methods

Cluster	Nearest Insertion	Farthest Insertion	Cheapest Insertion	Arbitrary Insertion	NN	Repetitive NN	2-Opt
Hub	5,018	5,018	5,018	5,018	5,147	5,109	5,018
Cluster 1	2,249	2,249	2,249	2,249	2,288	2,289	2,249
Cluster 2	3,319	3,010	3,032	3,010	3,074	3,074	3,010
Cluster 3	2,569	2,311	2,538	2,311	2,547	2,453	2,311
Cluster 4	3,244	3,220	3,244	3,220	3,222	3,220	3,220
Cluster 5	1,258	1,258	1,355	1,258	1,359	1,289	1,258

From Table 33, three methods are generating the lowest distance, namely 2-Opt, Farthest Insertion, and, Arbitrary Insertion. The yield of 2 – Opt method is used for the next step which is visualizing the route structure for each cluster. There is no particular reason to choose this method than the other two methods. It is because all three methods generate exactly similar value. Subsequently, the total distance result is converted to the nautical mile for sailing calculation reason. Recall that 1 km = 0.54 nm.

Table 33 Conversion Result

Cluster	Initial Total Distance (km)	Initial Total Distance (nm)
Hub	5,018	2,710
Cluster 1	2,249	1,215
Cluster 2	3,010	1,625
Cluster 3	2,311	1,248
Cluster 4	3,220	1,739
Cluster 5	1,258	679

Route Visualization

Aside from total distance, “tspmeta” package yields the sequence of port call which is minimized the total distance. The result of route structure is a circular network. It is because the TSP method has an aim to visit all objects (ports) and back to initial position. Summary of port call sequence for each cluster can be seen in the table below.

Table 34 Port Call Sequence

Cluster	Port Call Sequence
Hub	FKQ-WAN-TJP-SQN-ORA
Cluster 1	FKQ-KNG-TMK-AGA-MKQ-DBO
Cluster 2	TER-LKA-BIU-BAA-KBH-KIS-MOA-SXK-NAM-NRE-WAN-LWE
Cluster 3	MIA-KAK-MNA-LIR-OZI-TBO-TID-MAB-GEB-OBI-SQN-BIA-TAG-BUH-KAH-TAH-MAR
Cluster 4	SEB-SGQ-BEL-MAK-TJP-NNX
Cluster 5	ZRM-TEB-BIK-ORA-WSR-NBX-WAR-ZRI

From Table 34, the sequence of the route is depicted on column “Port Call Sequence”. The initial Port ID indicates the origin port and the last Port ID indicates the final port. However, in one route, the vessel should back to origin port (circular). For example, in the hub cluster, TSP model suggests to begin the journey from Fakfak, then the vessel sails to Wanci (clockwise) and end up in Oransbari before going back to Fakfak. This logic is applied to port call sequence in all clusters.

Figure 26 presents the visualization of circular route between hubs. The visualization generated using R Studio and “autoplot” package which is embedded to *ggplot2* package.

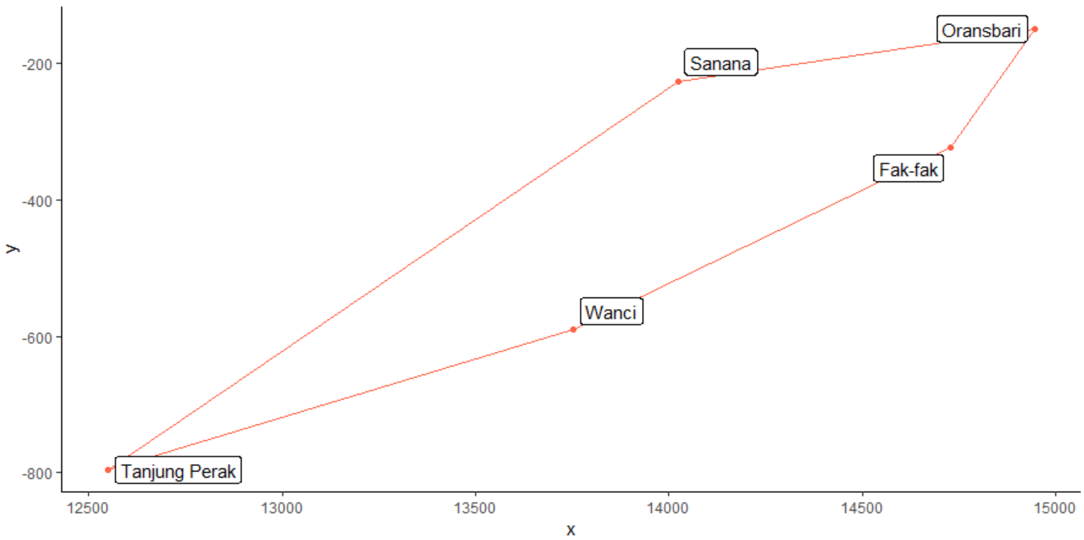

Figure 26 Hub Port Route Structure (TSP Calculation)

As discussed in the previous paragraph, the circular route is generated using the TSP method. The line embodies a connection between ports. In addition, X and Y axis are represented the location of the port in kilometer distance unit. The advantage of circular route structure is the port call sequence can be started anywhere as long as the next port follows the circular structure. It can be either clockwise or counter-clockwise. For example in Hub Cluster, Port of Fakfak (FKQ) becomes the starting point, but the goods will be originated from Tanjung Perak (TJP). This port can become a starting point as long as the next port call is to Wanci (WAN) or Sanana (SQN). All visualizations for each cluster can be seen in Appendix 11.

6.2.2 Distance Adjustment

The total distance obtained from the TSP model (Table 33) is computed using Euclidian distance. This method for some circumstances is not suitable to measure the sailing route. For example, Figure 27 below shows the TSP routing result for hub ports. We visualize using google maps to show the map of the island, so several infeasibilities of Euclidian distance measurement can be highlighted.

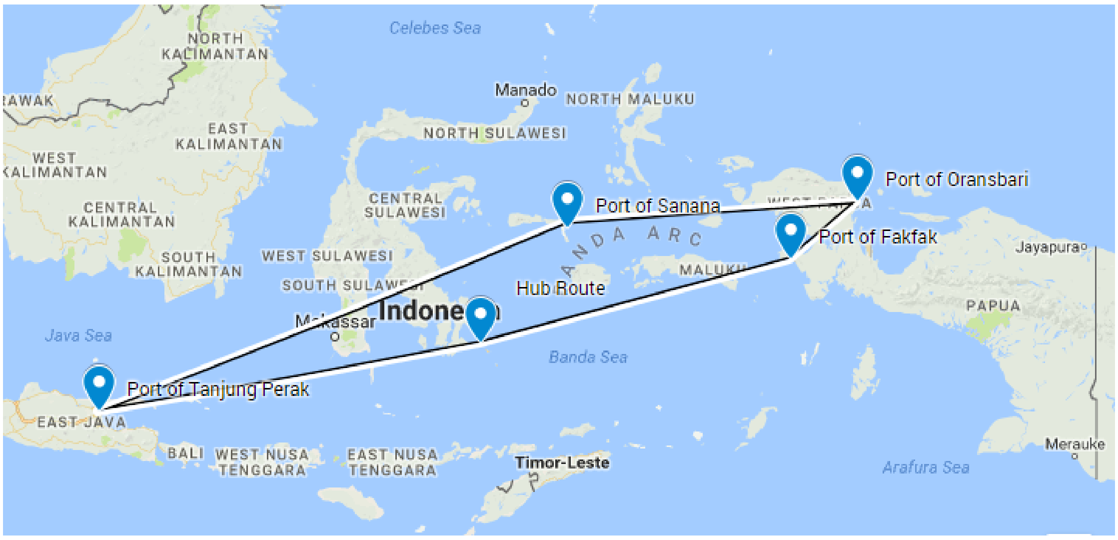

Figure 27 Euclidean Distance Infeasibility for Hub Port

It is clearly seen that the path between Tanjung Perak – Sanana, Sanana – Oransbari, and Oransbari – Fakfak will not exhibit the actual sailing distance. The vessels should detour their sailing route to reach Sanana directly from Tanjung Perak. This subsection has a goal to adjust the distance considering the actual sailing route and geographical limitation by using three alternatives. We establish several options to obtain the data because some route distances cannot be extracted from only one source.

1. Online Port Distance Data

Published online data becomes the first alternative to find the distance between ports. There are three sources used as a data source, namely sea-distance.org, ports.com, and Ministry of Transport of Republic Indonesia regulation regarding Public Service Obligation (see Bibliography).

For example, in Figure 28, the direct distance between Fakfak (FKQ) and Kaimana (KNG) should be detoured because it crosses the land. Euclidian distance measures that the length between two ports is 97 nm. Meanwhile, the government document stated that the distance is 183 nm.

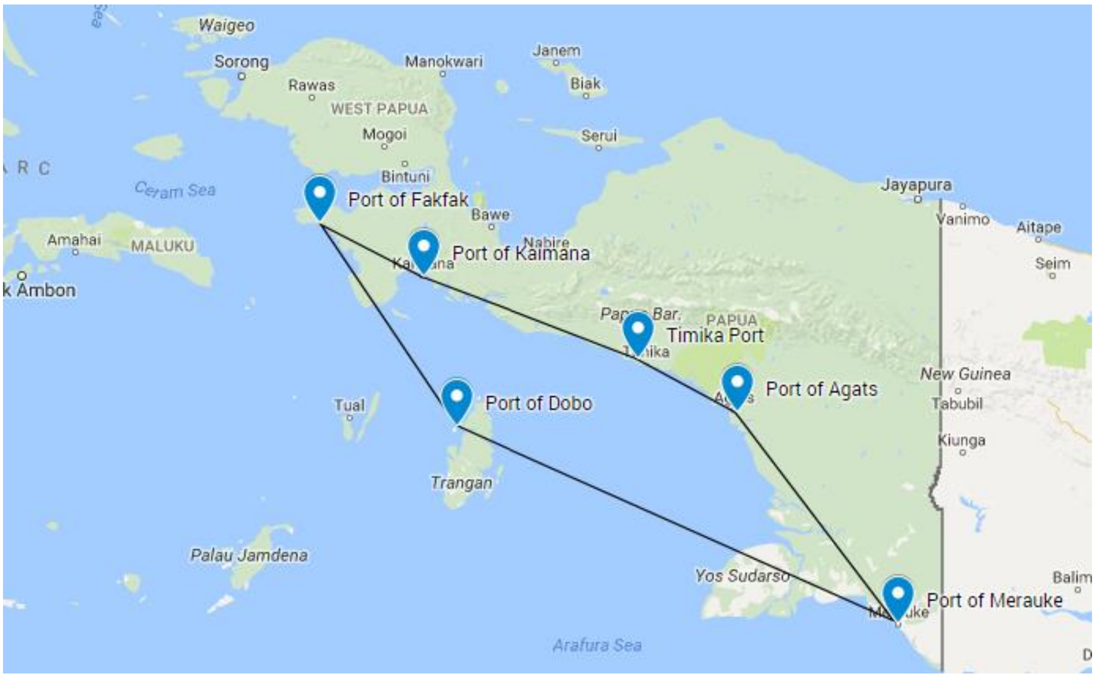

Figure 28 Detour in Consideration in Cluster 1 Route

TARIF ANGKUTAN BARANG DENGAN KAPAL KHUSUS KONTAINER DAN *GENERAL CARGO*

NO	TRAYEK			VIA	JARAK	Selisih Koef	KOEFISIEN	*Dry Container*	*Reefer Container*	*General Cargo*
1	Adonara (Terong)	-	Larantuka		13	75,00	5,77	1.689.000	2.534.000	205.000
2	Adonara (Terong)	-	Lewoleba		17	75,00	4,41	1.689.000	2.534.000	205.000
3	Adonara (Terong)	-	Tanjung Perak	Larantuka	685	785,00	1,15	3.464.000	5.196.000	286.000
65	Fakfak	-	Kaimana		182	246,60	1,35	2.118.000	3.177.000	225.000
66	Fakfak	-	Kaimana		[illegible]	210,20	1,36	2.027.000	3.041.000	221.000
67	Fakfak	-	Tanjung Perak		1.307	1340,95	1,03	4.853.000	7.280.000	349.000
68	Fakfak	-	Tanjung Perak	Kaimana	1.510	1513,50	1,00	5.284.000	7.926.000	369.000
69	Fakfak	-	Timika	Kaimana	397	486,70	1,23	2.718.000	4.077.000	252.000

Figure 29 Original Document from (Ministry of Transport Republic Indonesia, 2018)

2. Way Point

A way point is used when direct route (origin-destination) information cannot be obtained, but there is available information concerning the distance between intermediate ports to the destination port. Therefore, to collect the direct distance data, the distance from the origin to intermediate port is summed up with port distance from intermediate port to the destination port

For example, Figure 30 displays the route for Cluster 4. It is clear that route from Tanjung Perak to Port of Nunukan should make a detour. From the online source, there is no information regarding the direct distance from Tanjung Perak to Nunukan, however, there is a distance information from Tanjung Perak to Belang-belang **(433 nm)** and Belang-belang to Sangatta **(207 nm)**, and Sangatta to Nunukan **(322 nm)** (Ministry of Transport Republic Indonesia, 2018). So, the total distance of those ports become a distance between Tanjung Perak and Nunukan **(962 nm)**

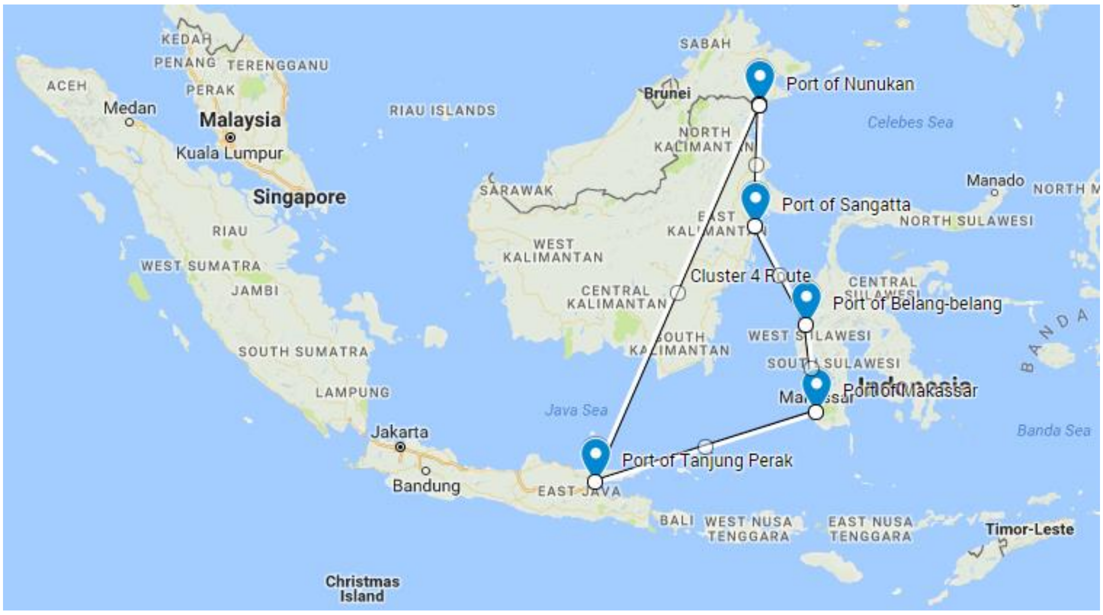

Figure 30 Detour Consideration in Cluster 4 Route

3. Google Maps

Google Maps is used when there is no information regarding the distance. We will establish some hypothetical points in google maps from origin to destination, then calculate the total distance of the line.

For example is a route from Sanana (SQN) to Biaro (BIA) in Cluster 3. The route with detour consideration can be seen in Figure 31 Port of Sanana located in the south of Mongoli Island and the sailing route could not be measured using Euclidean distance. However, there is no information regarding the distance between two ports because Biaro is low demand port and noncommercial port. Thus, alternative approach using Google Maps is applied. The hypothetical point can be seen in Figure 32 below. The distance between SQN – BIA are changed from **252 nm** to **274 nm.**

Summary of port distance adjustment for all clusters can be seen in Distance Adjustment SummaryTable 35. In addition, the complete data for each port distance can be obtained in Appendix 12.

Table 35 Distance Adjustment Summary

Cluster	Initial Total Euclidian Distance (nm)	Adjusted Distance (nm)	% Change
Hub	2,710	3,245	9%
Cluster 1	1,215	1,564	13%
Cluster 2	1,625	1,703	2%
Cluster 3	1,248	1,587	12%
Cluster 4	1,739	2,048	8%
Cluster 5	679	749	5%

From Table 35 above, Euclidian distance cannot be judged as a poor estimator for sailing distance. However, in terms of cost calculation, it may be a significant different. Therefore, a better proximity is still recommended to measure the port distance. From the approaches mentioned above, adjusted distances already consider several ways and sources to obtain port distance.

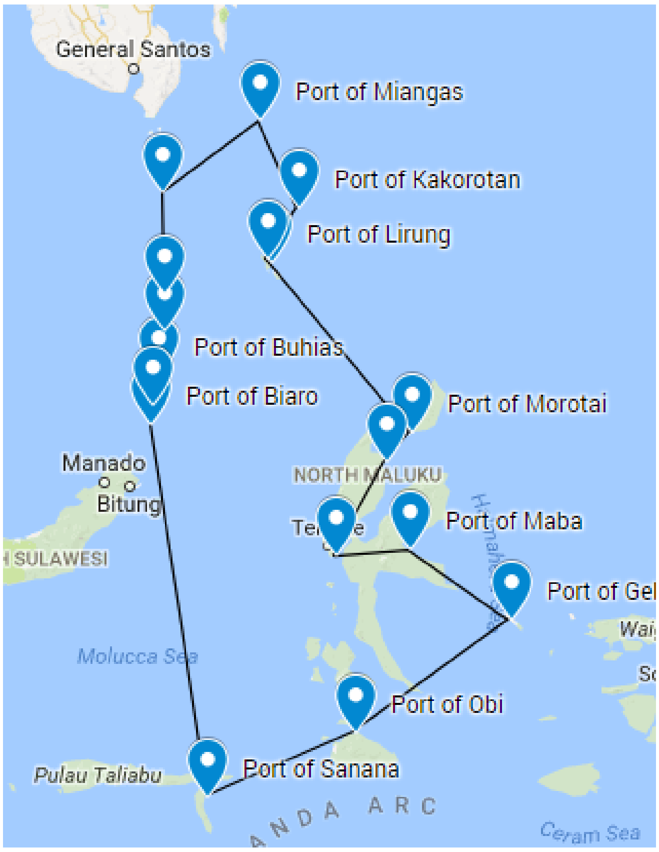

Figure 31 Cluster 3 with Detour Consideration

Figure 32 Hypothetical Point using Google Maps

6.2.3 Port Sequence Adjustment

Another consideration is the shift of port call order. Realizing the alteration of distance after the detour, it is possible to obtain a new port call sequence which minimized the distance. The solution is generated by manual enumeration. We will compare the initial solution after the detour with a possible new arrangement.

Here the following steps to obtain the new feasible order for every cluster.

1. Evaluate the route after the port location is plotted with the actual geographical condition
2. Then, after detour is implemented, asses the route concerning its sailing path. If there is a possibility that the vessel can visit another port formerly, new port sequence can be observed.
3. Plot a new port call sequence using google map to consider the detour.
4. Compare the initial total distance in one cluster with a new sequence distance.

Using the steps mentioned above, we shift the port call sequence of three clusters namely; hub, Cluster 3, and Cluster 4. For example, the consideration of changing an order for hub cluster is based on Figure 27. Initially, the route from Tanjung Perak is directly going to Sanana, but, after the detour, the sailing route will pass Wanci. Therefore, we try to generate a new solution where Wanci is visited after Tanjung Perak. Afterward, the vessel sails to Sanana, Oransbari, Fakfak, and back to Tanjung Priok. Figure 33 shows the new sequence for hub cluster.

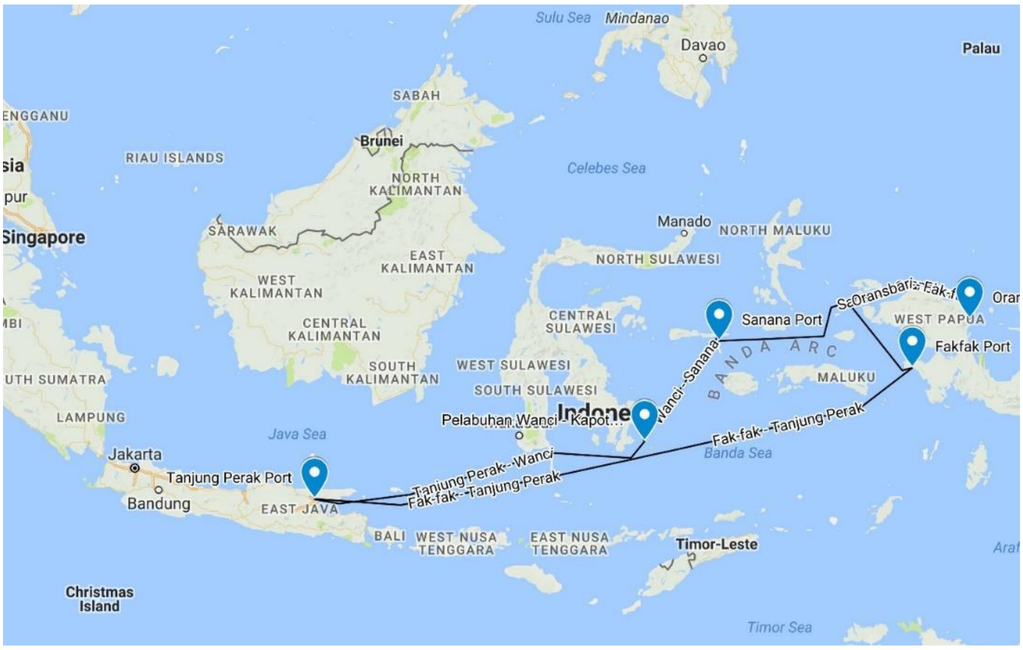

Figure 33 New Feasible Route for Hub Cluster

The manual enumeration is performed for Cluster 3 and 4 to establish the new port sequence. The steps are following the approach mentioned above. All results are shown in Appendix 13. To sum up, Table 36 below presents the summary of the shift of port sequence.

Table 36 Port Call Sequence Adjustment

Cluster	Initial Port Call Sequence	Initial Total Distance (nm)	Final Port Call Sequence	Final Total Distance (nm)
Hub	FKQ-WAN-TJP-SQN-ORA	3,245	TJP-WAN- SQN-FKQ- ORA	3,224
Cluster 1	FKQ-KNG-TMK-AGA-MKQ-DBO	-	-	-
Cluster 2	TER-LKA-BIU-BAA-KBH-KIS-MOA-SXK-NAM-NRE-WAN-LWE	-		-
Cluster 3	MIA-KAK-MNA-LIR-OZI-TBO-TID-MAB-GEB-OBI-SQN-BIA-TAG-BUH-KAH-TAH-MAR	1,587	SQN-BIA-TAG-BUH-KAH-TAH-MAR-MIA-KAK-MNA-LIR-OZI-TBO-MAB-GEB-TID-OBI	1,488
Cluster 4	SEB-SGQ-BEL-MAK-TJP-NNX	2,048	TJP-MAK-BEL-SEB-NNX-SGQ-SEB	2,048
Cluster 5	ZRM-TEB-BIK-ORA-WSR-NBX-WAR-ZRI	-	-	-

Hub cluster generates a lower distance than initial order, but the change is not significant. We still chose the new sequence because there is no difference, if the vessel visits Sanana than visit Wanci, in terms of distance. However, in terms of service, it is advisable to visit Wanci after Tanjung Perak because the vessel will pass that port. Thus, the network can serve this port faster without adding any cost (distance).

Cluster 4 still possesses similar distance although the port sequence is changed. The reason is in the approach of determining port distance. In this cluster, the distance is determined by weighted point, so the distance from Tanjung Perak to Nunukan is similar to the total distance of Tanjung Perak – Makassar – Belang-belang, and Sebatik. Furthermore, there is a condition in Sea-Toll Agenda that Makassar considered as the port of origin. It means that, in this cluster, some cargoes will flow not only from Tanjung Perak but also from Makassar.

6.2.4 Overall Network and Conclusion

To sum up, Section 6.2 has the aim to yield the path between ports within the cluster and hub port between clusters. By using the input from the clustering result, the TSP method already calculated with several limitations. Then, some adjustments have initiated to generate a result that relatively close to actual condition. The summary of the overall initial network that constructed from TSP method can be seen in Figure 34.

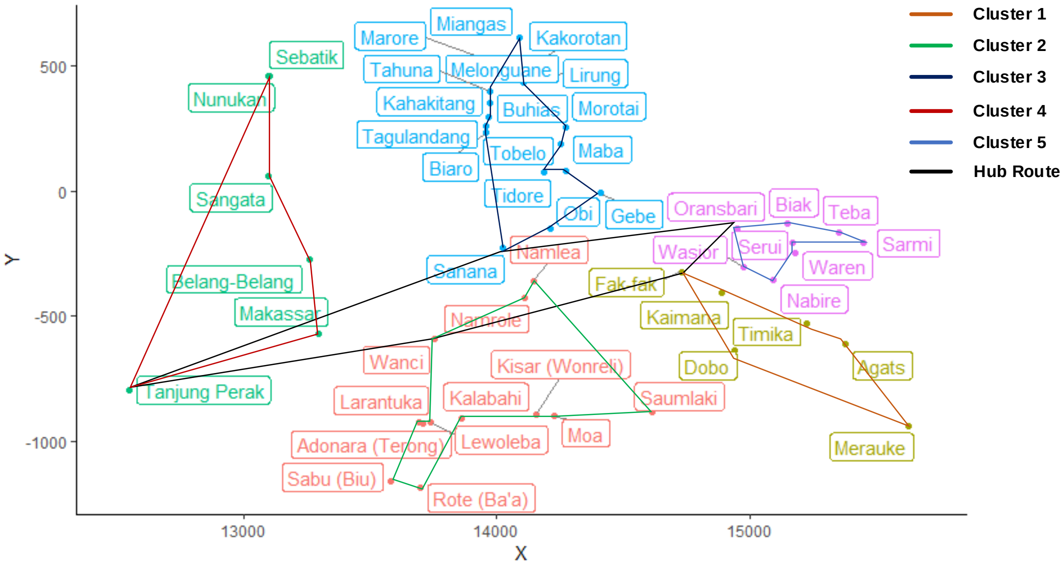

Figure 34 Overall Initial Network

Nevertheless, the result above is adjusted with some steps in Subsection 6.2.2 and 6.2.3. The adjustments are not yielded a lower distance than the initial network. However, the value is reflected the actual condition for vessel operation. The summary of network after adjustment is depicted in Figure 35

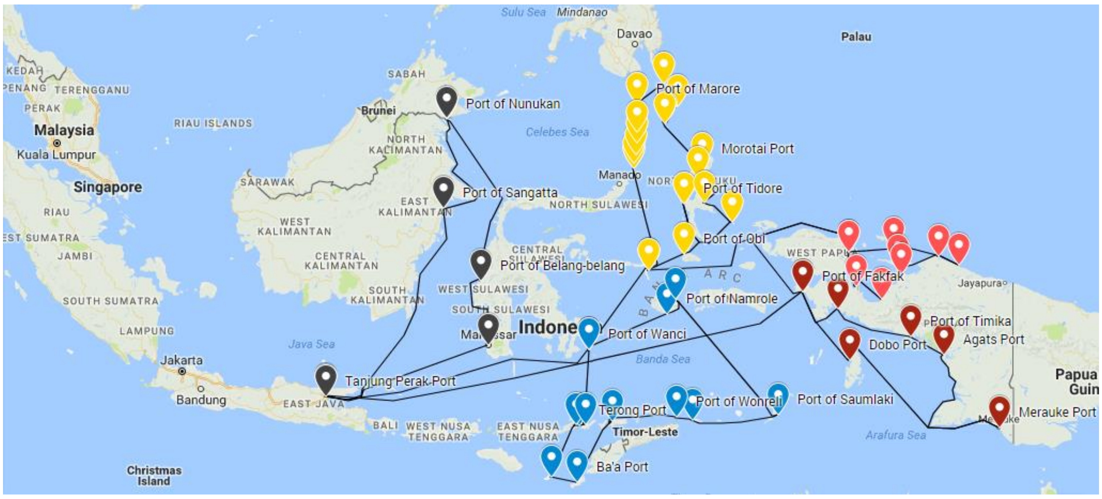

Figure 35 Overall Network after Adjustment

To conclude this Section, Table 37 presents the summary of initial network and port sequence adjustment. In the distance adjustment row, number 1, 2, and 3, implies the approach used for adjust the distance (Section 6.2.2). The difference between initial and final distance is quite low except in hub port distance and Cluster 4 routing. However, the difference will be significant in calculation of bunker cost, vessel speed, and scheduling. The difference in port distance will become an issue in estimating network performance. It is because those performances will affect the calculation both financially and operationally.

Table 37 Summary Port Routing

Cluster	Distance Adjustment	Port Sequence Adjustment	Initial Distance (nm)	Final Distance (nm)
Hub	Yes (1&3)	Yes	2,710	3,224
Cluster 1	Yes (1&3)	No	1,215	1,564
Cluster 2	Yes (1,2,&3)	No	1,625	1,703
Cluster 3	Yes (1&3)	Yes	1,248	1,488
Cluster 4	Yes (1,2&3)	Yes	1,739	2,048
Cluster 5	Yes (1&3)	No	679	749

6.3 Liner Shipping Planning Comparison

After establishing the network and estimating the demand, the next step is planning the liner shipping design from strategic, tactical, and operational. The decision should recognize all limitations and the Sea – Toll objectives (Chapter 3). This complexity will be solved by using all required parameters, which have obtained from several previous sections (e.g. cargo flow data, ship particular data, and port related data).

This section will describe and show the steps to achieve the liner shipping planning for each network options and scenarios. Then, the result of each network development will be compared. Those options and scenarios refer to the explanation in Section 4.5.

This section will begin with the presentation of all network structures (Subsection 6.3.1) and its difference. Then, some optimizations are performed by evaluating the possible options. In regard to strategic planning, the network design is already constructed, then fleet size and mix design will be calculated based on manual enumeration in Subsection 6.3.3. The consideration in determining the fleet size and mix will be based on demand disaggregation (once a week or once in two weeks schedule service) and vessel load factor (Subsection 6.3.2).

In this thesis, tactical planning consists of vessel scheduling, speed optimization, and the number of vessels deployed. Vessel scheduling will be assessed whether the network provides once a week service or once in two weeks service (Subsection 6.3.4). The decision will be based on shipping cost calculation. Then, for every vessel allocated in each route, the speed will be optimized to maintain the schedule (Subsection 6.3.5). Finally, if the speed exceeds maximum vessel speed, the number of vessels deployed per route should be increased (Subsection 6.3.6).

In regard to operational planning, the parameters will be predetermined. For example, in cargo routing problem, we already set that all cargo should be transported using a given route and network. The framework for the liner shipping planning calculation can be seen in Figure 36.

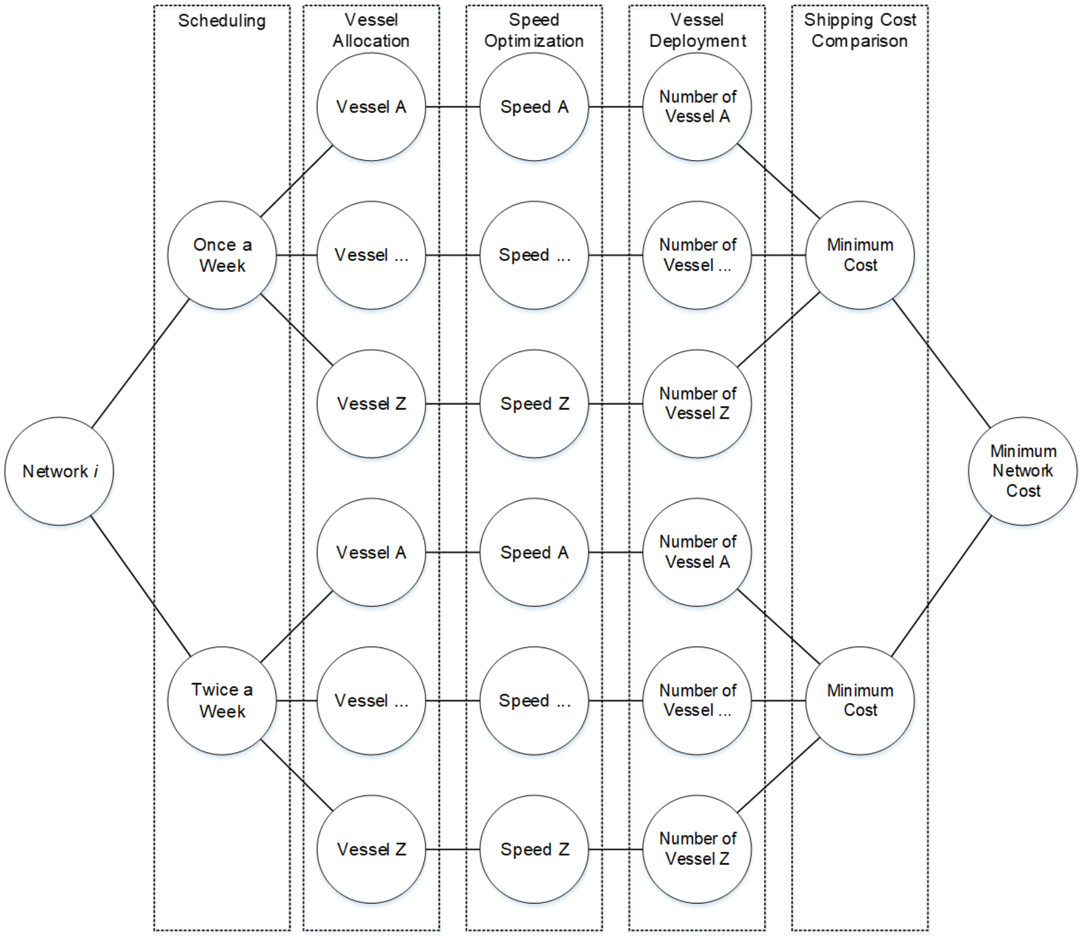

Figure 36 Framework for Liner Shipping Planning

6.3.1 Network Development

In this subsection we will show four network options that will be compared to decide a proposed network for liner network design in Sea-Toll Agenda. Every network will be evaluated for each decision level planning and financial performance. The network options are; current Sea – Toll Network (Section 3), Clustering Network (Section 6.2.4), Port Aggregation, and Butterfly Hub Route.

Port Aggregation and Butterfly Hub Route are developed because the consideration that the suboptimal approach establishes the clustering network. Port Aggregation is an alternative to reduce the port call based on demand. Then we let the service to the port provided by local shipping. Meanwhile, Butterfly Hub Route initiative is based the long distance in main hub route that we recognized after evaluating total distance in that route.

Furthermore, this thesis aims to analyze two scenarios which might happen in the network which are additional demand and spill-over effect. The spill-over effect means that there is a demand grow from the origin port and every port start to become the supplier. Further explanation will be described in the following subsections.

6.3.1.1 Current "Sea – Toll" Network

This network is used as the basis performance of overall network. For the calculation, the routes and some vessels are already set based on latest Sea – Toll operation, such as tender, etc. Some parameters, which is not set, will be assumed, i.e. vessel in route which is still in tender process. The summary of the network can be seen in the Figure 37 below.

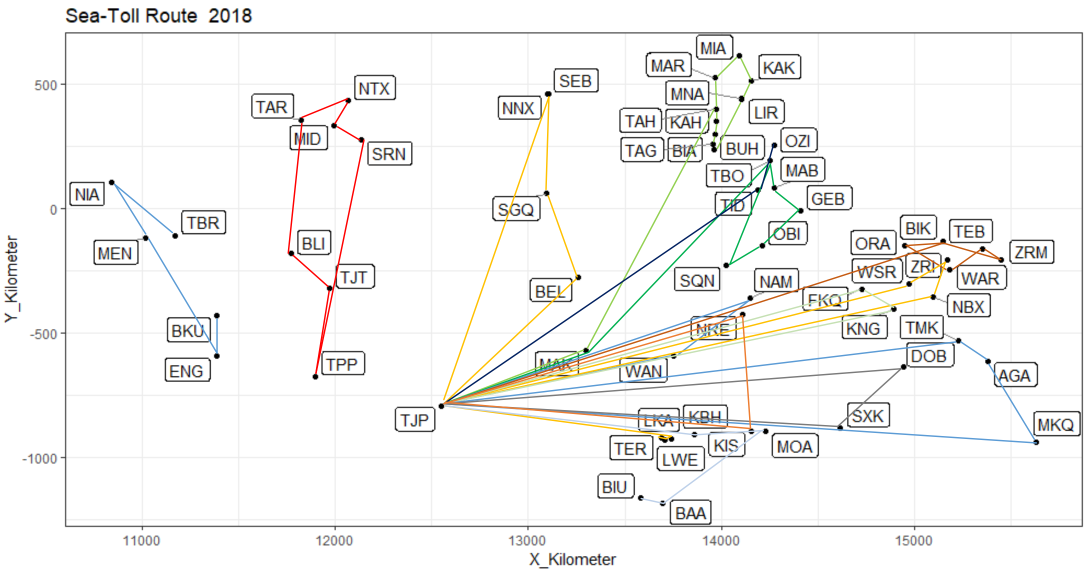

Figure 37 Current Sea Toll Agenda Network

As mentioned in Chapter 1, the thesis only considers the network originated from Tanjung Perak (TJP). Summary of overall routes within network can be recalled from Table 3. This study also will treat Sea – Toll routes as a circular considering the assumption there is no backhaul demand ate the beginning operation.

Looking at the network, the current Sea – Toll Agenda can be grouped by hub-and-spoke and non-hub-and-spoke route. Some groups of port situated quite far, such as the port in North Sulawesi archipelago and northern of coast Papua, will be reached by one direct service to hub port, then connected by feeder voyage in the circular route. The other routes structure are circular and pendulum, but with the only small number of port calls. Thus, the logical result of this network is the higher number of vessel deployed because of the high number of the route.

6.3.1.2 Clustering Network

The second network is the clustering network which already established in Section 6.1 and 6.2. The network visualization can be seen in Figure 38 below.

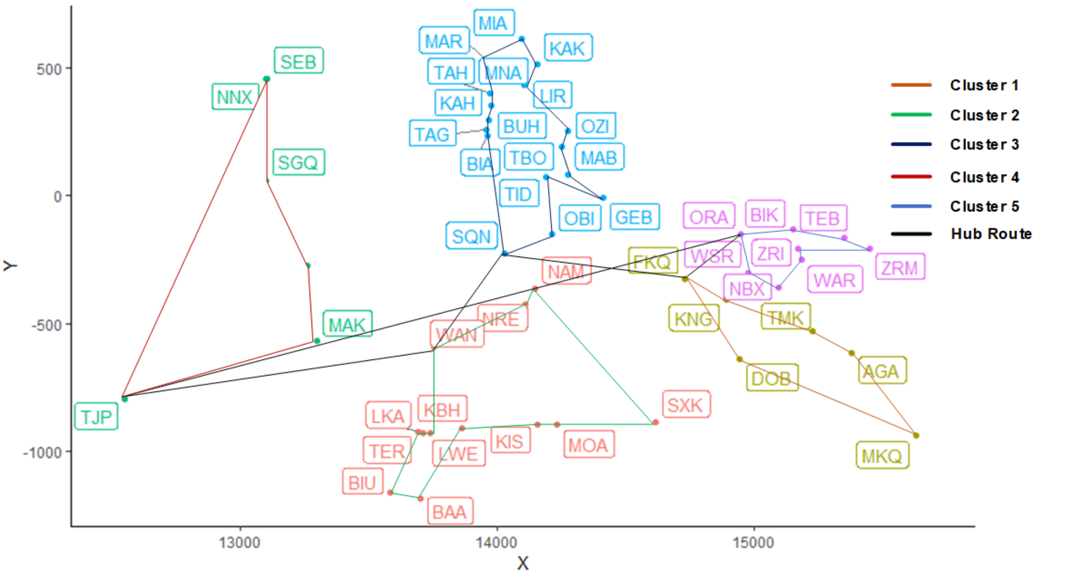

Figure 38 Clustering Network

The solution from k-means suggests the network to group in five clusters. We choose the TSP method as an approach to yield the route. Then, six circular routes are generated. The clustering network reduces a half route from current Sea – Toll Agenda. The reduction will impact in some operational planning such as minimum vessel deployed. However, the distance in one cluster possibly can be higher than the current network. It is because the additional bunker cost (high speed to maintain schedule) or additional chartering cost (more vessel to add the frequency). The cost performance will be calculated in Section 6.4.

6.3.1.3 Clustering Network with Port Aggregation

After calculating cargo flow, some ports only need a few demands. Consequently, shipping liner will not get a sufficient profit if the vessel provides service to that region. A network is developed by ignoring some ports which have a demand less than 10 containers in a month. Instead, the demand will be allocated to the nearest port. To ensure the service still maintained, we assume there is a local shipment who will deliver the goods to limited demand ports. This service cost will be considered to total network cost. **This network will be called Port Aggregation Network**. The route structure will follow the Clustering Network, but the number of visited ports is reduced.

Table 38 shows the port which possesses a low value of demand. In addition, the table depicts the nearest port allocated as a second level feeder and they will provide service to the ignored port.

Table 38 Aggregated Port

Cluster	***Port ID***	***Monthly Demand (TEU)***	***Second Level Feeder Port***
C5	ZRI	7	WAR
C3	BIA	2	TAG
	BUH	1	
	GEB	3	OBI

Cluster	Port ID	Monthly Demand (TEU)	Second Level Feeder Port
	KAH	2	TAH
	KAK	1	
	LIR	4	
	MAR	1	
	MNA	9	
	MIA	1	
	MAB	4	TID
C2	KIS	8	KBH
	MOA	4	
	BAA	8	BIU

In the Port Aggregation Network, we will introduce second level feeder port which plays a role in providing service for ignored port. We assume there is a local shipping line delivering the cargo directly to the destination. The assumption is based on the study by Muhana (2017). He investigated the importance of local shipping (*pelayaran rakyat*) to provide the service between ports, some of them are low demand ports. The structure of the network can be seen in Figure 39 below.

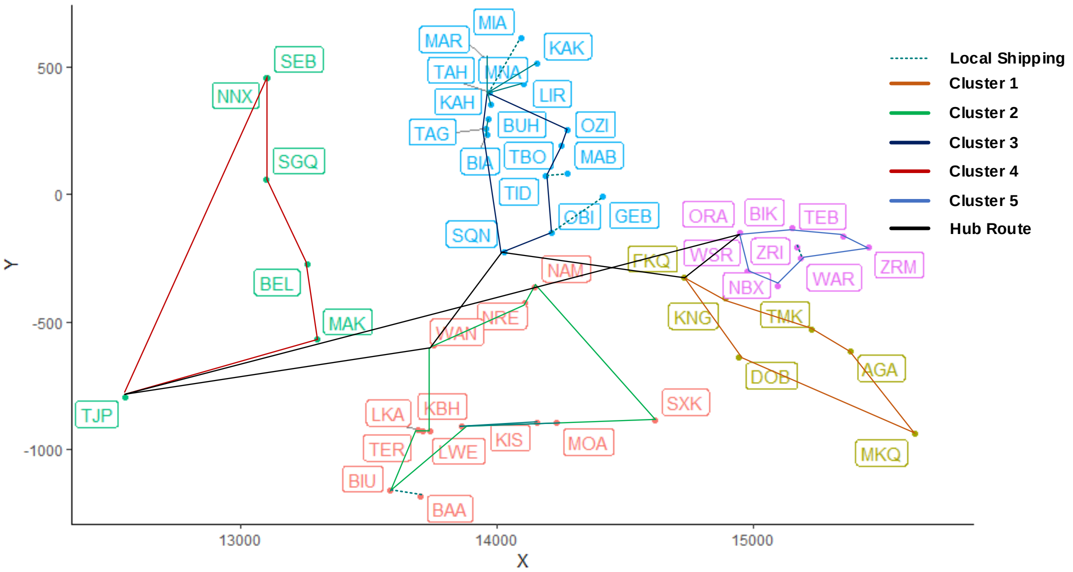

Figure 39 Port Aggregation Network

The service cost data is obtained from Muhana (2017). From his study, the average of local shipping freight rate for 360nm was 53 USD/ton. Thus, we assume that rate per nautical miles is 0.15 USD/ton. Because we assume that 1 TEU = 21.6 ton, then we convert the freight rate become USD/TEU. Table 39 below shows the freight rate for ignored port.

Table 39 Local Shipping Liner Freight Rate

Origin	Destination	Distance (nm)	Freight Rate (USD/Ton)	Freight Rate (USD/TEU)
ZRI	WAR	23	3.4	73.1
BIA	TAG	20	2.9	63.6

Origin	Destination	Distance (nm)	Freight Rate (USD/Ton)	Freight Rate (USD/TEU)
BUH	TAG	23	3.4	73.1
GEB	OBI	161	23.7	512.0
KAH	TAH	27	4.0	85.9
KAK	TAH	219	32.2	696.4
LIR	TAH	104	15.3	330.7
MAR	TAH	135	19.9	429.3
MNA	TAH	248	36.5	788.6
MIA	TAH	244	35.9	775.9
MAB	TID	278	40.9	884.0
KIS	KBH	159	23.4	505.6
MOA	KBH	232	34.2	737.8
BAA	BIU	80	11.8	254.4

6.3.1.4 Clustering Network + Port Aggregation with Butterfly Hub

From the last network development (reducing of feeder port), we consider that the main hub has a long travel distance. Therefore, we develop a **Butterfly Hub** which will deploy two vessels to provide a service for the main hub. **This network structure will have a route that combines Clustering Network and Port Aggregation.**

In this network, main hub route will be separated become two routes. The route selection is evaluated by examining all route combination possibilities concerning the total distance. The reason choosing distance as a parameter is because it is related with the shipping cost performance, especially bunker cost. The distance closely related with bunker consumption which will influence the fuel cost. Table below shows all route possibilities with their distance.

Table 40 Hub Route Alternatives Comparison

Route Possibilities	Sequence	Distance (nm)	Total Distance (nm)
1	TJP-WAN-SQN	1,919	5,264
	TJP-ORA-FKQ	3,344	
2	TJP-WAN-ORA	3,068	5,722
	TJP-SQN-FKQ	2,654	
3	TJP-WAN-FKQ	2,579	5,685
	TJP-SQN-ORA	3,106	

From Table 40, the route alternative that has the minimum distance is the first option. Therefore, in the first hub route, the vessel will sail from Tanjung Perak (Cluster 4), Sanana (Cluster 3), and Wanci (Cluster 4). Moreover, the sailing route sequence for the second route is; Tanjung Perak (Cluster 4) – Oransbari (Cluster 5) – Fak-fak (Cluster 1). The structure can be seen in Figure 40 below.

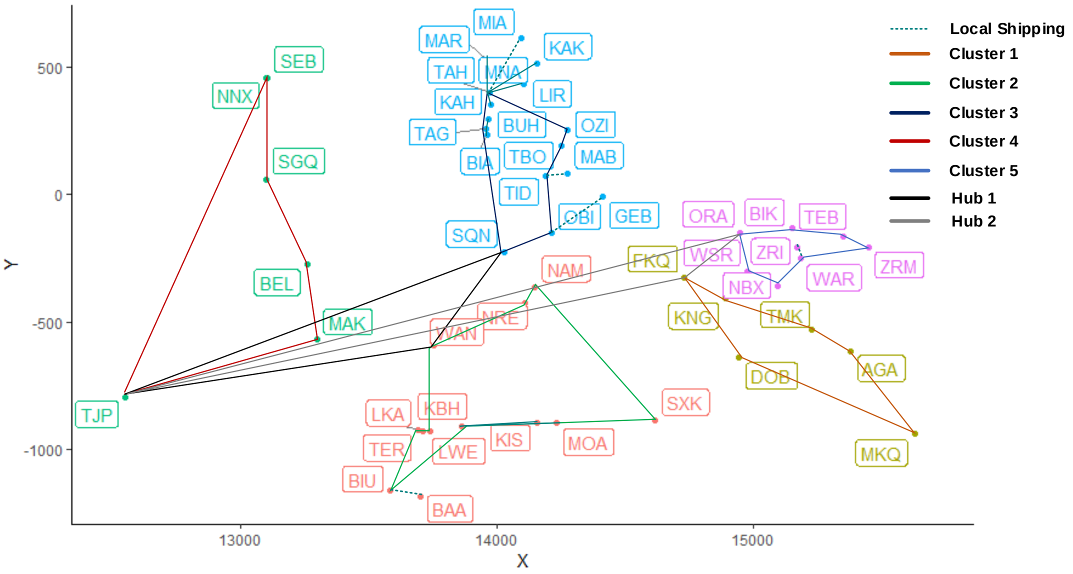

Figure 40 Butterfly Route with Port Aggregation

Further network consideration will try to realize the scenario of additional demand flow. This scheme may happen if the government liberalize the type of cargo that transported by the Sea-Toll program. It means that some shippers will try to deliver more cargo using this program. We try to develop two scenarios, which are;

6.3.1.5 Butterfly Hub Network with 10% Additional Cargo (Scenario 1)

After we perform the comparison between four network options (Sea – Toll, Clustering, Port Aggregation, and Butterfly Hub), **this scenario will use latest network option, which is the Butterfly Hub**, to see the impact of 10% additional cargo because of liberalization goods transported. This scenario will be named **Scenario 1**.

6.3.1.6 Butterfly Hub with 10% Backflow Cargo (Scenario 2)

This scenario is a continuation of Scenario 1 (10% additional cargo). In this scenario, we will see the impact of 10% additional backhaul cargo that delivered to the main port (Tanjung Perak).**This scenario will examine based on Butterfly Hub operation and it will be called as Scenario 2.**

The scenario is based on the possibility of the growth from the outer island because of trade. Moreover, because of the Sea – Toll Agenda, the outermost island obtain an infrastructure to sell their product to the main market (Java).

To conclude, network development is the initial step to introduce several options and scenatios that will be compared. The comparison will be based on overall network cost and the vessel operation given the route and cargo flow. Table 41 below presents the summary of network options and scenarios.

Table 41 Network Options Comparison

Network	Number of Port	Number of Route
Sea-Toll Network (STN)	49	12 (3 Hubs and 9 Feeders)
Clustering	49	6 (1 Hub and 5 Feeders)
Port Aggregation	35	6 (1 Hub and 5 Feeders)
Butterfly Hub	35	7 (2 Hubs and 5 Feeders)

Table 42 Scenarios Comparison

Scenario	Network Used
10% Additional Cargo (Scenario 1)	Clustering + Port Aggregation + Butterfly Hub
10% Additional Cargo + 10% Cargo Backflow (Scenario 2)	Clustering + Port Aggregation + Butterfly Hub

6.3.2 Demand Fulfillment Disaggregation

After determining all possible networks, demand estimation in every port is disaggregated in weekly basis (once a week and once in two weeks). The disaggregation is done for support a regularity of Sea – Toll Agenda to fulfill the demand in every port. We divide monthly demand by two for once in two weeks schedule and four for once a week schedule (assuming that one month = four weeks), then rounded up.

There are two sets of demand disaggregation; demand for initial network with 49 ports and demand with 35 ports (Port aggregation network). Moreover, **we assume there is no demand to Tanjung Perak and Makassar because both port are not the target of Sea – Toll Agenda, but they are the cargo origins port.** The demand disaggregation data for Cluster 1 presented in Table 43 , while the completed data can be found in Appendix 10.

Table 43 Demand Disaggregation for Clustering Network

Cluster	Port ID	Container Demand (per Month)	Container Demand (per Week)	Container Demand (per Two Weeks)
1	AGA	45	12	23
1	DBO	47	12	24
1	FKQ	39	10	20
1	KNG	34	9	17
1	MKQ	30	8	15
1	TMK	35	9	18

6.3.3 Vessel Allocation Decision

After knowing demand fulfillment both for once a week and once in two weeks, the next step is selecting the vessel type for every route in each network. Vessel selection is based on the suggested capacity which should comply International Maritime Organization load factor (70% Vessel Capacity). The data for vessels available and its ship particular can be found in Appendix 1.

Subsequently, using enumeration method from Section 4.2.4, we allocate the vessel to each route. The following is example to determine the vessel allocated for hub route in weekly demand scheme.

1. Calculating the suggested vessel capacity given that the route capacity is 231 TEUs. Weekly capacity can be obtained by summing up all demands in one route.

$$Suggested\ Vessel\ Capacity = \frac{231}{0.7} \approx 330$$

2. Matching the suggested capacity with the vessel. There are three vessels candidate that satisfy the calculation result;

Table 44 Possible Vessel for Hub Route (Weekly Demand Scheme)

ID	Type	Name	Size (TEU)	Dwt (Ton)	GT (Ton)	Speed (kn)	Cons (Ton/Day)	k
31	MPP	Freedom	330	5,314	4,303	13.5	12.0	0.00488
32	Container	Tanto Aman	338	5,958	3,994	14.5	14.8	0.00485
33	MPP	Tanto Sepakat	339	6,163	4,460	13.5	12.0	0.00488

From Table 44, the best vessel based on Step 2 is Freedom. It is because the size of vessel is similar with the suggested capacity (Step 1). In addition, this vessel owns a lowest consumption on fuel per day.

3. Comparing the vessels who has quite similar capacity. Because from Step 2 Freedom already satisfied the capacity, this step can be ignored. However, *k* value for Tanto Aman is lower than Freedom. This value can be a consideration if the difference between *k* values in different vessel is high.

Table 45 presents the selected vessel for clustering network in two scenarios of scheduling. The enumeration method for allocating the vessel will be performed for all networks, except Sea – Toll current network.

Table 45 Vessel Selection and Capacity of Route for Clustering Network

Route	Once a Week Demand (TEUs)	Suggested Vessel Capacity (TEUs)	Vessel Selected
Hub	272	389	Freedom
C1	50	72	KM Caraka Jaya Niaga III - 32
C2	75	108	KM Logistik Nusantara II
C3	45	65	KM Logistik Nusantara IV
C4	36	52	KM Kendhaga Nusantara
C5	37	53	KM Logistik Nusantara III

Route	Once in Two Weeks Demand (TEUs)	Suggested Vessel Capacity (TEU)	Vessel Selected
Hub	439	630	Tanto Bagus
C1	97	139	KM Logistik Nusantara II
C2	144	206	Territory Trader
C3	80	115	KM Logistik Nusantara III
C4	69	99	KM Kendhaga Nusantara
C5	71	102	KM Caraka Jaya Niaga III - 32

However, for “Sea - Toll Agenda the vessel already set for some routes because the government already obtained the operators and the vessels. In this network we assume that all hub ports will be served by KM Logistik Nusantara IV and the service for all feeder ports will be provided by KM Kendhaga Nusantara. The assumption is based on the current government plan (Ministry of Transport Republic Indonesia, 2018) to assign every Kendhaga Nusantara vessel for feeder routes and Logistik Nusantara for hub routes/ direct shipping. Moreover, we will set the schedule for once in two weeks. It is because the weekly demand schedule will not be beneficial. The cargo flow based on estimation will be quite low.

Table 46 Vessel Selection for Sea - Toll Network
**Vessel Selection is Predetermined by Tender*
***Vessel Selection is Assumed based on the Government Plan*

Route	***Once in Two Weeks (TEUs)***	***Suggested Vessel Capacity (TEUs)***	***Vessel Selected***
*T3***	69	99	KM Logistik Nusantara IV
*T4**	27	39	KM Logistik Nusantara I
*T4F**	18	26	KM Kendhaga Nusantara
*T5***	47	68	KM Logistik Nusantara IV
*T5F***	31	45	KM Kendhaga Nusantara
*T6**	21	30	KM Logistik Nusantara II
*T7**	24	35	KM Mentari Perdana
*T8***	55	79	KM Logistik Nusantara IV
*T8F***	35	50	KM Kendhaga Nusantara
*T9***	25	36	KM Logistik Nusantara IV
*T10***	37	53	KM Logistik Nusantara IV
*T11***	56	80	KM Logistik Nusantara IV
*T12**	43	62	KM Meratus Ultima II
*T13**	34	49	KM Logistik Nusantara III
*T14**	51	73	KM Logistik Nusantara IV
*T15**	19	28	KM Caraka Jaya Niaga III - 32

After selecting the network and fleet type, next step is planning for vessel operation. The operation covers vessel scheduling, vessel type selection, ship speed optimization and number of vessel deployed.

6.3.4 Scheduling

In the first attempt, we compare two alternatives schedule for clustering network, which are once a week and once in two weeks. The comparison has aim to analyze the tradeoff between number vessel deployed, number of voyage or service provided, and the total cost in a year. To obtain the result, we follow the steps from Figure 13. Table 47 and Table 48 present the summary of comparison for the schedule options. Steps to yield all results will be described in the following subsections.

Table 47 Scheduling: Vessel Operation Comparison

Route	***Schedule (Days)***	***Optimum Speed (knot)***	***Round Time Voyage (Days)***	***Number Ship Deployed (unit)***
Once a Week				
Hub	7	12.91	14	2
C1	7	6.01	14	2
C2	7	7.61	14	2
C3	7	6.88	14	2
C4	7	6.87	14	2
C5	7	7.98	7	1
Once in Two Weeks				
Hub	14	15.50	14	1
C1	14	6.38	14	1
C2	14	8.51	14	1
C3	14	7.35	14	1
C4	14	7.03	14	1
C5	14	3.24	14	1

Table 48 Scheduling: Cost Comparison

Parameter	***Unit***	***Once a Week***	***Once in Two Weeks***
Total Voyages	Voy/Year	312	156
Total Cost	USD/Year	19,694,678	14,730,406
Bunker Cost	USD/Year	11,067,064	7,865,805
Port Service Cost	USD/Year	174,448	126,071
Tariff Handling Charge	USD/Year	2,155,963	2,054,184
Charter Cost	USD/Year	6,297,203	4,684,346
Unit Cost per TEU	USD/TEU	1,420	1,115

Weekly fulfillment schedule generates more cost than another schedule. It is because more vessels are required to keep a regular weekly voyage. The vessel could not exceed the design speed if they try to keep in 7 days RTV. Therefore, the additional vessel is needed to maintain the target, yet, it will increase charter cost significantly.

Obviously, the weekly schedule is better in terms of reliability. This planning can keep demand fulfilment and prevent the shortage in every region. This situation is aligned with the government goal concerning price disparity between eastern and western regions. However, the cost for this planning is relatively high. The unit cost can reach $1420, while the market rate to the eastern region averagely $900 – $1,200 per TEU (depends on destination). Although the government provides the subsidy, the route will not sustain because shipping line will not obtain any profit. Furthermore, the unit cost provided by another schedule (once in two weeks), which is 1,115 USD/TEU, is investigated as a high number comparing with Asia – Europe freight rate. From several sources, the price is fluctuating around $800-$900 per TEU.

After finding that the weekly schedule generates higher total cost, for further calculation, we will only consider once in two weeks fulfillment schedule. It means that the vessel will keep Round Trip Voyage (RTV) for 14 days.

6.3.5 Ship Speed Optimization

In subsection 6.3.3 the vessel for every route in each network already selected. Then, all ship particular data are used for estimating the sailing speed. The objective of this problem is to maintain the RTV, so it always aligns with the schedule (once in two weeks demand fulfillment). Vessel speed optimization calculated based on Equation 15 and using *goal seek* formula in excel.

Calculation

For a sample calculation, we will find the optimum speed for the hub route (once in two weeks schedule). From the Equation 15, we need four parameters namely, total distance (d_r), target time T_r^t, total port service time T_r^p, and total terminal handling time T_r^h for hub route.

Table 49 Speed Optimization (Example: Hub Route)

Parameters	***Value***	***Unit***
Total Distance	3337.45	nm
Target Round-Trip Voyage	14	Days
Total Terminal Handling Time	3.82	Days
Total Port Service Time	1.21	Days
Sailing Time Target	8.97	Days
Ship Speed	15.50	knots
Actual Round-Trip Time	14.00	Days

theTotal distance between hub ports is obtained from the result of Travelling Salesman Problem (Recall Table 37), meanwhile, total target time (T_r^t) is determined from scheduling result in the previous section (once in two weeks/ every 14 days). The result terminal handling time is calculated based on Equation 17 and 18. The following is example calculation for total terminal handling time in hub route

$$T_{Hub\ Route}^{h} = \sum_{h \in r} T_h^h$$

$$T_{Hub\ Route}^{h} = loading\ time\ TJP + (un)loading\ time\ WAN + (un)loading\ time\ SQN + (un)loading\ time\ ORA + (un)loading\ time\ FKQ + unloading\ time\ TJP$$

$$T_{Hub\ Route}^{h} = \frac{(231)}{(25*2)} + 2*\frac{(6+70)}{(5*2)} + 2*\frac{(8+45)}{(5*2)} + 2*\frac{(5+37)}{(5*2)} 2*\frac{(10+50)}{(12*2)} + \frac{(231)}{(25*2)} = 91.71\ hours = 3.82\ days$$

Then, the example of total port service time computation for hub route is presented below

$$T_r^p = \sum_{h \in r} T_h^p = port\ service\ time\ in\ WAN + port\ service\ time\ in\ SQN + port\ service\ time\ in\ ORA + port\ service\ time\ in\ FKQ + port\ service\ time\ in\ TJP$$

$$T_r^p = 6 + 6 + 6 + 6 + 5 = 29\ hours = 1.21\ days$$

After obtaining target time, total terminal handling time, and total port service time, target sailing time can be obtained by using the following steps.

$$T_r^s = 14 - 3.82 - 1.21 = 8.97\ days$$

Finally, from the target sailing time, vessel speed can be optimized to meet the target. In this case, the vessel speed calculated as follows

$$s_r^v = \frac{3337.45}{8.97} = 15.5\ knots$$

In this case the actual round trip time is equal with the target. It means that vessel optimization is already done. However, if the vessel speed s_r^v exceeds the maximum design speed, the calculation will be iterated from the determining of target time.

Summary of Speed Optimization for Network and Scenario

Every network shows a different total distance because it consists of different set of route. From Table 50 the clustering network become the shortest route among all networks with 49 ports (port aggregation cut 14 ports call). This result portrays that the TSP model generate the shortest distance, however the result still not ensure the network will obtain an average lower vessel speed. Average vessel speed can indicate bunker consumption in one route which will lead to additional bunker cost.

Table 50 Summary of Vessel Speed Optimization (Network Development)

Network	***Total Route***	***RTV (Days)***	***Total Distance (nm)***	***Average Speed (knot)***
Sea Toll Network	16	14	36,415	8.07
Clustering Network	6	14	11,071	8.00
Port Aggregation	6	14	10,487	7.22
Butterfly Hub	7	14	12,413	6.70

The remarkable observation from the table above is the decline of speed in every network development. The finding is that the clustering network has an immense load in hub port route. When the main hub network is separated become two routes with two vessels, the average optimum speed is dropped. Thus, the cost for bunker went down significantly.

Furthermore, the vessel capacity is decreased when the butterfly route is applied. The cargo load in the main hub will be separated into two routes. Then, in this network option, the government can assign the low capacity vessel. Therefore, yearly charter cost will be decreased because the new vessels have a lower charter rate.

Table 51 Vessel Speed Optimization: Hub Route Comparison

Network	Vessel Deployed (Unit)	RTV (Days)	Vessel Capacity (TEU)	Total Distance (nm)	Vessel Speed (kn)
Clustering Network	1	14	630	3,337	15.5
Port Aggregation	1	14	630	3,337	15.5
Butterfly Hub					
Hub 1	1	14	373	1,919	7.34
Hub 2	1	14	312	3,344	11.72

For the scenario, we apply the network as mentioned in Subsection 6.3.1.5. Average speed in the route apparently will be higher because there is some additional cargo. This additional cargo will increase the terminal handling time because the terminal productivity still remain the same.

Furthermore, if the backflow cargo is grown, the average speed does not change. The reason is the cargo will not increase the terminal handling time. Time for loading the backflow cargo only replace unproductive movement from loading the empty cargo.

Table 52 Summary of Vessel Speed Optimization (Scenario Development)

Scenario	Total Route	RTV (Days)	Total Distance (nm)	Average Speed (knot)
Scenario 1	7	14	12,413	6.80
Scenario 2	7	14	12,413	6.80

6.3.6 Number of Vessel Deployed

In regards to keep the regularity of the schedule, vessel speed and number of the vessels will be different. As discussed in Sections 4.2.4, if the vessel speed exceeds its design speed to maintain schedule, another vessel will be deployed. The formula to obtain the number of the vessel in one route can be reviewed from Equation 13.

Calculation

The following is an example to find the number of vessels in the hub route (weekly schedule). First, we set target round-trip voyage is 7 days because the vessel intends to fulfill weekly demand. Then, using the similar steps in Sections 6.3.5, the optimal ship speed will be obtained.

Table 53 Vessel Ship Optimization (Weekly Schedule)

Parameters	Value	Unit
Target Round-Trip Voyage	7	Days
Total Terminal Handling Time	2.02	Days
Total Port Service Time	1.21	Days
Sailing Time Target	3.77	Days
Ship Speed	**36.88**	knots
Actual Round-Trip Time	7	Days

There are no vessels can sail in about 37 knots; thus this solution is infeasible. We recalculate the solution using the 14 days RTV target.

Table 54 Vessel Ship Optimization - 2 (Weekly Schedule)

Parameters	Value	Unit
Target Round-Trip Voyage	14	Days
Total Terminal Handling Time	2.02	Days
Total Port Service Time	1.21	Days
Sailing Time Target	10.77	Days
Ship Speed	12.91	knots
Actual Round-Trip Time	14	Days

We set 14 days as a new RTV target because the schedule will be on a weekly basis. By using Equation 13, the number of vessels that should be deployed in the hub route to fulfill weekly schedule is calculated as follows.

$$n_r^s = \left(\frac{14}{7}\right) = 2$$

Two tables below show the summary of fleet size in every network and scenario. It is clear that in once in two weeks schedule, every route only need one vessel to maintain the schedule. In the butterfly network, we set two different vessels on each route. Sea – Toll network possesses the highest amount of fleet size for the same amount of demand. This condition will lead to a high for the charter cost.

Table 55 Number of Vessel in Every Network

Network	Total Voyage (Voyage/year)	Fleet Size (Unit)
Sea Toll Network	26	16
Clustering Network	26	6
Port Aggregation	26	6
Butterfly	26	7

Table 56 Number of Vessel in Every Scenario

Scenario	Total Voyage (Voyage/year)	Fleet Size
10% Additional Cargo	26	7
10% Additional Cargo + 10% Backflow Cargo	26	7

6.4 Shipping Cost Result

After knowing the parameter for calculating the component of total cost, such as cargo flow which will influence terminal handling movement and port stay, vessel speed which is related with bunker consumption, and fleet size, the total cost can be achieved. All formulas and steps for obtaining all shipping cost components can be reviewed in Section 4.4.

This section will be dedicated for presenting the shipping cost in every option and scenario. The result becomes an indicator to decide the proposed network for Sea –

Toll Agenda. Subsequently, each cost component result will be analyzed in order to find the phenomena in every options and scenario. For the general point of view, Table 57 presents the summary of the total cost, revenue, and subsidy for every network in USD/year.

Table 57 Total Cost Components for Every Network

Parameter	***Unit***	***Sea Toll Network***	***Clustering Network***	***Port Aggregation***	***Butterfly Hub***
Total Cost	USD/Year	24,260,741	14,730,406	14,165,721	11,816,957
Bunker Cost	USD/Year	13,884,351	7,865,805	6,916,513	4,991,386
Port Cost	USD/Year	323,678	126,071	107,808	110,102
Terminal Handling Cost	USD/Year	1,139,852	2,054,184	2,052,670	2,052,670
Charter Cost	USD/Year	8,912,860	4,684,346	4,684,095	4,258,164
Additional Service Cost	USD/Year	-	-	404,636	404,636
Revenue	USD/Year	5,077,738	5,077,399	5,039,337	5,039,337
Subsidy	USD/Year	18,332,701	9,653,007	9,126,380	6,777,621
Unit Cost	USD/TEU	1,837	1,115	1,077	898

Bunker Cost

Comparing with Sea – Toll Network, Clustering Network significantly can reduce bunker cost. The k-means clustering algorithm has generated the lower number of routes which has an implication in the reduction of sailing distance (Table 50). Since the distance is related to bunker consumption, bunker cost will be reduced if the distance is declined. This phenomena also explains the cost saving on port aggregation alternative. Cutting some ports call are yielded the lower distance. Although this network has an additional service cost to ensure the cargo distribution, port aggregation still become a preferable network than clustering.

Our remarkable finding is when butterfly hub is implemented. Even though the distance is increased, the bunker cost is dropped. We observed that the optimum vessel speed in butterfly hub are decreased (Table 50). Consequently, bunker consumption is significantly fell since it is highly influenced by the vessel speed (Equation 12). Apart from distance, terminal handling time is also decreased when butterfly hub is applied. It is because the container flows are separated into two routes. This situation leads to an additional sailing time windows.

Port Cost

Port cost has a low proportion in shipping cost component in Indonesia. This finding is aligned with the result from Zamal (2017), Muhana (2017), and Komarudin et al. (2017) who were calculated shipping cost component for in Indonesia shipping context. This cost is highly related with the number of port calls. In Sea – Toll network, the calls are higher because of the number of route is the highest among all alternatives. Meanwhile, because of the option to cut the port visit, port aggregation alternative yields the lowest port cost among others.

Terminal Handling Cost

This thesis found that Sea – Toll Network has the best performance in Terminal Handling Cost (THC). The reason is behind the number of containers transshipped in the networks (Table 58). The movement of the transshipped container is counted twice because it should be transferred from the hub route to the feeder route. Thus, the cost is significantly higher in the clustering network and its options. Although the clustering network consists of one hub, there are some transshipment movements in every hub port (four ports). Meanwhile, Sea – Toll network has three hubs route with only three hub ports which is performed transshipment.

Table 58 Summary: Container Transshipped

Network	*Container Transhipped (TEUs)*
Sea-Toll Network	84
Clustering Network	383
Port Aggregation	381
Butterfly Hub	381

Charter Cost

The difference in charter cost represents the variation in the number and the size of vessels. Sea – Toll network operates more vessel among other; thus the charter rate is the highest. Furthermore, charter cost both for clustering and port aggregation network are almost the similar because they use the similar ship to transport similar equal number of containers (Table 45). However, butterfly route possesses the lowest chartering cost than the other three routes. The route capacity in this option is decreased as an impact of hub route separation (Appendix 15). This situation leads to a possibility to assign two low capacity vessels. Consequently, the charter cost is reduced because the low capacity vessel has a lower charter rate.

Additional Service Cost

Additional service cost is appeared because, in option Port Aggregation and Butterfly Hub, some ports are not visited anymore. However, we assume that the government still provide the service by paying the freight rate to local shipping line (Table 39). The calculation for each service is presented below. Total voyage in a year based on once in two weeks schedule are 26. Thus, to obtain additional service cost per year is by multiplying additional shipping cost per voyage with total voyage in a year.

Table 59 Additional Service Cost Calculation

Origin	*Destination*	*Freight Rate (USD/TEU)*	*Cargo Transported (TEU/Voy)*	*Additional Service Cost (USD/Voy)*	*Additional Service Cost (USD/Year)*
ZRI	WAR	73.1	4	2,022	52,584
BIA	TAG	63.6	2	1,476	38,364
BUH	TAG	73.1	4	1,018	26,458
GEB	OBI	512.0	1	64	1,654
KAH	TAH	85.9	1	73	1,902
KAK	TAH	696.4	2	1,024	26,623
LIR	TAH	330.7	1	86	2,232
MAR	TAH	429.3	1	696	18,107
MNA	TAH	788.6	2	661	17,197

Origin	Destination	Freight Rate (USD/TEU)	Cargo Transported (TEU/Voy)	Additional Service Cost (USD/Voy)	Additional Service Cost (USD/Year)
MIA	TAH	775.9	2	1,768	45,970
MAB	TID	884.0	1	429	11,162
KIS	KBH	505.6	5	3,943	102,523
MOA	KBH	737.8	1	776	20,174
BAA	BIU	254.4	6	1,526	39,686
		Total			**404,636**

Nevertheless, the additional service cost is not significantly changing the result. This cost only contributes about 5% of total shipping cost in a year. Amount of additional service cost is similar in both Port Aggregation and Butterfly Hub because the number of containers transported is not changed. Therefore, Butterfly Hub is considered the best option in terms of shipping cost performance.

Revenue and Subsidy

In the context of Sea – Toll Agenda, minimization of subsidy is one of the network objective. As discussed in Chapter 3, this program intends to attract commercial shipping line to enter the route and add the frequency of voyage to some noncommercial ports. Therefore, amount of subsidy and revenue should take into account. The revenue per container shipped can be obtained in Appendix 14 and, as we discussed in subsection 4.4.5, cargo rate will be originated either from Tanjung Perak or Makassar.

Total revenue per year is quite different after Port Aggregation is introduced. In the first two options (Sea – Toll and Clustering Network), the destination of containers are similar. Thus, the number is quite similar. Yet, after deciding to not visit low demand port, the revenue is decreasing. The reason is because the freight rate to the second level feeder is lower than to the actual destination. However, the difference is not significance because it involves very low number or cargo.

It is clear that in terms of subsidy Butterfly Hub is the most preferable network among all options. Developing the network from the clustering option reduces the subsidy gradually. This result is in line with the decline of total shipping cost.

Unit Cost

Unit cost is calculated by dividing total cost per year with total container shipped in that year. Align with other cost performance (total cost, revenue, and subsidy), the Butterfly Hub yields the lowest unit cost per TEU, around 900 USD/TEU. This network can reduce about 50% of unit cost comparing with the Current Sea – Toll Network. It is because, with the similar amount of containers transported, Butterfly Hub can keep a lower cost than their options.

However, comparing with Europe – Asia container rate ($800-$900 per TEU), unit cost in the proposed network still considerably high. The high number of containers and economic of scale generated by Ultra Large Container Vessel make the rate in Europe – Asia is inexpensive. The condition is the opposite of the situation in the eastern Indonesia where the container flow is low considering the small number of inhabitants.

Scenario Development
The first scenario simulates the possibility when the government revokes the policy concerning the limitation of goods. We assume that there will be 10% more containers within the network. By using the most preferable option (Butterfly Hub Network), the regulation will increase by about 500,000 USD of total revenue per year, yet it will also increase the total cost by around 700,000 USD. Therefore, this scenario will result in the higher subsidy for the route.

Two cost components go up in Scenario 1 (10% additional cargo scenario) compare to the preferable network (Butterfly Hub), viz. bunker cost and terminal handling cost. The additional cargo causes the increase of those cost components. More transported containers mean that the vessel will stay longer in the port to do the cargo handling. Consequently, time sailing target will be reduced and the vessel will be encouraged to sail faster. The condition will lead to surging of fuel consumption.

When the second scenario is applied (10% additional backflow cargo), we found that the network performs better in terms of revenue. There is extra revenue, around 800,000 USD in a year, without any significant additional costs. The bunker cost remains at the same level because backflow cargo only changes the proportion of empty and full container. Accordingly, the terminal handling cost is increasing because of the additional full container movement. The summary of the shipping cost calculation can be seen in Table 60.

Table 60 Total Cost Component for Scenario

Parameter	***Unit***	***Butterfly Hub***	***Scenario 1***	***Scenario 2***
Total Cost	USD/Year	11,816,957	12,313,348	12,533,682
Bunker Cost	USD/Year	4,991,386	5,192,374	5,192,374
Port Cost	USD/Year	110,102	111,749	111,753
Terminal Handling Cost	USD/Year	2,052,670	2,264,543	2,318,685
Charter Cost	USD/Year	4,258,164	4,259,021	4,259,021
Additional Service Cost	USD/Year	404,636	485,662	651,849
Revenue	USD/Year	5,039,337	5,565,929	6,353,869
Subsidy	USD/Year	6,777,621	6,747,419	6,179,813
Unit Cost	USD/TEU	898	846	771

6.5 Chapter Summary

This chapter has calculated all liner shipping plannings in all decision levels, viz. strategic, operational, and tactical. In the strategic level, this thesis generated five clusters as the best output. The list of clusters and its incorporated ports can be obtained in Appendix 2. Then, the hub ports were selected using a manual enumeration, i.e. TJP – WAN – SQN – FKQ – ORA. Those selected ports were the lowest distance ports combination and the decision was based on the cost performance. This combination generated 20% subsidy saving than the high demand ports combination. Subsequently, the TSP model yielded the route within the cluster and between clusters. The Clustering Network route has established with total distance 10,776 nm. This routes consisted of five feeder routes and one main hub route. The overall network can be seen in Figure 35.

Liner shipping planning and shipping cost calculation have been done to evaluate the performance for every network options and scenarios. The Butterfly Hub was chosen as a proposed network for Sea – Toll Agenda. This network can reduce the total shipping cost around 60% from the current Sea – Toll Network. In addition, this network can provide a better service than the previous Sea – Toll implementation (once in two weeks schedule) by using seven vessels (comparing the sea – toll plan which will operate 16 vessels).

This chapter revealed that the additional cargo scenario flow will not significantly affect the network performance because the extra revenue will not cover the additional cost. However, when the backflow cargo was introduced, the network could save more subsidy. It is because, the cargo backflow could generate more revenue without any significant additional cost. The cargo backflow would replace the unproductive movement of empty container.

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7. Discussion

This chapter has an aim to discuss the finding from Chapter 6 by comparing the result with other papers or theses. The actual condition related with Indonesia shipping context, particularly Sea – Toll Agenda, will also be taken into account. Subsequently, we will discuss this research limitation and perform a sensitivity analysis to see the how significance the change of each assumption. Finally, we will recommend some possible strategic regulations which can be implemented by the government to improve the performance of Sea – Toll network.

7.1 Hub Port Location: Demand vs Distance

In Subsection 6.1.5, the hub ports already selected by comparing the nearest distance ports with the highest number of demand ports in terms of shipping cost. Our finding (Table 31) is that choosing the hub port with lower distance is more preferable than hub port with a high demand. It is because the hub route with a lower distance saves about 40% bunker cost than another option. Moreover, the high demand ports cannot generate more revenue to cover the additional cost. Therefore, this condition is not positively improve the network with regard to cost, revenue, and subsidy.

Our finding is different from some studies conducted by Sun & Zheng (2016) and Zheng et al (2017). Both studies aim to find a potential hub for liner shipping network and they put cargo volume as a prominent factor to select the hub port. The case study is applied for international container shipping network which cargo flow is high. Therefore, it is reasonable to consider demand as a prominent determinant because the trade flow is already established.

Nevertheless, in Sea Toll Agenda case, the trade still not grow between eastern and western region. Recall from Chapter 1, the industry is concentrated in Java Island, so backhaul cargo from another island is not developed. It is because local products originated from outside Java is less competitive in terms of cost. Therefore, when selecting the hub port, the stakeholder should consider that the port has another role; to emerge the trade.

Network with a cost efficient should become an objective when the demand still low because, at the beginning, the revenue cannot cover the total cost of operation. Cost saving can be perform by selecting the hub port which is minimizing the distance. It is because the fuel cost is highly related with the distance. Moreover, another shipping cost component, such as port cost is quite not significance in the total cost proportion. In addition, charter cost will possibly low because the vessel operating in that route are small vessels. Similarly, terminal handling cost will possess a low value because the low amount of containers.

The study by Bahagia (2013) aligned with our suggestion to prioritize on cost reduction in order to grow the backflow cargo. The study found that Indonesia logistics cost is about 26% percent from total Gross Domestic Product where maritime transport contributes around 40% from that logistic cost. Thus, by streamlining the shipping line network, the local product from another island possibly can be more competitive to enter market in Java.

Furthermore, if we assess a hub selection based on Willmsmeier & Noteboom (2011), some of ports might not become a better solution. This study argued that the determinant of selecting hub port should be based port performance itself, such as hinterland access, infrastructure & superstructure, and cost. For example Port of Biak, which is located in an island on the north of Papua, will be not considered as a hub port although the demand is considerably high. It is because the hinterland access is not as high as the port which situated in main Papua Island.

To conclude, there may be a further study to determining the parameter in selecting hub port in Indonesia case. Especially the hub port that can connects the outermost island with a low cargo flow. Trade-off between cost efficiency and potential market growth can be observed as a research question to obtain the comprehensive view for this problem.

7.2 Network Performance Comparison (Transit Time vs Shipping Cost)

This thesis has objective to give a proposed network for Sea – Toll Agenda by evaluating operation planning and shipping cost to perform in several circumstances. One of them is maintaining the Round-Trip-Voyage, which is the schedule of the vessel to load/unload the container in the origin port. The proposed network success to save the subsidy approximately 60% from initial Sea – Toll Network Plan and it can satisfy all constraints.

Nevertheless, there is a notable finding in regard to transit time. This parameter shows how long the container can arrive at the port of destination from the origin port. There will be a difference between networks concerning this transit time because of the transshipment. The summary of transit time each network can be seen in Table 61.

Table 61 Transit Time and Shipping Cost Comparison

Parameter	***Unit***	***Sea Toll Network***	***Clustering Network***	***Port Aggregation***	***Butterfly Hub***
Average Transit Time	Days	7.57	11.18	10.40	12.13
Minimum Transit Time	Days	2.25	2.85	2.85	2.85
Maximum Transit Time	Days	13.48	20.60	19.50	19.98
Total Cost	USD/Year	24,260,741	14,730,406	14,165,721	11,816,957
Revenue	USD/Year	5,077,738	5,077,399	5,039,337	5,039,337
Subsidy	USD/Year	18,332,701	9,653,007	9,126,380	6,777,621
Unit Cost	USD/TEU	1,837	1,115	1,077	898

Sea – Toll Network generates the lowest transit time among all options. It means that averagely, every week the container will arrive at the destination port. Meanwhile, in the proposed network (Butterfly Hub), which is owned the lowest cost, the container will come at port destination approximately in 12 days. The reason is that Sea – Toll Network provides more direct routes than other networks. Besides, in clustering options and its development (Port Aggregation and Butterfly Hub), the route structure is circular which makes the vessel should visit every port.

The result shows the tradeoff between cost and transit time. The Butterfly Hub might be best for providing a low-cost network. But, this network could not satisfy the customer if they want the container to arrive every two weeks. For the farthest destination, the container can reach after 20 days. In the meantime, the maximum transit time for the current Sea – Toll Network is 14 days. From these numbers, the government should rethink the target for Sea – Toll Agenda, whether maintaining the RTV or keeping the transit time.

Furthermore, a reduction in transit time for the proposed network can be obtained at some costs in two ways: changing the main routes into direct routes, applying smaller ships and a higher frequency. Next, the feeder network can be changed correspondingly. Yet all changes will come at a certain cost.

Two simulations are examined to see the change of the network cost if the transit time problem can be solved. The first simulation is changing main routes into direct routes. In this simulation, all hub ports will be served by one direct service from Tanjung Perak, so there are four hub routes. The second simulation is applying smaller ships with a higher frequency. We build this simulation based on weekly schedule with a higher speed. The result can be seen in the table below.

Table 62 Reducing Transit Time

Parameter	***Unit***	***Butterfly Hub***	***Direct Route (Main Hub)***	***Smaller Vessel & High Frequency***
Average Transit Time	Days	12.13	10.77	8.94
Minimum Transit Time	Days	2.85	2.85	2.08
Maximum Transit Time	Days	19.98	19.20	16.10
Vessel Deployed	Units	7	9	9
Schedule	-	Once in two weeks	Once in two weeks	Once in a week
Average Vessel Speed	Knot	6.70	6.86	9.60
Total Cost	USD/Year	11,816,957	14,987,681.26	23,202,946.50

Direct hub scenario decreases the average transit time of around two days. However, the total cost will increase by about 3 million in a year because of additional charter cost for new vessels and bunker cost for each vessel. In addition, the average vessel speed is also increasing which will impact on bunker consumption. The transit time performance will be better if the network deploys a smaller vessel with higher frequency. Yet, the total cost will be doubled because of the increase in average vessel speed. This parameter (vessel speed) has a cubic relation with bunker consumption. In the high frequency simulation, the vessel will sail faster to meet the schedule (once a week). It can be seen from the decrease of maximum transit time for the network.

To conclude, the proposed network will generate the lowest network cost, but the highest average transit time among all options. From the simulations, some direct hubs and a higher frequency voyage can reduce the transit time. However, the improvement should be compensated by some costs. Direct hub simulation can improve the transit time with less cost than a higher frequency simulation. A further comparison can be arranged to reduce the transit time, such as adjusting the feeder network because this simulation only considers main hubs combination.

7.3 Cost Structure Breakdown: Result Comparison

In the previous section, we stated that reducing distance will result in cost saving. The reason is based on our finding in cost structure of Sea – Toll Agenda. In the proposed network (Butterfly Hub), we found that fuel cost is dominated the cost structure. Since we already know that the distance will be related with bunker consumption, reducing distance might be the best choice for hub selection in this thesis.

However, a remarkable finding is obtained when the cost structure is compared with other studies result. As stated in Section 6.4, Koning (2018) concluded that fuel cost has a highest proportion in cost structure, yet study by Komarudin (2017) generated a different output. The terminal handling cost play a major role in the total cost. The summary of comparison can be seen in Table 63.

Table 63 Cost Structure Breakdown

Cost Structure	***Koning (2018)***	***Komarudin (2017)***	***Zamal (2018)***
Fleet Cost (%)	14%	16%	37%
Fuel Cost (%)	40%	24%	44%
Port Cost (%)	16%	0%	1%
Terminal Handling Cost (%)	30%	59%	18%
Case	Europe - Asia	Indonesia (Major Hub Port)	Indonesia (Eastern Corridor Sea - Toll Agenda)
Route Capacity (TEUs)	6,170,000	11,800	250
Total Network Distance (nm)	n/a	7,802	12,413

The variation is come from the different structure of network. Koning (2017) considered the study scope in Europe – Asia trade line, meanwhile Komarudin (2017) only examined the trade flow in major hub ports in Indonesia. Hence, the study by Koning (2017) generated the higher fuel cost because of the higher distance. This condition is quite similar with this thesis where network distance is relatively high.

In regard of cargo flow, Sea – Toll network in eastern of Indonesia owns a low cargo demand and a low route capacity. This situation leads to a low terminal handling cost because the number of container is a variable for this cost. Therefore, study by Komarudin (2017) generated a high terminal handling cost because the number of container flow is relatively higher than the problem in this thesis. Another impact is the proportion of fleet cost in thesis finding by Zamal (2018) quite high compared with other studies. It is because the cost incorporated in this thesis is smaller among others considering the low containers flow.

To sum up, every network has own characteristics, so the solution to develop the efficiency for each network will be different. The difference can be seen from the network structure as well as the cost proportion for each shipping cost components. Understanding the context of the problem becomes a key to find a better solution for establishing a more efficient network.

7.4 Possibility of "Sea – Toll" Network without Subsidy

Table 57 presented a summary of total cost, revenue and subsidy for all network options. It is clear that all networks need a subsidy to cover the total operation cost. The revenue regulated by the government is below commercial shipping rate price. However, after calculating unit cost per TEU to transport one container in one network, the problem is in the main hub route. Table 64 presents the network cost for Proposed Network and its breakdown per route.

Table 64 Unit Cost of Proposed Network (Butterfly Hub)

Route	Port Visited	Unit Cost (USD/TEU)
H1	TJP – WAN – SQN	1,822
H2	TJP – ORA – FKQ	4,679
C1	FKQ-KNG-TMK-AGA-MKQ-DBO	605
C2	TER-LKA-BIU-BAA-KBH-KIS-MOA-SXK-NAM-NRE-WAN-LWE	496
C3	MIA-KAK-MNA-LIR-OZI-TBO-TID-MAB-GEB-OBI-SQN-BIA-TAG-BUH-KAH-TAH-MAR	616
C4	SEB-SGQ-BEL-MAK-TJP-NNX	797
C5	ZRM-TEB-BIK-ORA-WSR-NBX-WAR-ZRI	576
Network Unit Cost (USD/TEU)		**900**

Unit cost per route is calculated by dividing total cost for operating one route with total cargo in that route. Similarly, unit cost for network is computed by dividing total cost with total container flow in the network. We observe a remarkable finding that if we treat a network by route (one route – one operator), the hub route will suffer a high unit cost. It is because the hub route provide a service for all containers in the network. Yet, the direct demands for hub ports which are a source for revenue is quite small. In addition, unit cost in main hub route is still including some costs for feeder network, such as bunker cost and chartering cost. It is because, separating those two costs are quite difficult than tariff handling cost which attributed to each container.

Nevertheless, when we see the network as a whole, the unit cost for hub route considerably falls, but the unit cost for other clusters is increased to 900 USD/TEU. Comparing with the rate of commercial shipping in some profitable routes. The Sea – Toll network cost can be profitable in some routes but less competitive in the others. The range of freight rate can be obtained in Table 65 below.

Table 65 Commercial Shipping Freight Rate (Own Compilation)

Destination	Range of Freight Rate (USD/TEU)
Timika, Fak-fak, Merauke (C1)	900 – 1,200
Saumlaki (C2)	600 – 900
Tidore (C3)	800 – 1,000
Makassar (C4)	500 – 900
Nabire, Biak (C5)	1,000 – 1,500

The data is obtained from direct interview to some commercial shipping lines sales staff and email correspondence with some shipping companies (Meratus, Samudera Indonesia, and Tanto Line). Freight rate in Indonesia is not only influenced by market condition, but also the competition between commercial shipping lines. In addition, the freight rate displayed is the range of price in the last six months. Therefore, the range is quite huge. Table 65 also shows the rate not for an exact route, but for some ports destination because we collect the data for cluster comparison reason. Furthermore, the data only considers the main commercial ports and the voyage to some routes are not regular (based on demand) which lead to a quite low price.

The proposed network can be more competitive when the cargo backflow starts to emerge. This scenario yields a reduction of unit cost per TEU approximately 10%. The government can start to recalibrate the policy, particularly in regard to goods limitation. In addition, the program to push local entrepreneur to expand their market can be initiated.

Another point from the comparison between unit cost per route and per network is the possibility to establish a subsidy based on distance. It means that the route which has short haul can give their revenue to cover the expense for the long haul journey. However, this policy will add some complexities in terms of organizational implementation. It is because, the shipping line should transparent with their revenue so that policy can be implemented.

To conclude, for short term planning, the government can initiate two activities to increase the competitiveness of the network. The coordination between routes is preferable to reduce the cost in main hub if the proposed network is implemented. Another action is to start arranging the regulation that can grow the trade of local product to Java.

7.5 Sensitivity Analysis

In this section, we intend to check our assumption whether it will significantly affect the network performance concerning total cost or not. Transshipment cost will be considered to the total shipping cost component because this thesis assumes that transshipment cost is not involved. Subsequently, the others input value will be checked such as handling the cost, port due, fuel price and charter cost. It is because some values of them are assumed considering a limitation of data.

For transshipment cost sensitivity analysis, we will assume this cost and introduced it to the total cost per network. The percentage of change will be analyzed. Moreover, for the other inputs value, we will gradually increase the value from 10% to 30%, while the other inputs remain the same. Then, the change in total cost will be observed.

Transshipment Cost
In some papers, usually, the transshipment cost calculation is taken into account. It is because the cost might change the decision because of the cargo flow considerably high (such as in Europe – Asia trade). In the study by Mulder & Dekker (2016), they assumed transshipment cost in the calculation of network cost between main ports in Indonesia; meanwhile Adiliya (2017) was not considered transshipment cost when assessed Port Tenau Kupang as a potential hub for Sea – Toll route. In this thesis,

we found that the terminal handling cost can be represented as a transshipment cost. It is because the container, which is transshipped, will be moved two times by the crane.

Nevertheless, the assumption could not become a justification to ignore the actual transshipment cost. Thus, we assumed that the transshipment cost is 40 USD instead of 0 USD for each container. The following table shows the change of total cost for each network option after introducing transshipment cost.

Table 66 Transshipment Cost Sensitivity Analysis

Network	***Unit***	***Sea -Toll Network***	***Clustering Network***	***Port Aggregation***	***Butterfly Hub***
Cargo Transhipped	TEUs/Voyage	84	383	381	381
Total Transhipment Cost	USD/Year	87,360	398,320	396,240	396,240
Total Cost	USD/Year	24,341,587	15,128,726	14,586,611	12,213,197
Percent Change	% Total Cost	0.4%	2.7%	2.8%	3.4%
Unit Cost	USD/TEU	1,843	1,145	1,109	928
Percent Change	% Unit Cost	0.4%	2.7%	2.8%	3.4%

From the table above, transshipment cost is not significant both for total cost and unit cost. This cost will change the total cost less than 4% for each option. It is because the container flow in the Sea – Toll Agenda is quite low. Therefore, ignoring transshipment cost for this thesis is acceptable.

Port Service Price

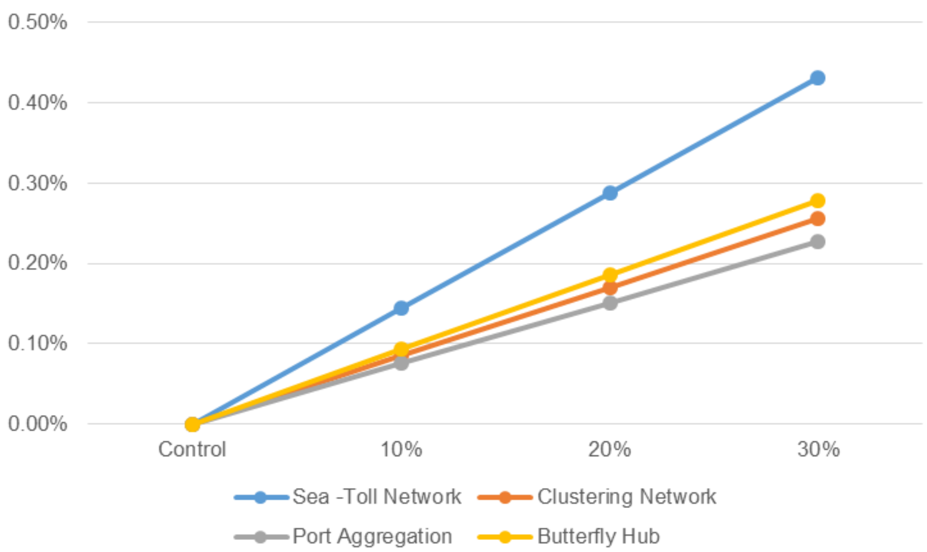

Figure 41 Port Service Price Sensitivity

In regard to port service cost, Sea – Toll Network is more sensitive than others. It is because of the number of port call in the network Sea – Toll network consists of 16 routes which will lead to a high port call in one voyage. All in all, the change of price is not significantly affect the total cost. Moreover, it is relatively difficult to change the decision of the network design because of port service cost.

Terminal Handling Price

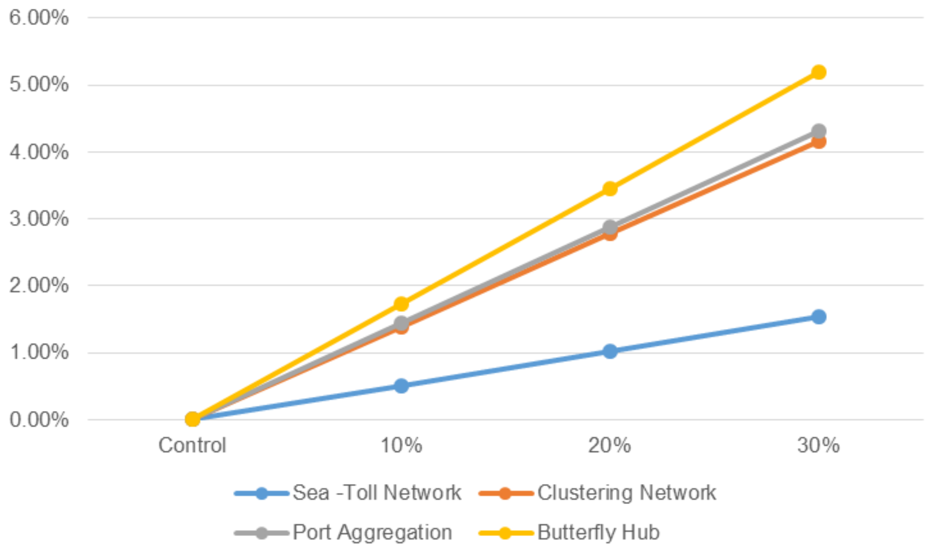

Figure 42 Terminal Handling Price Sensitivity

Butterfly hub is relatively more sensitive than others concerning terminal handling price. It is because the route has two main hubs which are carrying the transshipped containers. Increasing in terminal handling price might lead to an additional total cost, especially when the cargo is growing. The impact is that the butterfly hub route can suffer a high terminal handling cost. Meanwhile, the current Sea – Toll network possesses the lowest change if the charge of terminal handling is increasing. The container in this network mostly come from Tanjung Perak which the THC is considered as the lowest among all in terms of price.

The change of tariff handling charge is quite low because an additional price will change the total cost only around 1% until 5%. The decision for the preferable network is possible to change if the tariff handling cost is very expensive. The linear relation among all parameters could change the efficient network since the butterfly hub is the most sensitive network.

Fuel Price

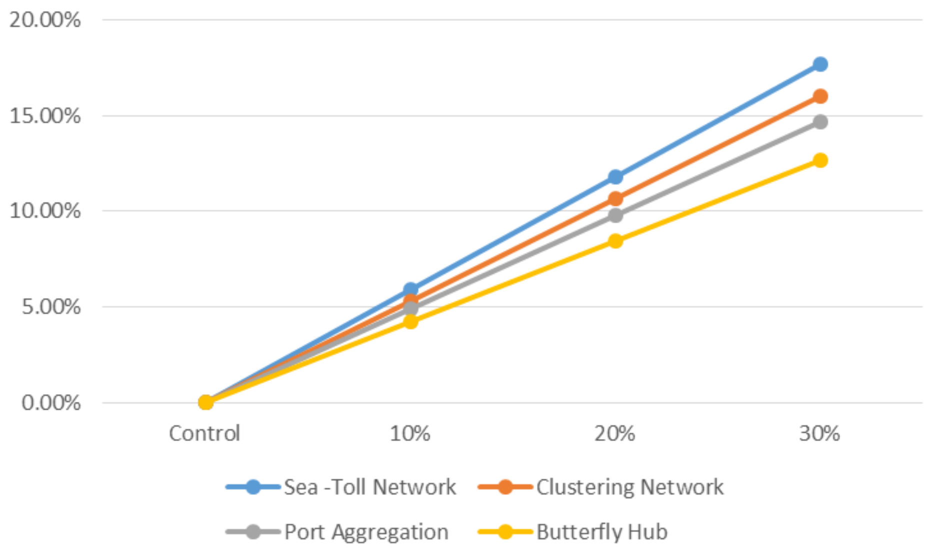

Figure 43 Fuel Price Sensitivity

Align with the previous parameter, the relation of fuel change in every network is linear. The shift in fuel price will not impact in changing the most efficient route. However, this value will notably change the total shipping cost. It is because, in this thesis, the fuel cost contributes around 40% of the total cost. Besides, the change of the fuel price will highly be affected to total cost than other cost parameters.

Charter Price

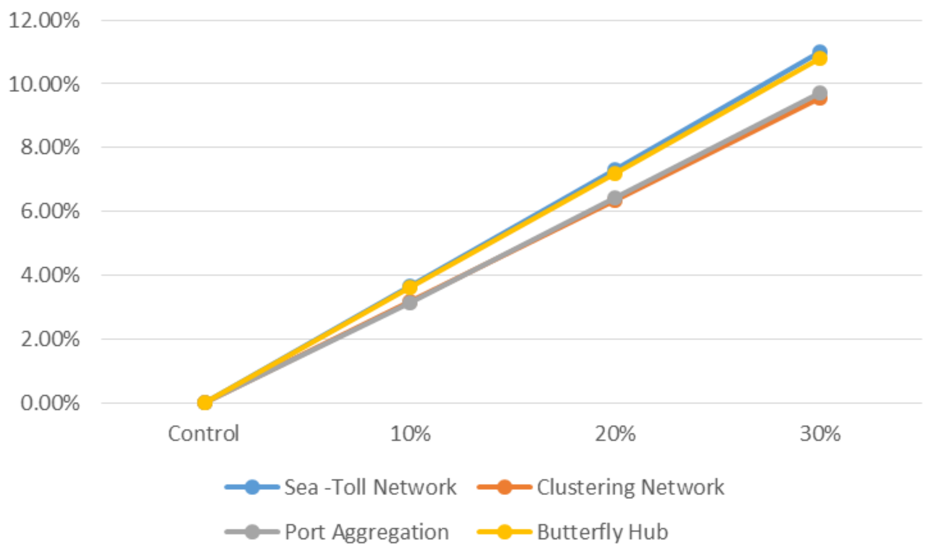

Figure 44 Charter Price Sensitivity

It is clear that the route with a high number of vessel will be more influenced by the charter rate. Sea – Toll network operates 16 vessels to run the network, meanwhile Butterfly Hub organizes only one ship more than both Clustering and Port Aggregation Network. Therefore, two lines are quite parallel because of the similarity in the number of vessel chartered.

Although charter cost considerably contributes in total shipping cost (35%), the change of rate is not significantly impacting the total cost. Most of vessel operated in Sea – Toll Agenda are the vessels with the lower charter cost. Thus, the change of charter price will not change the cost efficient network.

7.6 Recommendation

Based on our result, analysis, and discussion, this section reveals some point of recommendations which the government might consider. The suggestion is mostly policy-related with the expectation it can increase the performance of Sea – Toll. Also, this recommendation is constructed because the program is designed by the Ministry of Trade and Ministry of Transport, the Republic of Indonesia, which potentially can improve the network performance in the policy-making sector.

Revokes the Regulation Concerning Limitation of Goods
From both scenario development (additional cargo and cargo backflow), it is clear that transporting more containers will have an impact on reducing unit cost. From Table 60, the unit cost of Scenario 1 can decrease about 6% of unit cost from the proposed network (Butterfly Hub). Moreover, Scenario 2 can make the cost more competitive to become about 770 USD/TEU.

In shipping lines point of view, if the container flow is increasing, it will make the route become attractive. Therefore, in case the government intend to establish a sustain network, the regulation regarding goods transported should be reconsidered. Also, it can grow an opportunity for local entrepreneur to sell their product to the bigger market. This situation will impact to the 2nd scenario which will lead to a more competitive unit cost per TEU.

Coordination of Shipping Lines between Routes
Due to the fact from Table 64 that if the unit cost is seen for each route, hub route will suffer the incredibly high cost per TEU. It is because the bigger vessels are allocated, and the long journey is traveled. In the current operation, the government assigns some liner shipping in each route who are not coordinated with each other. Therefore, if the proposed network is implemented, the joint understanding between operators are required to run the operation and make the network more competitive.

The Role of Local Shipping Line
Based on the port aggregation option, the government should consider traditional shipping activity to provide a service to the outer most island with low demand. Although the local shipping lines are regarded as the informal sector in Indonesia maritime business, this option possibly reduces the total cost of the Sea – Tol" network. Moreover, the opportunity to establish the cooperation with local shipping line can give demand for them, to keep operating their business. The study by Muhana (2017) found that this sector contributed 3% of total Indonesia Gross Domestic Product (GDP) and it is employed around 30,000 workers.

Certainly, this effort will add the complexity of the Sea – Toll program because the stakeholders involved are increasing. The hidden cost will appear for this such policy which will influence the network performance. Moreover, the commercial shipping will not consider service to the port with very low demand because it will not generate the revenue. Meanwhile, the government, who is obligated to provide the service to all populated islands, still attempts to solve this shipping problem. Therefore, cooperation with local shipping line might become a consideration for establishing a service to some populated islands in outermost region of Indonesia.

Massive Marketing of Sea – Toll Agenda in the Port Target Area
Based on the development of Scenario 1 (additional cargo) and 2 (cargo backflow), the government is suggested to focus on growing cargo backflow. Aside, it can reduce the subsidy, as portrayed in Section 6.4, the remote region can get the benefit from the trade. The government can reduce the price disparity between eastern regions and western regions by growing the economic activity. Some regions in the Sea – Toll Agenda target have some potential natural resources, such as fish product and spices. By giving proper information and guidance to the local entrepreneur to utilize the program, the goal of Sea – Toll Agenda, i.e. reducing economic disparity, can be achieved.

Establish a Trade Agreement with Neighboring Country for Outermost Island
By location, some outermost islands such as Nunukan and Sebatik, are closer to neighbor country (Malaysia or Philippines) than the economic center in Java. The government can set some trade agreements for import and export. Again, this agreement can support the goal for price disparity of basic goods. It is because logistical cost might be reduced. By distance, neighbor country is closer than Java.

The government can begin to study regarding the cost and benefit in establishing such an agreement. When the shipping activity provided by the Sea – Toll Agenda is less efficient than a trade treaty, it is better to formulate the agreement. Then, the network of Sea – Toll can be optimized by focusing to other regions.

Long Term Planning in Industrial Development
From the shipping cost calculation in Section 6.4, the highest cost component is the bunker cost. Vessel speed and port distance influence this cost. Building a high-tech vessel, which can save the bunker consumption, may be a better choice. However, considering the rural area development, the government can set a plan to build some factories in Maluku or Papua region. Therefore, the nearest port to the industrial plant can serve as a hub port. This plan might lead to a significant cost reduction because of distance between hub port and feeder port.

From Figure 35, we can infer that most of the port target are located around Maluku. If Maluku serves as the port of origin, the liner shipping operation might be better. The vessel speed can be reduced because to fulfil the weekly demand; the speed will not as high as the current network.

Cross Subsidy Short Haul - Long Haul Shipment
Compared with another commercial route, for instance, Tanjung Perak – Tanjung Priok, Tanjung Perak – Makassar, and Tanjung Priok – Banjarmasin, Sea – Toll route is not preferable (from shipping line company point of view) because of the low demand and the long distance between ports. This condition leads to unattractiveness the route for the commercial shipping lines.

From market share report in Syaiful (2017), the cargo flow between Tanjung Perak and Tanjung Priok was 24,000 TEU in a year. The number is considerably high for the annual container flow at just 438 nm. The idea is to give the subsidy for every container transported in this type of route (short distance, but high container flow). Therefore, the subsidy comes from the market itself. Another advantage is the sustainability of the subsidy realizing that this type of trade line is well established, although the number of container flow is fluctuating.

8. Conclusion

The present thesis was designed to propose a better shipping liner network for Sea – Toll Agenda in Indonesia in terms of vessel operation and total shipping cost. The Indonesian government attempts to reduce economic disparity through lowering logistics cost. Since Indonesia consists of many islands, maritime transport plays an important role in connecting most of the regions. Therefore, the Sea – Toll Agenda, a subsidized liner shipping network, is introduced to connect the main economic center to minor ports in Indonesia.

However, after yearly evaluation, the Sea – Toll program has not met the desired performance stated by the Indonesian government, i.e., long round-trip-voyage time. In addition, the ports target that must be visited increases every year because the government want to expand the subsidized regions. Such a policy adds to the complexity for the program. On the one hand, the government wants to ensure the distribution of basic goods in the right time. On the other hand, they keep expanding the ports which will lead to additional travel distance. Realizing the problem that arise from the current shipping network and the government target, this thesis aims to design and propose an efficient liner network by using a comprehensive approach.

The LSND (Liner Shipping Network Design) model allows us to understand the level of planning from a strategic, operational, and tactical level and approach to obtain each level decisions. Network and fleet mix design problem are solved at strategic planning. Subsequently, tactical planning is solved based on the result of strategic planning, such as scheduling, speed optimization, and the number of vessels deployed. However, operational planning, such as cargo routing, is already predetermined align with the context of the problem.

The K-means clustering algorithm is used as a first step to establish the network to solve the problem of port distance. The calculation generated four clusters as a preferable result, yet, we observed that k means clustering had a limitation. The Euclidean distance measurement could not represent the sailing route of the vessel. Thus, we decide to use five clusters to group the ports. The algorithm yielded a clustering network with 5,764,903 of the total within sum-square, 27,469,065 between sum-square, and 82.26% of variance explained by the model.

After the ports are grouped, the hub port should be chosen to connect every cluster. This study found that the combination of port with a closer distance is more cost efficient than choosing hub ports with a higher demand. The port combination of Tanjung Perak – Wanci – Sanana – Fak-fak – Oransbari are chosen as the hub ports. The total final distance of this route is 3,224 nm with 20% cost saving than the high demand port combinations.

The TSP (Travelling Salesman Problem) model is used to develop the route within the clusters and between the hub ports. Six circular routes and their sequences are generated by this method with some adjustments. Total distance in the clustering network after adjustment is 10,776 nm.

Realizing that the clustering network is established by the sub-optimal method, this study offers some options to compare, which are Sea – Toll Network (current network as a basis), Port Aggregation, and Butterfly Hub. In Port Aggregation option, we ignore

14 ports that have a demand less than 10 containers a month. The demand will be combined to the nearest port and as a compensation, the additional service cost is introduced. Butterfly Hub is an option to separate the hub route become two routes using two vessels. Tactical and operational planning are assessed for these three network structures.

Butterfly Hub option is the considered as a proposed network for Sea Toll - Agenda. This network offers a lowest total shipping cost for all components. Comparing with the current Sea – Toll Network, this option can reduce about 50% of total cost and save around 60% of the government subsidy for the Sea – Toll Agenda. Butterfly Hub route structure allows the decrease in bunker cost (65% fuel cost saving). It is because the container flow is separated into two routes and lead to a reduction of optimum vessel speed. This network will provide service once in two weeks using total seven vessels (one vessel per route). This operation provides a better regularity by using less vessel than the current Sea – Toll Network (16 vessels). Moreover, this result proves that clustering network, resulted by k means clustering and TSP, can be further optimized in network design level.

Furthermore, this thesis develops two scenarios, which are additional cargo flow and the growth of cargo backflow. We observed that additional cargo is not significant to reduce the network subsidy (only about 0.5% reduction). Yet, this first scenario should be considered by the government because it reduces the unit cost per TEU from about 1840 USD/TEU to around 850 USD/TEU comparing with the current Sea – Toll Network. This scenario embodies the impact when the government revokes the policy regarding goods limitation. However, the second scenario even provides a better result. It can save a higher subsidy up to 10% (comparing the proposed network) and provide a lower unit cost per TEU (770 USD/TEU).

Based on sensitivity analysis, our assumption to not involve transshipment cost is not significantly change the result of the network performance. Meanwhile, the increase in the terminal handling cost may have an impact on cost structure in Butterfly Hub. It is because of this network quite sensitive to the terminal handling charge. The fuel cost is considered as the most sensitive input, therefore, finding the precise data for fuel price is preferable to obtain the better results.

Finally, from all findings and discussions, we recommend the government not only focus on operation but also the regulatory framework. The regulation regarding type cargo leads to a limitation of cargo flow which will reduce the efficiency of the network. Subsidy scheme also needs to be evaluated because long-haul transport always generate a high cost. When the industry still concentrated in Java, cross-subsidy between short-haul and long-haul transport can be recognized since the cargo flow within ports in Java considerably high compared with the eastern port.

Contribution and Further Research

Our remarkable finding is the clustering method success to cut the total shipping cost for Sea – Toll Agenda comparing with the original network by generating proposed network using Liner Shipping Network Design (LSND) approach. However, the network resulting by k means clustering and TSP model still need to develop because the output, multiple circular routes, is suboptimal. Thus, two new options are established in this study and yield a better cost performance. Yet, the problem is revealed in the main hub routes. The journey takes too long distance, but the demand was quite low to the port destination. Further research initiative can observe the path formulation in Sea – Toll Agenda, especially for hub route to generate another alternative of route structure.

Refer to Mulder and Dekker (2016), who have conducted the strategic liner shipping network design in six major ports in Indonesia. We realize our contribution is revealing relationship between main hub ports with the feeder port in Indonesia regarding route connectivity. In regard to the broader scope, the study conducted by Koning (2018) already discussed the regional network in Europe – Asia route. Therefore, the opportunity to study the whole structure of the shipping network in archipelago case is widely open. Especially in determining the combination of the network between the hub and feeder ports or the alternative to establish second level feeder. Analysis for the route structure combination for multilevel feeder network can become another alternative for a research initiative. Our finding regarding the possibility of second level feeder port embodied in the option to outsource the shipping service to the outermost island (ignoring the port with very low demand).

Furthermore, regarding the result, this thesis can only satisfy the government RTV target. However, concerning transit time, the proposed network (Butterfly Hub) is still underperformed. This network owning the highest average container travel time. A multi-criteria decision model might become another opportunity to find the better solution align with route structure development for hub network.

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Appendix

Appendix 1 Ship Particular

ID	Type	Name	Size (TEU)	Dwt (Ton)	GT (Ton)	Speed (kn)	Cons (Ton/Day)	k	Charter Rate (USD/Day)
1	Container	KM Kendhaga Nusantara	100	2,194	2,000	8.0	4.0	0.00781	1,500
2	MPP	KM Caraka Jaya Niaga III - 32	118	3,650	3,257	8.5	5.0	0.00814	1,500
3	MPP	KM Logistik Nusantara IV	126	3,900	3,040	12.9	8.0	0.00373	1,500
4	MPP	KM Logistik Nusantara III	126	3,900	3,040	8.0	4.0	0.00781	1,500
5	MPP	KM Logistik Nusantara II	145	4,500	3,050	9.2	4.5	0.00578	1,500
6	MPP	Meratus Sangatta	170	3,625	2,532	11.5	6.5	0.00427	1,500
7	MPP	KM Mentari Perdana	199	4,985	4,180	12.0	7.5	0.00434	1,500
8	MPP	KM Meratus Ultima II	194	6,013	4,896	7.5	4.0	0.00948	1,500
9	MPP	KM Logistik Nusantara I	305	9,412	7,738	8.0	4.5	0.00879	1,900
10	MPP	Tanto Fajar III	221	4,705	3,988	12.5	12.5	0.00640	1,900
11	MPP	Multi Express	256	3,194	2,826	12.5	7.3	0.00374	1,900
12	MPP	Territory Trader	256	3,194	2,826	12.5	6.5	0.00333	1,900
13	MPP	Multi Spirit	256	3,180	2,826	13.0	7.5	0.00341	1,900
14	MPP	Tanto Fajar I	270	4,712	3,972	13.1	12.7	0.00565	1,900
15	MPP	Mataram Express	300	5,058	3,790	12.0	13.0	0.00752	1,900
16	MPP	Tanto Hawari	300	4,584	3,777	14.3	9.5	0.00325	1,900
17	MPP	Tanto Harmoni	300	4,546	3,843	12.0	9.0	0.00521	1,900
18	MPP	Red Rover	312	6,375	4,459	14.0	16.9	0.00616	1,900
19	Container	Tanto Berkat	319	6,425	5,203	14.6	14.0	0.00450	1,900
20	MPP	Tanto Handal	320	5,063	3,814	12.0	13.0	0.00752	1,900
21	MPP	Mentaya River	326	4,447	4,238	13.0	13.0	0.00592	1,900
22	MPP	Ayer Mas	326	4,256	3,283	13.0	7.0	0.00319	1,900
23	MPP	Freedom	330	5,314	4,303	13.5	12.0	0.00488	1,900
24	Container	Tanto Aman	338	5,958	3,994	14.5	14.8	0.00485	1,900
25	MPP	Tanto Sepakat	339	6,163	4,460	13.5	12.0	0.00488	1,900
26	MPP	Sinar Papua	343	6,520	4,532	13.5	12.5	0.00508	1,900
27	MPP	Reliance	373	6,006	4,489	14.5	14.0	0.00459	1,900
28	MPP	Red Resource	380	6,016	4,489	14.5	14.0	0.00459	1,900
29	Container	Tanto Subur II	385	6,810	4,811	14.2	14.7	0.00513	1,900
30	Container	Tanto Subur I	385	6,796	4,811	14.2	14.7	0.00513	1,900
31	Container	Sendang Mas	406	6,200	4,225	22.3	88.0	0.00794	4,969
32	MPP	Mentari Perdana	408	4,950	4,180	15.0	16.0	0.00474	4,969
33	Container	CTP Bravo	420	7,041	4,914	14.0	13.4	0.00488	4,969

ID	*Type*	*Name*	*Size (TEU)*	*Dwt (Ton)*	*GT (Ton)*	*Speed (kn)*	*Cons (Ton/Day)*	*k*	*Charter Rate (USD/Day)*
34	Container	Bahar Mas	436	6,687	5,450	14.5	16.0	0.00525	4,969
35	MPP	Mentari Sentosa	444	7,121	4,980	14.0	16.5	0.00601	4,969
36	Container	Armada Sentani	451	7,826	5,087	15.0	21.0	0.00622	4,969
37	Container	Armada Segara	453	7,866	5,320	13.7	18.5	0.00719	4,969
38	Container	Armada Serasi	453	7,600	5,320	13.7	18.5	0.00719	4,969
39	MPP	Meratus Ultima 2	455	6,013	4,883	13.6	15.0	0.00596	4,969
40	MPP	Meratus Ultima 1	455	6,013	4,882	14.0	15.0	0.00547	4,969
41	Container	Tanto Surya	480	8,972	8,168	15.0	18.0	0.00533	4,969
42	MPP	Meratus Project 1	512	5,350	4,410	17.0	17.3	0.00352	4,969
43	MPP	Red Rock	514	5,350	4,410	17.0	17.3	0.00352	4,969
44	MPP	Mitra Progress III	518	5,600	4,400	15.4	16.0	0.00438	4,969
45	Container	Tanto Lestari	569	9,918	6,969	15.0	19.5	0.00578	4,969
46	Container	Tanto Sinergi	584	7,864	5,938	15.0	18.0	0.00533	4,969
47	Container	CTP Java	585	8,703	7,167	15.0	18.0	0.00533	4,969
48	Container	Tanto Raya	588	9,114	6,875	15.6	26.3	0.00693	4,969
49	Container	Meratus Dili	600	6,853	5,553	16.5	23.0	0.00512	4,969
50	Container	Meratus Ambon	604	8,122	7,197	12.0	13.0	0.00752	4,969
51	Container	Meratus Banjar 1	605	7,018	6,249	16.5	18.0	0.00401	4,969
52	MPP	Meratus Pekanbaru	618	7,853	5,272	15.0	20.0	0.00593	4,969
53	MPP	Meratus Palembang	618	7,853	5,612	15.0	20.0	0.00593	4,969
54	MPP	Tanto Bagus	630	8,127	7,091	16.0	20.7	0.00505	4,969
55	Container	Meratus Tangguh 1	637	8,721	6,245	14.5	19.0	0.00623	4,969
56	Container	Tanto Permai	662	11,250	8,652	18.0	33.0	0.00566	5,594
57	Container	Tanto Express	662	11,244	8,652	18.0	33.0	0.00566	5,594
58	MPP	Tanto Sakti II	664	6,750	5,500	16.5	22.0	0.00490	5,594
59	Container	Mentari Persada	674	9,517	7,330	17.5	29.5	0.00550	5,594
60	Container	Armada Permata	714	12,723	9,048	15.0	23.0	0.00681	5,594

Appendix 2 Summary: Average Distance between Ports

Cluster	***Port***	***Average Distance Between Ports (km)***
2	Adonara (Terong)	1108
2	Kalabahi	1051
2	Kisar (Wonreli)	1001
2	Larantuka	1112
2	Lewoleba	1096
2	Moa	1002
2	Namlea	802
2	Namrole	819
2	Rote (Ba'a)	1280
2	Sabu (Biu)	1311
2	Saumlaki	1053
2	Wanci	958

Cluster	***Port***	***Average Distance Between Ports (km)***
3	Biaro	880
3	Buhias	900
3	Gebe	809
3	Kahakitang	923
3	Kakorotan	998
3	Lirung	948
3	Maba	812
3	Marore	1029
3	Melonguane	952
3	Miangas	1076
3	Morotai	862
3	Obi	780
3	Sanana	806
3	Tagulandang	888
3	Tahuna	949
3	Tidore	811
3	Tobelo	836

Cluster	*Port*	*Average Distance Between Ports (km)*
5	Waren	1104
5	Wasior	983
5	Biak	1095
5	Nabire	1054
5	Oransbari	977
5	Sarmi	1316
5	Serui	1097
5	Teba	1239

Appendix 3 Port Status and Service Time

Port ID	***Port Class***	***Status***	***Port Service Time (Hour)***
AGA	Second Class	Non Commercial	6
DBO	First Class	Non Commercial	6
FKQ	First Class	Commercial	6
KAI	First Class	Non Commercial	6
MKQ	First Class	Commercial	6
TMK	First Class	Non Commercial	6
TER	Third Class	Non Commercial	6
KBH	First Class	Commercial	6
KIS	Second Class	Commercial	6
LKA	First Class	Non Commercial	6
LWE	Second Class	Non Commercial	6
MOA	First Class	Non Commercial	6
NAM	First Class	Non Commercial	6
NRE	First Class	Non Commercial	6
BAA	Third Class	Non Commercial	6
BIU	First Class	Non Commercial	6
SXK	First Class	Commercial	6
WAN	Second Class	Non Commercial	6
BIA	Third Class	Non Commercial	6
BUH	Third Class	Non Commercial	6
GEB	Second Class	Non Commercial	6
KAH	Third Class	Non Commercial	6
KAK	Third Class	Non Commercial	6
LIR	Second Class	Non Commercial	6
MAB	Second Class	Non Commercial	6
MAR	Second Class	Non Commercial	6
MNA	Second Class	Non Commercial	6
MIA	Third Class	Non Commercial	6
OZI	Second Class	Non Commercial	6
OBI	Second Class	Non Commercial	6
SQN	Second Class	Non Commercial	6
TAG	Third Class	Non Commercial	6
TAH	Third Class	Non Commercial	6
TID	Second Class	Non Commercial	6
TBO	Second Class	Commercial	6
BEL	First Class	Non Commercial	6
MAK	Main Class	Commercial	4
NNX	First Class	Commercial	6

Port ID	*Port Class*	*Status*	*Port Service Time (Hour)*
SGQ	Second Class	Commercial	6
SEB	Second Class	Commercial	6
TJP	Main Class	Commercial	5
WAR	Second Class	Non Commercial	6
WSR	Second Class	Non Commercial	6
BIK	Second Class	Commercial	6
NBX	First Class	Commercial	6
ORA	Second Class	Non Commercial	6
ZRM	Second Class	Non Commercial	6
ZRI	Second Class	Non Commercial	6
TEB	Second Class	Non Commercial	6

Appendix 4 Terminal Performance

Port ID	Terminal Performance Box/Crane/ Hour	Terminal Handling Charge 20' Full (USD/ Movement)	20' Empty (USD/ Movement)
AGA	5	41.7	24.19
DBO	5	41.7	24.19
FKQ	12	41.7	24.19
KAI	5	41.7	24.19
MKQ	12	41.7	24.19
TMK	5	41.7	24.19
TER	5	18.11	10.86
KBH	9	27.46	7.32
KIS	5	32.9	18.54
LKA	5	27.16	5.21
LWE	5	27.16	5.21
MOA	5	32.9	18.54
NAM	5	32.9	18.54
NRE	5	32.9	18.54
BAA	5	18.11	10.86
BIU	5	18.11	10.86
SXK	5	41.7	24.19
WAN	5	32.9	19.54
BIA	5	18.11	10.86
BUH	5	18.11	10.86
GEB	5	32.9	18.54
KAH	5	18.11	10.86
KAK	5	18.11	10.86
LIR	5	18.11	10.86
MAB	5	18.11	10.86
MAR	5	18.11	10.86
MNA	5	18.11	10.86
MIA	5	18.11	10.86
OZI	5	18.11	10.86
OBI	5	32.9	18.54
SQN	5	32.9	18.54
TAG	5	18.11	10.86
TAH	5	18.11	10.86
TID	5	32.9	18.54
TBO	5	32.9	18.54
BEL	9	15.84	8.24
MAK	20	15.84	8.24
NNX	9	32.9	19.54

Port ID	Terminal Performance	Terminal Handling Charge	
	Box/Crane/ Hour	20' Full (USD/ Movement)	20' Empty (USD/ Movement)
SGQ	5	32.9	19.54
SEB	5	32.9	19.54
TJP	25	15.84	8.24
WAR	5	41.7	24.19
WSR	5	41.7	24.19
BIK	5	41.7	24.19
NBX	9	41.7	24.19
ORA	5	41.7	24.19
ZRM	5	41.7	24.19
ZRI	5	41.7	24.19
TEB	5	41.7	24.19

Appendix 5 Port Service Cost

Port ID	Pilot		Tug Boat		Anchoring Fee (USD/ GT)	Berthing (USD/Day)	Mandatory Pilotage Zone
	Fixed (USD/ move)	Variable (USD/ GT)	Fixed (USD/ move)	Variable (USD/ GT)			
AGA	0	0	0	0	0.01	0.01	No
DBO	0	0	0	0	0.01	0.01	No
FKQ	0	0	0	0	0.01	0.01	No
KAI	0	0	0	0	0.01	0.01	No
MKQ	4.93	0	24.1	0	0.01	0.01	Yes
TMK	0	0	0	0	0.01	0.01	No
TER	0	0	0	0	0.01	0.01	No
KBH	0	0	0	0	0.01	0	No
KIS	0	0	0	0	0.01	0.01	No
LKA	0	0	0	0	0.01	0.01	No
LWE	0	0	0	0	0.01	0.01	No
MOA	0	0	0	0	0.01	0.01	No
NAM	0	0	0	0	0.01	0.01	No
NRE	0	0	0	0	0.01	0.01	No
BAA	0	0	0	0	0.01	0.01	No
BIU	0	0	0	0	0.01	0.01	No
SXK	0	0	0	0	0.01	0.01	No
WAN	0	0	0	0	0.01	0.01	No
BIA	0	0	0	0	0.01	0.01	No
BUH	0	0	0	0	0.01	0.01	No
GEB	0	0	0	0	0.01	0.01	No
KAH	0	0	0	0	0.01	0.01	No
KAK	0	0	0	0	0.01	0.01	No
LIR	0	0	0	0	0.01	0.01	No
MAB	0	0	0	0	0.01	0.01	No
MAR	0	0	0	0	0.01	0.01	No
MNA	0	0	0	0	0.01	0.01	No
MIA	0	0	0	0	0.01	0.01	No
OZI	0	0	0	0	0.01	0.01	No
OBI	0	0	0	0	0.01	0.01	No
SQN	0	0	0	0	0.01	0.01	No
TAG	0	0	0	0	0.01	0.01	No
TAH	0	0	0	0	0.01	0.01	No
TID	0	0	0	0	0.01	0.01	No
TBO	0	0	0	0	0.01	0.01	No
BEL	7.67	0	34.3	0	0.01	0.01	Yes
MAK	24.6	0.03	29.1	0	0.01	0.01	Yes
NNX	8.32	0	26.7	0	0.01	0.01	Yes
SGQ	0	0	0	0	0.01	0.01	No

Port ID	Pilot		Tug Boat		Anchoring Fee (USD/ GT)	Berthing (USD/Day)	Mandatory Pilotage Zone
	Fixed (USD/ move)	Variable (USD/ GT)	Fixed (USD/ move)	Variable (USD/ GT)			
SEB	0	0	0	0	0.01	0.01	No
TJP	45	0.03	30	0.01	0.1	0.13	Yes
WAR	0	0	0	0	0.01	0.01	No
WSR	0	0	0	0	0.01	0.01	No
BIK	0	0	0	0	0.01	0.01	No
NBX	6.45	0	24.1	0	0.01	0.01	Yes
ORA	0	0	0	0	0.01	0.01	No
ZRM	0	0	0	0	0.01	0.01	No
ZRI	0	0	0	0	0.01	0.01	No
TEB	0	0	0	0	0.01	0.01	No

Appendix 6 Calculation Result: Total Spending per Region

Port ID	Population Nearby (Citizen)	Total Spending (USD/day)	Total Spending (USD/ month)
AGA	90,316	234,988	7,049,655
BIK	156,023	405,948	12,178,443
DOB	93,722	243,850	7,315,512
FAK	77,112	200,634	6,019,011
KAI	67,291	175,081	5,252,428
MKQ	236,693	615,839	18,475,175
NBX	130,314	339,057	10,171,716
ORA	35,188	91,554	2,746,615
SAR	40,570	105,557	3,166,709
SXK	149,790	389,731	11,691,924
ZRI	24,290	63,199	1,895,967
TEB	22,598	58,797	1,763,897
TMK	183,633	477,785	14,333,554
WAR	35,167	91,499	2,744,976
WAS	30,371	79,021	2,370,622
BIA	3,248	8,451	253,524
BUH	730	1,899	56,980
GEB	5,000	13,009	390,277
KAH	2,088	5,433	162,980
KAK	784	2,040	61,195
LIR	5,639	14,672	440,155
MAB	7,116	18,515	555,442
MAR	845	2,199	65,957
MNA	16,720	43,503	1,305,087
MIA	785	2,042	61,274
OZI	52,860	137,534	4,126,010
NNX	65,602	170,686	5,120,593
OBI	46,491	120,963	3,628,875
SQN	56,636	147,358	4,420,748
SGQ	119,345	310,518	9,315,526
SEB	80,000	208,148	6,244,435
TAG	19,795	51,504	1,545,107
TAH	34,268	89,160	2,674,804
TID	48,678	126,653	3,799,583
TBO	161,580	420,407	12,612,197
TER	72,293	188,095	5,642,862
BEL	373,609	972,074	29,162,213
KBH	190,026	494,419	14,832,562
KIS	15,296	39,798	1,193,936
LKA	179,527	467,102	14,013,058

Port ID	*Population Nearby (Citizen)*	*Total Spending (USD/day)*	*Total Spending (USD/ month)*
LWE	117,829	306,573	9,197,194
MAK	1,469,601	5,748,191	172,445,742
MOA	7,200	18,733	561,999
NAM	120,798	314,298	9,428,941
NRE	59,785	155,551	4,666,544
BAA	119,711	311,470	9,344,094
BIU	72,960	189,831	5,694,925
TJP	2,765,000	10,815,010	324,450,295
WAN	92,922	241,769	7,253,067

Appendix 7 Calculation Result: Trade Volume

Port ID	Total Trade Value – Food (USD/Month)	Total Trade Value – General (USD/Month)	Total Trade Value (USD/Month)
AGA	2,072,598	1,367,633	3,440,232
BIK	3,580,462	2,362,618	5,943,080
DOB	2,150,760	1,419,209	3,569,970
FAK	1,769,589	1,167,688	2,937,277
KAI	1,544,214	1,018,971	2,563,185
MKQ	5,431,702	3,584,184	9,015,886
NBX	2,990,485	1,973,313	4,963,797
ORA	807,505	532,843	1,340,348
SAR	931,012	614,342	1,545,354
SXK	3,437,426	2,268,233	5,705,659
ZRI	557,414	367,818	925,232
TEB	518,586	342,196	860,782
TMK	4,214,065	2,780,709	6,994,774
WAR	807,023	532,525	1,339,548
WAS	696,963	459,901	1,156,863
BIA	74,536	49,184	123,720
BUH	16,752	11,054	27,806
GEB	114,741	75,714	190,455
KAH	47,916	31,618	79,534
KAK	17,991	11,872	29,863
LIR	129,405	85,390	214,795
MAB	163,300	107,756	271,056
MAR	19,391	12,796	32,187
MNA	383,696	253,187	636,882
MIA	18,014	11,887	29,901
OZI	1,213,047	800,446	2,013,493
NNX	1,505,454	993,395	2,498,849
OBI	1,066,889	704,002	1,770,891
SQN	1,299,700	857,625	2,157,325
SGQ	2,738,765	1,807,212	4,545,977
SEB	1,835,864	1,211,420	3,047,284
TAG	454,262	299,751	754,012
TAH	786,392	518,912	1,305,304
TID	1,117,077	737,119	1,854,196
TBO	3,707,986	2,446,766	6,154,752
TER	1,659,001	1,094,715	2,753,716
BEL	8,573,691	5,657,469	14,231,160
KBH	4,360,773	2,877,517	7,238,290
KIS	351,017	231,624	582,641
LKA	4,119,839	2,718,533	6,838,372

Port ID	*Total Trade Value – Food (USD/Month)*	*Total Trade Value – General (USD/Month)*	*Total Trade Value (USD/Month)*
LWE	2,703,975	1,784,256	4,488,231
MAK	50,699,048	33,454,474	84,153,522
MOA	165,228	109,028	274,256
NAM	2,772,109	1,829,214	4,601,323
NRE	1,371,964	905,310	2,277,274
BAA	2,747,164	1,812,754	4,559,918
BIU	1,674,308	1,104,815	2,779,123
TJP	95,388,387	62,943,357	158,331,744
WAN	2,132,402	1,407,095	3,539,497

Appendix 8 Calculation Result: Cargo Demand Estimation

Port ID	***Cargo Demand – Food (TEU/Month)***	***Cargo Demand - General Containers (TEU)***	***Total Containers (TEU)***
AGA	68	44	112
BIK	118	76	194
DOB	71	46	117
FAK	58	38	96
KAI	51	33	84
MKQ	178	115	293
NBX	98	64	162
ORA	27	18	45
SAR	31	20	51
SXK	113	73	186
ZRI	19	12	31
TEB	17	11	28
TMK	138	90	228
WAR	27	18	45
WAS	23	15	38
BIA	3	2	5
BUH	1	1	2
GEB	4	3	7
KAH	2	2	4
KAK	1	1	2
LIR	5	3	8
MAB	6	4	10
MAR	1	1	2
MNA	13	9	22
MIA	1	1	2
OZI	40	26	66
NNX	50	32	82
OBI	35	23	58
SQN	43	28	71
SGQ	90	58	148
SEB	60	39	99
TAG	15	10	25
TAH	26	17	43
TID	37	24	61
TBO	122	79	201
TER	55	36	91
BEL	281	182	463
KBH	143	93	236
KIS	12	8	20
LKA	135	88	223

Port ID	***Cargo Demand – Food (TEU/Month)***	***Cargo Demand - General Containers (TEU)***	***Total Containers (TEU)***
LWE	89	58	147
MAK	-	-	-
MOA	6	4	10
NAM	91	59	150
NRE	45	29	74
*BAA***	90	59	149
BIU	55	36	91
*TJP**	-	-	-
WAN	70	46	116

Appendix 9 Calculation Result: Effective Cargo Demand

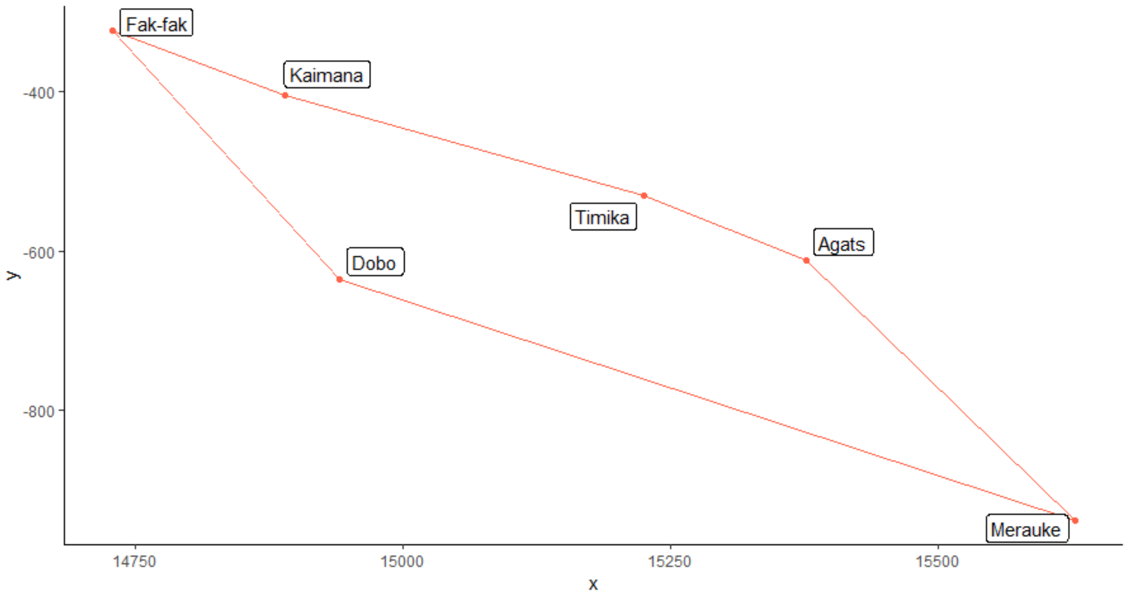
Port ID	Competitor	Market Share (%)	Total Effective Cargo Demand (TEU/Month)
AGA	1	40%	45
BIK	2	20%	39
DOB	1	40%	47
FKQ	1	40%	39
KAI	1	40%	34
MKQ	4	10%	30
NBX	3	15%	25
ORA	1	40%	18
SAR	1	40%	21
SXK	2	20%	38
ZRI	2	20%	7
TEB	1	40%	12
TMK	3	15%	35
WAR	1	40%	18
WAS	1	40%	16
BIA	1	40%	2
BUH	1	40%	1
GEB	1	40%	3
KAH	1	40%	2
KAK	1	40%	1
LIR	1	40%	4
MAB	1	40%	4
MAR	1	40%	1
MNA	1	40%	9
MIA	1	40%	1
OZI	1	40%	27
NNX	2	20%	17
OBI	1	40%	24
SQN	1	40%	29
SGQ	2	20%	30
SEB	2	20%	20
TAG	1	40%	10
TAH	1	40%	18
TID	2	20%	13
TBO	3	15%	31
TER	1	40%	37
BEL	3	15%	70
KBH	3	15%	36
KIS	1	40%	8
LKA	3	15%	34

Port ID	***Competitor***	***Market Share (%)***	***Total Effective Cargo Demand (TEU/Month)***
LWE	2	20%	30
*MAK**	-	-	-
MOA	1	40%	4
NAM	3	15%	23
NRE	1	40%	30
*BAA***	1	-	8
BIU	2	20%	19
*TJP**	-	-	-
WAN	2	20%	24

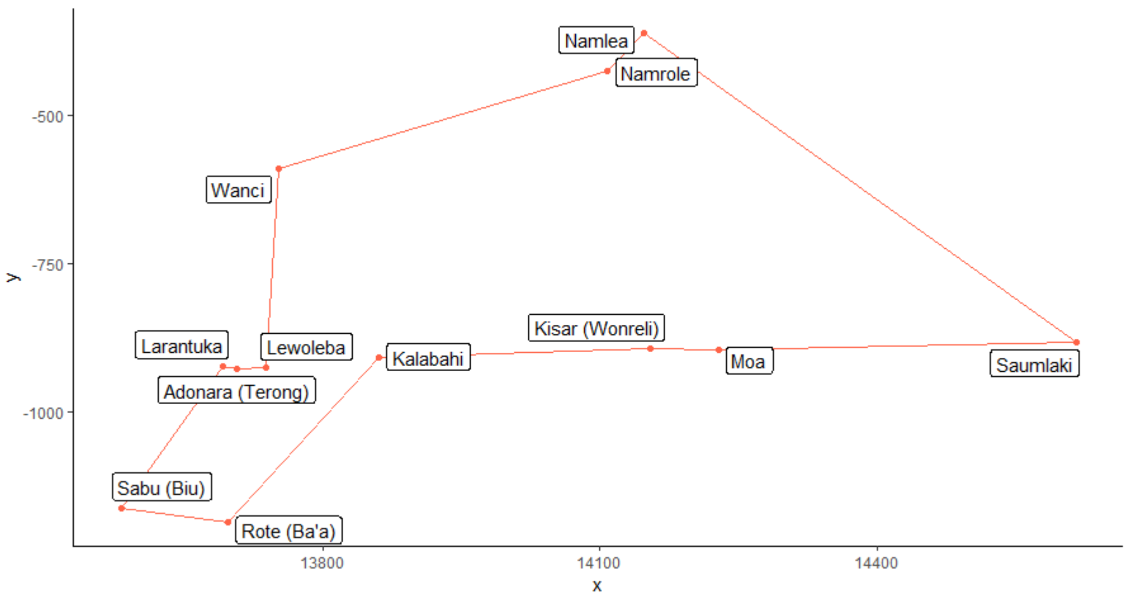
Appendix 10 Clustering Result and Demand Disaggregation

Cluster	***Port ID***	***Monthly Demand (TEU/Month)***	***Weekly Demand (TEU/Week)***	***Container Demand (per Two Weeks)***
1	AGA	45	12	23
1	DBO	47	12	24
1	FKQ	39	10	20
1	KAI	34	9	17
1	MKQ	30	8	15
1	TMK	35	9	18
2	TER	37	10	19
2	KBH	36	9	18
2	KIS	8	2	4
2	LKA	34	9	17
2	LWE	30	8	15
2	MOA	4	1	2
2	NAM	23	6	12
2	NRE	30	8	15
2	BAA	8	2	4
2	BIU	19	5	10
2	SXK	38	10	19
2	WAN	24	6	12
3	BIA	2	1	1
3	BUH	1	1	1
3	GEB	3	1	2
3	KAH	2	1	1
3	KAK	1	1	1
3	LIR	4	1	2
3	MAB	4	1	2
3	MAR	1	1	1
3	MNA	9	3	5
3	MIA	1	1	1
3	OZI	27	7	14
3	OBI	24	6	12
3	SQN	29	8	15
3	TAG	10	3	5
3	TAH	18	5	9
3	TID	13	4	7
3	TBO	31	8	16
4	BEL	70	18	35
4	MAK	-	-	-
4	NNX	17	5	9
4	SGQ	30	8	15
4	SEB	20	5	10

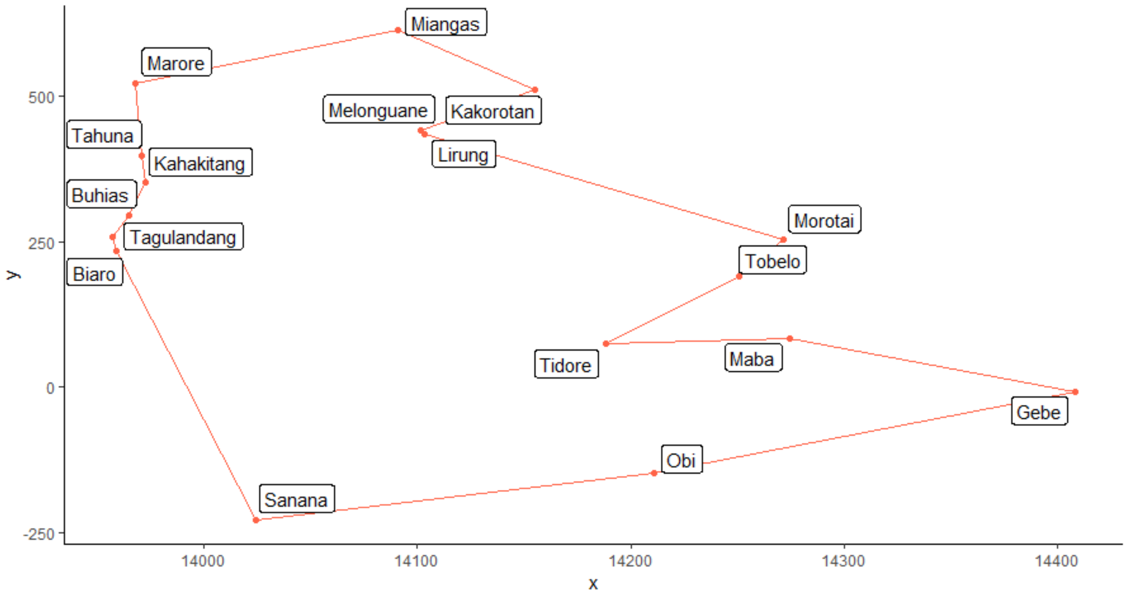
Cluster	*Port ID*	*Monthly Demand (TEU/Month)*	*Weekly Demand (TEU/Week)*	*Container Demand (per Two Weeks)*
4	TJP	-	-	-
5	WAR	18	5	9
5	WSR	16	4	8
5	BIK	39	10	20
5	NBX	25	7	13
5	ORA	18	5	9
5	ZRM	21	6	11
5	ZRI	7	2	4
5	TEB	12	3	6



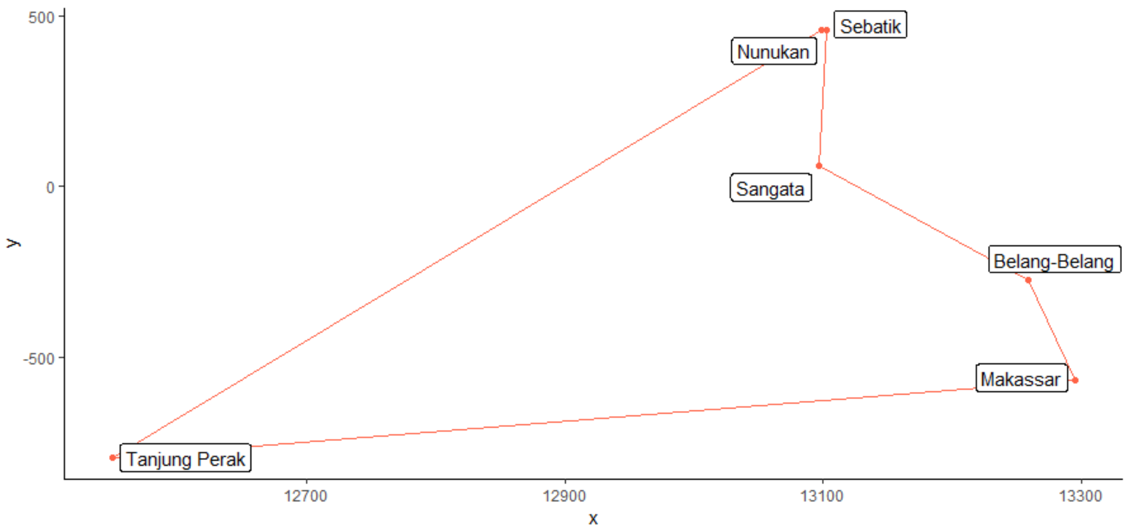
TSP RESULT: CLUSTER 1



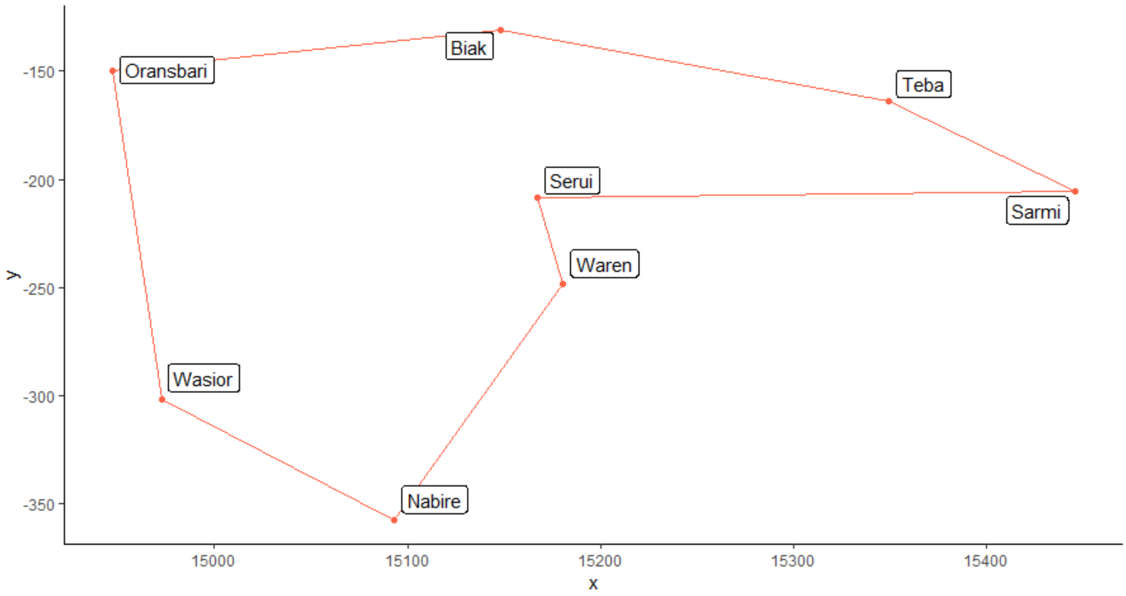
TSP RESULT: CLUSTER 2



TSP RESULT: CLUSTER 3



TSP RESULT: CLUSTER 4



TSP RESULT: CLUSTER 5

Appendix 12 Adjusted Distance

Route		Distance (nm)
Origin	Destination	
Tanjung Perak	Wanci	700
Wanci	Sanana	260
Sanana	Oransbari	590
Oransbari	Fak-fak	481
Fak-fak	Tanjung Perak	1307
Fak-fak	Kaimana	182
Kaimana	Timika	215
Timika	Agats	85
Agats	Merauke	365
Merauke	Dobo	510
Dobo	Fak-fak	207
Wanci	Namrole	290
Namrole	Namlea	63
Namlea	Saumlaki	386
Saumlaki	Moa	224
Moa	Kisar	41
Kisar	Kalabahi	182
Kalabahi	Rote	176
Rote	Sabu	80
Sabu	Larantuka	143
Larantuka	Adonara	13
Adonara	Lewoleba	17
Lewoleba	Wanci	188
Sanana	Biaro	274
Biaro	Tagulandang	20
Tagulandang	Buhias	23
Buhias	Kahakitang	30
Kahakitang	Tahuna	27
Tahuna	Marore	73
Marore	Miangas	81
Miangas	Kakorotan	65
Kakorotan	Melonguane	50
Melonguane	Lirung	4
Lirung	Morotai	152
Morotai	Tobelo	27
Tobelo	Maba	113
Maba	Gebe	86
Gebe	Tidore	208
Tidore	Obi	158
Obi	Sanana	93

Route		Distance (nm)
Origin	***Destination***	
Tanjung Perak	Sangata	613
Sangata	Nunukan	322
Nunukan	Sebatik	2
Sebatik	Belang-belang	453
Belang-belang	Makassar	213
Makassar	Tanjung Perak	434
Oransbari	Biak	109
Biak	Teba	115
Teba	Sarmi	150
Sarmi	Serui	167
Serui	Waren	23
Waren	Nabire	80
Nabire	Wasior	110
Wasior	Oransbari	90

Appendix 13 Port Call Sequence Adjustment Result

Cluster 3 Re-Routing

Cluster 4 Re-Routing

Appendix 14 Container Freight Rate (Ministry of Transport, 2018)

From	Tanjung Perak		Makassar	
To	Dry (USD/TEU)	Reefer (USD/TEU)	Dry (USD/TEU)	Reefer (USD/TEU)
AGA	381	572	-	-
DBO	342	513	-	-
FKQ	338	507	-	-
KAI	351	527	-	-
MKQ	435	653	-	-
TMK	397	595	-	-
TER	243	364	-	-
KBH	249	374	-	-
KIS	276	416	-	-
LKA	245	367	-	-
LWE	248	379	-	-
MOA	287	430	-	-
NAM	291	437	-	-
NRE	323	484	-	-
BAA	340	509	-	-
BIU	351	527	-	-
SXK	320	481	-	-
WAN	244	366	-	-
BIA	320	481	273	410
BUH	320	480	265	397
GEB	377	565	341	512
KAH	320	480	263	394
KAK	355	532	-	-
LIR	319	478	275	412
MAB	364	546	328	492
MAR	320	481	269	404
MNA	355	532	300	449
MIA	355	532	300	449
OZI	355	532	-	-
OBI	394	591	353	530
SQN	368	552	338	508
TAG	320	480	273	410
TAH	304	455	258	387
TID	308	462	-	-
TBO	350	525	286	428
BEL	196	294	155	232
MAK	196	294	-	-
NNX	287	430	240	360
SGQ	234	350	191	287

From	***Tanjung Perak***		***Makassar***	
To	***Dry (USD/TEU)***	***Reefer (USD/TEU)***	***Dry (USD/TEU)***	***Reefer (USD/TEU)***
SEB	328	492	240	360
TJP	-	-	196	294
WAR	397	595	-	-
WSR	411	616	-	-
BIK	375	563	-	-
NBX	413	620	-	-
ORA	397	595	-	-
ZRM	394	591	-	-
ZRI	391	586	-	-
TEB	413	620	-	-

Appendix 15 Result Vessel Selected Butterfly Hub

Route	***Once in Two Weeks Demand (TEUs)***	***Suggested Vessel Capacity (TEUs)***	***Vessel Selected***
Hub 1	240	343	Reliance
Hub 2	197	282	Red Rover
C1	97	139	KM Logistik Nusantara II
C2	135	193	Territory Trader
C3	80	115	KM Logistik Nusantara III
C4	69	99	KM Kendhaga Nusantara
C5	71	102	KM Caraka Jaya Niaga III - 32

Appendix 16 Result: Sea Toll Network Vessel Operation (Once in Two Weeks)

Route	***TRV (Days)***	***Speed (kn)***	***Vessel Deployment***	***Vessel Utilization***
T3	14	7.30	1	55%
T4	14	7.27	1	9%
T4F	7	4.43	1	18%
T5	14	8.97	1	37%
T5F	7	6.46	1	31%
T6	14	8.36	1	14%
T7	14	6.32	1	12%
T8	14	11.15	1	44%
T8F	7	5.16	1	35%
T9	14	11.70	1	20%
T10	14	9.47	1	29%
T11	14	12.16	1	44%
T12	14	8.92	1	22%
T13	14	9.30	1	27%
T14	14	4.48	1	40%
T15	14	7.66	1	16%

Appendix 17 Result: Clustering Vessel Operation (Once in Two Weeks)

Route	***TRV (Days)***	***Speed (Kn)***	***Vessel Deployment***	***Vessel Utilization***
Hub	14	15.50	1	70%
C1	14	6.38	1	67%
C2	14	8.51	1	53%
C3	14	7.35	1	63%
C4	14	7.03	1	69%
C5	14	3.24	1	60%

Appendix 18 Result: Port Aggregation Vessel Operation (Once in Two Weeks)

Route	***TRV (Days)***	***Speed (Kn)***	***Vessel Deployment***	***Vessel Utilization***
Hub	14	15.47	1	69%
C1	14	6.38	1	67%
C2	14	7.66	1	53%
C3	14	3.73	1	62%
C4	14	7.03	1	69%
C5	14	3.01	1	60%

Appendix 19 Result: Butterfly Hub Vessel Operation (Once in Two Weeks)

Route	***TRV (Days)***	***Speed (Kn)***	***Vessel Deployment***	***Vessel Utilization***
Hub 1	14	7.34	1	64%
Hub 2	14	11.72	1	63%
C1	14	6.38	1	67%
C2	14	7.66	1	53%
C3	14	3.73	1	62%
C4	14	7.03	1	69%
C5	14	3.01	1	60%

Appendix 20 Scenario 1 Vessel Operation

Route	***TRV (Days)***	***Speed (Kn)***	***Vessel Deployment***	***Vessel Utilization***
Hub 1	14	7.52	1	71%
Hub 2	14	11.86	1	70%
C1	14	6.46	1	74%
C2	14	7.86	1	59%
C3	14	3.78	1	68%
C4	14	7.05	1	77%
C5	14	3.04	1	66%

Appendix 21 Scenario 2 Vessel Operation

Route	***TRV (Days)***	***Speed (Kn)***	***Vessel Deployment***	***Vessel Utilization***
Hub 1	14	7.52	1	71%
Hub 2	14	11.86	1	70%
C1	14	6.46	1	74%
C2	14	7.86	1	59%
C3	14	3.78	1	68%
C4	14	7.05	1	77%
C5	14	3.04	1	66%