TUGAS AKHIR – TI 141501

ANALISA KONEKTIVITAS PELABUHAN INDONESIA TIMUR MENGGUNAKAN PENDEKATAN TEORI GRAFIK UNTUK MENDESAIN JARINGAN PELABUHAN YANG LEBIH EFISIEN MENGGUNAKAN HUB AND SPOKE MODEL

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Surabaya 2015

FINAL PROJECT – TI 141501

EASTERN INDONESIA PORTS CONNECTIVITY ANALYSIS USING GRAPH THEORETICAL APPROACH TO DESIGN MORE EFFICIENT PORTS NETWORK USING HUB AND SPOKE MODEL

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APPROVAL SHEET

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FINAL PROJECT

Submitted as one of the Requirements
in acquiring the Degree of Bachelor of Engineering
Department of Industrial Engineering
Faculty of Industrial Technology
Institut Teknologi Sepuluh Nopember
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SURABAYA
2015

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ABSTRACT

Hampir sebagian besar pengangkutan barang nasional menggunakan tranportasi laut, terutama Indonesia bagian Timur. Karakteristik geografi di darat dan laut dan infrastruktur yang ada di Indonesia Timur mendukung pengangkutan barang lebih efisien menggunakan transportasi laut. Akan tetapi, biaya logistik (kontainer/km) di wilayah Indonesia Timur lebih mahal dibanding dengan Indonesia Barat. Upaya peningkatan konektivitas antar pelabuhan-pelabuhan di Indonesia, khususnya wilayah Indonesia Timur diyakini akan mampu mereduksi biaya logistik yang ada sekarang ini. Penelitian ini berupaya menganalisa konektivitas antar pelabuhan-pelabuhan di wilayah Indonesia Timur seperti pelabuhan hub, pelabuhan pengumpan dan pelabuhan perintis. Pola pelayaran untuk pengangkutan barang juga dipertimbangkan untuk diperhatikan seperti pola pelayaran Ro-Ro, ferry antar pulau, perintis dan lainnya. Hasil dari penelitian ini diharapkan dapat diketahui bagaimana tingkat densitas konektivitas dari pelabuhan-pelabuhan Indonesia Timur. Berdasarkan tingkat densitas konektivitas yang ada, akan dilakukan analisa bagaimana pola konektivitas antar pelabuhan-pelabuhan di wilayah Indonesia Timur yang lebih efisien dan rekomendasi kebijakan apa yang diperlukan untuk meningkatkan konektivitas antar pelabuhan-pelabuhan tersebut.

Kata Kunci : *Connectivity Level, Pelabuhan Indonesia Timur, Pendekatan Teori Grafik, Hub-and-Spoke Model*

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EASTERN INDONESIA PORTS CONNECTIVITY ANALYSIS USING GRAPH THEORETICAL APPROACH TO DESIGN MORE EFFICIENT PORTS NETWORK USING HUB AND SPOKE MODEL

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ABSTRACT

Most of national logistics transportation system use sea transportation especially in Eastern Indonesia. The geographical characteristic and infrastructure in the land and sea support the logistic transportation system is more efficient if use sea transportation. However, there are significant gap between inflow and outflow goods in most of eastern Indonesia seaports. Consequently, the logistics cost (container/km) in Eastern Indonesia is more expensive than in Western Indonesia. The effort to improve the connectivity between seaports in Eastern Indonesia believed can reduce to logistic cost. The goal of this research is to analyze connectivity each seaports in Eastern Indonesia and designing more efficient network pattern.

This research will be divided into two main parts, the first part is the connectivity analysis and the correlation between transportation cost, and the second part is designing new network pattern based on the connectivity analysis. In the first part, graph theoretical approach is used to analyze the connectivity in this research. This approach can measure the accessibility of seaports using geographical analysis that considers distance between ports, and frequency of transfers. The outcome of graph theoretical approach is connectivity index for each seaports. The connectivity results then used as standard to design network pattern using hub and spoke model. The second parts of the research is to develop some scenarios that could be applied to the network. The scenarios developed are based on the demand weighted distance, the administrative level of seaports, and "Pendulum Nusantara" concept that developed by PT. Pelindo II. There will be one chosen scenario that proposed.

Key words : *Connectivity Level, Eastern Indonesia Seaports, Graph Theoretical Approach, Hub And Spoke Model*

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ACKNOWLEDGMENT

Alhamdulillah, all praises are belonging to Allah SWT. By whose grace, guidance, and blessing the author can finish this final research entitled "Eastern Indonesia Ports Connectivity Analysis Using Graph Theoretical Approach To Design More Efficient Ports Network Using Hub And Spoke Model" by the end of fourth year study in Department of Industrial Engineering of Institut Teknologi Sepuluh Nopember Surabaya.

This final research is conducted as a requisite to finish Industrial Engineering major and to achieve Bachelor degree from Institut Teknologi Sepuluh Nopember (ITS). During the completion of this research, author receives countless support, motivation, inspiration, and help from various people and communities. Therefore, in this opportunity, the author would like to express his biggest appreciation and gratitude sincerely to those who contribute most and play important part during the completion of this final research, namely:

1. Suharno and Wari Dyah Astati the most beloved father and mother, and my siblings, Nirmala Manohara Harnanda, Silma Luthfika Harnanda, and Kenzie Mahadi Harnanda who have always been there for the author to support in any kind and in every situation. May in the future the author can repay your love with utmost service.
2. Prof. Iwan Vanany, S.T., M.T.,Ph.D as supervisor, the best lecturer for the author, under whose great guidance, clear direction, patient supervision, and wise advise in tutoring the author for the whole time, this final research can finish on time.
3. Prof. Ir. Budi Santosa, M.Sc., Ph.D., as head of Department of Industrial Engineering and Putu Dana Karningsih ST., M.Eng.Sc., Ph.D., as secretary of Department of Industrial Engineering, whose support and advise have helped the author for the last couple years.
4. Dr. Nurhadi Siswanto, Dr. Ahmad Rusdiansyah, who had given very useful lecture in Operation Research and Distribution Management which are very helpful to did this final research.
5. All faculty members and academic staffs of Department of Industrial Engineering of Institut Teknologi Sepuluh Nopember, for all knowledge, experience, and help for the author and other friends and students during the years of study.

6. For Gebang FC, Fiqi, Fadel, Rio, Evans, Randy, Eko and all members, you are my best friend ever. Thank you for the continuous support, motivation, help, all awesomeness, and all coolness.
7. For all member of KSR PMI ITS and LMB ITS 2014-2015, Zacky, Arun, Hilmi, Rifky, Luqman, Prama, Yanda, Lutfi, Nurul, Fika, Dida, Nuzul, Adlin, Nita, Rizal for continuous support, help, and awesomeness.
8. For four years togetherness, Q-Class, Shiro, Sasa, Tole, Firza, Wike, Ghea, ninin, Aghni, Satrio, Argon, Andre, Faizal, etc. You are my best classmates with all the jokes during the class. No time in university will be as colorful as it is if it is not because of you all.
9. For all "Anak Pak Iwan", Elvi, Putri, Aseng, Lihawa who inspire me to do my thesis research using my topic during internship. My pleasure to work with you all, even in short time.
10. Veresis!, Industrial Engineering students class of 2011, as families and buddies, the best group of people, the most cheerful and adorable class and fellow class of 2011. All this life will not be as colorful and wonderful as it is if it is not because of you all.
11. Everyone else whom the author cannot mention explicitly due to the limit of this acknowledgement. Deepest gratitude is expressed towards you all.

Last, the author realizes that this research is far from perfect. Therefore, the author welcomes positive suggestion and constructive critics from anyone. May this research contribute to academic world and provide improvement for better future.

Surabaya, 3 July 2015

Author

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CHAPTER I
INTRODUCTION

This chapter explains about background, problem identification, objectives and benefits, experiment scope of doing thesis research which contains of limitations and assumptions, and thesis outline.

1.1 Background of Study

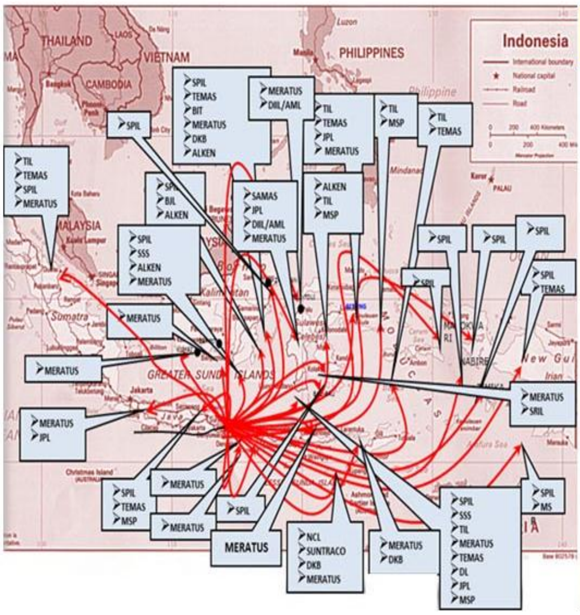
As a maritime nation, Indonesia has tremendous potential. Both in terms of marine resources as well as in the field of marine transportation. This is shown by most of the transport of goods in Indonesia conducted using sea transportation which is about 88% (Peraturan Presiden RI, 2012). Payload power capability compared with other types of transportation such as (land, and air) causes the carriage of goods by sea transport more efficient. This condition indicates that efforts to improve the policy and management of marine transportation are important to improve the performance of the national logistics. It is expected an increase in the performance of logistics will be able to lower the cost of national logistics.

Logistics issue is an important issue for Indonesia which has geographical conditions consists of more than 17 thousand islands with a diversity of natural resources and other commodities. Indonesia's logistics performance is not optimal compared with other ASEAN countries such as Singapore and Malaysia. From World Bank report, based on the value of its logistics performance index for 2010 shows that Indonesia was ranked 75th out of 155 countries. Singapore has been ranked 2nd, Malaysia is ranked 29 and Thailand was ranked 35th (Peraturan Presiden RI, 2012). In addition, Indonesia's logistics costs more expensive compared with other countries in ASEAN that nearly 27% of Indonesia's GDP product.

Eastern Indonesia logistics costs are the highest, at 50% -60% of the product price compared with western Indonesia (eg Sumatra) and the central part of

Indonesia that is only 30% (eg Bali and Makassar) (Peraturan Presiden RI, 2012). This condition can be shown by the price of one sack of cement in Makassar range between Rp.45.000, until Rp.50.000, but the price in Papua reaches Rp.200.000,-. This indicates that, there are marine transportation problems in eastern Indonesia and affect the economy and prosperity in eastern Indonesia.

Ports have a role and a very important function in the movement and economic growth in Indonesia, particularly eastern Indonesia archipelago. Some pioneering port is also built to support the transport of goods to the eastern part of Indonesia. Figure 1 below is the existing route between ports in eastern Indonesia that centralized in Surabaya.



Perusahaan Pelayaran	Rute Pelayaran		
	Barat	Timur	
TIL	Medan	Ambon	Kotabaru
SPIL	Jakarta	Ternate	Kendari
Meratus Line	Semarang	Manado	Palu
BIT		Luwuk	Lembar
Alken		Jayapura	Badas
SAMAS		Merauke	Ende
JPL		Timika	Maumere
MSP		Nabire	Waingapu
Suntraco		Denpasar	Kalabahi
DKB		Kupang	Bitung
AML		Tarakan	
SSS		Ujung Pandang	
NCL		Biak	
SRIL		Sorong	
Temas		Sangkulirang	
TAL		Samarinda	
TK		Banjarmasin	
BJL		Sampit	
Kanaka Line		Kumai	

Figure 1.1 Shipping Route in Eastern Indonesia (Source: PT. Pelindo III, 2009)

There are 32 shipping routes in eastern Indonesia. Almost all of them pass through Surabaya port. It is shown in Figure 1 the density of shipping network in eastern Indonesia is very high. There are 19 shipping companies serve eastern Indonesian logistics distribution network. Moreover there are 41 ports in connecting eastern Indonesia shipping network. However, the cost of logistics eastern Indonesia is still expensive compared with the West.

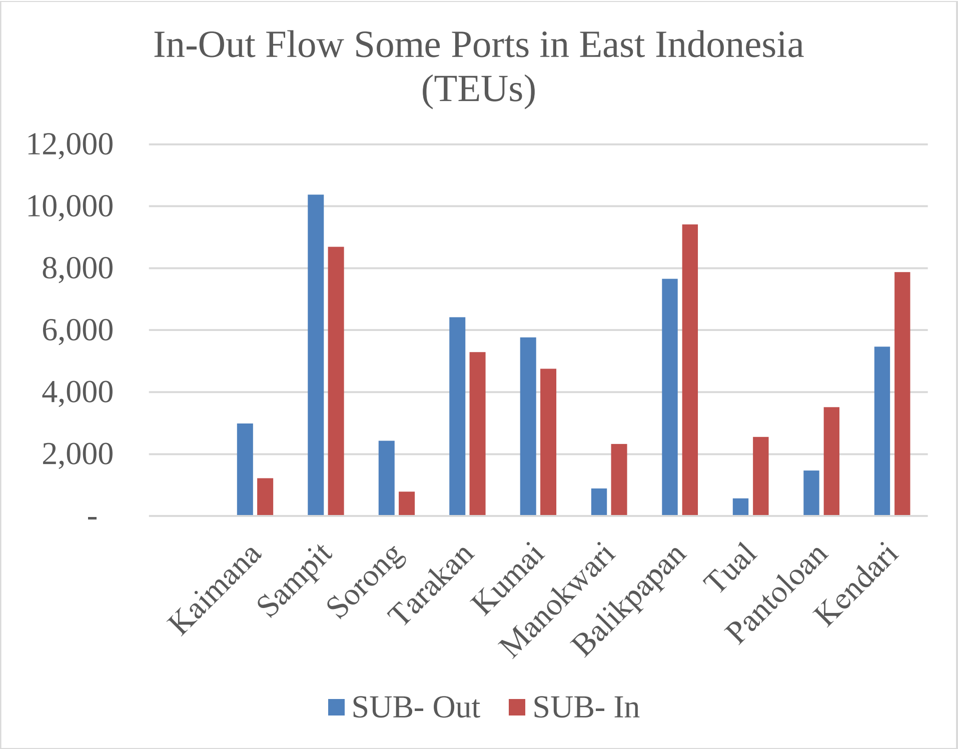


Figure 1.2 In-Flow and Out-Flow In Eastern Indonesia Ports per Year (Source: PT. Pelindo II, 2013)

Observers believe that the low connectivity level between ports in eastern Indonesia is the main constraint. Efforts to increase connectivity density will be able to bring down the cost of the logistics of transporting goods in eastern Indonesia. One of the causes of low connectivity density is the unbalanced in-flows and out-flows of each port. Figure 1.2 shows that there are some ports like Kaimana, Kumai, Tarakan, and Sorong that have higher out-flow then its in-flow. In contrast, some ports like Manokwari, Kendari, Tual, and Balikpapan have higher in-flow then it's out-flow. Those gaps between inflow and outflow in each seaports are exceed 1000 TEUs. If the transportation cost is Rp 7.000.000/TEUs (Pelindo Marine, 2014), then the estimated loss every year is more than 7 billion rupiah each seaports. Consequently, the loss will be weighted on the transportation cost for routes that have low density. Therefore, unbalanced density causes the logistics cost to that ports becomes very high.

Hardly many previous studies that seek to analyze the density connectivity between ports in Indonesia, particularly eastern Indonesia. Some existing researches in international journals mostly in the air and land transport modes. (Kim & Park, 2012) Had analyzed the connectivity of freight/cargo at airports. (Manzano, et al., 2014) Conducted a study to determine the hub airports in Spain, and the flight pattern using connectivity linear transfer function methods. However, there are some methods that can be used to measures connectivity, such as total connectivity, graph theoretical approach, gravity model, and liner shipping connectivity index (Kemenhub RI, 2015). In this research graph theoretical approach is used because this method focuses on the network connectivity. This indicator shows the relative connectivity in a network and measures accessibility of a location. The higher the connectivity index the more important the location to the network (Kemenhub RI, 2015). The outcome of this method is used to decide to hubs and spokes in the designing phase of the research. While the other method needs more data and does not shows the network connectivity.

This study will attempt to analyze the density level based on connectivity between ports in eastern Indonesia. The results of the analysis will be used to determine more efficient pattern based on connectivity using hubs and spokes model. In addition, to give recommendations related to the improvement of what needs to be done by the central government, in this case the department of transportation and local governments to increase the density of connectivity between ports in eastern Indonesia.

1.2 Problem Statements

Based on the background, this research is aiming to analyze existing eastern Indonesia container shipping network, and design some possible shipping networks that can improve the quality of the network based on hub and spoke model. As mentioned in background, there are several aspects to be considered such as, connectivity index, the difference between outbound and inbound connecting power, and the demand weighted distance.

1.3 Research Objectives

The objectives of this research of connectivity level in eastern Indonesia seaports are:

1. To analyze the existing eastern Indonesia container shipping network. Based on connectivity index, the difference between outbound and inbound connecting power, and the demand weighted distance.
2. To develop possible scenarios of eastern Indonesia container shipping network that will give better quality in connectivity index, the difference between outbound and inbound connecting power, and the demand weighted distance.
3. To give recommendation for government, seaports companies and shipping line companies based on the most appropriate scenario of eastern Indonesia container shipping network

1.4 Research Benefits

Benefits of this research is divided into three, benefits for the Ports Companies, Expedition/Line Companies.

1. Ports companies will get balance workload of each seaports in Eastern Indonesia
2. Expedition/line companies will get additional routes option to increase the demand of expedition and minimization cost of transportation
3. The country will get reduction of national logistics cost and relatively equal price in eastern Indonesia and western Indonesia

1.5 Research Scopes

This research scopes are divided into two parts, limitation and assumption. The research limitation and assumption are:

1.5.1 Limitation of the Research

The limitation of this research of connectivity level in eastern Indonesia seaports such as:

1. The ports that included in Eastern Indonesia are 43 ports in east and south Kalimantan, east Java, and Sulawesi, Papua, Bali, Lombok, Ambon island.
2. The connectivity indicator measurement uses graph theoretical approach

3. The type of shipping for this research is containers distribution network through sea transportation while bulk type of shipping is not observed.
4. This research is done until improvement suggestion and not until improvement implementation.
5. Surabaya is the single destination in the network. Therefore, the container flow is limited from and to Surabaya.

1.5.2 Research Assumptions

Here are the limitation of this research of connectivity level in eastern Indonesia seaports such as:

1. Demand used for this research is total demand in 2014.
2. The improvement suggestion can be done by the company

1.6 Structure of Final Report

This subchapter explained about the writing system of this research. The writing system of this research is as follows:

a. CHAPTER 1 INTRODUCTION

   This chapter contains the introduction of this research. This chapter contains research background, problem formulation, research objective, research benefit, research scope and structure of final report.

b. CHAPTER 2 LITERATURE REVIEW

   This chapter contains the literature that used as a framework and based theory to do this research. The literature for this research consist of definition of connectivity, connectivity indicator, graph theoretical approach, hub and spoke model, Indonesia national logistics system blueprint, and tools for designing proposed network pattern.

c. CHAPTER 3 RESEARCH METHODOLOGY

   This chapter contains the steps and explanation of each steps that done in this research. The research methodology divided into four stage, the first stage is initial stage consist of literature study, discussion, and data collection, the second stage is connectivity measurement consist of measuring connectivity level using graph theoretical approach, the third stage is analysing the correlation between connectivity and the transportation cost using Pearson Product-Moment Correlation, and the final stage is designing proposed network pattern using hub and spoke model.

d. CHAPTER 4 DATA COLLECTION AND PROCESSING

This chapter contain the data collecting result which have done in this research. In this chapter the collected data is process and it will be analyse in the next chapter. The data that will be collected are existing shipping network in eastern Indonesia, the transfer flow of goods in each seaports, transportation cost for each routes, capacity of each seaports, and the distance between seaports. While the processing of the data is following the methodology.

e. CHAPTER 5 DATA ANALYSIS AND INTERPRETATION

This chapter contain the analysis of data and interpretation of data which have been collected and processed in the previous chapter. The analysis consists of connectivity measurement analysis, correlation analysis, and proposed network pattern analysis.

f. CHAPTER 6 CONCLUSSION AND SUGGESTION

This chapter contains conclusion of this research and suggestion after this research conducted.

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CHAPTER II
LITERATURE REVIEW

This chapter explained about the literature review or basic theory that used to conduct this research. The concepts and theories provided in this chapter are about connectivity, connectivity indicator, graph theoretical approach,

2.1 Definition of Connectivity

Network connectivity can be used as a measure to study the performance of the transportation system that will help decision-makers to prioritize investment in transport and decided termination (stop / lines which require immediate attention in terms of operational and maintenance (Hadas & Ceder, 2010). In this context, connectivity is one of the indices of measurement that can be used to measure and evaluate the performance of transport (Borgatti, 2005).

The size of the transport connectivity can be used for multiple purposes. First, in a public institution, connectivity can be used as a measure of the public expenditure to calculate the transport and termination as well as to evaluate the performance of the overall system performance. Second, in rural or suburban areas where the appropriate information on passengers, boarding, and stop are not available (which is generally a function or task of transporting a comprehensive and well designed in a travel package or an advanced transport system in which smart cards are used to keep track of income) to obtain a measure of performance to develop service delivery strategies. Third, as a measure of performance in a multi-modal urban network consisting of a large-scale local bus, express bus, metro, train local, inter-regional train, bus transport, and other transportation services that serve rural and urban areas, where transport services provided by public and private institutions in contrast to the system of coordination.

2.2 Connectivity Indicator

Connectivity as an indicator is used to quantify and evaluate transit service in terms of prioritizing transit location for funding, assessing the effectiveness and efficiency for node/stop prioritization and making a user friendly tool to determine locations with highest connectivity while choosing transit as a mode of travel (Mishra, et al., 2012).

Nodes and lines represent the layout of transit network. The nodes called stops and the lines are called links or route segment. Frequency, speed, and capacity are critical terms that define the characteristics of a route for a transit link. Similarly, transit nodes are composed of a different set of characteristics than highway nodes. The nodes and links of the transit system are synonymous with the analysis of connectivity in graph theory (Harary, 1971).

Graphs more or less connected are determined from two invariants such as node and line connectivity. The transit system consists of many different routes. Determining the extent to which the routes are integrated and coordinated so that the transit system is connected, is another complex task (Lam & Schuler, 1982). The structure of the public transit network is critical in determining performance, coverage, and service of the network. Centrality measures are well studied in the literature. However, their application to public transit is rare. Table 2.1 represents a summary of connectivity index measures (or derivatives thereof) found in the literature (Mishra, et al., 2012).

Table 2.1 Literature on Centrality and Connectivity Measures In Social Networks And Transportation.

Measure	**Mathematical Construct**	**Eq. No**	**Definition**
Node-measure degree centrality	$Dc\ (n) = \frac{\sum_{p \in N} \delta np}{n-1}$, where	1	Normalized score based on total number of direct connections to other network nodes
	$\delta np = \begin{cases} 1\ if\ p\ dependent\ on\ n, \forall p \in (N \\ 0\ otherwise \end{cases}$	2	

Source: (Mishra, et al., 2012)

Table 2.2 Literature on Centrality and Connectivity Measures In Social Networks And Transportation. (part 2)

Measure	**Mathematical Construct**	**Eq No**	**Definition**
Node-measure eigenvector centrality	$De = \frac{\sum_{p \in N} \delta np\ x\ Dc(n)}{\lambda}$	3	Assigns relative 'scores' to all nodes in the network based on the principle on connections
Node-measure closeness centrality	$Dcc(n) = \frac{\sum_{n1 \in N} Ln,n1}{N-1}, \forall N > 2$	4	Sum of graph-theoretic distances from all other nodes
Node-measure betweeness centrality	$Db\ (n) = \sum n1 \sum n2 \frac{\delta n-1n2}{\delta n1,n2}, n1 \neq n \neq N2$	5	Sum of the number of geodesic paths that pass through a node n
Node measure connectivity index	$\theta n = \sum_{i \in L} P_{i,n}^{t}\, \mu_{l,n}$	6	Sum of connecting powers all lines crossing through a node n

Source: (Mishra, et al., 2012)

Table 2.3 Literature on Centrality and Connectivity Measures In Social Networks And Transportation. (part 3)

Measure	**Mathematical Construct**	**Eq. No**	**Definition**
Node measure connectivity	$\theta n = \sum_{i\in L} P_{i,n}^{t}\,\mu_{l,n}$	6	Sum of connecting powers all lines crossing through a node n
Node-measure transfer center (cluster) connectivity	$\theta\omega = \frac{1}{\lvert S\omega\rvert - 1}\sum_{n1\in S\omega}\sum_{n\in S\omega, n1\neq n} \theta n\rho n1,$	7	Sum of connecting powers all lines crossing through a transfer center
Node-measure region connectivity	$\theta\omega = \frac{1}{\lvert S\sigma\rvert - 1}\sum_{n\in SR} \theta n$	8	Sum of connecting powers all nodes in a region
Line - measure connecting power	$P_{i,n}^{t} = \frac{P_{l,n}^{0} + P_{i,n}^{i}}{2}$	9	Connectivity power of a line which is a function of transit characteristics
Line-measure connectivity index	$\theta l = \frac{1}{\lvert Sl\rvert - 1}\sum_{n\in S1}, n \neq no\ \theta n$	10	Sum of connecting powers all nodes in a line

Source: (Mishra, et al., 2012)

Many measures of transit service and accessibility have been put forth in the literature, but few offer a metric to measure the quality of service and performance of a large multi-modal regional transit system. The literature that does purport to offer such insight requires significant amounts of data not only about the transit system, but also of the complete demographics of the service area (Beimborn, et al., 2003). Other methods require a full transportation demand and transit assignment models, tools that are prohibitively expensive for many localities (Lam & Schuler, 1982). However, this research used a methodology that purposed (Mishra, et al., 2012) in Transportation Research Journal that provides a strong measure of system performance with the lowest possible data requirements. The proposed methodology is presented in the next section.

2.3 Graph Theoretical Approach

This research incorporates a graph theoretic approach to determine the performance of large-scale multimodal transit networks to quantify the measures of connectivity at the node, line, transfer center, and regional level. This is achieved through an assessment of connectivity that incorporates unique qualities of each transit line and measures of accessibility. By combining these criteria in a single connectivity index, a quantitative measure of transit performance is developed that goes beyond the traditional measure of centrality. The new connectivity index significantly extends the set of performance assessment tools decision makers can utilize to assess the quality of a transit system (Mishra, et al., 2012).

2.3.1 Node Connectivity

The methodology used consist of better representation of transit node index measures. This methodology considers the congestion effects achieved because of lane sharing of transit lines of buses, light rail, bus rapid transit and other similar transit facilities. The formula for node connectivity used in this research are (Mishra, et al., 2012):

$$P_{l,n}^{o} = \alpha(C_l \times F_l) \times \beta V_l \times \gamma D_{l,n}^{o} \tag{1}$$

$$P_{l,n}^{i} = \alpha(C_l \times F_l) \times \beta V_l \times \gamma D_{l,n}^{o} \tag{2}$$

where C_l is the average vehicle capacity of line l, F_l is the frequency of the line in a year, V_l is the speed of line l, and $D_{l,n}^{o}$ is the distance of line l from node n to the destination. The parameter α is the scaling factor coefficient for capacity which is the reciprocal of the average capacity of the system multiplied by the average number of daily operations of each line, β is the scaling factor coefficient for speed represented by the reciprocal of the average speed on each line, and γ is the scaling factor coefficient for distance which is the reciprocal of the average network route distance (Mishra, et al., 2012).

The addition in Eq. (1) is a term for activity density of transit line ‘‘l’’ at node ‘‘n’’, and ϑ is the scaling factor for the variable. The density measurement represents the development pattern based on both land use and transportation characteristics. The literature defines the level of development a number of ways, but for simplification purposes we have considered it to be the ratio of households and employment in a zone to the unit area. However, in this research, we don’t use the level of development, because it is assumed that all of the ports have the same level of development (Mishra, et al., 2012).

2.3.2 Line Connectivity

The total connecting power of a line is the sum of the averages of inbound and outbound connecting powers for all transit nodes on the line as presented in Eq. (1) scaled by the number of stops on each line. The scaling measure is used to reduce the connecting score of lines with many stops like bus lines to properly compare to lines with only a few stops like rail. The line connectivity can be defined as following (Mishra, et al., 2012):

$$\theta_l = (|S_l| - 1)^{-1} \sum P_{l,n}^{t} \tag{3}$$

2.4 Hub and Spoke Model

The hub-and-spoke network consists of a set of fully interconnected facilities called hubs among a potential set of locations, and spokes that directly connect the hubs (Elhedli & Hu, 2005). The flow between spokes is maintained through hubs. This network structure achieves economies of scale by consolidating and rerouting shipments at hubs. Using consolidating scheme to the hubs, the hub-and-spoke network strategy enables to provide flexible transportation service even though the quantity of shipment from various origins is inconsistent and fluctuates (Kim, 2005). Currently, a hub-and-spoke network is being widely used in airline, shipping, postal industries, and other communication systems (Shin & Kim, 2009).

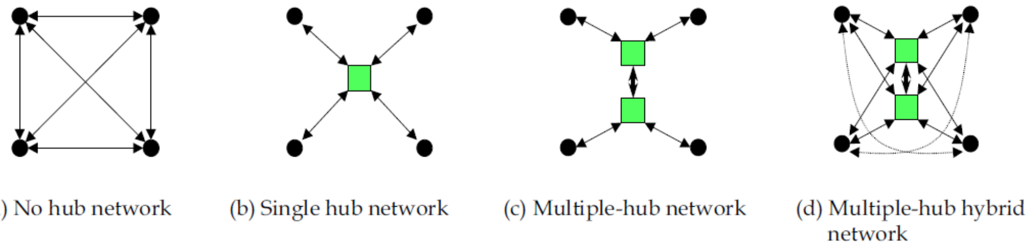
In general, designing such a network is comprised of several sub-problems such as hub location problem, spoke allocation to designated hubs, and route planning between hubs and spokes. Among such problems, we focus on deciding the number of hubs, hub locations, and allocating spokes to hubs to minimize the total transportation cost.. The *P*-median problem (PMP) model is used to design the hub-and-spoke.

The PMP is one of the representative location problems to find the location of P facilities on a network so that the total cost is minimized (Melkote & M.S., 2001). The PMP and its extensions are beneficial to model many real world conditions, such as the location of plants, warehouses, and other public facilities (Ebery, et al., 2000). The PMP is classified as NP(non-deterministic polynomial-time)-hard so that the instances of practical size cannot be solved within reasonable time. Many studies had been conducted for the PMP (Alp, et al., 2003). The solution approaches found in previous literature are broadly categorized into exact algorithms and heuristics. Due to the nature of complexity of the real world problems, various heuristic approaches are mainly proposed for the PMP.

In general, the hub location in hub-and-spoke network is determined by modelling hub location problem in which the total transportation cost is minimized with the given demand between all origin and destination pairs. The PMP is a binary integer linear program model to decide on the optimal hub location minimizing the total distance travelled to hubs with the given constraints. The PMP is a type of the combinatorial optimization problem; thus, the computation time is extremely increased as the number of decision variables increase (Kim, 2011).

Hub-and-Spoke network can be categorized into four types depending on whether hub(s) should be visited between source and destination as illustrated in

Figure 2.4. Material (or passenger) movement originated from a source can reach a destination without visiting any hub (Figure 2.4-(a)); go to a hub from which it moves to its destination (Figure 2.4-(b)); go to a hub from which it moves to another hub after being consolidated with other materials (passengers) and then moves to its final destination (Figure 2.4-(c)); some materials (passengers) to their destination directly whereas the others go through one or two hubs (Figure 2.4-(d)) (Jeong, 2003).


(a) No hub network

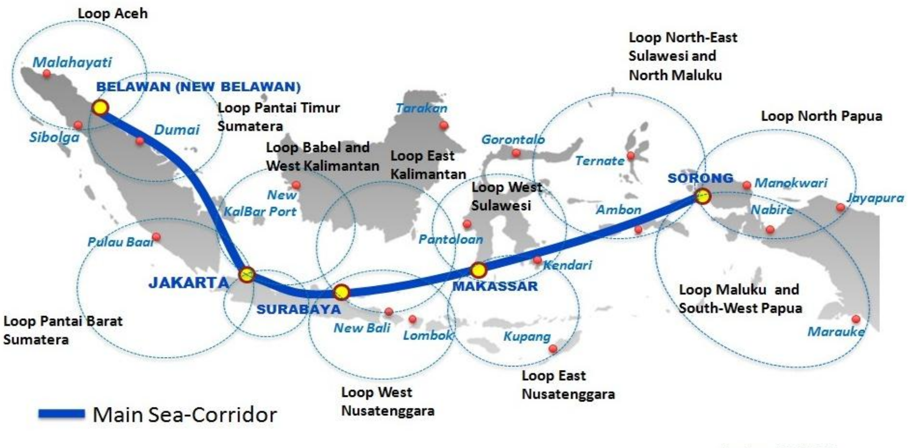
(b) Single hub network

(c) Multiple-hub network

(d) Multiple-hub hybrid network

Figure 2.1 Hub and Spoke Networks. Source: **(Jeong, 2003)**

In this research, the hub and spoke network that suitable for eastern Indonesia seaports are multiple-hub network and multiple-hub hybrid network. Therefore, there will be two scenario in this research. The first scenario is using multiple-hub network. In this scenario ships form any ports that become the spokes should move to their hub first, and moves to another hub after being consolidated with other goods and then moves to its final destination, where Surabaya is the final destination of all ports. This scenario is the same as the Nusantara Pendulum developed by Indonesia Port Corporation (PT. Pelindo II).



Sumber: IPC (2012)

Figure 2.2 Nusantara Pendulum Development Scheme. Source: (IPC, 2012)

The next scenario is using multiple-hub hybrid network. In this scenario a ship may moves to the final destination without moves to the hubs first. These two scenarios are evaluated to decide which scenario is the best to reduce the transportation cost in east Indonesia seaports network,

2.5 Indonesia National Logistic System Blueprint

National logistic system will be developed become integrated logistics system that is more effective and efficient using supply chain management concept. This blueprint is focused on logistics activities such as transportation, warehousing, and distribution.

2.5.1 Indonesian Logistics Vision 2025

"Logistics System that integrated locally, connected globally, in order to increase national competitiveness and social welfare". This vision mainly focusses on two points, integrated locally, and connected globally. Integrated locally means that all of logistics activities in Indonesia from the lowest level until national level are operated effectively and efficiently as a unity. While globally connected means that national logistics system should be connected with regional logistics system and global logistics system through International Hub Port.

2.5.2 Indonesian Logistics Mission 2025

National logistics system's missions are:

a. Accelerate the flow of goods effectively and efficiently to guarantee the fulfillment of people basic needs and increase competitiveness of national product in domestic, regional and global market.

b. Build national logistics' knots and its connectivity from villages, cities, inter regional, inter-island, until international hub through collaboration between stakeholders

2.5.3 Indonesian Logistics Strategic Objectives 2025

Based on the vision and mission of Indonesian logistics, the strategic objectives of Indonesian logistics are:

a. Decreasing logistics cost, accelerating flow of goods, and improving logistics service.
b. To guarantee the availability of basic commodities in all Indonesian regions with rational price.
c. Preparing the integration of ASEAN logistics service, and global logistic service.

2.5.4 Policies for National Logistics System.

Based on the vision, mission and strategic objectives, the government policies for national logistics system are:

1. Determining main commodities in logistics network and supply chain that is effective and efficient.
2. Integrating the logistics infrastructure knots, whether the logistics node and correlation between logistics knots (logistics link). Logistics node are logistics service providers and consumers, while logistics link are the distribution network, transportation network, information network and finance network.
3. Developing and applying information and communication system that secured and reliable
4. Developing world class logistics service providers
5. Developing professional human resources
6. Managing the laws in logistics to guarantee the legal certainty and synchronize the logistics stakeholders in the central and regional area.
7. Implementation of good governance in national logistics system.

From the vision, mission, strategic objectives and policies of national logistics system it can be concluded that this research supports the government to achieve the effective and efficient national logistics system.

2.6 Method for Designing Proposed Shipping Network

This sub-chapter consists of two parts. The linear programming method and simulation method. Those method is used to solve the hub and spoke model of proposed shipping network.

2.6.1 Linear Programming

The linear programming method used to solve the proposed shipping network based on hub and spoke model is P-median problem (PMP). The PMP is formulated as follows (Kim, 2011):

Minimize:

$$\sum_i \sum_j s_i d_{ij} Y_{ij} \tag{7}$$

Subject to

$$\sum_j Y_{ij} = 1 \tag{8}$$

$$Y_{ij} - X_j \leq 0 \tag{9}$$

$$\sum_j X_j = P \tag{10}$$

$$X_j = 0,1 \tag{11}$$

$$Y_{i,j} = 0,1 \tag{12}$$

Where:

s_i = demand at port i

d_{ij} = distance between port i and potential hub location j

P = number of hubs to locate

X_j = 1, if hub is located at potential hub location j
0, otherwise

Y_{ij} = 1, if demand at port i is serviced by hub location j
0, otherwise

The objective function (7) this objective function will shows the hubs and spokes location based on minimum demand-weighted distance. The constraint (8) ensures that each seaport is clustered into exactly one hub. The constraint (9) requires that demand at seaport i can only be assigned to a hub j if a hub is located at stop j. The constraint (10) guarantees that the P number of hubs should be located. The constraint (11) and (12) represent that all variables must be binary (Kim, 2011).

However, the PMP model above does not consider the connectivity index and the gap between in-flow and out-flow of goods. Therefore, the result should be tested afterwards.

CHAPTER III

RESEARCH METHODOLOGY

This chapter will explain all steps conducted in the research in order to make the research can be run in systematic way.

The flowchart of methodology used is given as follows,

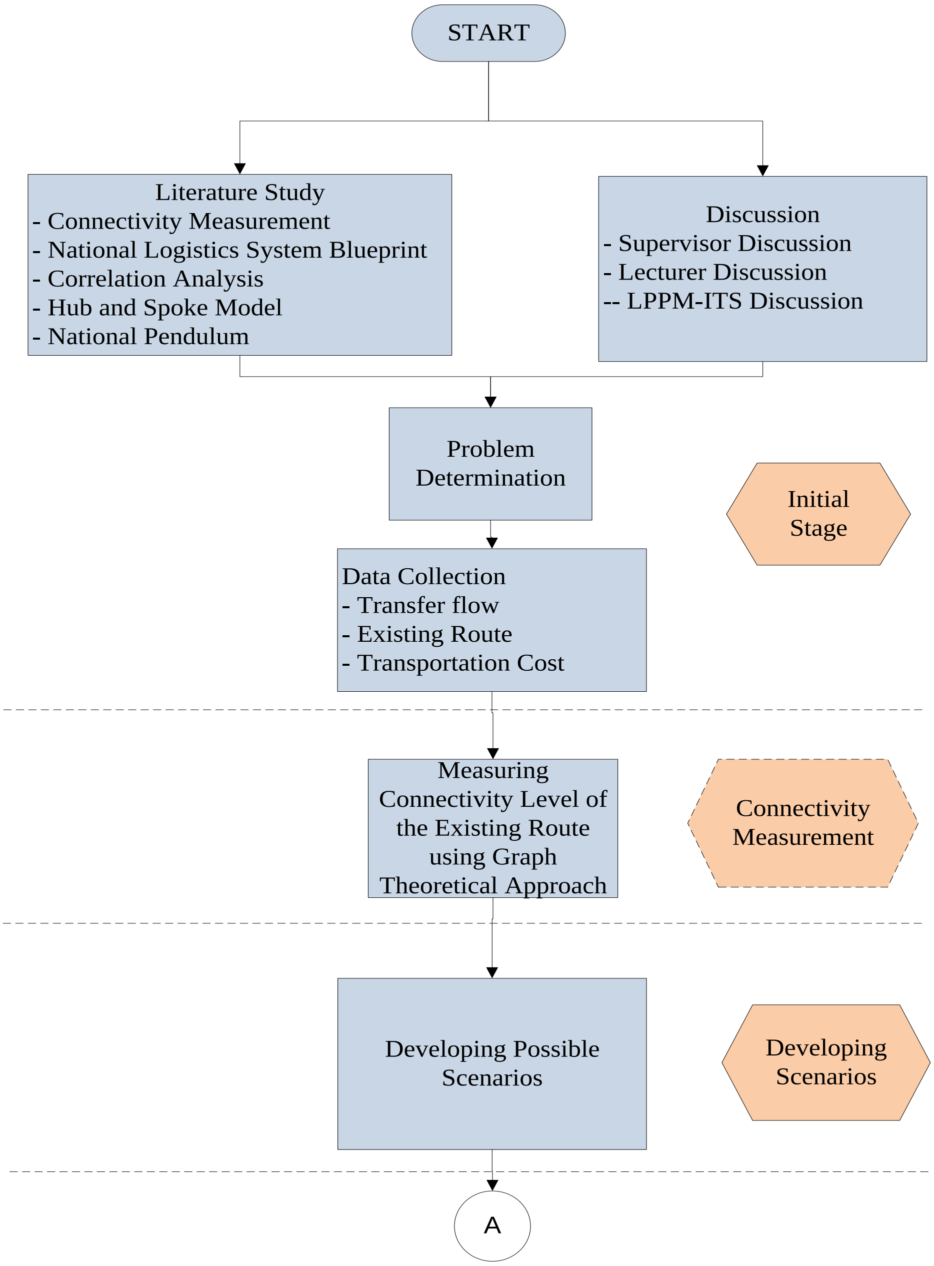


Figure 3.1 The Research Methodology (part 1)

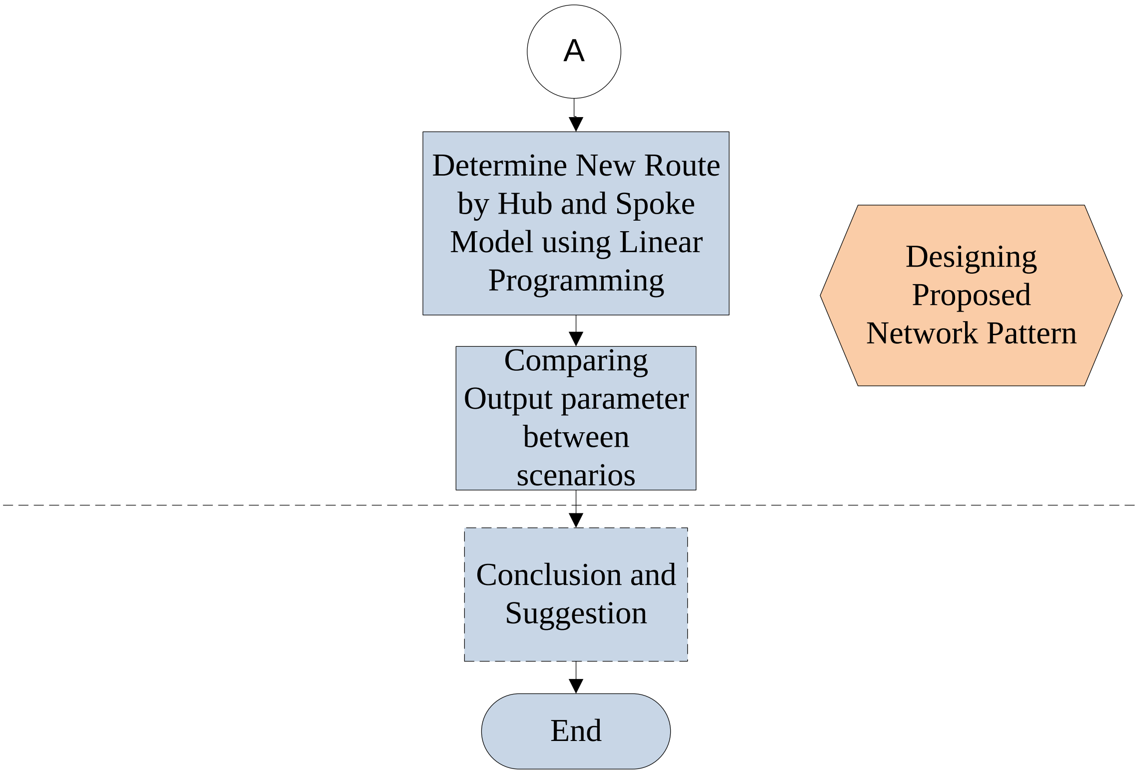


Figure 3.2 The Research Methodology (Part 2)

Mainly, the research is done in three steps, connectivity measurement, analysis of relationship between connectivity and transportation cost, and improvement using hub and spoke model.

3.1 Initial Stage

This initial stage consists of literature study, discussion, problem determination and data collection. The objectives of this stage to find the problem in Indonesia shipping network especially in eastern area, to find the related theory, and to collect the data to support this research.

3.1.1 Literature Study

This step conducted by studying literatures about national logistics system blueprint and Nusantara pendulum in order to find the existing problems in

Indonesia shipping network especially in eastern Indonesia. Besides that, this step also conducted by studying literatures and previous researches about connectivity measurement, correlation analysis to support the problem identification methods. Moreover, this step also studying literatures about hubs and spokes model to find the appropriate theories to design proposed network pattern. Those literatures are found in the journal articles, news, press release, books, and reports.

3.1.2 Discussions

The objective of this step is to find experts' judgments to supports this research besides the literature study. The discussions are conducted with several respondents such as supervisor of this research, the industrial engineering lecturer, and Institute of Research and Social Service (LPPM-ITS). The discussions are mostly about the problem identification and the methodology of the research.

3.1.3 Problem Determination

The results from discussions and literature study become the foundation to support this research. From those previous steps, problem that will be solved in this research can be determined. Moreover, the methodology and data needed to conduct this research is also chosen in this step.

3.1.4 Data Collection

In this step all of data needed is collected. The data needed for this research has big scope. Therefore, this research use secondary data, it means that this research does not conduct a survey or direct data collection. Most of the data in this research came from PT. Pelindo II and PT. Pelindo III. The data needed for this research are existing shipping network in eastern Indonesia, the transfer flow of goods in each seaports, transportation cost for each routes, capacity of each seaports, and the distance between seaports.

3.2 Connectivity Measurement

The first step of the research is measuring the existing routes connectivity level. As explained in the previous chapter, the connectivity is analyzed based on the route, speed, capacity, and frequency of the transfer. The connectivity measurement is conducted to all of 45 seaports in this research. This measurement is conducted in order to know the connectivity level of the existing routes and to provide data to do the analysis for the next steps.

There are three kinds of connectivity will be measured, the first is inbound connectivity level, outbound connectivity level, and total connectivity level. They are divided into three parts in order to make the improvement easier. If the inbound connectivity level is lower than the in-flow should be improved, vice versa. While total connectivity level shows which seaports needed more improvements.

3.3 Developing Scenarios

After the connectivity level of existing route is measured the next step is developing possible scenarios. To develop scenarios intensive research through literature and discussion should be done. The scenarios that have been developed will be tested in the next step.

3.4 Designing Proposed Network Pattern

After finding the factors that affect the transportation cost, the next step is designing new routes based on those factors using hub and spoke model.

3.4.1 Determine New Route by Hub and Spoke Model using Linear Programming

This model is focused on finding the nodes or ports that can become the hub or the main node that will connect the other nodes that become the spokes. In order to find the most optimal network, linear programming method is used. This method will determine which seaports are the most optimal hubs and which seaports become the spokes. Therefore, a new routes based on hub and spoke can be created and the connectivity level can be improved.

3.4.2 Comparing Output Parameter between Scenarios

After the scenarios are computed using hub and spoke model. The output parameters of each scenarios are compared to decide which scenario is the most appropriate to be applied in the real case.

3.5 Conclusion and Suggestion

The last step of this research is to conclude the results of the research and give recommendation. The conclusion answers the objectives of this research and recommendation for all stakeholder in logistics especially in maritime industries to make the best decision for improving the national logistics performance especially in eastern Indonesia.

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CHAPTER IV

DATA TABULATION AND PROCESSING

This chapter contains connectivity analysis of existing eastern Indonesia shipping network. Moreover, it also contains the designing process of proposed shipping network based on hub and spoke model.

4.1 Existing Condition of Eastern Indonesia Shipping Network

This subchapter discuss about the data collection of the existing shipping network. The data collected by using secondary data from PT. Pelindo III. This sub-chapter consists of existing shipping network, the number of seaports, and flow of containers in each seaports, and the connectivity analysis of existing network.

4.1.1 Existing Shipping Network

Eastern Indonesia shipping network is consists of 43 seaports that is divided into five classes based on administrative level and the work load of a seaports. Those 43 seaports that will be the object of this research. The existing container shipping network which is managed by PT. Pelindo I-IV in 2007 reach 7.6 million TEUs. This number consists of both international and national cargo. In this research the flow containers that considered are only from and to 43 seaports in east Indonesia that centralized in Tanjung Perak seaport. The flow of containers that was mentioned before is stated in Table 4.1 and Table 4.2 below.

Table 4.1 Container Flow In-Out Surabaya in 2014

No	**Seaports**	**Jumlah (TEUS) Sub-Out 2014**	**Jumlah (TEUS) Sub-in 2014**
1	Surabaya	212,860	209,755
2	Tual	571	2,549
3	Manokwari	889	2,331
4	Kaimana	2,984	1,222
5	Tenau	22,122	19,813
6	Sorong	2,434	787

(Source: PT. Pelindo III)

Table 4.2 Container Flow In-Out Surabaya in 2014 (Continued)

No	Seaports	Jumlah (TEUS) Sub-Out 2014	Jumlah (TEUS) Sub-in 2014
7	Ternate	592	1,425
8	Kendari	5,463	7,880
9	Bitung	2,067	1,281
10	Makassar	36,500	32,300
11	Pantoloan	1,472	3,515
12	Serui	598	-
13	Jayapura	3,543	3,164
14	Banjarmasin	58,505	62,906
15	Ambon	2,617	3,379
16	Tarakan	6,422	5,295
17	Bau-bau	1,470	478
18	Merauke	2,275	2,559
19	Balikpapan	7,658	9,420
20	Nabire	739	168
21	Biak	968	646
22	Sampit	10,376	8,693
23	Fak-fak	1,030	693
24	Gorontalo	1,066	719
25	Toli-Toli	629	172
26	Luwuk	1,185	1,369
27	Samarinda	13,720	12,885
28	Batulicin	749	100
29	Tobelo	215	318
30	Kupang	3,223	3,634
31	Kumai	5,764	4,751
32	Lembar	1,064	1,663
33	Ende, Flores	1,254	1,065
34	Larantuka	629	750
35	Timika	1,560	1,486
36	Maumere	6,274	6,334
37	Dili	1,562	1,423
38	Badas	-	184
39	Malili	73	159
40	Nunukan	359	271
41	Benoa	313	114
42	Benete	1,723	1,648
43	Waingapu	203	206

(Source: PT. Pelindo III)

As it can be inferred from Table 4.1 and Table 4.2 there are many ports in eastern Indonesia and the flow of container is not small. Total containers flow in and out Surabaya to eastern Indonesia seaports is 422.615 TEUs in 2013.However, that much number have not been integrated yet. The figure 4.1 shows the existing national container shipping network.

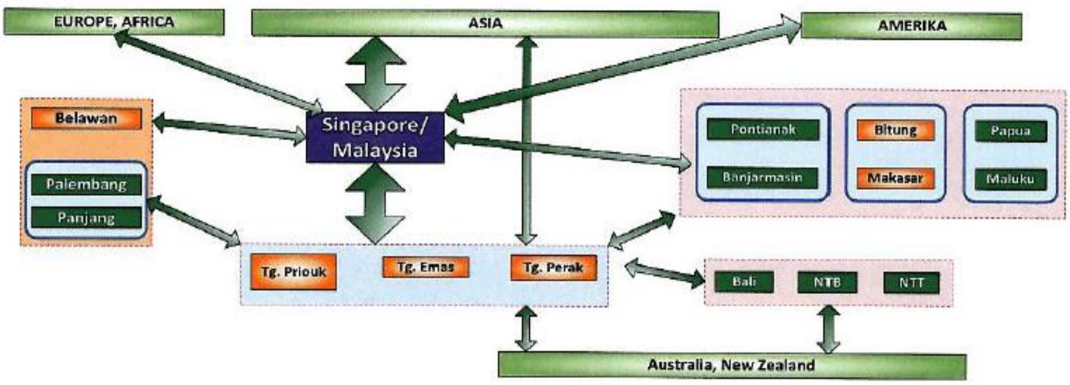


Figure 4.1 Existing National Container Shipp**ing Network (Peraturan Presiden RI, 2012)**

Figure 4.1 shows that the national container shipping network centralized on six major seaports, Belawan, Tanjung Priok, Tanjung Emas, Tanjung Perak, Bitung, and Makassar. However, it does not integrated to the smaller seaports. Consequently, the connectivity of each ports will be relatively low.

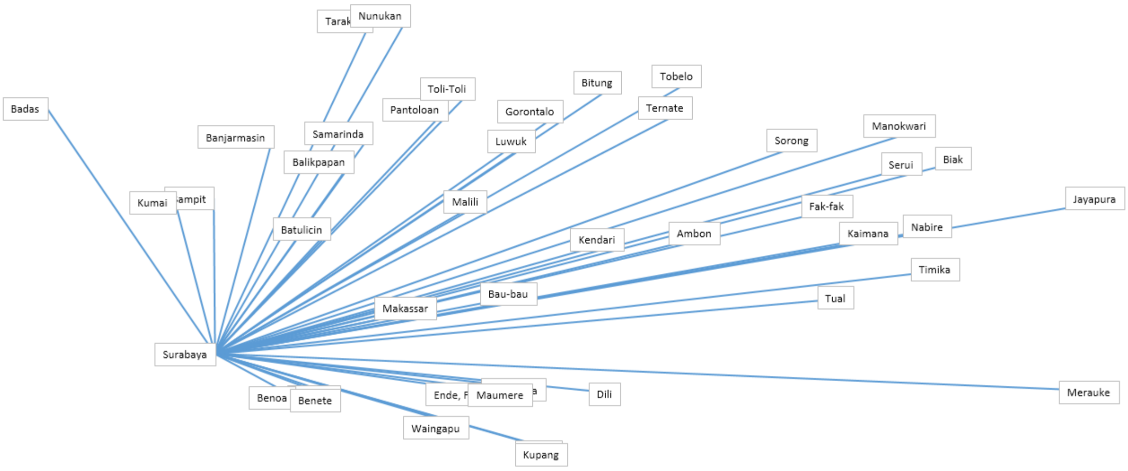


Figure 4.2 Existing Shipping Network

Figure 4.2 above shows the existing shipping network that centralized in Surabaya.

4.1.2 Existing Network Connectivity Analysis

The existing shipping network of eastern Indonesia seaports as mentioned in previous subchapter is not using any hub ports. It is centralized in Surabaya. Connectivity index as one of the main parameter of the quality of a transportation network is measured. Connectivity represents the transit performance of a network in order to assist decision makers to make priority in investment and deciding which nodes that need immediate attention. Moreover, to evaluate the transit performance.

To calculate the network connectivity, the first step is to calculate inbound and outbound connecting power of every nodes in the network using formula (1) and (2) that have been stated in chapter 2.

The inbound connecting power represents the quality of a nodes as a transit to connect the inbound flow to the node. After that average those connecting power to get the connectivity index of a node. Then the network connecting power is the sum of all nodes' connectivity index in the network. (Mishra, et al., 2012). The connecting power of seaports in eastern Indonesia is stated in Table 4.3 and 4.4 below.

Table 4.3 Node Connectivity Index of Seaports in Eastern Indonesia

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
1	Surabaya	40.271	(0.5694)
2	Tual	0.478	(0.6106)
3	Manokwari	0.520	(0.4722)
4	Kaimana	0.372	0.3069
5	Tenau	6.048	0.5774
6	Sorong	0.318	0.3220
7	Ternate	0.219	(0.1836)
8	Kendari	1.434	(0.5397)
9	Bitung	0.170	0.0774

Table 4.4 Node Connectivity Index of Seaports in Eastern Indonesia (Continued)

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
10	Makassar	5.723	0.6149
11	Pantoloan	0.833	(0.6925)
12	Serui	0.121	0.2415
13	Jayapura	0.382	0.0376
14	Banjarmasin	12.061	(1.0514)
15	Ambon	0.501	(0.1345)
16	Tarakan	0.831	0.1477
17	Bau-bau	0.376	0.3784
18	Merauke	0.254	(0.0336)
19	Balikpapan	2.318	(0.5120)
20	Nabire	0.145	0.1816
21	Biak	0.049	0.0187
22	Sampit	2.863	0.4637
23	Fak-fak	0.167	0.0631
24	Gorontalo	0.159	0.0595
25	Toli-Toli	0.067	0.0758
26	Luwuk	0.157	(0.0249)
27	Samarinda	0.819	0.0394
28	Batulicin	0.122	0.1864
29	Tobelo	0.046	(0.0184)
30	Kupang	0.196	(0.0264)
31	Kumai	0.262	0.0467
32	Lembar	0.144	(0.0655)
33	Ende, Flores	0.159	0.0236
34	Larantuka	0.205	(0.0389)
35	Timika	0.190	0.0065
36	Maumere	0.977	(0.0236)
37	Dili	0.161	0.0126
38	Badas	0.012	(0.0237)
39	Malili	0.018	(0.0139)
40	Nunukan	0.013	0.0035
41	Benoa	0.011	0.0102
42	Benete	0.199	0.0059
43	Waingapu	0.171	(0.0050)

From Table 4.3 and 4.4 above it can be inferred that there are some ports that already have good connectivity index such as Banjarmasin, Makassar, Tenau and Surabaya. The total connectivity index for the existing network is 80,542 with mean 1.875. However, the standard deviation is very high it reach 6.373. It means that the connectivity index is not equally distributed but only centralized in Surabaya. For transit network this is not appropriate. There should be more transit ports that have relatively equal connectivity index.

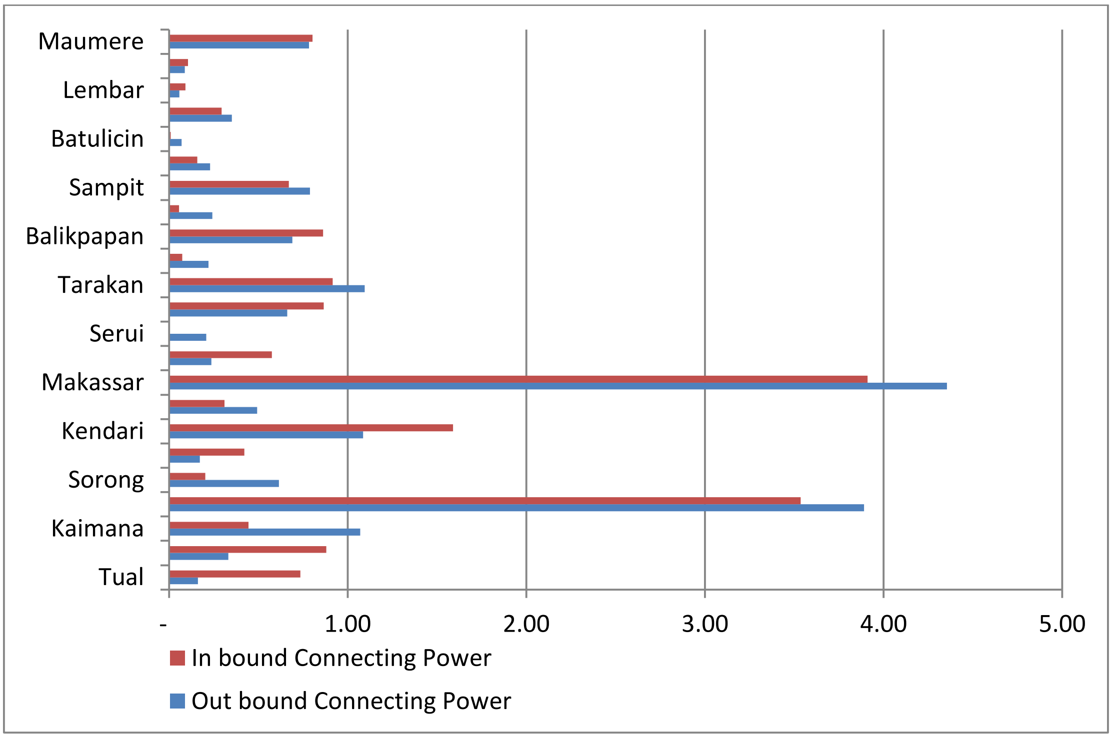


Figure 4.3 Graph of Existing Seaports' Inbound and Outbound Connecting Power

Moreover, as can be seen from the Figure 4.3, the difference of Outbound and Inbound connecting power in each seaports is relatively wide. This is also inappropriate, because inequality of connecting power means there will be empty ship transfer to the node. Consequently, the transportation cost will be higher.

4.2 Optimization Model Formulation

Based on the calculation in the previous sub-chapter the existing condition of eastern Indonesia shipping network is not optimal. Therefore, this research design proposed network that will improve the quality of the network based on connectivity and demand weighted distance.

4.2.1 P-Median Problem Model

The objective of P-Median Problem Model (PMP) is to minimize the total demand weighted distance that is closely related goal to high quality of service. The PMP and its extensions are beneficial to model many real world conditions such as the location of plants, warehouses, and other public facilities (Kim, 2011). PMP model is used to design the hub-and-spoke seaports shipping network. In general, the hub location in hub and spoke network is determined by modelling hub location problem in which the total transportation cost is minimized with the given demand between all origin and destination pairs. Due to a single destination in this case Surabaya as the main port, the hub location decision is accomplished by solving PMP.

There are some limitations that should be set to design hub-and-spoke model for this problem. The limitations are:

1. The ports that included in Eastern Indonesia are 43 ports in east and south Kalimantan, east Java, and Sulawesi, Papua, Bali, Lombok, Ambon Island.
2. The type of shipping for this research is containers distribution network through sea transportation while bulk type of shipping is not observed.
3. This research only observed the container flow network limited from and to Surabaya.
4. The data available are the demand from and to Surabaya and distance matrix from and to all seaports.

There are also some assumptions to solve this problem. The assumptions are:

1. There is no other demand from other seaports to another seaports except to Surabaya.

After the assumptions and limitation are already set. The P-Median Problem model designed to solve this problem is.

Minimize:

$$\sum_i \sum_j s_i d_{ij} Y_{ij} \tag{7}$$

Subject to

$$\sum_j Y_{ij} = 1 \tag{8}$$

$$Y_{ij} - X_j \leq 0 \tag{9}$$

$$\sum_j X_j = P \tag{10}$$

$$X_j = 0{,}1 \tag{11}$$

$$Y_{i,j} = 0{,}1 \tag{12}$$

Where:

s_i = demand at port i

d_{ij} = distance between port i and potential hub location j

P = number of hubs to locate

X_j = 1, if hub is located at potential hub location j
0, otherwise

Y_{ij} = 1, if demand at port i is serviced by hub location j
0, otherwise

The objective function (7) this objective function will shows the hubs and spokes location based on minimum demand-weighted distance. The constraint (8) ensures that each seaport is clustered into exactly one hub. The constraint (9) requires that demand at seaport i can only be assigned to a hub j if a hub is located at stop j. The constraint (10) guarantees that the P number of hubs should be located. The constraint (11) and (12) represent that all variables must be binary (Kim, 2011).

Mathematical model above is translated to Lingo using data from PT. Pelindo III in 2013. The Lingo Model is:

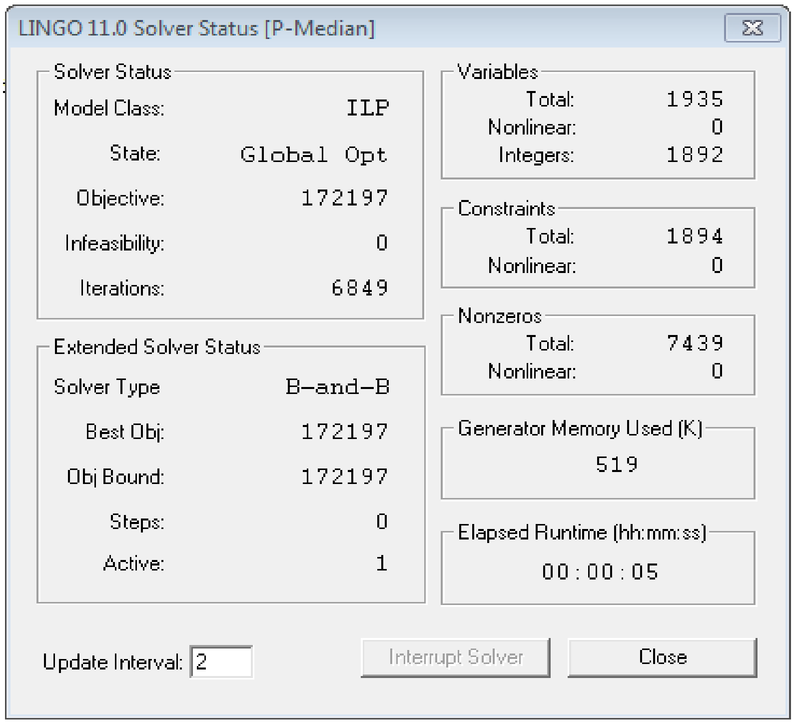
```
sets:
ports/1..43/:demand,x;
route(ports, ports):distance,y;
endsets

data:
demand = @OLE ('D:\Kuliah Odhi\Bismillah Tugas Akhir\Hitung Hub
and Spoke 2.xls');
distance = @OLE ('D:\Kuliah Odhi\Bismillah Tugas Akhir\Hitung Hub
and Spoke 2.xls');

enddata
[OBJ] Min=@Sum(route(i,j):y(i,j)*distance(i,j)*demand(i));
@For(ports(i):
@Sum(ports(j):y(i,j))=1;);
@For(route(i,j):y(i,j)-x(j)<=0;);
@Sum(ports(j):x(j))=3;
@for(ports:@bin(x));
@for(route:@bin(y));
END
```

4.2.2 Verification of Optimization Model

After the optimization model is made, then verification test is conducted in order to verify whether the model that have been made in the Lingo language is already appropriate and can be run.



LINGO 11.0 Solver Status [P-Median]

Solver Status
Model Class: ILP
State: Global Opt
Objective: 172197
Infeasibility: 0
Iterations: 6849

Extended Solver Status
Solver Type B-and-B
Best Obj: 172197
Obj Bound: 172197
Steps: 0
Active: 1

Variables
Total: 1935
Nonlinear: 0
Integers: 1892

Constraints
Total: 1894
Nonlinear: 0

Nonzeros
Total: 7439
Nonlinear: 0

Generator Memory Used (K)
519

Elapsed Runtime (hh:mm:ss)
00:00:05

Update Interval: 2

Figure 4.4 Solver Status of Optimization Model

In Lingo software there is a dialog box like in Figure 4.4 that shows there are no errors that means the model is verified.

4.2.3 Validation of Optimization Model

A model is called valid if it can give trusted prediction from the process of a system, besides that it also validates whether the model is already identical to the real condition or not. Methods that usually used to validates the model is to compare the result with the available historical data.

The first method used it to compare the result of computation using Lingo with the real condition. Here are the result of computation using Lingo in the existing condition (Surabaya as single hub), the parameter set that $\sum_j X_j = 1$, and X_1 (Surabaya) = 1.

Table 4.5 Comparison between Linear Programming and Existing Condition

No	Parameter	Linear Programming Result	Existing Condition
1	Number of Hub	1	1
2	Hub Port	Surabaya	Surabaya
3	Total Demand Weighted Distance	470676	470676

From the Table 4.5 it can be inferred that the result of linear programming that the parameter have been modified to the existing condition is the same with the existing condition. Therefore, it can be concluded that the model is valid.

4.3 Improvement Scenarios

To design better shipping network, in this research there are three scenarios developed based on the government planning, and the possible solutions that can applied in the real condition.

4.3.1 Scenario I: P-Median Problem Solution

Scenario I that can be applied to design proposed shipping network is purely based on the P-Median Problem optimization model. There is no constraint for capacity or limitation of the seaports that can be chosen as hubs seaports. This scenario is developed in order to find the most optimal solution for the network and to find the seaports that should be developed more to get the best network design.

4.3.1.1 Scenario I Result from Optimization Model

The result from the optimization model is a set of spokes with its hub seaports. The distance between the spokes and its hub should be distributed fairly and minimum. The larger number of hubs is capable to increase the fairness and decrease the total demand weighted distance. However, too many sets of hubs locations makes it difficult to establish an effective routing plan from hub to destination (Surabaya). In addition, an excessive number of hubs would increase long travel distance from hubs to Surabaya while relatively short distance can be accomplished using small number of hub. Moreover, the larger number of hubs means that there will be more investments needed to increase the performance of the ports to reach the desired level of a hub ports. Therefore, this research choose 3 hubs to locate because it is appropriate with the government development plant. The result of optimization model is stated in Table 4.6 below.

Table 4.6 Scenario I Set of Hubs and its Spokes

Hub Bau-Bau		**Hub Fak-Fak**		**Hub Batu Licin**	
Spokes		**Spokes**		**Spokes**	
1	Tenau	1	Tual	1	Surabaya
2	Kendari	2	Manokwari	2	Pantoloan
3	Bitung	3	Kaimana	3	Banjarmasin
4	Makassar	4	Sorong	4	Tarakan
5	Fak-Fak	5	Ternate	5	Bau-bau
6	Gorontalo	6	Serui	6	Balikpapan
7	Luwuk	7	Jayapura	7	Sampit
8	Batulicin	8	Ambon	8	Toli-toli
9	Kupang	9	Merauke	9	Samarinda
10	Ende, Flores	10	Nabire	10	Kumai
11	Larantuka	11	Biak	11	Lembar
12	Maumere	12	Tobelo	12	Badas
13	Dili	13	Timika	13	Nunukan
14	Malili			14	Benoa
15	Waingapu			15	Benete

In the Table 4.6 above is the sets of hubs and its spokes results from the scenario I computation. There are three hubs, the first hub is Bau-Bau with 15 seaports as its spokes, the second hub is Fak-Fak with 13 seaports as its spokes, the third hub is Batu Licin with 15 seaports as its spokes. While Surabaya as destination port is included in Batu Licin hub. Consequently, all ships from other hubs should enter Batu Licin first then goes to Surabaya. The main line of the first scenario is

Fak-Fak – Bau-Bau – Batu Licin – Surabaya. Illustration for scenario I is described in Figure 4.5 below.

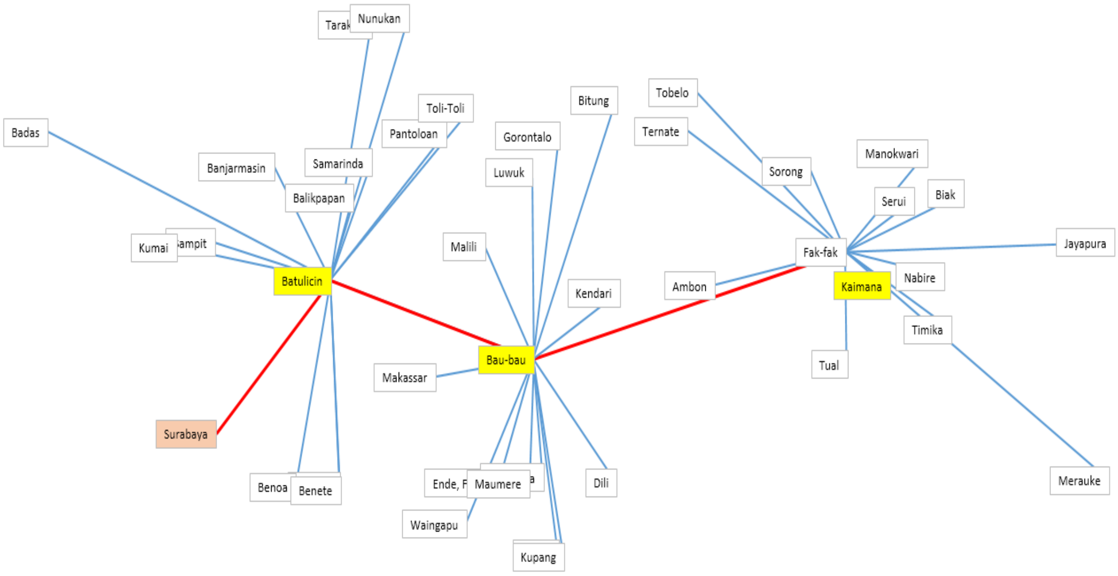


Figure 4.5 Shipping Network for Scenario I

The output parameter for scenario I is stated in Table 4.7 below.

Table 4.7. Output Parameter of Scenario I (TEUs/Year)

Hubs	**Max Consolidated Demand**	**Cons. Demand In**	**Cons. Demand Out**	**Difference Cons. Out-In**
Hub Bau-Bau	86682	77726	83400	5674
Hub Fak-Fak	25387	20034	19985	(49)
Hub Batu licin	118464	111995	109475	(2520)
Main Line Distance (miles)	**1521.431**			
Total Demand Weighted Distance	**173142.693**			

From Table 4.7 it can be inferred that total demand weighted distance is 17342.693 and the main line distance from Fak-Fak. Bau-Bau, Batu licin Surabaya is 1521.431 miles. However, the difference in consolidated demand in the hubs is still large.

4.3.1.2 Scenario I Connectivity Analysis

Connectivity of scenario I shipping network is likely to have more value than the existing condition, because in scenario I there are 3 hubs that become the transit ports. The hubs ports are Bau-Bau, Fak-Fak, and Batu Licin. The number of transit ports will increase the connectivity because the network flow is not centralized into one port anymore, it is divided to the hubs that already mentioned before. Table 4.8 shows the recapitulation of connectivity index in each ports.

Table 4.8 Node Connectivity Index of Seaports in Scenario I

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
1	Surabaya	11.057	0.026
2	Pantoloan	0.122	(0.101)
3	Banjarmasin	1.724	(0.146)
4	Tarakan	0.354	0.064
5	Balikpapan	0.141	(0.031)
6	Sampit	0.334	0.055
7	Toli-Toli	0.023	0.026
8	Samarinda	0.324	0.016
9	Kumai	0.194	0.035
10	Lembar	0.057	(0.026)
11	Badas	0.007	(0.015)
12	Nunukan	0.020	0.005
13	Benoa	0.009	0.008
14	Benete	0.086	0.003
15	Tenau	0.999	0.098
16	Kendari	0.199	(0.075)
17	Bitung	0.114	0.052
18	Makassar	1.166	0.128
19	Gorontalo	0.051	0.019
20	Luwuk	0.059	(0.009)
21	Kupang	0.136	(0.018)
22	Ende, Flores	0.035	0.005
23	Larantuka	0.017	(0.003)
24	Maumere	0.155	(0.003)
25	Dili	0.050	0.004
26	Malili	0.003	(0.002)

Table 4.9 Node Connectivity Index of Seaports in Scenario I (Continued)

No	**Seaports**	**Node Connectivity Index**	**Difference Outbound-Inbound Connecting Power**
27	Waingapu	0.008	(0.000)
28	Tual	0.039	(0.049)
29	Manokwari	0.054	(0.049)
30	Kaimana	0.033	0.028
31	Sorong	0.029	0.029
32	Ternate	0.064	(0.053)
33	Serui	0.007	0.015
34	Jayapura	0.303	0.030
35	Ambon	0.121	(0.032)
36	Merauke	0.230	(0.030)
37	Nabire	0.012	0.016
38	Biak	0.028	0.011
39	Tobelo	0.016	(0.006)
40	Timika	0.049	0.002
41	Bau-bau	35.563	0.271
42	Fak-fak	33.554	(0.014)
43	Batulicin	47.023	(0.006)

From the table 4.9 above the connectivity for the hub ports are very high it reach 35.563, 33.554, and 47.023 for Bau-bau, Fak-fak, Batulicin respectively. While the destination port Surabaya still relatively high connectivity. However, the other ports connectivity is decreased. While for the comparison between outbound and inbound connecting power can be seen in the graph below.

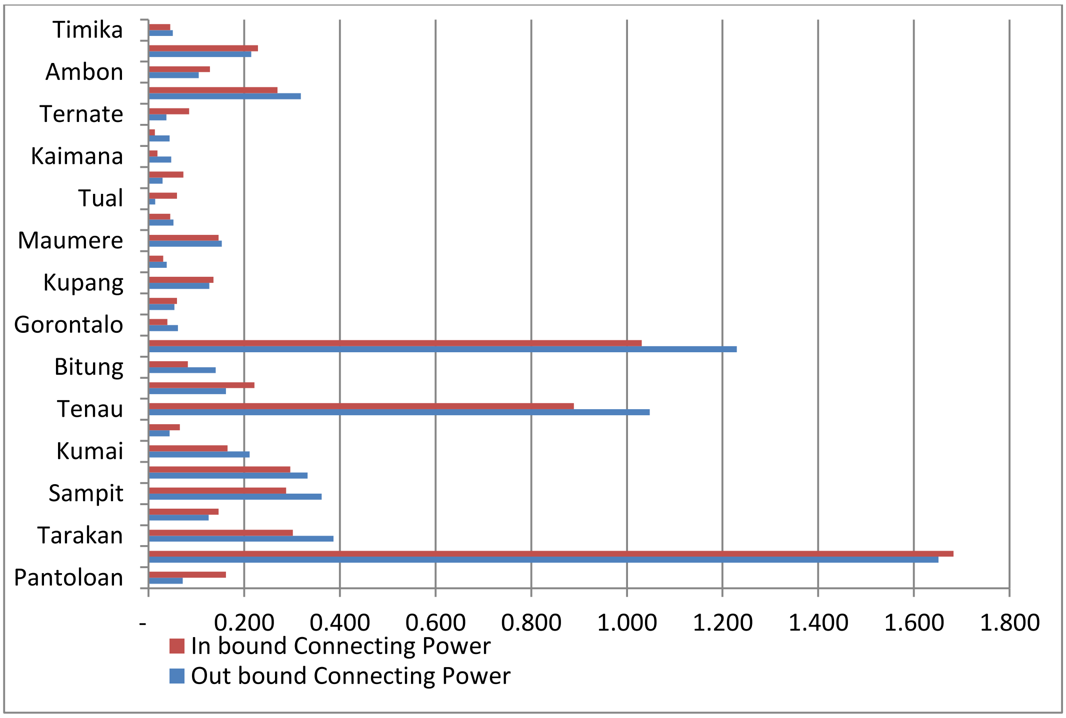


Figure 4.6 Graph of Scenario I Seaports' Inbound-Outbound Connecting Power

From the graph above it can be inferred that there are still gap between outbound and inbound connecting power. However, it is slightly decreased compare to the existing condition.

4.3.2 Scenario II: Main Class and First Class Seaports as Candidate Hubs

The next scenario that can be applied is making the main class and first class seaports as the candidate hubs. The main class and first class seaports are classification based on the administrative level and organization structure of a seaport. This classification also based on the existing workload of a seaport. Therefore, main class and first class seaports is the appropriate candidate hubs because they already has the administration level ready for busy flow of goods in the seaports. Since, hub seaports consolidate the demands from the its spokes ports.

4.3.2.1 Scenario II Result from Optimization Model

Scenario II for designing proposed network is using main class and first class seaports as candidates for hubs. From 43 seaports in this research there are 2 main class seaports and 6 first class seaports. The main class seaports are Surabaya and Makassar, while first class seaports are Benoa, Banjarmasin, Balikpapan, Bitung, Ambon, and Sorong. From the result of optimization model the network is illustrated in Figure 4.7 below.

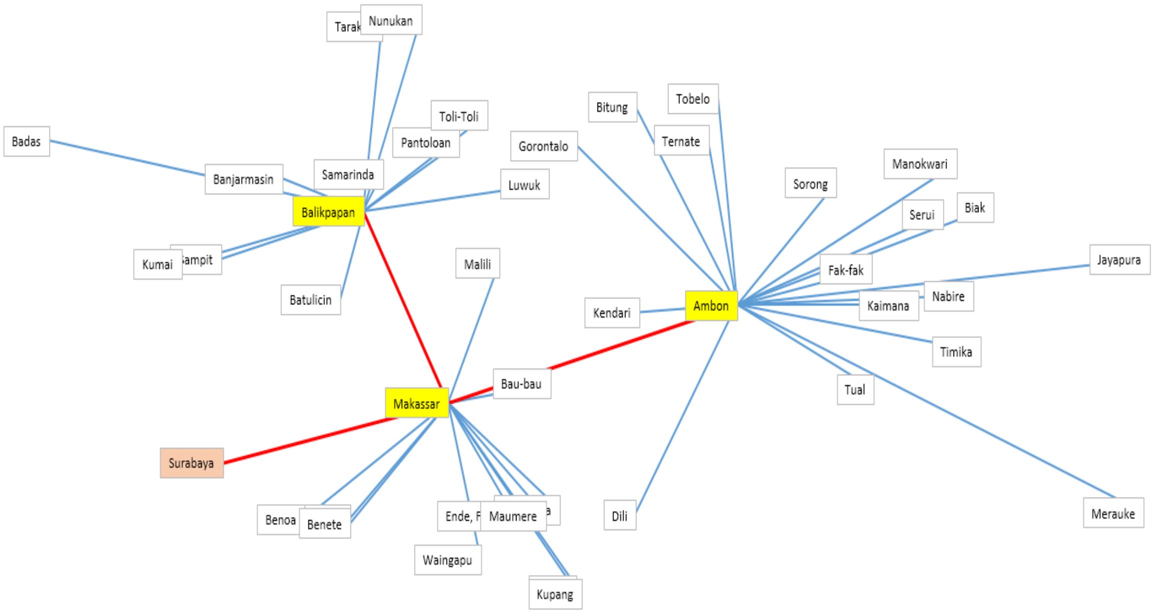


Figure 4.7 Shipping Network for Scenario II

The selected set of hubs and its spoke are stated in Table 4.10 below.

Table 4.10 Set of Hubs and Spokes from Scenario II

Hub Makassar		**Hub Ambon**		**Hub Balikpapan**	
Spokes		**Spokes**		**Spokes**	
1	Surabaya	1	Tual	1	Makassar
2	Tenau	2	Manokwari	2	Pantoloan
3	Ambon	3	Kaimana	3	Banjarmasin
4	Bau-Bau	4	Sorong	4	Tarakan
5	Balikpapan	5	Ternate	5	Sampit
6	Kupang	6	Kendari	6	Toli-Toli
7	Lembar	7	Bitung	7	Luwuk
8	Ende, Flores	8	Serui	8	Samarinda
9	Larantuka	9	Jayapura	9	Batulicin
10	Maumere	10	Merauke	10	Kumai
11	Malili	11	Nabire	11	Badas

Table 4.11 Set of Hubs and Spokes from Scenario II (Continued)

Hub Makassar		**Hub Ambon**		**Hub Balikpapan**	
Spokes		**Spokes**		**Spokes**	
12	Benoa	12	Biak	12	Nunukan
13	Benete	13	Fak-Fak		
14	Waingapu	14	Gorontalo		
		15	Tobelo		
		16	Timika		
		17	Dili		

From the Table 4.11 it can be inferred that the chosen hubs for scenario II is Makassar that has 14 ports as its spokes, Ambon that has 17 ports as its spokes, and Balikpapan that has 12 ports as its spokes. While Surabaya as the destination ports is included in Makassar hub. Therefore the main line for scenario II is Ambon – Balikpapan - Makassar – Surabaya. Consequently, the ships that goes to Surabaya from both Ambon and Balikpapan hubs have to straightly consolidated in Makassar first then go to Surabaya. Moreover, the output parameter for scenario II is stated in Table 4.12 below.

Table 4.12 Output Parameter of Scenario II TEUs/Year

Hubs	**Max Consolidated Demand**	**Cons. Demand In**	**Cons. Demand Out**	**Difference Cons. Out-In**
Hub Makassar	52427	48663	48623	(40)
Hub Ambon	35613	28651	28556	(95)
Hub Balikpapan	141864	132441	135681	3240
Main Line Distance (miles)	**1470.696**			
Total Demand Weighted Distance	**204462**			

From the table 4.12 above it can be inferred that the total demand weighted distance is 204462 and total distance between hubs until reach the destination port Surabaya is 1470.696 miles.

4.3.2.2 Scenario II Connectivity Analysis

In the scenario II there will be three hubs Ambon, Makassar and Balikpapan. Makassar and Balikpapan hubs in the existing condition already have relatively high connectivity. Therefore, the total connectivity index in the shipping network of scenario II is likely not as high as the scenario I. The connectivity of each seaports in scenario II is stated in Table 4.13 below.

Table 4.13 Connectivity Index of Seaports in Scenario II

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
1	Tual	0.051	(0.0646)
2	Manokwari	0.089	(0.0807)
3	Kaimana	0.090	0.0743
4	Sorong	0.041	0.0411
5	Ternate	0.034	(0.0284)
6	Kendari	0.145	(0.0546)
7	Bitung	0.069	0.0315
8	Serui	0.015	0.0292
9	Jayapura	0.352	0.0343
10	Merauke	0.236	(0.0314)
11	Nabire	0.022	0.0273
12	Biak	0.043	0.0165
13	Fak-fak	0.027	0.0103
14	Gorontalo	0.045	0.0166
15	Tobelo	0.010	(0.0040)
16	Timika	0.074	0.0025
17	Dili	0.052	0.0040
18	Pantoloan	0.063	(0.0524)
19	Banjarmasin	1.024	(0.0903)
20	Tarakan	0.185	0.0328
21	Sampit	0.300	0.0482
22	Toli-Toli	0.013	0.0147
23	Luwuk	0.058	(0.0092)
24	Samarinda	0.085	0.0040
25	Batulicin	0.008	0.0117
26	Kumai	0.169	0.0300
27	Badas	0.006	(0.0114)

Table 4.14 Connectivity Index of Seaports in Scenario II (Continued)

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
28	Nunukan	0.011	0.0029
29	Makassar	29.508	0.0520
30	Ambon	19.614	0.0058
31	Balikpapan	20.132	(0.0399)
32	Surabaya	9.900	(0.0098)
33	Tenau	0.941	0.0889
34	Bau-bau	0.022	0.0222
35	Kupang	0.128	(0.0174)
36	Lembar	0.034	(0.0152)
37	Ende, Flores	0.026	0.0038
38	Larantuka	0.019	(0.0036)
39	Maumere	0.152	(0.0038)
40	Malili	0.003	(0.0022)
41	Benoa	0.007	0.0060
42	Benete	0.050	0.0014
43	Waingapu	0.005	(0.0002)

As in the scenario I the connectivity index for hubs is much higher than the other ports. Makassar has the highest connectivity (29.508) because it connects two hubs Ambon and Balikpapan to destination ports Surabaya. While Ambon and Balikpapan has relatively same connectivity. While the difference between outbound and inbound connecting power is stated in Figure 4.8 below.

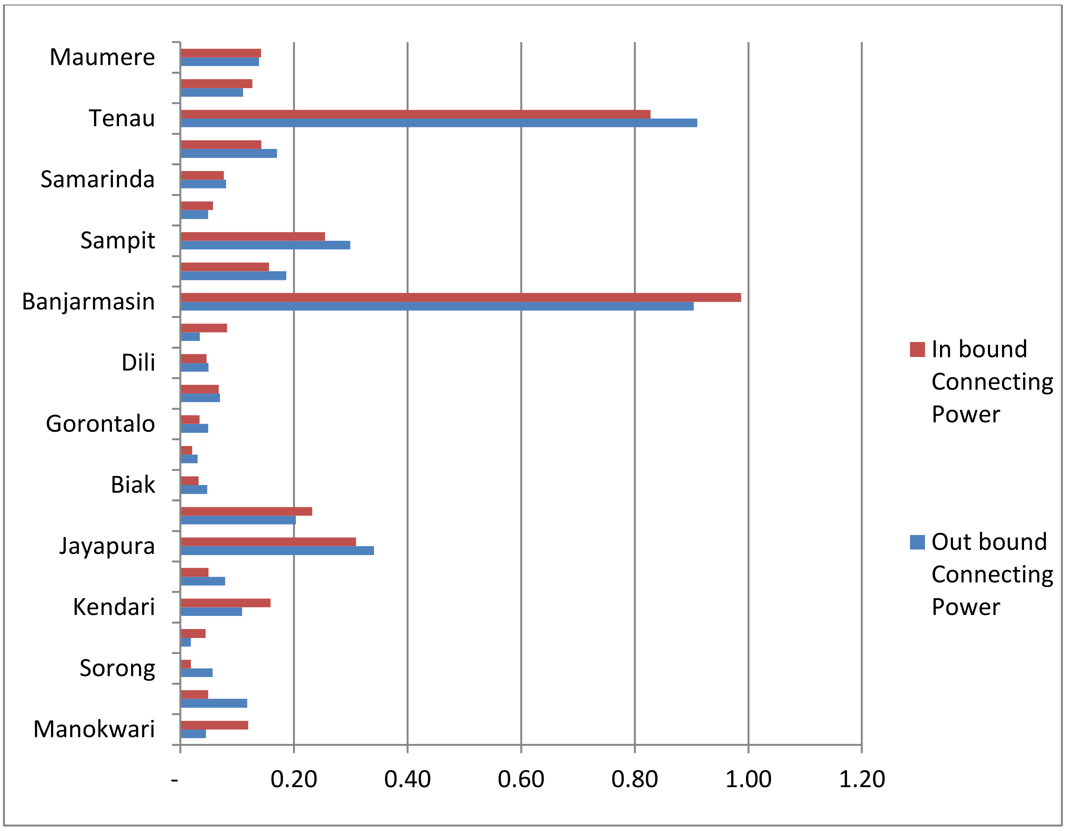


Figure 4.8 Graph of Outbound and Inbound Connecting Power

There is still difference in outbound and inbound connecting power. However, the objective of the proposed shipping network is still achieved. The highest difference is only 0.093 in Banjarmasin.

4.3.3 Scenario III: Nusantara Pendulum (Surabaya, Makassar, and Sorong as Hubs)

The last scenario is using Pendulum Nusantara concept that is developed by PT. Pelindo II or IPC. In this concept, the route will be Belawan – Tanjung Priok – Tanjung Perak – Makassar – Sorong. In this research only Tanjung Perak (Surabaya), Makassar and Sorong will be considered as hubs. This scenario is used to know which ports that will be the spokes for the Pendulum Nusantara hubs and how much it affect the connectivity in the shipping network.

4.3.3.1 Scenario III Result from Optimization Model

The seaports used as hubs in Pendulum Nusantara is main class (Surabaya and Makassar) and first class (Sorong) seaports. Pendulum Nusantara concept is believed to reduce the transportation cost. Therefore, in this research the objective function is to minimize the demand weighted distance. Although it is simpler than the transportation cost it also can be used to find more efficient shipping network. The result from optimization model for scenario III is stated in Table 4.15 and 4.16 below.

Table 4.15 Set of Hubs and Spokes for Scenario III

Hub Surabaya		**Hub Sorong**		**Hub Makassar**	
Spokes		**Spokes**		**Spokes**	
1	Makasssar	1	Tual	1	Surabaya
2	Banjarmasin	2	Manokwari	2	Tenau
3	Sampit	3	Kaimana	3	Sorong
4	Kumai	4	Ternate	4	Kendari
5	Badas	5	Bitung	5	Pantoloan
6	Benoa	6	Serui	6	Tarakan
		7	Jayapura	7	Bau-Bau
		8	Ambon	8	Balikpapan
		9	Merauke	9	Gorontalo
		10	Nabire	10	Toli-Toli
		11	Biak	11	Luwuk
		12	Fak-Fak	12	Samarinda
		13	Tobelo	13	Batulicin
		14	Timika	14	Kupang
				15	Lembar
				16	Ende, Flores
				17	Larantuka
				18	Maumere
				19	Dili
				20	Malili
				21	Nunukan
				22	Benete
				23	Waingapu

From the result of optimization model the network is illustrated in Figure 4.9 below.

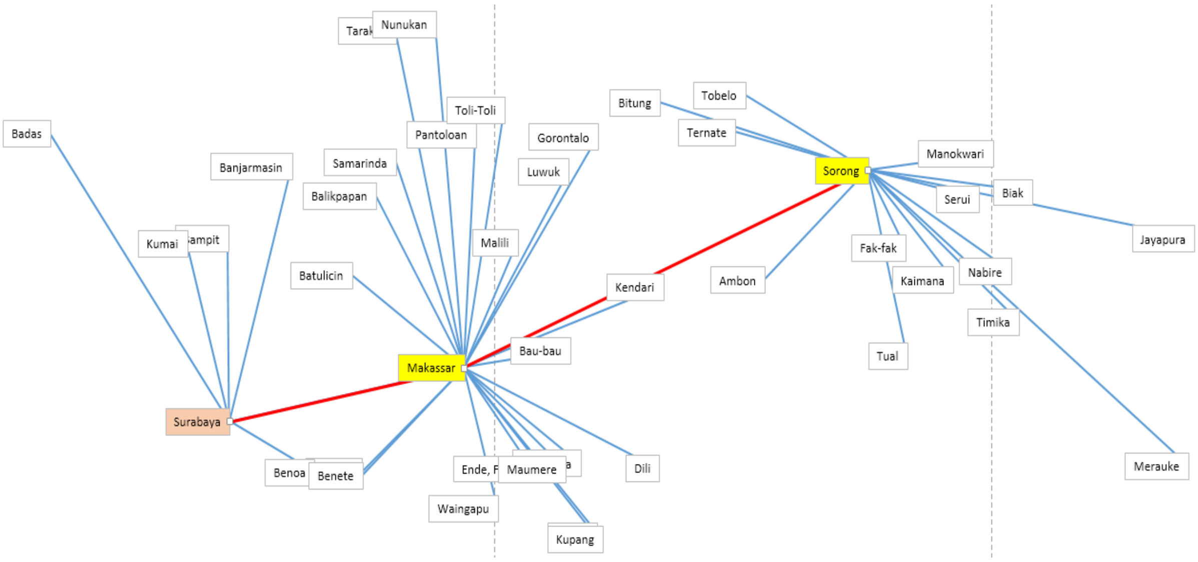


Figure 4.9 Shipping Network for Scenario III

The result from computation with Lingo, Makassar has the most number of spokes, there are 23 spokes associated with Makassar as its hub. While Sorong only 14 seaports as its spokes, and seaports that straightly goes to the destination ports Surabaya is only 6 including Makassar. The main line of this scenario as stated before is Sorong – Makassar – Surabaya. While the output parameter for this scenario is stated in Table 4.17 below.

Table 4.17 Output Parameters of Scenario III TEUs/Year

Hubs	**Max Consolidated Demand**	**Cons. Demand In**	**Cons. Demand Out**	**Difference Cons. Out-In**
Hub Surabaya	116043	108948	111458	2510
Hub Sorong	26050	21221	20648	(573)
Hub Makassar	88440	79586	80754	1168
Main Line Distance (miles)	**1371.097**			
Total Demand Weighted Distance	**252880**			

From the Table 4.17 it can be inferred that Surabaya has the highest density from all hubs. The consolidated demand from its spokes is 116043 TEUs/Year. The spoke that goes directly to Surabaya has high flow container. While Sorong is the lowest from all hubs.

4.3.3.2 Scenario III Connectivity Analysis

Pendulum Nusantara concept has not been analysis its connectivity in the previous researches. In this research, the network design of Pendulum Nusantara will be analyzed its effect on the connectivity of the whole shipping network. Table 4.18 shows the connectivity measurement for scenario III.

Table 4.18 Connectivity Index of Seaports in Scenario III

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
1	Surabaya	47.182	0.1688
2	Sorong	43.650	0.3453
3	Makassar	47.165	0.3552
4	Tenau	1.541	0.1608
5	Kendari	0.495	(0.1819)
6	Pantoloan	0.187	(0.1543)
7	Tarakan	0.622	0.1160
8	Bau-bau	0.036	0.0367
9	Balikpapan	0.438	(0.0929)
10	Gorontalo	0.083	0.0318
11	Toli-Toli	0.032	0.0367
12	Luwuk	0.097	(0.0145)
13	Samarinda	0.752	0.0428
14	Batulicin	0.024	0.0362
15	Kupang	0.210	(0.0264)
16	Lembar	0.055	(0.0244)
17	Ende, Flores	0.042	0.0066
18	Larantuka	0.031	(0.0056)
19	Maumere	0.249	(0.0038)
20	Dili	0.100	0.0087

No	Seaports	Node Connectivity Index	Difference Outbound-Inbound Connecting Power
21	Malili	0.005	(0.0036)
22	Nunukan	0.034	0.0092
23	Benete	0.082	0.0032
24	Waingapu	0.009	(0.0002)
25	Tual	0.087	(0.1108)
26	Manokwari	0.068	(0.0611)
27	Kaimana	0.103	0.0854
28	Ternate	0.056	(0.0465)
29	Bitung	0.129	0.0596
30	Serui	0.012	0.0246
31	Jayapura	0.442	0.0474
32	Ambon	0.153	(0.0398)
33	Merauke	0.353	(0.0436)
34	Nabire	0.025	0.0310
35	Biak	0.042	0.0167
36	Fak-fak	0.025	0.0096
37	Tobelo	0.014	(0.0054)
38	Timika	0.097	0.0041
39	Banjarmasin	4.304	(0.3369)
40	Sampit	0.568	0.0969
41	Kumai	0.251	0.0470
42	Badas	0.009	(0.0181)
43	Benoa	0.007	0.0061

From the result of connectivity measurement, Pendulum Nusantara concept has high connectivity index. The hubs has more than 40 connectivity index. The total connectivity index of the network reach 149.862. While the difference in connecting power is shown in the graph at Figure 4.6 below.

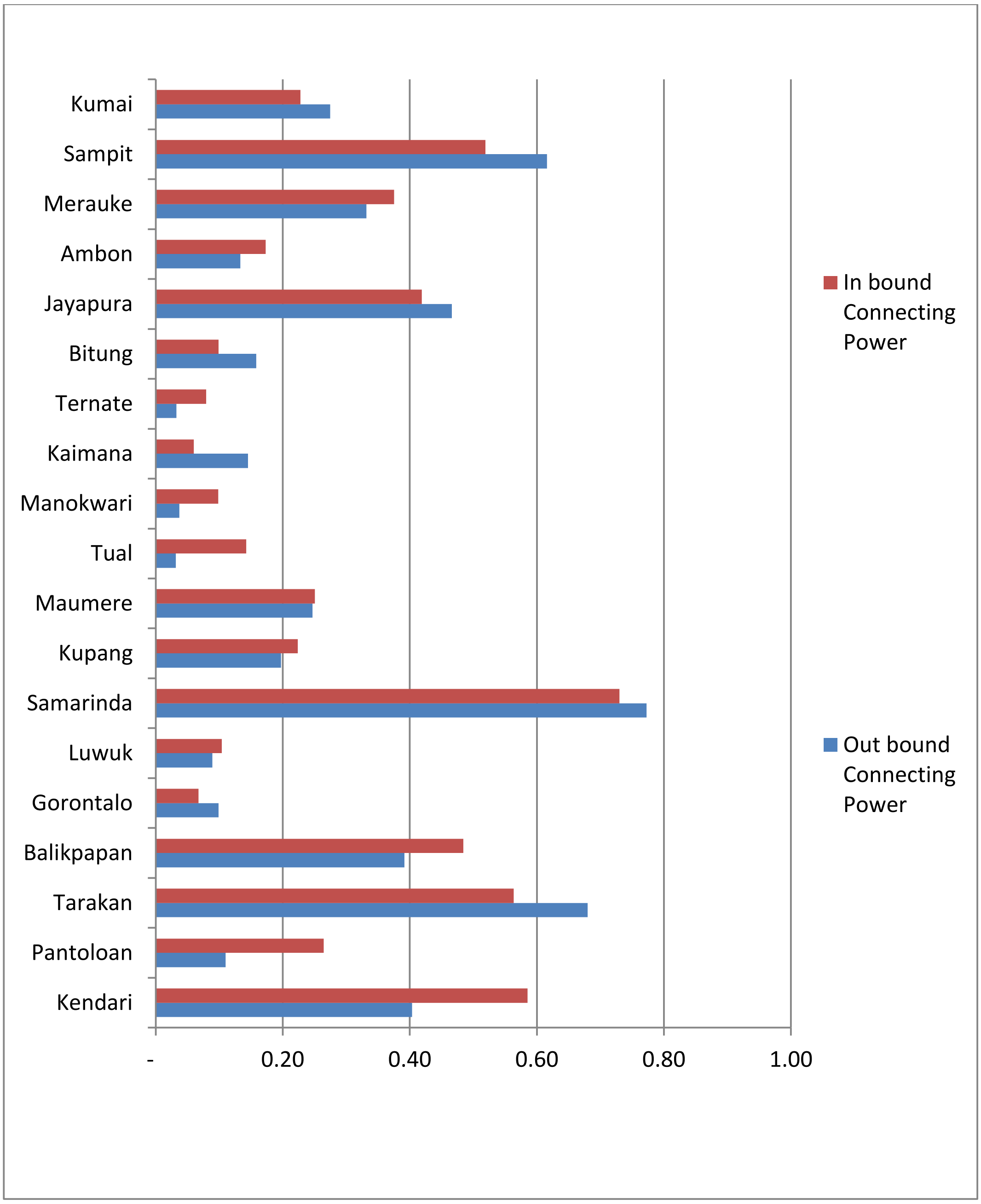


Figure 4.10 Graph of Outbound and Inbound Connecting Power in Scenario III

From the graph above it can be seen that the gap is relatively wide. The highest difference is in Makassar with 0.355. This shows that the Pendulum Nusantara concept is increasing the total connectivity index in the shipping network. However, does not improve the difference between outbound and inbound connecting power.

4.4 Comparison between Scenarios

In this subchapter, the three scenarios will be compared based on parameters, such as connectivity, and the output parameter from the P-Median Problem model. These comparison are used to help decision makers to choose the appropriate scenario that should be applied in the eastern Indonesia shipping network existing condition.

4.4.1 Comparison in Connectivity

One of the parameters that help to decide is the connectivity. As explained before connectivity represents the transit performance of a network in order to assist decision makers to make priority in investment and deciding which nodes that need immediate attention. Therefore, to decide the best solution is to find the scenario that can increase the connectivity as a whole network. The comparison of descriptive statistics for connectivity index in the scenarios are stated in Table 4.19 below.

Table 4.19 Comparison of Descriptive Statistics between Scenarios and Existing Condition

Parameter	***Existing***	***Scenario I***	***Scenario II***	***Scenario III***
Mean	1.8731	3.1296	1.9501	3.4852
Median	0.2048	0.0639	0.0516	0.0965
Standard Deviation	6.3737	10.1288	6.1675	11.8089
Sample Variance	40.6237	102.5921	38.0382	139.4510
Range	40.2597	47.0199	29.5049	47.1772
Minimum	0.0111	0.0032	0.0030	0.0048
Maximum	40.2708	47.0231	29.5079	47.1820
Sum	80.5416	134.5722	83.8549	149.8619

Table 4.19 shows that scenario III has the highest data mean, but with the highest standard deviation and sample variance. It means that in scenario III there is a big difference between a seaport connectivity indexes with another seaports. It also shows that the data range is very high. This can be happened because the hubs in the scenario III is very high while the other seaports' connectivity are very low.

This situation also happened in the scenario I. It has high mean but also high standard deviation. In contrast, scenario II has less value of mean however the standard deviation and sample variance is the lowest from all possible condition including the existing condition. It means that, scenario II produces better network connectivity. Moreover, the distribution of the data is not very wide compare to other conditions.

Another parameter that can be considered to choose the appropriate connectivity is the difference between outbound and inbound connecting power. As explained before this parameter used to know how the network balancing the flow of containers. Table 4.20 shows the comparison of descriptive statistics of the difference between outbound and inbound connecting power.

Table 4.20 Descriptive Statistics Comparison of Difference between Outbound and Inbound Connecting Power

Parameters	*Existing*	*Scenario I*	*Scenario II*	*Scenario III*
Mean	0.2079	0.0376	0.0263	0.0688
Median	0.0655	0.0255	0.0166	0.0367
Standard Deviation	0.2536	0.0498	0.0252	0.0908
Range	1.0479	0.2705	0.0901	0.3550
Minimum	0.0035	0.0002	0.0002	0.0002
Maximum	1.0514	0.2708	0.0903	0.3552
Sum	8.9406	1.6154	1.1311	2.9563

As can be seen from the Table 4.20. Scenario that has lowest total difference between outbound and inbound connecting power is scenario II. It also has the lowest mean and standard deviation. It means that scenario II gives the highest impact for balancing the outbound and inbound connecting power.

4.4.2 Comparison in Output Parameter

The output parameter from P-Median Problem model are demand weighted distance, total consolidated demand in the hubs from its spokes and the main line distance. The comparison of the output parameters is stated in Table 4.21 below.

Table 4.21 Comparison of Output Parameters between Scenarios

Sc.	Hubs	Max Consolidated Demand	Cos. Demand In	Cons. Demand Out	(Out-In)	Total Demand Weighted Distance
III	Hub Surabaya	116043	108948	111458	2510	252889
	Hub Sorong	26050	21221	20648	-573	
	Hub Makassar	88440	79586	80754	1168	
II	Hub Makassar	52427	48663	48623	-40	204462
	Hub Ambon	35613	28651	28556	-95	
	Hub Balikpapan	141864	132441	135681	3240	
I	Hub Bau-Bau	86682	77726	83400	5674	173143
	Hub Fak-Fak	25387	20034	19985	-49	
	Hub Batu licin	118464	111995	109475	-2520	
Exist.	Single Hub Surabaya	212860	209755	212860	3105	470676

Table 4.21 shows that the minimum demand weighted distance is in scenario I, however it has highest difference of consolidated between consolidated demand out and in. While the lowest difference of consolidated between consolidated demands out and in is in scenario II. In two hubs the gap are less than 100 TEUs per year.

CHAPTER V

DISCUSSION AND ANALYSIS

After calculating the scenarios that could be applied for eastern Indonesia shipping network, this chapter analyze the effect for the seaports and the shipping company. Moreover, to analyze the existing condition seaports that become the hubs and the expected performance to become a hub. Therefore, an appropriate scenario can be chosen.

5.1 Scenario I Effects to Seaports and Shipping Line Company

As had been calculated in subchapter 4.3.1 scenario I has the most optimum total demand weighted distances with value 173143. This means that the total demand that flows from one port to another is follow the minimum distance between ports. The average distance between ports is 335.119 miles with 140.496 standard deviation. While main line distance is 1521.431 miles.

The effects of scenario I if implemented is the seaports will become integrated each other. The demand of seaports will be consolidated in hubs. It means that hubs seaports should increase the capacity and add more infrastructure to support the high density of container flow. The hubs of this scenario is Bau-Bau, Fak-Fak and Batulicin. Figure 5.1 shows the comparison between the existing flow and consolidated demand if scenario I is applied in each hubs.

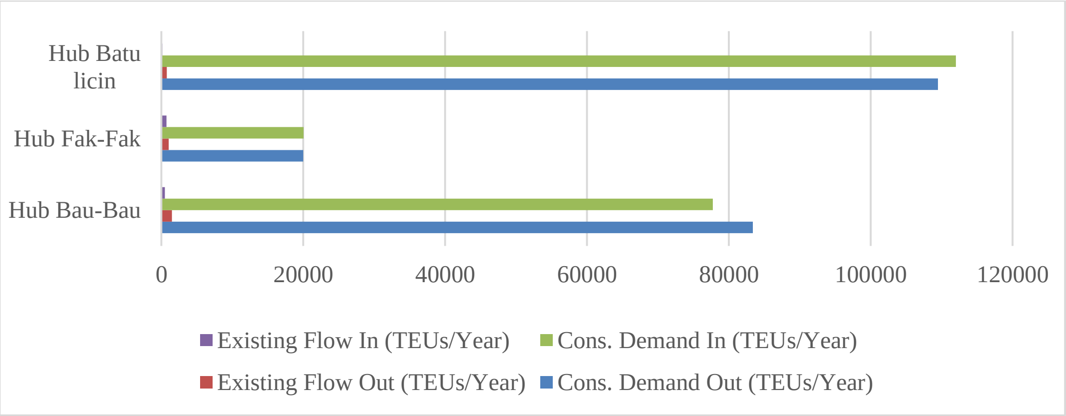


Figure 5. 1 Graph of Comparison between Existing Flow and Consolidated Demand for Scenario I

The graph at Figure 5.1 clearly shows that the difference between existing flow and consolidated demand from the scenario is very wide. It means that government and PT. Pelindo IV and PT.Pelindo III as the operator of the seaports should increase the whole capacity more than ten times higher than the existing capacity. Moreover, the administrative class for hubs seaports in scenario I is still below main class and first class. Therefore, there should be restructuration in the organization structure of the hubs.

While in terms of connectivity, scenario I provides higher connectivity in the hubs ports. It means that the hubs is very functional to become the transit hub. The mean of the connectivity index for the network also increased. However, the standard deviation is very high and difference between the outbound and inbound connecting power is also high. The effect for the Shipping Line Company is there will be many ships that still have underutilized capacity flows through the network. The total difference in Outbound-Inbound connecting power is 1.615 while the difference in out-in flow is 8243 TEUs/year in the hubs.

5.2 Scenario II Effects to Seaports and Shipping Line Company

Scenario II develop main class and first class seaports to become the candidate hubs. The total demand weighted distance is 204462. It is the second minimum after scenario I. The average distance from one port to another is 370.752 miles. While the main line distance is 1470.696 miles. The effects to the Shipping Line Companies is the companies should provide more ships that can bring an average 5.361 TEUs per year to accommodate the demand from hubs to spokes, and bigger capacity ships to accommodate the main line with average line capacity between hubs is 76635 TEUs per year.

The effects of scenario II if implemented is the seaports will become integrated each other. The demand of seaports will be consolidated in hubs. It means that hubs seaports should increase the capacity and add more infrastructure to support the high density of container flow. The hubs of this scenario is Makassar, Ambon, and Balikpapan. Figure 5.2 shows the comparison between the existing flow and consolidated demand if scenario I is applied in each hubs.

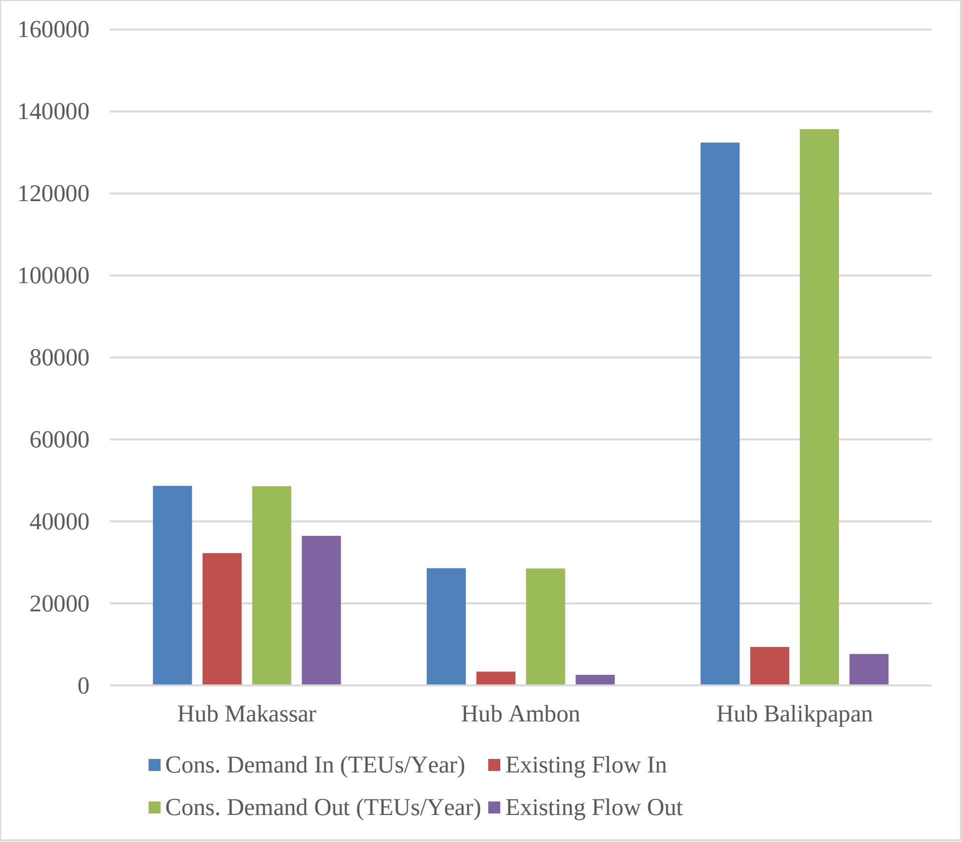


Figure 5.2 Graph of Comparison between Existing Flow and Consolidated Demand for Scenario II

The graph at Figure 5.2 clearly shows that the difference between existing flow and consolidated demand from the scenario is very wide in Ambon and Balikpapan. While there is only little difference in Makassar. It means that government and PT. Pelindo IV and PT.Pelindo III as the operator of the seaports should increase the whole capacity more than ten times higher than the existing capacity in Balikpapan and Ambon port. However, the administrative class for hubs seaports in scenario II is already main class and first class. Therefore, there should not be restructuration in the organization structure of the hubs.

While in terms of connectivity, scenario II provides higher connectivity in the hubs ports. It means that the hubs is very functional to become the transit hub.

The mean of the connectivity index for the network also increased. Moreover, the standard deviation is not very high and difference between the outbound and inbound connecting power is also low. The effect for the Shipping Line Company is there will be high possibility the transportation cost is decreased because the ship could be fully or almost fully utilized. The total difference in Outbound-Inbound connecting power is 1.131 with average of 0.026 while the difference in out-in flow is 3375 TEUs/year in the hubs.

5.3 Scenario II Effects to Seaports and Shipping Line Company

Scenario III is developed from Pendulum Nusantara concept, Surabaya, Makassar, and Sorong become the hubs ports. The total demand weighted distance is 252889. It is the third minimum after scenario I and scenario II. The average distance from one port to another is 390.025 miles. While the main line distance is 1371.097 miles. The effects to the Shipping Line Companies is the companies should provide more ships in the Makassar hub because it has many spokes related to it with average capacity 3511 TEUs/year. While in Surabaya hubs bigger capacity ships are needed since average demand in its spokes is 18576 TEUs/year. In contrast, in Sorong hub the average demand is smaller, 1475 TEUs/ year.

The effects of scenario III if implemented is the seaports will become integrated each other. The demand of seaports will be consolidated in hubs. It means that hubs seaports should increase the capacity and add more infrastructure to support the high density of container flow. The hubs of this scenario is Makassar, Surabaya, and Sorong. Figure 5.3 shows the comparison between the existing flow and consolidated demand if scenario I is applied in each hubs.

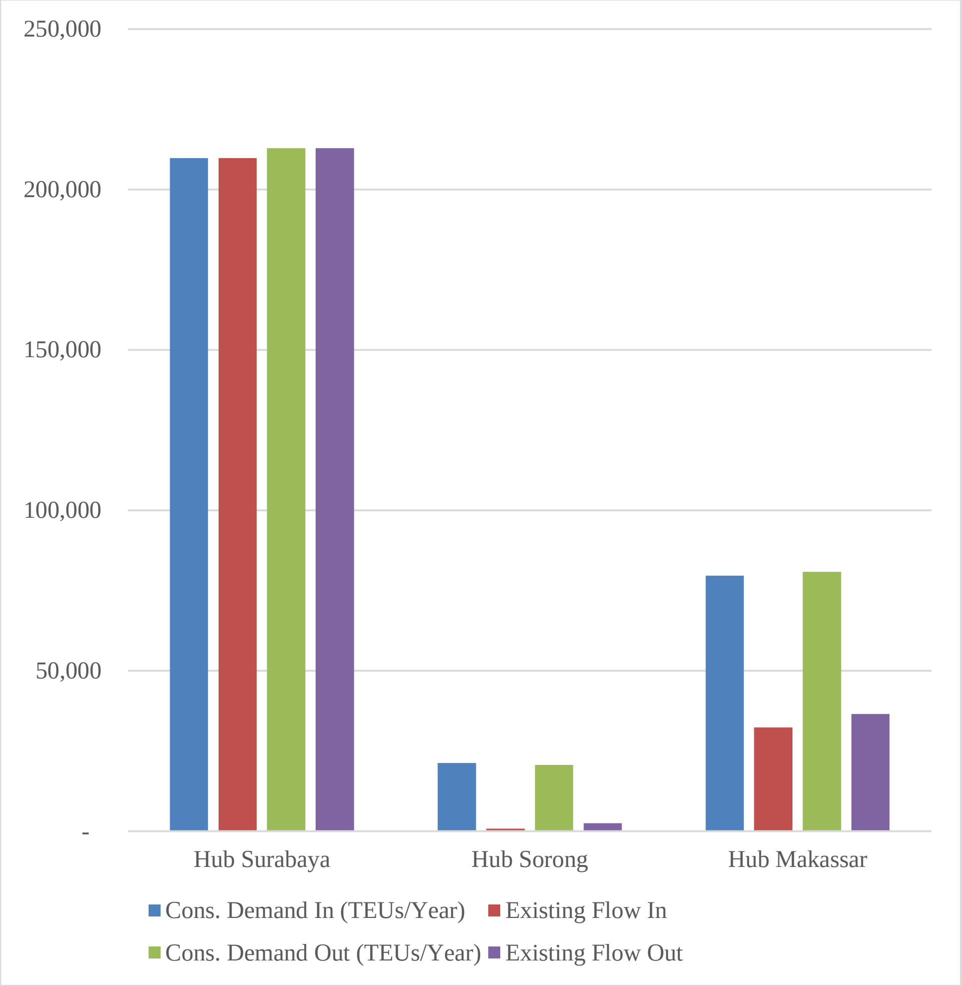


Figure 5.3 Graph of Existing Flow and Consolidated Demand for Scenario III

The graph at Figure 5.3 clearly shows that the difference between existing flow and consolidated demand from the scenario is not very wide, except in Sorong ports. It means that government and PT. Pelindo IV and PT.Pelindo III as the operator of the seaports should increase the whole capacity more than ten times higher than the existing capacity in Sorong port. However, the administrative class for hubs seaports in scenario III is already main class and first class. Therefore, there should not be restructuration in the organization structure of the hubs. While in Surabaya the existing flow and consolidated demand is the same because it is the destination of all ports. Therefore, all containers in this network will be ended in Surabaya.

While in terms of connectivity, scenario III provides higher connectivity in the hubs ports. It means that the hubs is very functional to become the transit hub.

The mean of the connectivity index for the network also increased. Moreover, the standard deviation is very high and difference between the outbound and inbound connecting power is also high. The effect for the Shipping Line Company is there will be high possibility the transportation cost is increased because the ship could not be fully utilized. The total difference in Outbound-Inbound connecting power is 2.956 with average of 0.069 while the difference in out-in flow is 4846 TEUs/year in the hubs

5.4 Choosing Proposed Scenario for Eastern Indonesia Shipping Network

Three scenarios that have been developed and analyzed in the previous subchapters then compared and chosen to get the appropriate scenario that suitable to be proposed. In subchapter 4.4 the scenarios have been compared based on the connectivity and output parameters from P-Median Problem. The recapitulation of the comparison between scenarios is stated in Table 5.1 below.

In terms of connectivity, the highest network connectivity index is scenario III with total connectivity index is 149.58. However, the better connectivity for the whole network is scenario II because the total connectivity index is higher than the existing (83.855) and the standard deviation is also the lowest (6.167).

While in terms of difference in connecting power, scenario II is the lowest with total difference is 1.131, and average 0,026. This shows that scenario II has the biggest effect on balancing the outbound and inbound connecting power.

In contrast the output parameter shows the minimum demand weighted distance is in the scenario I, while the lowest gap between out and in flow of container is in scenario II.

There are three criteria to choose the appropriate scenario to be proposed. Each criteria represents the effect that might be happened if one of those scenarios is applied. The criteria are:

1. Total Difference between Outbound-Inbound Connecting powers represents the difference of outflow and inflow of containers that would enter and out a seaport. The larger the difference, the possibility of empty capacitated ships would flow thorough network is higher. The empty capacitated ships will increase the cost/unit miles.

2. Demand weighted distance represents how far the demand would flow through network. The higher the demand weighted distance, the transportation cost will also higher. This could be happened because one of the variable of transportation cost is distance between nodes (Jeong, 2003).
3. Total difference between existing flow and consolidated demand represents how much a seaport needs to be upgraded. The larger the difference means that a seaport need more investment cost.

Table 5.1 Recapitulation Comparison between Scenarios

Criteria	**Existing**	**Scenario I**	**Scenario II**	**Scenario III**
Total Difference between Outbound-Inbound Connecting Power	8.941	1.615	1.131	2.956
Demand Weighted Distance	470676	173143	204462	252889
Total Difference between Existing Flow and Consolidated Demand	-	418095	330741	130188

From the Table.5.1 and analysis from previous chapter it can be concluded that each scenarios has its advantages and disadvantages. The advantages of Scenario I are:

1. Total demand weighted distance is minimum
2. The average distance between ports is minimum.
3. Suitable to reduce the travel time between ports.

However, the disadvantages of scenario I are:

1. High possibility of underutilized ship capacity
2. The difference in existing flow and consolidated demand is very high. Therefore, upgrade capacity in the hubs ports is needed.
3. Possible cost of investment is high.
4. Restructuration of hub seaports organization is needed. Consequently, the administrative procedure may take long time.

The advantages and disadvantages of scenario I can be taken as consideration to choose the appropriate scenario. While the advantages for scenario II are:

1. The difference between outbound and inbound connecting power is low. Therefore, the possibility of a ship is fully utilized is high.
2. Suitable to reduce transportation cost caused by underutilized ships.
3. There is no need to restructure the seaports organization, because the hubs ports are already first and main class.

While the disadvantages for scenario II are:

1. The difference in existing flow and consolidated demand is very high. Therefore, upgrade capacity in the hubs ports is needed.
2. Possible cost of investment is high.

The advantages and disadvantages of scenario II can be taken as consideration to choose the appropriate scenario. While the advantages for scenario III are:

1. The difference in existing flow and consolidated demand is not very high. Therefore, possible cost of investment is not as high as the other scenarios.
2. Connectivity index is high. Therefore, the transit network is in good quality to connect the all ports in the network.
3. There is no need to restructure the seaports organization, because the hubs ports are already first and main class.

While the disadvantages for scenario II are:

1. High possibility of underutilized ship capacity, because unbalanced outbound and inbound connecting power.
2. Demand weighted distance is not minimum. Therefore, Shipping Line Companies needs longer travel time from spokes to its hubs.

From the explanation of advantages and disadvantages in each scenario. All scenarios can be applied to eastern Indonesia shipping network based on the priority of the decision makers, in this case government, seaports companies, and shipping line companies. However, this research proposed scenario II as the most appropriate shipping network because as explained in the background. The cause of high transportation cost is unbalanced inbound and outbound connecting power.

Therefore, the minimum difference in the inbound and outbound connecting power is the main priority. Moreover, scenario II also has higher connectivity index than the existing and lowest standard deviation from all scenarios. While demand weighted distance of scenario II is relatively high. In conclusion, the proposed scenario for eastern Indonesia seaports is scenario II, with Balikpapan, Makassar, and Ambon as the hubs.

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CHAPTER VI
CONCLUSION AND RECOMMENDATION

This chapter included conclusion from the analysis and interpretation which done in previous chapter. This chapter also provided recommendation for future research.

6.1 Conclusion

After conduction this research, there are several conclusion to presents. Those are,

1. Eastern Indonesia shipping network is consists of 43 seaports that is divided into five classes based on administrative level and the work load of a seaports. The existing shipping network of eastern Indonesia seaports as mentioned in previous subchapter is not using any hub ports. It is centralized in Surabaya. The total connectivity index for the existing network is 80,542 with mean 1.875. However, the standard deviation is very high it reach 6.373. It means that the connectivity index is not equally distributed but only centralized in. Moreover, the difference of Outbound and Inbound connecting power in each seaports is relatively wide total difference is 8.941. While the total demand weighted distance is very high the value is 470476.
2. There are three scenarios is developed. Scenario I that can be applied to design proposed shipping network is purely based on the P-Median Problem optimization model. Scenario I has the most optimum total demand weighted distances with value 173143. This means that the total demand that flows from one port to another is follow the minimum distance between ports. Total connectivity index for scenario I is 134.572. The total difference in Outbound-Inbound connecting power is 1.615 while the difference in out-in flow is 8243 TEUs/year in the hubs. Scenario II develop main class and first class seaports to become the candidate hubs. The total demand weighted distance is 204462. It is the second minimum after scenario I.

Total connecting power is 83.855. The total difference in Outbound-Inbound connecting power is 1.131 with average of 0.026. Scenario III is developed from Pendulum Nusantara concept, Surabaya, Makassar, and Sorong become the hubs ports. The total demand weighted distance is 252889. It is the third minimum after scenario I and scenario II.. Total connecting power is 149.862. . The total difference in Outbound-Inbound connecting power is 2.956 with average of 0.069.

3. This research proposed scenario II as the most appropriate shipping network. The effects to the Shipping Line Companies is the companies should provide more ships that can bring an average 5.361 TEUs per year to accommodate the demand from hubs to spokes. It means that government and PT. Pelindo IV and PT.Pelindo III as the operator of the seaports should increase the whole capacity more than ten times higher than the existing capacity in Balikpapan and Ambon port. However, the administrative class for hubs seaports in scenario II is already main class and first class. Therefore, there should not be restructuration in the organization structure of the hubs.

6.2 Suggestion

There are several suggestion for future research.

1. In this research, the investment analysis of the chosen hubs ports is not conducted. Thus, it is suggested in the next research the investment analysis can be done to become parameter in choosing hubs.
2. For governments, to implement proposed network design needs some preparation such as infestation for upgrading the infrastructure in seaports, and available ships that can serve the desired capacity.

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Appendix 1

Distance Matrix of Eastern Indonesia Seaports

From\To (Miles)	**Surabaya**	**Tual**	**Manokwari**	**Kaimana**	**Tenau**	**Sorong**	**Ternate**	**Kendari**	**Bitung**	**Makassar**	**Pantoloan**	**Serui**	**Jayapura**	**Banjarmasin**	**Ambon**	**Tarakan**
Surabaya	689643	1384	1590	1471	778	1365	1144	907	1047	478	712	1571	1958	473	1110	784
Tual	1384	689643	390	153	709	347	542	521	682	912	977	316	589	1317	329	1195
Manokwari	1590	390	689643	238	1032	230	498	685	647	1116	1027	82	443	1407	491	1197
Kaimana	1471	153	238	689643	839	256	507	575	659	994	997	163	486	1357	369	1198
Tenau	778	709	1032	839	689643	852	778	468	794	415	773	982	1297	927	569	1003
Sorong	1365	347	230	256	852	689643	278	464	431	894	802	237	654	1179	286	981
Ternate	1144	542	498	507	778	278	689643	314	154	696	530	515	932	912	274	704
Kendari	907	521	685	575	468	464	314	689643	333	432	475	664	1059	796	207	708
Bitung	1047	682	647	659	794	431	154	333	689643	628	390	668	1084	775	381	551
Makassar	478	912	1116	994	415	894	696	432	628	689643	423	1095	1481	512	633	623
Pantoloan	712	977	1027	997	773	802	530	475	390	423	689643	1038	1454	384	648	240
Serui	1571	316	82	163	982	237	515	664	668	1095	1038	689643	417	1412	463	1219
Jayapura	1958	589	443	486	1297	654	932	1059	1084	1481	1454	417	689643	1827	853	1635
Banjarmasin	473	1317	1407	1357	927	1179	912	796	775	512	384	1412	1827	689643	994	338
Ambon	1110	329	491	369	569	286	274	207	381	633	648	463	853	994	689643	868
Tarakan	784	1195	1197	1198	1003	981	704	708	551	623	240	1219	1635	338	868	689643
Bau-bau	697	694	902	774	342	684	516	221	486	220	438	877	1260	667	415	675
Merauke	1918	573	694	576	1174	826	1082	1092	1233	1460	1550	626	411	1888	902	1764
Balikpapan	497	1132	1233	1175	771	1004	743	612	613	361	232	1234	1647	184	810	304
Nabire	1597	247	222	126	953	340	610	701	764	1120	1114	143	361	1478	494	1310
Biak	1681	387	134	240	1077	344	621	774	772	1204	1146	111	312	1522	571	1323
Sampit	330	1386	1513	1442	915	1284	1027	869	899	514	515	1511	1921	163	1074	500
Fak-fak	1396	195	230	106	803	158	401	492	553	919	897	181	569	1262	287	1095
Gorontalo	894	759	783	762	722	558	286	306	155	494	244	795	1212	626	434	438
Toli-Toli	791	935	962	944	794	739	464	451	318	474	81	976	1393	460	607	261
Luwuk	826	764	823	782	662	595	334	277	221	419	215	828	1244	584	435	436
Samarinda	570	1110	1189	1143	798	961	695	593	559	397	170	1195	1610	218	784	239
Batulicin	363	1141	1286	1201	689	1056	812	627	699	277	350	1278	1683	241	832	451
Tobelo	1198	579	483	526	850	280	72	386	170	758	560	511	924	944	337	714
Kupang	784	707	1031	837	7	852	781	471	798	423	779	980	1294	934	570	1009
Kumai	330	1463	1592	1520	976	1363	1106	947	977	582	591	1590	1999	225	1152	561
Lembar	288	1126	1368	1226	491	1151	965	688	898	271	647	1340	1709	576	878	801
Ende, Flores	596	815	1086	924	201	881	744	434	720	220	613	1049	1402	729	597	831
Larantuka	701	709	991	822	142	793	679	365	676	288	631	951	1298	797	506	861
Timika	1600	220	314	160	926	409	667	719	819	1126	1154	234	371	1509	516	1358
Maumere	674	740	1021	852	146	821	702	388	694	272	632	981	1328	783	535	859
Dili	894	530	846	655	186	669	621	329	662	460	726	796	1120	954	390	965
Badas	623	1766	1855	1809	1312	1629	1359	1246	1216	913	828	1863	2278	452	1445	704
Malili	677	811	934	857	553	705	468	291	377	259	223	928	1335	506	490	461
Nunukan	829	1136	1125	1134	985	912	635	661	481	623	212	1149	1565	400	811	76
Benoa	206	1213	1449	1311	577	1230	1035	766	960	340	682	1422	1795	558	960	813
Benete	293	1124	1368	1225	486	1151	967	688	901	273	652	1339	1708	584	878	807
Waingapu	554	891	1174	1006	224	971	835	526	809	262	677	1134	1480	749	686	885

	Bau-bau	Merauke	Balikpapan	Nabire	Biak	Sampit	Fak-fak	Gorontalo	Toli-Toli	Luwuk	Samarinda	Batulicin	Tobelo	Kupang	Kumai
Surabaya	697	1918	497	1597	1681	330	1396	894	791	826	570	363	1198	784	330
Tual	694	573	1132	247	387	1386	195	759	935	764	1110	1141	579	707	1463
Manokwari	902	694	1233	222	134	1513	230	783	962	823	1189	1286	483	1031	1592
Kaimana	774	576	1175	126	240	1442	106	762	944	782	1143	1201	526	837	1520
Tenau	342	1174	771	953	1077	915	803	722	794	662	798	689	850	7	976
Sorong	684	826	1004	340	344	1284	158	558	739	595	961	1056	280	852	1363
Ternate	516	1082	743	610	621	1027	401	286	464	334	695	812	72	781	1106
Kendari	221	1092	612	701	774	869	492	306	451	277	593	627	386	471	947
Bitung	486	1233	613	764	772	899	553	155	318	221	559	699	170	798	977
Makassar	220	1460	361	1120	1204	514	919	494	474	419	397	277	758	423	582
Pantoloan	438	1550	232	1114	1146	515	897	244	81	215	170	350	560	779	591
Serui	877	626	1234	143	111	1511	181	795	976	828	1195	1278	511	980	1590
Jayapura	1260	411	1647	361	312	1921	569	1212	1393	1244	1610	1683	924	1294	1999
Banjarmasin	667	1888	184	1478	1522	163	1262	626	460	584	218	241	944	934	225
Ambon	415	902	810	494	571	1074	287	434	607	435	784	832	337	570	1152
Tarakan	675	1764	304	1310	1323	500	1095	438	261	436	239	451	714	1009	561
Bau-bau	689643	1249	489	900	986	706	700	389	453	324	495	459	584	348	780
Merauke	1249	689643	1704	491	573	1951	682	1326	1505	1336	1683	1704	1102	1169	2027
Balikpapan	489	1704	689643	1297	1345	286	1081	460	313	410	73	147	780	779	364
Nabire	900	491	1297	689643	154	1566	217	877	1059	900	1264	1326	620	951	1644
Biak	986	573	1345	154	689643	1622	287	903	1083	938	1305	1389	612	1075	1701
Sampit	706	1951	286	1566	1622	689643	1352	746	594	693	345	247	1066	923	79
Fak-fak	700	682	1081	217	287	1352	689643	660	842	683	1047	1114	421	802	1430
Gorontalo	389	1326	460	877	903	746	660	689643	182	74	409	545	320	727	824
Toli-Toli	453	1505	313	1059	1083	594	842	182	689643	175	249	429	488	800	670
Luwuk	324	1336	410	900	938	693	683	74	175	689643	367	482	377	667	772
Samarinda	495	1683	73	1264	1305	345	1047	409	249	367	689643	218	728	805	421
Batulicin	459	1704	147	1326	1389	247	1114	545	429	482	218	689643	859	697	322
Tobelo	584	1102	780	620	612	1066	421	320	488	377	728	859	689643	853	1144
Kupang	348	1169	779	951	1075	923	802	727	800	667	805	697	853	689643	983
Kumai	780	2027	364	1644	1701	79	1430	824	670	772	421	322	1144	983	689643
Lembar	467	1643	499	1350	1447	497	1160	760	712	685	562	357	1028	497	537
Ende, Flores	234	1326	580	1046	1153	715	868	616	649	547	614	490	813	208	776
Larantuka	204	1219	636	943	1053	799	769	591	654	528	659	564	750	148	864
Timika	906	418	1326	93	238	1588	266	921	1103	939	1297	1345	684	923	1666
Maumere	215	1248	626	973	1083	780	800	604	659	538	652	548	773	153	843
Dili	295	1027	780	771	892	974	617	620	729	572	790	731	692	185	1042
Badas	1099	2336	635	1931	1973	398	1714	1072	897	1035	668	642	1385	1319	336
Malili	215	1382	322	981	1038	586	766	235	242	161	305	352	522	559	664
Nunukan	649	1702	336	1243	1252	560	1030	377	210	385	265	483	642	991	625
Benoa	547	1732	509	1436	1530	457	1244	816	752	743	577	362	1096	583	486
Benete	467	1640	506	1349	1446	505	1160	763	717	689	568	364	1030	492	544
Waingapu	324	1387	616	1126	1237	714	953	700	720	629	658	508	905	230	769

	Lembar	Ende, Flores	Larantuka	Timika	Maumere	Dili	Badas	Malili	Nunukan	Benoa	Benete	Waingapu
Surabaya	288	596	701	1600	674	894	623	677	829	206	293	554
Tual	1126	815	709	220	740	530	1766	811	1136	1213	1124	891
Manokwari	1368	1086	991	314	1021	846	1855	934	1125	1449	1368	1174
Kaimana	1226	924	822	160	852	655	1809	857	1134	1311	1225	1006
Tenau	491	201	142	926	146	186	1312	553	985	577	486	224
Sorong	1151	881	793	409	821	669	1629	705	912	1230	1151	971
Ternate	965	744	679	667	702	621	1359	468	635	1035	967	835
Kendari	688	434	365	719	388	329	1246	291	661	766	688	526
Bitung	898	720	676	819	694	662	1216	377	481	960	901	809
Makassar	271	220	288	1126	272	460	913	259	623	340	273	262
Pantoloan	647	613	631	1154	632	726	828	223	212	682	652	677
Serui	1340	1049	951	234	981	796	1863	928	1149	1422	1339	1134
Jayapura	1709	1402	1298	371	1328	1120	2278	1335	1565	1795	1708	1480
Banjarmasin	576	729	797	1509	783	954	452	506	400	558	584	749
Ambon	878	597	506	516	535	390	1445	490	811	960	878	686
Tarakan	801	831	861	1358	859	965	704	461	76	813	807	885
Bau-bau	467	234	204	906	215	295	1099	215	649	547	467	324
Merauke	1643	1326	1219	418	1248	1027	2336	1382	1702	1732	1640	1387
Balikpapan	499	580	636	1326	626	780	635	322	336	509	506	616
Nabire	1350	1046	943	93	973	771	1931	981	1243	1436	1349	1126
Biak	1447	1153	1053	238	1083	892	1973	1038	1252	1530	1446	1237
Sampit	497	715	799	1588	780	974	398	586	560	457	505	714
Fak-fak	1160	868	769	266	800	617	1714	766	1030	1244	1160	953
Gorontalo	760	616	591	921	604	620	1072	235	377	816	763	700
Toli-Toli	712	649	654	1103	659	729	897	242	210	752	717	720
Luwuk	685	547	528	939	538	572	1035	161	385	743	689	629
Samarinda	562	614	659	1297	652	790	668	305	265	577	568	658
Batulicin	357	490	564	1345	548	731	642	352	483	362	364	508
Tobelo	1028	813	750	684	773	692	1385	522	642	1096	1030	905
Kupang	497	208	148	923	153	185	1319	559	991	583	492	230
Kumai	537	776	864	1666	843	1042	336	664	625	486	544	769
Lembar	689643	317	424	1345	395	617	867	524	821	88	8	267
Ende, Flores	317	689643	107	1035	78	299	1111	409	823	406	314	92
Larantuka	424	107	689643	929	31	193	1197	412	843	513	421	184
Timika	1345	1035	929	689643	960	749	1961	1006	1294	1432	1343	1111
Maumere	395	78	31	960	689643	221	1178	416	843	483	392	154
Dili	617	299	193	749	221	689643	1372	504	933	705	613	365
Badas	867	1111	1197	1961	1178	1372	689643	956	780	807	874	1105
Malili	524	409	412	1006	416	504	956	689643	434	583	528	484
Nunukan	821	823	843	1294	843	933	780	434	689643	841	827	882
Benoa	88	406	513	1432	483	705	807	583	841	689643	92	353
Benete	8	314	421	1343	392	613	874	528	827	92	689643	262
Waingapu	267	92	184	1111	154	365	1105	484	882	353	262	689643

Appendix 2
Ports Classification based on KM No. 17 year 2004

No	Seaports	Category	Location
1	Surabaya	Utama	Surabaya
2	Ujung Pandang		Makassar
3	Benoa	I	Badung
4	Banjarmasin		Banjarmasin
5	Balikpapan		Balikpapan
6	Bitung		Bitung
7	Ambon		Ambon
8	Sorong		Sorong
9	Samarinda	II	Samarinda
10	Kendari		Kendari
11	Jayapura		Jayapura
12	Gresik	III	Gresik
13	Tanjung Wangi		Banyuwangi
14	Lembar		Lombok Barat
15	Kupang/Tenau		Kupang
16	Tarakan		Tarakan
17	Manado		Manado
18	Pantoloan		Donggala
19	Ternate		Ternate
20	Biak		Cendrawasih Bay
21	Merauke	IV	Merauke
22	Manokwari	V	Manokwari
23	Fak-fak		Fak-fak
24	Toli-toli		Toli-toli
25	Nunukan		Nunukan
26	Kotabaru		Kotabaru
27	Waingapu		Sumba Timur
28	Ende		Ende
29	Maumere		Sikka
30	Badas		Sumbawa

Appendix 3
Existing Condition Connectivity Index Measurement

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Route SUB-OUT	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Rute SUB-IN	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
1	Surabaya		212,860			30.04					29.84	29.94
2	Tual	SUB-TUAL	571	11.58	1384.4365	0.16	TUAL-SUB	2,549	11.58	1384.436	0.73	0.45
3	Manokwari	SUB-MANOKWARI	889	13.21	1590.1656	0.33	MANOKWARI-SUB	2,331	13.21	1590.166	0.88	0.61
4	Kaimana	SUB-KAIMANA	2,984	13.75	1471.3565	1.07	KAIMANA-SUB	1,222	13.75	1471.357	0.44	0.76
5	Tenau	SUB-TENAU	22,122	12.76	777.85188	3.89	TENAU-SUB	19,813	12.76	777.8519	3.54	3.71
6	Sorong	SUB-SRG	2,434	10.46	1364.5385	0.62	SUB-SRG	787	10.46	1364.538	0.20	0.41
7	Ternate	SUB-TERNATE	592	14.40	1144.2963	0.17	TERNATE-SUB	1,425	14.40	1144.296	0.42	0.30
8	Kendari	SUB-KDI	5,463	12.37	907.057	1.09	KDI-SUB	7,880	12.37	907.057	1.59	1.34
9	Bitung	SUB-BIT	2,067	12.85	1046.8465	0.49	SUB-BIT	1,281	12.85	1046.846	0.31	0.40
10	Makassar	SUB-MKS	36,500	14.10	477.58213	4.35	MKS-SUB	32,300	14.10	477.5821	3.91	4.13
11	Pantoloan	SUB-PANTOLOAN	1,472	12.79	712.32411	0.24	PANTOLOAN-SUB	3,515	12.79	712.3241	0.58	0.41
12	Serui	SUB-SERUI	598	12.54	1571.0939	0.21	SERUI-SUB	-	12.54	1571.094	-	0.10
13	Jayapura	SUB-JYP	3,543	14.53	1957.6929	1.79	SUB-JYP	3,164	14.53	1957.693	1.62	1.70
14	Banjarmasin	SUB-BDJ	58,505	10.80	473.077	5.30	BDJ-SUB	62,906	10.80	473.077	5.78	5.54
15	Ambon	SUB-AMQ	2,617	12.85	1109.8747	0.66	AMQ-SUB	3,379	12.85	1109.875	0.87	0.76
16	Tarakan	SUB-TARAKAN	6,422	12.28	783.80165	1.10	TARAKAN-SUB	5,295	12.28	783.8016	0.92	1.01
17	Bau-bau	SUB-BAU	1,470	12.18	697.40334	0.22	BAU-SUB	478	12.18	697.4033	0.07	0.15
18	Merauke	SUB-MERAUKE	2,275	12.76	1918.2157	0.99	MERAUKE-SUB	2,559	12.76	1918.216	1.13	1.06
19	Balikpapan	SUB-BPN	7,658	10.25	496.84219	0.69	BPN-SUB	9,420	10.25	496.8422	0.86	0.78
20	Nabire	SUB-NABIRE	739	11.55	1596.9328	0.24	NABIRE-SUB	168	11.55	1596.933	0.06	0.15
21	Biak	SUB-BIAK	968	11.01	1680.8405	0.32	BIAK-SUB	646	11.01	1680.841	0.21	0.27
22	Sampit	SUB-SAMPIT	10,376	12.99	330.46063	0.79	SAMPIT-SUB	8,693	12.99	330.4606	0.67	0.73
23	Fak-fak	SUB-FAK	1,030	13.13	1396.3788	0.33	FAK-SUB	693	13.13	1396.379	0.23	0.28
24	Gorontalo	SUB-GOR	1,066	13.60	894.47442	0.23	GOR-SUB	719	13.60	894.4744	0.16	0.19
25	Toli-Toli	SUB-TOLI	629	12.28	790.98535	0.11	TOLI-SUB	172	12.28	790.9853	0.03	0.07
26	Luwuk	SUB-LUWUK	1,185	12.99	826.14338	0.23	LUWUK-SUB	1,369	12.99	826.1434	0.26	0.24
27	Samarinda	SUB-SRI	13,720	10.25	570.2914	1.42	SRI-SUB	12,885	10.25	570.2914	1.35	1.39
28	Batulicin	SUB-BATULICIN	749	14.60	362.52992	0.07	BATULICIN-SUB	100	14.60	362.5299	0.01	0.04
29	Tobelo	SUB-TOBELO	215	13.21	1198.2495	0.06	TOBELO-SUB	318	13.21	1198.25	0.09	0.08
30	Kupang	SUB-KUPANG	3,223	10.46	784.46368	0.47	KUPANG-SUB	3,634	10.46	784.4637	0.54	0.50

No	Seaports	Outbound					Inbound					TOTAL CONNECTING POWER
		Route SUB-OUT	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Rute SUB-IN	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
31	Kumai	SUB-KUMAI	5,764	10.46	329.50938	0.35	KUMAI-SUB	4,751	10.46	329.5094	0.29	0.32
32	Lembar	SUB-LEMBAR	1,064	10.70	287.87123	0.06	LEMBAR-SUB	1,663	10.70	287.8712	0.09	0.08
33	Ende, Flores	SUB-ENDE	1,254	11.82	596.49615	0.16	ENDE-SUB	1,065	11.82	596.4961	0.13	0.15
34	Larantuka	SUB-LARANTUKA	629	11.19	701.34387	0.09	LARANTUKA-SUB	750	11.19	701.3439	0.11	0.10
35	Timika	SUB-TIMIKA	1,560	11.19	1600.4706	0.50	TIMIKA-SUB	1,486	11.19	1600.471	0.48	0.49
36	Maumere	SUB-MAUMERE	6,274	10.46	673.80133	0.78	MAUMERE-SUB	6,334	10.46	673.8013	0.80	0.79
37	Dili	SUB-DILLI	1,562	10.46	893.67435	0.26	DILLI-SUB	1,423	10.46	893.6744	0.24	0.25
38	Badas	SUB-BADAS	-	11.38	622.80987	-	BADAS-SUB	184	11.38	622.8099	0.02	0.01
39	Malili	SUB-MALILI	73	11.58	676.76611	0.01	MALILI-SUB	159	11.58	676.7661	0.02	0.02
40	Nunukan	SUB-NUNUKAN	359	12.32	828.62866	0.06	NUNUKAN-SUB	271	12.32	828.6287	0.05	0.06
41	Benoa	SUB-BOA	313	10.70	206.33238	0.01	BOA-SUB	114	10.70	206.3324	0.00	0.01
45	Benete	SUB-BENETE	1,723	12.85	293.374	0.12	BENETE-SUB	1,648	12.85	293.374	0.11	0.11
43	Waingapu	SUB-WAINGAPU	203	11.58	554.28166	0.02	WAINGAPU-SUB	206	11.58	554.2817	0.02	0.02

α	0.0002	α	0.0002
β	0.0825	β	0.0825
ϒ	0.0011	ϒ	0.0011

Appendix 4
Scenario I Connectivity Index Measurement

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
1	Surabaya	Batulicin	212,860	13.21	63.77679	11.070	Batulicin	209,755	13.21	362.5299	10.337	10.70
2	Pantoloan	Batulicin	1,472	12.79	61.5366	0.071	Batulicin	3,515	12.79	349.7959	0.162	0.12
3	Banjarmasin	Batulicin	58,505	10.80	42.35285	1.651	Batulicin	62,906	10.80	240.7486	1.683	1.67
4	Tarakan	Batulicin	6,422	12.28	79.39986	0.386	Batulicin	5,295	12.28	451.337	0.302	0.34
5	Balikpapan	Batulicin	7,658	10.25	25.92397	0.126	Batulicin	9,420	10.25	147.3611	0.146	0.14
6	Sampit	Batulicin	10,376	12.99	43.53129	0.362	Batulicin	8,693	12.99	247.4473	0.287	0.32
7	Toli-Toli	Batulicin	629	12.28	75.41891	0.036	Batulicin	172	12.28	428.7078	0.009	0.02
8	Samarinda	Batulicin	13,720	10.25	38.32616	0.333	Batulicin	12,885	10.25	217.8595	0.296	0.31
9	Kumai	Batulicin	5,764	10.46	56.70978	0.211	Batulicin	4,751	10.46	322.3585	0.165	0.19
10	Lembar	Batulicin	1,064	10.70	62.7634	0.044	Batulicin	1,663	10.70	356.7695	0.065	0.05
11	Badas	Batulicin	-	11.38	112.9017	-	Batulicin	184	11.38	641.7731	0.014	0.01
12	Nunukan	Batulicin	359	12.32	84.9027	0.023	Batulicin	271	12.32	482.6171	0.017	0.02
13	Benoa	Batulicin	313	10.70	63.68822	0.013	Batulicin	114	10.70	362.0264	0.005	0.01
14	Benete	Batulicin	1,723	12.85	64.01901	0.087	Batulicin	1,648	12.85	363.9068	0.079	0.08
15	Tenau	Bau-Bau	22,122	12.76	60.15199	1.048	Bau-Bau	19,813	12.76	341.9252	0.889	0.97
16	Kendari	Bau-Bau	5,463	12.37	38.82677	0.162	Bau-Bau	7,880	12.37	220.7052	0.221	0.19
17	Bitung	Bau-Bau	2,067	12.85	85.53306	0.140	Bau-Bau	1,281	12.85	486.2003	0.082	0.11
18	Makassar	Bau-Bau	36,500	14.10	38.72485	1.230	Bau-Bau	32,300	14.10	220.1258	1.031	1.13
19	Gorontalo	Bau-Bau	1,066	13.60	68.42542	0.061	Bau-Bau	719	13.60	388.9544	0.039	0.05
20	Luwuk	Bau-Bau	1,185	12.99	56.91096	0.054	Bau-Bau	1,369	12.99	323.5021	0.059	0.06
21	Kupang	Bau-Bau	3,223	10.46	61.17339	0.127	Bau-Bau	3,634	10.46	347.7312	0.136	0.13
22	Ende, Flores	Bau-Bau	1,254	11.82	41.16838	0.038	Bau-Bau	1,065	11.82	234.0157	0.030	0.03
23	Larantuka	Bau-Bau	629	11.19	35.97079	0.016	Bau-Bau	750	11.19	204.4707	0.018	0.02
24	Maumere	Bau-Bau	6,274	10.46	37.85316	0.153	Bau-Bau	6,334	10.46	215.1708	0.147	0.15

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
25	Dili	Bau-Bau	1,562	10.46	51.91391	0.052	Bau-Bau	1,423	10.46	295.0971	0.045	0.05
26	Malili	Bau-Bau	73	11.58	37.88562	0.002	Bau-Bau	159	11.58	215.3553	0.004	0.00
27	Waingapu	Bau-Bau	203	11.58	56.94406	0.008	Bau-Bau	206	11.58	323.6902	0.008	0.01
28	Tual	Fak-Fak	571	11.58	34.36954	0.014	Fak-Fak	2,549	11.58	195.3687	0.059	0.04
29	Manokwari	Fak-Fak	889	13.21	40.46318	0.029	Fak-Fak	2,331	13.21	230.0071	0.073	0.05
30	Kaimana	Fak-Fak	2,984	13.75	18.57471	0.047	Fak-Fak	1,222	13.75	105.5852	0.018	0.03
31	Sorong	Fak-Fak	2,434	10.46	27.84039	0.044	Fak-Fak	787	10.46	158.2547	0.013	0.03
32	Ternate	Fak-Fak	592	14.40	70.61978	0.037	Fak-Fak	1,425	14.40	401.4279	0.085	0.06
33	Serui	Fak-Fak	598	12.54	31.88788	0.015	Fak-Fak	-	12.54	181.262	-	0.01
34	Jayapura	Fak-Fak	3,543	14.53	100.1338	0.318	Fak-Fak	3,164	14.53	569.1962	0.269	0.29
35	Ambon	Fak-Fak	2,617	12.85	50.41916	0.105	Fak-Fak	3,379	12.85	286.6004	0.128	0.12
36	Merauke	Fak-Fak	2,275	12.76	119.9086	0.215	Fak-Fak	2,559	12.76	681.6032	0.229	0.22
37	Nabire	Fak-Fak	739	11.55	38.236	0.020	Fak-Fak	168	11.55	217.347	0.004	0.01
38	Biak	Fak-Fak	968	11.01	50.40923	0.033	Fak-Fak	646	11.01	286.544	0.021	0.03
39	Tobelo	Fak-Fak	215	13.21	74.12845	0.013	Fak-Fak	318	13.21	421.3724	0.018	0.02
40	Timika	Fak-Fak	1,560	11.19	46.7566	0.050	Fak-Fak	1,486	11.19	265.7811	0.045	0.05
41	Bau-bau	Main Line	212,860	12.18	203.8757	35.698	Main Line	209,755	12.18	1521.432	42.685	39.19
42	Fak-fak	Main Line	212,860	12.18	203.8757	33.547	Main Line	209,755	12.18	1521.432	40.939	37.24
43	Batulicin	Main Line	212,860	12.18	203.8757	47.020	Main Line	209,755	12.18	1521.432	53.542	50.28

α	0.000050	α	0.0001
β	0.0830	β	0.0830
ϒ	0.0150	ϒ	0.0025

Appendix 5
Scenario II Connectivity Index Measurement

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
1	Tual	Ambon	571	11.58	328.9821	0.02	Ambon	2,549	11.58	328.9821	0.08	0.05
2	Manokwari	Ambon	889	13.21	491.113	0.04	Ambon	2,331	13.21	491.113	0.12	0.08
3	Kaimana	Ambon	2,984	13.75	368.959	0.12	Ambon	1,222	13.75	368.959	0.05	0.08
4	Sorong	Ambon	2,434	10.46	286.3215	0.06	Ambon	787	10.46	286.3215	0.02	0.04
5	Ternate	Ambon	592	14.40	274.014	0.02	Ambon	1,425	14.40	274.014	0.04	0.03
6	Kendari	Ambon	5,463	12.37	206.5766	0.11	Ambon	7,880	12.37	206.5766	0.16	0.13
7	Bitung	Ambon	2,067	12.85	381.2585	0.08	Ambon	1,281	12.85	381.2585	0.05	0.06
8	Serui	Ambon	598	12.54	462.5572	0.03	Ambon	-	12.54	462.5572	-	0.01
9	Jayapura	Ambon	3,543	14.53	852.8985	0.34	Ambon	3,164	14.53	852.8985	0.31	0.32
10	Merauke	Ambon	2,275	12.76	901.6968	0.20	Ambon	2,559	12.76	901.6968	0.23	0.22
11	Nabire	Ambon	739	11.55	494.0174	0.03	Ambon	168	11.55	494.0174	0.01	0.02
12	Biak	Ambon	968	11.01	571.4124	0.05	Ambon	646	11.01	571.4124	0.03	0.04
13	Fak-fak	Ambon	1,030	13.13	286.6004	0.03	Ambon	693	13.13	286.6004	0.02	0.03
14	Gorontalo	Ambon	1,066	13.60	433.7904	0.05	Ambon	719	13.60	433.7904	0.03	0.04
15	Tobelo	Ambon	215	13.21	336.5437	0.01	Ambon	318	13.21	336.5437	0.01	0.01
16	Timika	Ambon	1,560	11.19	515.9433	0.07	Ambon	1,486	11.19	515.9433	0.07	0.07
17	Dili	Ambon	1,562	10.46	390.2502	0.05	Ambon	1,423	10.46	390.2502	0.05	0.05
18	Pantoloan	Balikpapan	1,472	12.79	232.1025	0.03	Balikpapan	3,515	12.79	232.1025	0.08	0.06
19	Banjarmasi	Balikpapan	58,505	10.80	184.3618	0.90	Balikpapan	62,906	10.80	184.3618	0.99	0.95
20	Tarakan	Balikpapan	6,422	12.28	304.2233	0.19	Balikpapan	5,295	12.28	304.2233	0.16	0.17
21	Sampit	Balikpapan	10,376	12.99	285.8027	0.30	Balikpapan	8,693	12.99	285.8027	0.25	0.28
22	Toli-Toli	Balikpapan	629	12.28	312.9042	0.02	Balikpapan	172	12.28	312.9042	0.01	0.01
23	Luwuk	Balikpapan	1,185	12.99	409.9619	0.05	Balikpapan	1,369	12.99	409.9619	0.06	0.05
24	Samarinda	Balikpapan	13,720	10.25	73.45265	0.08	Balikpapan	12,885	10.25	73.45265	0.08	0.08
25	Batulicin	Balikpapan	749	14.60	147.3611	0.01	Balikpapan	100	14.60	147.3611	0.00	0.01
26	Kumai	Balikpapan	5,764	10.46	363.9754	0.17	Balikpapan	4,751	10.46	363.9754	0.14	0.16

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
27	Badas	Balikpapan	-	11.38	635.0938	-	Balikpapan	184	11.38	635.0938	0.01	0.01
28	Nunukan	Balikpapan	359	12.32	336.3337	0.01	Balikpapan	271	12.32	336.3337	0.01	0.01
29	Makassar	Main Line	212,860	10.25	1470.697	35.35	Main Line	209,755	10.25	1470.697	35.31	35.33
30	Ambon	Main Line	212,860	10.25	1470.697	26.20	Main Line	209,755	10.25	1470.697	26.20	26.20
31	Balikpapan	Main Line	212,860	10.25	1470.697	26.65	Main Line	209,755	10.25	1470.697	26.70	26.68
32	Surabaya	Makassar	212,860	11.58	477.5821	9.14	Makassar	209,755	11.58	477.5821	9.15	9.14
33	Tenau	Makassar	22,122	12.76	415.3031	0.91	Makassar	19,813	12.76	415.3031	0.83	0.87
34	Bau-bau	Makassar	1,470	12.18	220.1258	0.03	Makassar	478	12.18	220.1258	0.01	0.02
35	Kupang	Makassar	3,223	10.46	422.5942	0.11	Makassar	3,634	10.46	422.5942	0.13	0.12
36	Lembar	Makassar	1,064	10.70	270.682	0.02	Makassar	1,663	10.70	270.682	0.04	0.03
37	Ende, Flore	Makassar	1,254	11.82	220.156	0.03	Makassar	1,065	11.82	220.156	0.02	0.02
38	Larantuka	Makassar	629	11.19	287.582	0.02	Makassar	750	11.19	287.582	0.02	0.02
39	Maumere	Makassar	6,274	10.46	271.8952	0.14	Makassar	6,334	10.46	271.8952	0.14	0.14
40	Malili	Makassar	73	11.58	259.3645	0.00	Makassar	159	11.58	259.3645	0.00	0.00
41	Benoa	Makassar	313	10.70	340.0828	0.01	Makassar	114	10.70	340.0828	0.00	0.01
42	Benete	Makassar	1,723	12.85	273.1004	0.05	Makassar	1,648	12.85	273.1004	0.05	0.05
43	Waingapu	Makassar	203	11.58	261.7674	0.00	Makassar	206	11.58	261.7674	0.00	0.00

α	0.0000	α	0.0000
β	0.0835	β	0.0835
ϒ	0.0022	ϒ	0.0022

Appendix 6
Scenario III Connectivity Index Measurement

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
1	Surabaya	Main Line	212,860	10.46	1371.098	47.27	Main Line	209,755	10.46	1371.098	47.10	47.18
2	Sorong	Main Line	212,860	10.46	1371.098	43.82	Main Line	209,755	10.46	1371.098	43.48	43.65
3	Makassar	Main Line	212,860	10.46	1371.098	47.34	Main Line	209,755	10.46	1371.098	46.99	47.17
4	Tenau	Makassar	22,122	12.76	415.3031	1.62	Makassar	19,813	12.76	415.3031	1.46	1.54
5	Kendari	Makassar	5,463	12.37	431.7105	0.40	Makassar	7,880	12.37	431.7105	0.59	0.49
6	Pantoloan	Makassar	1,472	12.79	422.5351	0.11	Makassar	3,515	12.79	422.5351	0.26	0.19
7	Tarakan	Makassar	6,422	12.28	623.1355	0.68	Makassar	5,295	12.28	623.1355	0.56	0.62
8	Bau-bau	Makassar	1,470	12.18	220.1258	0.05	Makassar	478	12.18	220.1258	0.02	0.04
9	Balikpapan	Makassar	7,658	10.25	360.5033	0.39	Makassar	9,420	10.25	360.5033	0.48	0.44
10	Gorontalo	Makassar	1,066	13.60	493.8123	0.10	Makassar	719	13.60	493.8123	0.07	0.08
11	Toli-Toli	Makassar	629	12.28	473.8048	0.05	Makassar	172	12.28	473.8048	0.01	0.03
12	Luwuk	Makassar	1,185	12.99	419.392	0.09	Makassar	1,369	12.99	419.392	0.10	0.10
13	Samarinda	Makassar	13,720	10.25	397.2966	0.77	Makassar	12,885	10.25	397.2966	0.73	0.75
14	Batulicin	Makassar	749	14.60	276.5546	0.04	Makassar	100	14.60	276.5546	0.01	0.02
15	Kupang	Makassar	3,223	10.46	422.5942	0.20	Makassar	3,634	10.46	422.5942	0.22	0.21
16	Lembar	Makassar	1,064	10.70	270.682	0.04	Makassar	1,663	10.70	270.682	0.07	0.05
17	Ende, Flores	Makassar	1,254	11.82	220.156	0.05	Makassar	1,065	11.82	220.156	0.04	0.04
18	Larantuka	Makassar	629	11.19	287.582	0.03	Makassar	750	11.19	287.582	0.03	0.03
19	Maumere	Makassar	6,274	10.46	271.8952	0.25	Makassar	6,334	10.46	271.8952	0.25	0.25
20	Dili	Makassar	1,562	10.46	459.6562	0.10	Makassar	1,423	10.46	459.6562	0.10	0.10
21	Malili	Makassar	73	11.58	259.3645	0.00	Makassar	159	11.58	259.3645	0.01	0.00
22	Nunukan	Makassar	359	12.32	623.0053	0.04	Makassar	271	12.32	623.0053	0.03	0.03
23	Benete	Makassar	1,723	12.85	273.1004	0.08	Makassar	1,648	12.85	273.1004	0.08	0.08
24	Waingapu	Makassar	203	11.58	261.7674	0.01	Makassar	206	11.58	261.7674	0.01	0.01
25	Tual	Sorong	571	11.58	347.0083	0.03	Sorong	2,549	11.58	347.0083	0.14	0.09
26	Manokwari	Sorong	889	13.21	229.6884	0.04	Sorong	2,331	13.21	229.6884	0.10	0.07
27	Kaimana	Sorong	2,984	13.75	255.8139	0.15	Sorong	1,222	13.75	255.8139	0.06	0.10

No	Seaports	Outbound					Inbound					Total Connectivity Index
		Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	Out bound Connecting Power	Hubs	Container Flow (TEUS) Year 2014	Speed (knot)	Distance (mil)	In bound Connecting Power	
28	Ternate	Sorong	592	14.40	277.6616	0.03	Sorong	1,425	14.40	277.6616	0.08	0.06
29	Bitung	Sorong	2,067	12.85	430.9496	0.16	Sorong	1,281	12.85	430.9496	0.10	0.13
30	Serui	Sorong	598	12.54	237.2733	0.02	Sorong	-	12.54	237.2733	-	0.01
31	Jayapura	Sorong	3,543	14.53	654.4945	0.47	Sorong	3,164	14.53	654.4945	0.42	0.44
32	Ambon	Sorong	2,617	12.85	286.3215	0.13	Sorong	3,379	12.85	286.3215	0.17	0.15
33	Merauke	Sorong	2,275	12.76	825.9016	0.33	Sorong	2,559	12.76	825.9016	0.38	0.35
34	Nabire	Sorong	739	11.55	340.1562	0.04	Sorong	168	11.55	340.1562	0.01	0.02
35	Biak	Sorong	968	11.01	344.3142	0.05	Sorong	646	11.01	344.3142	0.03	0.04
36	Fak-fak	Sorong	1,030	13.13	158.2547	0.03	Sorong	693	13.13	158.2547	0.02	0.02
37	Tobelo	Sorong	215	13.21	279.7265	0.01	Sorong	318	13.21	279.7265	0.02	0.01
38	Timika	Sorong	1,560	11.19	408.7024	0.10	Sorong	1,486	11.19	408.7024	0.09	0.10
39	Banjarmasin	Surabaya	58,505	10.80	473.077	4.14	Surabaya	62,906	10.80	473.077	4.47	4.30
40	Sampit	Surabaya	10,376	12.99	330.4606	0.62	Surabaya	8,693	12.99	330.4606	0.52	0.57
41	Kumai	Surabaya	5,764	10.46	329.5094	0.27	Surabaya	4,751	10.46	329.5094	0.23	0.25
42	Badas	Surabaya	-	11.38	622.8099	-	Surabaya	184	11.38	622.8099	0.02	0.01
43	Benoa	Surabaya	313	10.70	206.3324	0.01	Surabaya	114	10.70	206.3324	0.00	0.01

α	0.0001	α	0.0001
β	0.0831	β	0.0831
ϒ	0.0024	ϒ	0.0024

BIOGRAPHY

Dhi Fadlin Harnanda was born in Kendari, August 30th 1993. He has been finished his study in MIS PESRI Kendari (1999-2005), SMP Negeri 4 Kendari (2005-2008), and SMA Negeri 1 Surakarta (2008-2011). In 2011, the writer is accepted in Industrial Engineering Department, Sepuluh Nopember Institute of Technology.

During his study, the writer actively worked in some organization such as Executive Students Body in his first and second year. He also became the head of human resource department in KSR PMI ITS in his second year, and become the Commander of the same organization in his third year. In his last year, the writer become the head of human resource department of LMB ITS.

Besides organization and academic life, the writer also became the first winner of national social business plan competition held The New You Institute in 2013. He also participated in PKM in 2011 and 2015.