Adaptive policy decision pathways for robust shipping network investment planning in Indonesia

A model application to Indonesian export trade

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MSc Transport, Infrastructure and Logistics

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By

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Preface

Not because of my strength, but only because of His love is so great that makes these two legs strong enough to walk in a such winding road.

All praise and honor only to my Lord, my Father, my Hiding Place, and my Source of Hope. I believe as without His grace and faithfulness, I would not be able to finish this master thesis. This master thesis is a form of appreciation for the knowledge that I have learned in my life, a form of responsibility as a human to spread the benefits through the works created, and a form of thankfulness for the opportunity that has been received.

This master thesis is part of my dream. Addressing Indonesia's ports development challenges has always been my main motivation in achieving this master's degree. Looking back at Indonesia's sea transportation, we are still facing many challenges. Though, our ambition is not easy, which requires intense effort to achieve that. As an archipelago country, I believe that there are still spaces waiting for improvement in our maritime. One of them is through development of international container gateways to improve international trade flows in Indonesia. Therefore, this research is studied to provide Indonesian government a guidance of policy making in shipping network planning in dealing with future uncertainties. This research is a tiny part of the big effort.

I would like to thank all persons who have been there to always support and help me get through this process. First, I give my thank to Prof. Lóri Tavasszy. I am truly inspired by the way you supervise me, who instead of saying "Go!", I received "Let's go!" I thank you for your trust and opportunity to let me be your graduate student, giving me your time to discuss which always make me come out of the room with no empty hands, but list of challenges that encourage me to do more for another mile. I believe that challenges shape people to become stronger. Further, it is also going to be memorable moments to sit and work together with Yousef Maknoon. His great keenness in operations research especially in related to decision making for transport system as well as optimization approaches has proven that he is the right supervisor to work with. I thank Yousef for his positive motivation to me along this process, especially when come the time I see this journey seems has no end. Next, I also thank my second supervisor, Bart Wiegmans who has urged me to improve the way I work during this thesis journey. I thank Bart for the coaching, all valuable feedbacks, and brainstorming sessions to solve problems together and make things clearer. Finally, the last but not least, I give my thank to Carlos Zepeda, my company supervisor from Port of Rotterdam International Department (PoRInt). I am truly blessed to have him not only as supervisor but more as friend who always has the same excitement when talking about Indonesia or port development in general. I thank him for the invaluable opportunity he has opened to me to do this graduate thesis in the company of my dream, for all the discussions, weekly meetings, understandings, knowledge sharing, and lessons learned throughout this process.

Furthermore, I would like to thank all of my family members, MPS Family, for their endless support and trust having long-distance family relationship with their youngest girl for the past two years. Next, is to my partner, Agung Christy, who always been there in my good and bad times. Believing in me as he first believes that God lives in me and never leaves me. I also would like to thank all colleagues in PoRInt. Another 6-months I spent in this lovely department together with all of you is a gift from God. Not to mention I give my thanks to all of my Indonesian friends here in Delft, my second family. My prayer goes to all of you. May God bless you all.

I hope this thesis can be the light, no matter how small the impact is, for the world of science and research as well as for Indonesia. At last, I would say that I am truly grateful for this thesis journey.

Delft, August 2019

Ingrid Rosalyn Indriana Sitorus

Summary

Due to its archipelagic nature, Indonesia enforces to make substantial investments in its maritime sector, especially port infrastructure, in order to promote trade, economic growth, and ease disparity among Indonesia's island regions. The challenge, of course, is that Indonesia has many ports to invest in and a limited budget; it must prioritize among various port development projects. The government therefore needs to choose wisely in order to avoid wasting money by constructing shipping network plans.

To improve the current state of policy decision-making for the Indonesian shipping network, we hereby develop adaptive policy decision pathways focused on Indonesian containerized exports. The objective of this study is to build adaptive policy decision pathways that can cope with dynamic future uncertainties and results to help the government develop robust network investment plan that helps the Indonesian government achieve its objective of improving connectivity and value-added exports through lower logistics costs. One of the most important aspects in shipping network planning in Indonesia is deciding which ports are to become international container gateways.

The export flows data are collected and formed into an Origin-Destination ("OD") matrix of 31 main ports in Indonesia and major 16 regional ports in the world. This set of export data not only represents the flows between ports in Indonesia, but also the direction the flows take between Indonesian ports and ports in the world. Moreover, from the methodological point of view, export data can help the model to capture the importance of a port to take a role as international container gateway, which is the key decision of shipping network planning in Indonesia.

The policy-making approach used for the purpose of this research is adaptive policy decision pathways for shipping network planning. The paradigm used in this approach is called 'Dynamic Adaptive Policymaking', which aims to build policies that change over time just because the future cannot be predicted. The characteristics of adaptive policy decision pathways for shipping network planning are identified from several aspects such as focus of the approach, planning process, and types of actions that can be taken. The focus of this approach is to explore actions for achieving objectives over time by including dynamic interaction between the network infrastructure and market. The dynamic interaction comes from the difference future scenarios represented by different demand values over specified periods of time. In the planning process, a short stepwise consisted of 5 steps for designing adaptive pathways is taken. This stepwise is considered as the core of methodology of this research. The steps involved are: (1) describe current, future situations and objectives; (2) problem analysis; (3) network flow model; (4) develop policy decisions; (5) selection of preferred policy decision pathways.

There have been several port development policies by the government over last few years emphasizing shipping network plans and consisting of selections of priority ports designated as international gateways or domestic ports of Indonesia. There are changes in the shipping network configurations among the various development policies that capture the uncertainties within the process of shipping network planning. Moreover, the difficulties in prioritizing port infrastructure investments can already been seen in Indonesia's port planning policies of the previous two presidential administrations. Even though both plans have a clear goal of promoting economic growth outside of Java, Indonesia's most

economically developed island, so as to reduce the disparity between islands, they differ in many regards. Despite the huge stakes involved, what does matter is there may be significant inconsistency between aforementioned shipping network plans due to inadequacy of planning towards the real-world needs.

The model involved in building adaptive policy for shipping network planning is Minimum Cost-Flow (MCF) problem. The objective of MCF is to minimize the shipping network cost to meet export demand. Here, costs are defined as generalized cost that is calculated by considering two types of costs: shipping-related costs and container-related costs. Shipping-related costs are the costs that depend on the location of the ports as it is calculated with the distance and depend on the vessel size thus it is calculated with container volumes (in TEUs) as well. Meanwhile, container-related costs are the costs that depend on the number of TEUs being handled as it is calculated with the container volumes.

Forecasting and anticipating the future are essential elements of shipping network planning, particularly demand projection. The potential container volumes of Indonesia for export trade in this research is forecasted by two approaches. First is using demand forecast model and second is by generating random numbers with respect to results from demand forecast model. The random number generation follows the rule of normal distribution. The first approach results in two scenarios: optimistic and pessimistic. Both scenarios are categorized as parent scenarios. Moreover, the second approach results in 13 scenarios, which originally come from 100 cases randomly generated, those are categorized as branch scenarios.

Based on application of MCF model for all developed scenarios, the results of the model are two: optimal solution of shipping network cost and flow pattern. From flow pattern analysis, we identify that there are some scenarios that have identical flow pattern, and some are significantly distinct with each other. Moreover, in each flow pattern, there are gateways that either have high number of throughputs in TEUs but fluctuate over periods or have gradual increased throughput growth though the yearly total demand values drop at the same time.

These flow pattern analyses lead us to several findings. Firstly, Tanjung Priok, Tanjung Perak, and Belawan are the top three gateways that have higher throughput in TEUs throughout different scenarios. Secondly, compare to Bitung and Sorong, which gateways are located in eastern part of Indonesia, export throughput of Makassar remains higher. Moreover, in most of scenarios, throughput growth of Palembang steadily growing with amount of TEUs that is comparable with Makassar, even though the yearly total demand tends to fluctuate from year to year. In regard to flow pattern, though some yearly total demands are in the same range, and in the same period, the flow pattern possibly result differently. Lastly, there are several scenarios that have identical flow pattern in particular period, which are classified into three different flow patterns.

Flow pattern A: in average 30% of exports are handled by Tanjung Priok, Belawan and Tanjung Perak are followed in second and third highest percentage of handling exports. Flow pattern B: Tanjung Priok, Belawan and Tanjung Perak having similar average percentage in handling exports, yet Belawan has the highest percentage. Smaller number of provincial ports come to Tanjung Priok Flow pattern C: No provincial ports come to Tanjung Priok, though it still handles export flows originated from its pair-province (Jakarta and West Java). Palembang shows more significant average percentage of handling exports and provincial ports that are used to transship via Tanjung Priok, shift to Palembang.

Based in these flow patterns, we analyze how each of them being effective in certain period and range of demand. Then, we can build policy pathways map with x-axis represents demand volumes and mapping the flow pattern for each period. Linked to each flow pattern is a policy decision. Policy decisions are the recommendations for policymakers in regard to international container gateways development.

Policy Decision A

The focus in this policy is the development of Tanjung Priok. Tanjung Priok is developed to cope with big yearly demand volume in the future. In other words, it is developed to be the main international container gateway in the country. Belawan and Tanjung Perak become other main gateways with smaller scale than Tanjung Priok. Moreover, Makassar become feeder gateway. The most optimal condition to implement this policy decision is when the flow pattern A is effective.

Policy Decision B

The focus in this policy is the development of Belawan, Tanjung Priok, and Tanjung Perak as main gateways with relatively same scale in handling the exports. They are developed with similar scale in a mid-range of yearly demand volumes. Moreover, Palembang and Makassar become feeder gateways. The most optimal condition to implement this policy decision is when the flow pattern B is effective.

Policy Decision C

The highlight in this policy is the development of Palembang to function as feeder gateway. Palembang is developed to deal with small yearly demand volume in the future that results in more optimal shipping network cost for that range of demand. Tanjung Perak, Belawan, and Tanjung Priok still become the main gateway. The most optimal condition to implement this policy decision is when the flow pattern C is effective.

Based on these policy decisions we can conclude that there are **3 main gateways** remain important for the export trade in Indonesia: ***Belawan, Tanjung Priok, and Tanjung Perak***. Moreover, there are 2 gateways those are likely to become **feeder gateways: *Palembang and Makassar***.

Furthermore, we do validation and sensitivity analysis for the model used in this research. The validation is done in two cases. This validation is related to an additional gateway candidate namely Kuala Tanjung, which is currently still a greenfield port project in Indonesia. The two cases are: (1) 50:50 case, with demand estimation: Kuala Tanjung takes 50% of total demand volumes of Belawan and (2) extreme case, which only Kuala Tanjung and Bitung developed as international container gateways. The first case leads to conclusion that Kuala Tanjung is more optimal to be developed as international container gateways compare to Belawan. Activating Kuala Tanjung in the network also makes the shipping network cost lower than if the network does not have Kuala Tanjung. Moreover, the second case leads to conclusion that it is not efficient to invest only on Kuala Tanjung and Bitung as gateways since the shipping cost per TEU for the resulted flow pattern is 22% higher compare to the initial flow pattern under the same scenario. On the other hand, considering this extreme plan might be potential to significantly promote eastern part of Indonesia. Since the flow pattern shows that Kuala Tanjung be the dedicated gateway for western part and so is Bitung for eastern part of Indonesia. By focusing only on two international container gateways may lead to efficient and effective spending of investment and thus the quality of both gateways become stronger and significantly improved.

Furthermore, we perform sensitivity analysis with respect to changes in number and type of cranes. A study done on two big ports in Indonesia Tanjung Priok and Tanjung Perak indicates that there are two types of crane currently used in both ports: single-lift crane and twin-lift crane. Besides varying the type of crane, we also set variation of number of cranes which is set from 0 (initial number of cranes), +1, +2, and +3. The first finding of this sensitivity analysis is that as the number of cranes increased, the cost gets lower. Moreover, change all cranes into twin-lift type makes the cost per TEU the lowest no matter how many additional cranes is. This variation of cranes will result in different flow pattern once the improvement of cranes applies differently for some gateways.

As the conclusion, the main finding is that flow pattern is very sensitive to demand volumes. Secondly, MCF model is able to identify the flow pattern so that is very useful to analyze the potential of gateways. In regard to this, it is therefore very important to deal with future uncertainties which considering variation of demand volumes. By applying adaptive policy decisions for shipping network planning, the results show that there could be more than one plausible policy decision for a single period. Moreover, given that shipping network planning is future long-term plan with full of uncertainties, using the approach of adaptive policy decision pathways with integration of network flow model is thus one of the solutions. The key factor in this model is demand volumes which results in flow pattern that can be further analyzed to identify under which condition the flow is being effective. Since each of flow pattern gives the information about flows in each port and how ports connect to each other, we can determine the promising ports within each flow pattern. Based on this, policy decision pathways are able to be built, thus supports more robust investment planning for ports development in Indonesia under future uncertainties.

The recommendations are divided into several perspectives. In terms of model improvement, it is recommended to take the model to the higher level of operational research and computational model. Since the model is used the very classic one, nodes and arcs are predetermined. Therefore, the model used in this research is not yet designing a network. Moreover, the recommendation for further research is to consider different types of commodities as one additional variable in the shipping network problem, which may result in more detailed policy recommendations. This is due to the fact that export trade in Indonesia also includes other types of commodities. As insights for policymaker, the approach used in this research is done in strategic level. Therefore, further analysis once the results want to be applied in tactical and operational level are required. Lastly, the recommendation from the perspective of data collection is by expanding the system to intermodal transport to capture the accessibility and connectivity amongst ports and their hinterland through other modes such as road transport.

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ABBREVIATIONS

ABP	Assumption-Based Planning
APM	Adaptive Policy-Making
BPS	Badan Pusat Statistik (Central Bureau of Statistics)
CAGR	Compound Annual Growth Rate
CAS	Complex Adaptive Systems
FTA	Free Trade Agreement
GDP	Gross Domestic Product
GMF	Global Maritime Fulcrum
LSCI	Liner Shipping Connectivity Index
MCF	Minimum Cost-Flow
MoF	Ministry of Finance
MoT	Ministry of Transportation
MP3EI	The Masterplan for Acceleration and Expansion of Indonesia's Economic Development
OD	Origin-Destination
Pelindo	PT Pelabuhan Indonesia
QPI	Quality of Port Infrastructure
RKP/RKPD	Rencana Kerja Pemerintah/Rencana Kerja Pemerintah Daerah (Government Work Plan)
RPI2JMN	Rencana dan Program Investasi Infrastruktur Jangka Menengah National (Mid-Term National Infrastructure Investment Program and Plan)
RPJMN/D	Rencana Pengembangan Jangka Menengah Nasional/Daerah (Mid-Term National/Local Development Plan)
RPJPN/D	Rencana Pengembangan Jangka Panjang Nasional/Daerah (Long-Term National/Local Development Plan)
TEU	Twenty-Foot Equivalent Unit

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1 INTRODUCTION

1.1 BACKGROUND: GENERAL CONTEXT

Given an increasingly fast-paced and dynamic world order, the need for a dynamic and adaptive policy making process to generate optimal policy decisions is becoming increasingly important for governments. This is especially true in port infrastructure planning given that port infrastructure investments are major decades-long investment decisions. This is especially relevant for Indonesia where due to the country's archipelagic nature, ports play a crucial role in not only domestic but also international connectivity. Moreover, since containers account for around 60% of the value of Indonesia's total international trade, there has been a strong focus on container shipping in Indonesia.

1.2 PROBLEM STATEMENT

Due to its archipelagic nature, Indonesia needs to make substantial investments in its maritime sector, especially port infrastructure, in order to promote trade, economic growth, and ease disparity among Indonesia's island regions. The challenge, of course, is that Indonesia has many ports to invest in and a limited budget; it must prioritize among various port development projects. The government therefore needs to choose wisely in order to avoid wasting money. There have been several port development policies by the government over last few years emphasizing shipping network plans and consisting of selections of priority ports designated as international gateways or domestic ports of Indonesia. There are changes in the shipping network configurations among the various development policies that capture the uncertainties within the process of shipping network planning. Figure 1 below illustrates two of four recent network plans that highlight several ports as priorities of Indonesia's development agenda. Both plans are showing different network designs which implies different configurations and connections of ports throughout the country. More background behind these policies are described in sub-chapter 4.3.

A shipping network plan should take future demand projections into consideration. This would normally imply developing at least two long-term scenarios for a specific year in the future and projecting cargo volumes for each. Even this, however, may not be sufficiently robust due to the fact that there are plausible uncertainties that might happen in between the year the plan is developed and the forecasted year which are difficult to capture in a single year in the future. These uncertainties can affect the projections in certain period and leads to different needs of demand. Moreover, given that port infrastructure development is a long-term process, the investment provided to the selected ports based on single forecasted year assumption may not generate the expected added value. Therefore, this may yield to inefficient investment planning towards port infrastructure development.

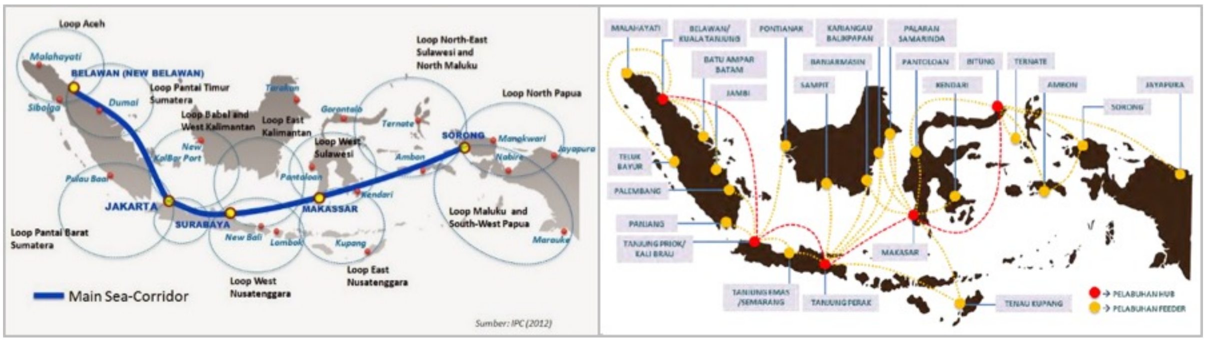

Figure 1 Pendulum Nusantara 2012 (left) and Maritime Highway 2014 (right)
(Source: Bappenas, 2016)

The difficulties in prioritizing port infrastructure investments can already been seen in Indonesia's port planning policies of the previous two presidential administrations. The previous presidential administration of President of Susilo Bambang Yudhoyono (2009-2014) drafted the *Pendulum Nusantara* in which the government advocated a shipping network with 5 main ports across the country with various loops around these five main ports as illustrated in Figure 1 above on the left. In 2014, President Joko Widodo succeeded President Yudhoyono and introduced a new port network policy called *Nawacita* 2014-2019 wherein the government aims to develop 24 main (existing and new) ports across the archipelago. This plan has now evolved into a shipping network plan on 61 port locations.

Even though both plans have a clear goal of promoting economic growth outside of Java, Indonesia's most economically developed island, so as to reduce the disparity between islands, they differ in many regards. Despite the huge stakes involved, what does matter is there may be significant inconsistency between aforementioned shipping network plans (Tu, Adiputranto, Fu, & Li, 2018) due to inadequacy of planning towards the real-world needs.

These changes in network configuration definitely affect the port investment planning in the policy decisions. Within the shipping network planning there are two main outputs: which ports should be developed and when they should be developed. With regards to port investment, the government has a budget plan that the government upgrades on a regular basis (e.g. yearly, 5-years, or 10-years) and the aforementioned outputs become the main assumptions. Underlying the budgeting plan is a set of selected ports infrastructure that needs to be funded/invested to realize the ports development based on shipping network plan within the intended policies. Consequently, changes in shipping network plan mean changes in selected ports and thus changes in port investment planning.

One of the most important aspects in shipping network planning in Indonesia is designating which ports are to become international container gateways as these ports will play an important role in connecting Indonesia with foreign markets and therefore have a strong impact on its economy. According to the data from the Seabury Ocean Trade database, international containerized trade flows account for half of the value of Indonesia's total exports, 67% of the value of Indonesia's imports, and half of the value of Indonesia's total international trade as shown in the Figure 2 below. Containers can therefore significantly impact Indonesia's trade balance. Therefore, robust investment planning to develop international container gateways based on an adaptive policy framework is recently becoming a major issue in the maritime sector of Indonesia. This issue is then shaped as the core problem of this research with a focus on containerized exports given that one of the aims of the government is to promote value added exports which typically go in containers. Specifically, export is very important and has been one of the pivotal development agenda points in Indonesian economic development due to the wave of globalization since the 1980s that implies rapid growth of global trade (Presidential Decree No 26/2012, 2012).

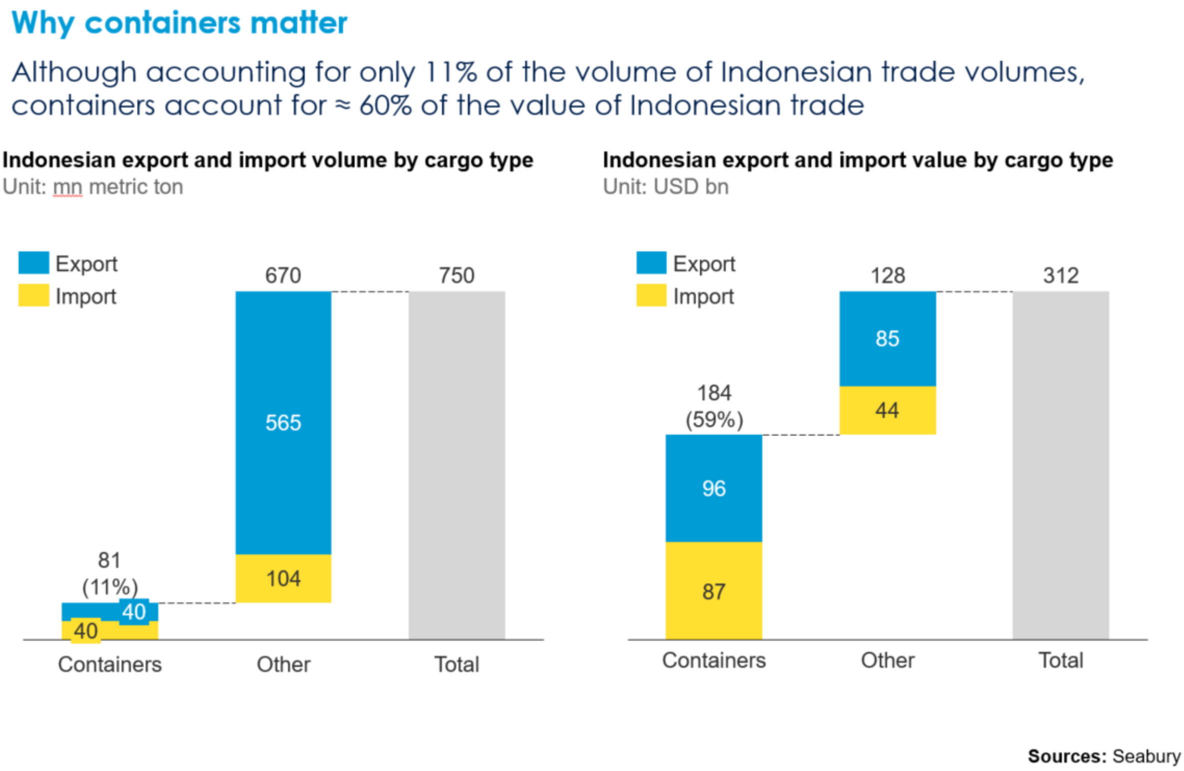

Figure 2 Importance of the container segment to Indonesian trade

Summarizing the preceding discussion: a key problem in policy decisions for shipping network planning that aims for robust investment is the inadequacy of adaptivity for long-term development plans which are particularly sensitive to uncertainties. Shipping network planning in Indonesia is inadequate throughout the long-term implementation because the policy analysis process does not yet result in adaptive selection with respect to future developments happening periodically during implementation term. This lack of adaptivity is the result of the fact that (a) there are very few studies addressing the adaptive pathways to produce policy decisions for shipping network planning; (b) most of the research only considers a single point of future demand projection as the input for the network plan, rather than considering plausible uncertainties that could influence outcomes periodically; and (c) established network masterplans in Indonesia are static, in that it does not have any mechanisms in place for reacting to changing conditions between periods. Another major challenge is lack of detailed data which makes it difficult to create demand projections.

To improve the current state of policy decision-making for the Indonesian shipping network, we hereby develop adaptive policy decision pathways focused on Indonesian containerized exports using both historical data and containerized export projections. The export flows data are collected and formed into an Origin-Destination (“OD”) matrix of 31 main ports in Indonesia and major 16 regional ports in the world. This set of export data not only represents the flows between ports in Indonesia, but also the direction the flows take between Indonesian ports and ports in the world. Moreover, from the methodological point of view, export data can help the model to capture the importance of a port to take a role as international container gateway, which is the key decision of shipping network planning in Indonesia. The bigger the flow through a particular port in the network, the more promising the port is as an international container gateway.

1.3 Research objective

In light of the aforementioned context, the objective of this study is to build adaptive policy decision pathways that can cope with dynamic future uncertainties and results to help the government develop robust network investment plan that helps the Indonesian government achieve its objective of improving connectivity and value added exports through lower logistics costs.

Due to data availability and for the sake of simplicity, the connection between ports outside Indonesia are predetermined based on existing container shipping line data from the eeSea database (e.g. there is for example a direct connection between Colombo and Singapore but not between Colombo and Caucedo). This is due to the fact that connection between ports in other countries is beyond the control of Indonesian policy. In addition, this research is focused on the decisions made for port development in Indonesia, which is the main target of Indonesian government investment plans and public policies.

1.4 Research questions

The research objectives have been formulated into the following main question:

How to build adaptive policy decision pathways for shipping network planning in Indonesia that supports robust investment decisions under future uncertainties?

In order to answer this main question, several sub questions need to be answered, namely

1. *What are the characteristics and stepwise policy analysis of adaptive policy decision pathways for shipping network planning?*
2. *What is the model involved in adaptive policy for shipping network planning and to what extent is the model useful in analyzing the policy based on Indonesian export trade data?*
3. *What is Indonesia’s containerized export volume potential under ensembles of scenarios?*
4. *How to map policy pathways and select preferred policy pathways?*
5. *What are the promising policy decisions over ranges of demand and periods?*
6. *How sensitive do the adaptive policy decision pathways perform towards other factors?*

1.5 RESEARCH APPROACH

The approach described in the figure below was used to address the aforementioned research questions.

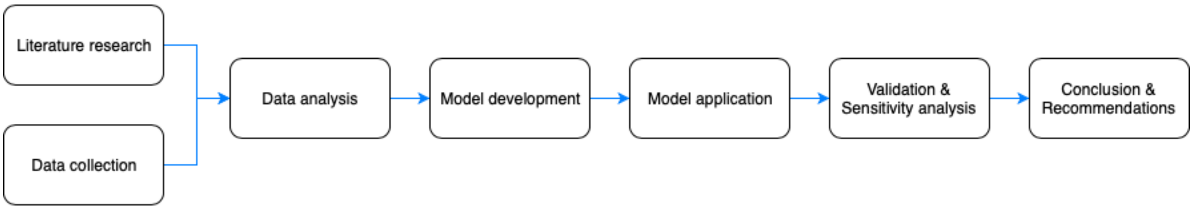

Figure 3 The research approach

To answer the first two sub questions, an extensive literature research is performed with two objectives. The first objective is to understand the adaptive policy decision pathways tool including its characteristics and stepwise policy analysis. The second objective is discovering the gaps between policy decision-making and shipping network planning, particularly in Indonesia. The focus of second objective is on the network model selection to perform shipping network planning.

Data collection of Indonesian export trade is extensively performed through the access to BPS Statistics of Indonesia and is complemented by other sources such as the Seabury Ocean Trade database and eeSea database. Afterwards, the data are analyzed to identify to what extent the selected network model is useful in analyzing Indonesia's shipping network policy. The initial schematization of the network structure is developed from the available export data so that we have clear picture of the current export flow network. Furthermore, future inflow and outflow values, which are the numbers of containers originated from Indonesian ports and destined to worldwide ports, are obtained based on potential container volumes in the future. This statistics work produces ensembles of future scenarios based on total demand values, which answers the third sub question.

Based on the understanding of adaptive policy decisions on shipping network planning in Indonesia, the Minimum Cost-Flow (MCF) problem is used as the model to identify which ports volumes go through based on optimal shipping cost. Shipping network cost is analyzed based on several assumptions explained in model development. This network flow model is then incorporated with the adaptive policy decision pathways and thus the model structure is developed. Here, the model flow-chart is constructed as the guidance to answer the fourth question and carried out in model application in the next approach. The model is applied to select preferred policy pathways in dealing with future uncertainties in several periods.

Next, sensitivity analysis is performed to evaluate the robustness of policy pathways towards other factors such as cost and share of demand values amongst 31 ports of origin in Indonesia. Finally, conclusion and recommendations are formulated based on the findings.

1.6 RESEARCH CONTRIBUTION

The contribution of this research can be summarized as follows. The result of this study will contribute to fill the research gaps of how to develop adaptive policy decision pathways for robust investment network plan taking into account export trade of Indonesia. The policy should consider the periodic implementation of optimal shipping network plan in dealing with the future plausible uncertainties. This model improves on previous studies by satisfying the following criteria: (1) addressing uncertainties in a deeper approach by generating ensembles of scenarios; (2) building adaptive policy decision pathways which deals with shipping network plan problem in Indonesia; (3) identifying the performance of implemented network plan based on Minimum Cost Flow (MCF) problem. Beyond that, this research will be useful for the government in building a master plan for shipping network in the country, especially in making decisions of international container gateways development. As the investment costs of ports development are incredibly high, this issue is crucial for the government assessment. For larger scale of relevance, the study will help the government to have a strategic adaptive policy recommendation for the country development in period-based implementation.

1.7 THE STRUCTURE OF THE THESIS

The report contains eight chapters as described in this section. Chapter 2 provides a summary of the literature review of adaptive planning approaches and incorporates shipping network planning into one of the approaches, then identifies the scientific gap. Chapter 3 explains the methodology used in this research. In Chapter 4, the current, past and future situation of Indonesia are elaborated as the starting stage of the methodology in this research. Chapter 5 provides data analysis of container export trade in Indonesia including the results of the demand forecast model. In Chapter 6, the model is applied for all scenarios and periods. Chapter 7 performs model validation and identifies sensitivity analysis results. Finally, Chapter 8 concludes the study by answering the research questions and summarizing the main findings. This document also identifies research limitations and identifies areas for further research.

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2 UNDERSTANDING ADAPTIVE POLICY DECISION PATHWAYS FOR SHIPPING NETWORK PLANNING

2.1 GENERAL REVIEW: ADAPTIVE PLANNING APPROACHES

From a planning process perspective, the uncertainties in the future can be very unpredictable and intrinsically unknowable. The challenge in defining the future is to provide a means to deal with surprises and irreducible uncertainties (van der Pas, Walker, Marchau, van Wee, & Kwakkel, 2013). As policy decision-making is about the future, therefore policy-makers are always confronted with uncertainty. The concept of adaptive policy planning therefore emerged as one of the solutions to anticipate future uncertainties and challenges in supporting many policy domains including decisions in shipping network planning.

There are three paradigms in adaptive policy planning/policy-making process that is considering future uncertainties. In their paper, (van der Pas, Walker, Marchau, van Wee, & Kwakkel, 2013) distinguished based on literature three basic approaches that policy-makers apply when dealing with future uncertainties. First is ‘Predict-and-Act’ which is the traditional paradigm where the future is assumed well predictable to result in an optimal policy decision for that future. This paradigm assumes a single future situation and takes analysis to select the policy which showing best performance. Secondly, ‘Static Robust Policymaking’ which the paradigm used in this process is like what (Walker, et al., 2003) stated in the paper that is as ‘scenario uncertainty’ and the approach is often called ‘scenario planning’. Third is the so-called ‘Dynamic Adaptive Policymaking’ which aims to build policies that change over time just because the future cannot be predicted. The decisions made in the beginning of the process could be different from what will be made somewhere in the future under specific conditions of uncertainty. Figure 4 below illustrates the three paradigms.

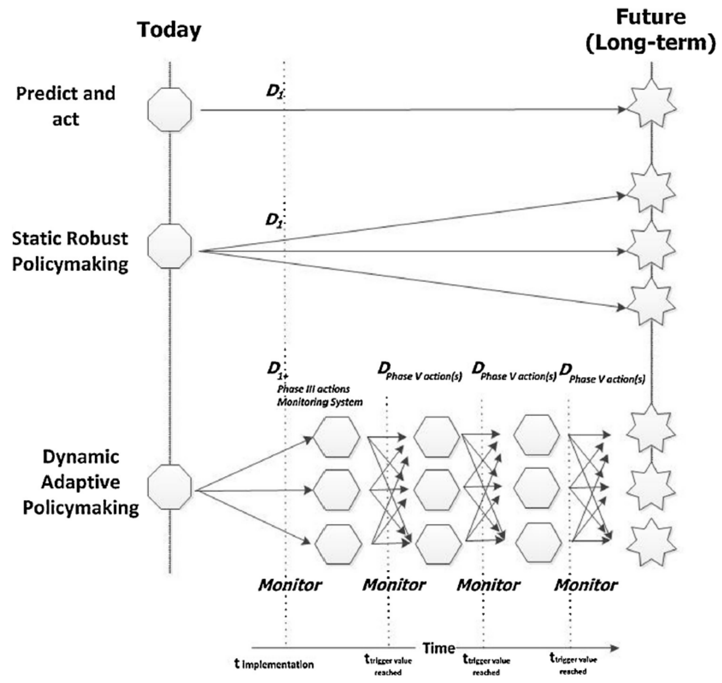

Figure 4 Three paradigms in policy-making under future uncertainties

The fact that policy-making is about actions taken to deal with future uncertainties should not be unappreciated. Implementation of adaptive policy-making processing is still very much in question. Most of the existing research in the field of adaptive policy planning emphasized the concept of structured analytical process that is finding a framework or scheme to support the policy decision-making process taking into account future uncertainties (van der Pas, Walker, Marchau, van Wee, & Kwakkel, 2013). There are several tools and innovative framework studied for the purpose of policy-making (De Neufville, 2000), (Dewar, Builder, Hix, & Levin, 1993), (Marchau, Walker, & van Wee, 2010), (Walker, Marchau, & Swanson, 2010). Another approach to decide policies taking into account uncertainties is by identifying adaptive policy pathways (Haasnoot, Kwakkel, Walker, & Maat, 2013).

Furthermore, there are a number of approaches and computational techniques to support decision-making under uncertainties, some of them are reviewed in (Walker, Haasnoot, & Kwakkel, 2013) and (Swanson, et al., 2010). The first one is called Assumption-Based Planning ("ABP"). Based on the literature by (Dewar, Builder, Hix, & Levin, 1993), ABP is elaborated as a systematic way of thinking about a future full of basic uncertainties in a policy-making framework for dealing explicitly with those over time uncertainties. The systematic way is detailed into five steps: (1) identify important assumptions; (2) identify assumption vulnerabilities; (3) define signposts; (4) define shaping actions; and (5) define hedging actions. The second one is Complex Adaptive Systems ("CAS"). Based on the literature by (Swanson & Bhadwal, 2009), there are three stages of the policy cycle have been reviewed that generate principle for intervention in CAS: (1) policy setup; (2) policy design and implementation; (3) monitoring and continuous learning and improvement. The first stage is detailed into some principles, such as respecting history, understanding local conditions; strengths; and assets, understanding interactions with the natural; built and social environment (Glouberman, Campsie, Gemar, & Miller, 2003). The second stage is detailed into some principles, such as facilitate copying of successes, encourage variation, and promote variation and redundancy (Berkes, Colding, & Folke, 2003). The third stage has principles as follows: learn to live with change and uncertainty (Berkes, Colding, & Folke, 2003), fine-tune process, and evaluate performance of potential solutions and select the best candidates for further support (Glouberman, Campsie, Gemar, & Miller, 2003). The third one is called Adaptive Policymaking ("APM"). (Walker, Rahman, & Cave, 2001) In a paper written by Walker, Rahman, and Cave in 2001, a generic and structured approach to support long-term dynamic robust plans was proposed. Conceptually, APM is embedded in ABP approach (Haasnoot, Kwakkel, Walker, & Maat, 2013). There are five steps in the APM framework those are: (1) setting the stage; (2) assembling the basic plan; (3) increasing the robustness of the basic plan; (4) setting up the monitoring system; and (5) preparing the trigger responses. The focus of the approach starts from a vision of the decisionmaker and creates a plan for realizing this vision and protecting it from failure. There are different types of actions that can be taken such as hedging, mitigation and shaping.

Next is the adaptation pathways approach that is also referred to as the "decision pathways" approach. This approach is used herein to build policy decisions for shipping network planning. This paper uses term Adaptive Policy Decision Pathways to refer to this approach. Deeper explanation of this approach is presented in next sub chapter.

2.2 ADAPTIVE POLICY DECISION PATHWAYS

This paper deals with dynamic robustness to build the adaptive policy decisions. A policy that is able to adapt responsively to suit different future conditions. In light of plausible future uncertainties, one needs to design dynamic adaptive plans that overcome changes experienced over time. These changes cannot be projected precisely based on past experiences and future extrapolations thereof, but also by what will happen on the way to the future (Yohe, 1990). Adaptive policy decision pathways approach used in this paper drives the decision-makers to perform “what if” analysis over situations and think about the outcomes as the decisions over time to deal with future changes (Jeuken & Reeder, 2011).

<u>The characteristics</u>

There are several aspects assessed to understand more about the characteristics of adaptive policy decision pathways approach, such as focus, planning process, and types of actions that can be taken. Given that the original version of this approach is developed with the core issue of water management, the characteristics will be adapted to fit the context of this research that is shipping network planning.

The focus of this approach is to explore actions for achieving objectives over time by including dynamic interaction between the network infrastructure and market. The dynamic interaction comes from the difference future scenarios represented by different demand values over specified periods of time. Therefore, this approach explicitly considers the multiplicity of futures via ensembles of scenarios. In the planning process, a short stepwise approach for designing adaptive pathways is taken and will be further explained in the model development later in this research. In terms of orientation of the planning, this approach focuses on application of models to develop a specific plan of shipping network. Furthermore, there is no specific categorization of actions built in this approach. Several actions can be identified based on different range of values of factors that influence the model.

The approach actions used in this research will be mainly based on two key decisions: which ports should be the focus of development based on potential and when should these ports be developed. Therefore, the actions are in the form of development policy options in the preferred pathways. In generating a desirable plan, this approach presents several preferred pathways with focus on how to identify promising ports as in this case where the model is confronted with a limited number of possible actions. In terms of types of uncertainties, this approach explicitly concentrates on uncertainties in demand values which is the core decision variable in modelling shipping network flow. Other factors related to parameters such as cost and capacity, however, can also be performed to test the desirable policy. The last characteristic is in regard to dynamic robustness of resulting plan. This approach results in clear pathways showing when a policy should be changed and what the next decision should be. The dynamic robustness is produced by involving certain periods as the timeline of policy realization.

As mentioned before, the core of Adaptation Policy Decision Pathways is Adaptation Pathways. Figure 5 below shows an example of an Adaptation Pathways map that illustrates the current situation, transfer station to new decision, adaptation tipping point of a decision, and range of decision being effective or ineffective in certain period of time. Tipping points represent conditions under which a decision no longer meets the desirable objectives. Transfer stations are decisions available to be chosen after experiencing tipping points. (Haasnoot, Kwakkel, Walker, & Maat, 2013) make an interesting analogy towards this Adaptation Pathways map as 'different ways leading to Rome' just like maps of public transport routes that consists of several options to go to Rome.

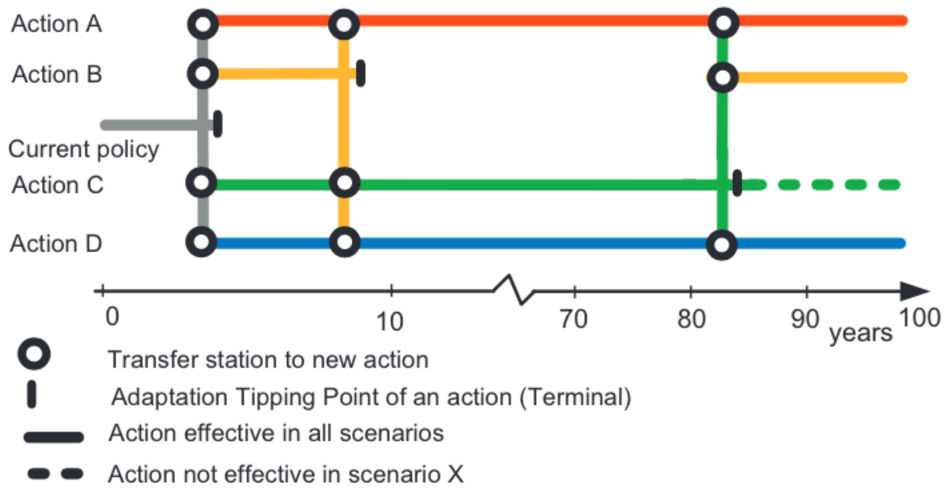

Figure 5 Adaptation Pathways Map
(Source: (Haasnoot, Kwakkel, Walker, & Maat, 2013)

2.3 INCORPORATING SHIPPING NETWORK PLANNING

The two key decisions of the policy vis-à-vis shipping network planning are which ports should be developed and when they should be developed. These outputs furthermore lead to an investment plan provided to the selected ports which is embedded in the policy decisions.

The challenge in port development is that ports are very vulnerable to a wide range of internal and external factors including geopolitics, economic growth, demographic changes, environmental concerns, IT trends, automation, and many other factors which create uncertainty both during the planning and implementation phases. The influential factors in the future, therefore, push the policy-makers design flexible policies in order to face those uncertainties over time. Moreover, port development is challenging as it involves investing millions if not billions of US dollars in infrastructure that will last decades, have environmental impacts, and potentially result in significant economic multiplier effects; the multiplier effects, however, are not always felt in the location of the port and the benefits of the port infrastructure investments may be felt by those directly living near the port thereby creating a challenge for public officials. This pushes even more the need for efficient spending by the government. Therefore, the missing yet very important process in turning the outcome of shipping network planning into policy decisions is specifying dynamic robustness for the policy implementation. This process will lead to adaptive way in dealing with uncertainties yet still performing robustness in each period.

The shipping network is defined as a graph consisting of nodes where the ports are located and sets of arcs representing the connections between ports that form a path for the unit of freight to go from the origin to destination. As part of a global supply chain, a port plays a pivotal role in the logistics activities as a logistics node connecting origin and destination. It attracts the demand both from its hinterland as well as captive cargos to be handled at the port and shipped to the rest of the world and vice versa

(Heaver, 2002). The cost of shipping freight from one port to another is largely determined based on the connections in the whole network. Consequently, plans on maritime transport network, such as investment in port capacity, productivity, and dedicated shipping connections, are critical tasks for the country-level government (Wan, Basso, & Zhang, 2016).

Furthermore, the objectives of strategic shipping and port planning must, by their very nature, be dynamic and permit consideration of ever-changing external and internal factors (Frankel, 1989), including planning the shipping network. In international trade for example, the growth of containerisation, the significant shift of maritime trade to Asia, rising oil prices, economies of other countries, spatial shifts in transport chains and between ports, political issues, as well as production systems and logistics services that become more sophisticated are uncertainties expected to have influence on the patterns of global freight network (Tavasszy, Minderhoud, Perrin, & Notteboom, 2011). The shifting functions of a port network, as well as many logistical, technological, political and economic uncertainties under which a port must operate, make the planning and design of these strategic network very challenging (Taneja, Walker, Ligteringen, Van Schuylenburg, & Van Der Plas, 2010). Therefore, in the middle of striving for optimal network plan for robust port investment while allowing uncertainties to be resolved over time within an ever-changing environment, several adaptive policy-making tools are emerged for the treatment solution of uncertainty (Swanson, et al., 2010).

Aside from its benefits, there are some concerns related to adaptive policy decision-making for supporting shipping network investment planning. The first concern is that policy choices depend not only on measuring the outcomes of interest relative to the goals and objectives, but identifying the preferences and trade-offs among the outcomes of interest given these various sets of preferences (Walker W. E., 2000). To overcome this concern, a structured analytical process that supports the policy-making process is required. Next concern is that the use of adaptive policy decisions should consider the fact that the effects of policy choices depend on information about events that have happened (past) and events that are yet to happen (future). The process of examining of what happened in the past is highly dependent on data availability. It also involves identifying the current plans/policies taking into account the performance of the underlying policy. The more the data is sufficient and accessible, the more useful the information is for the assessment.

Moreover, forecasting and anticipating the future is an essential element of shipping network planning, particularly demand projection. The government/policy-maker must always strive to carefully and accurately forecast the future in order to cope with the medium- to long-term master planning, make decisions, and identify the most preferred policies (Walker, Rahman, & Cave, 2001). On top of that, no single expert can perfectly forecast the future as the possibilities must be made on the basis of incomplete knowledge. The other concern is how well the adaptive policy decisions fit to the real world. The application of policy in the real world implies accepting that the world will change over time/period so that the changing of policy context is not impossible. Adaptive policy decision pathways in which the time period is taken into account therefore is the paradigm used to make the policy coping with many conditions of real-world uncertainties.

Figure 6 below shows an adaptive policy decision pathways approach for shipping network planning that allows policy-makers to consider there are more than one possibility of decisions in each period possible due to the uncertainties exist in between. Further, this approach is considering demand or port throughput growth in each period (the dashed lines) that represents future uncertainties in shipping network planning.

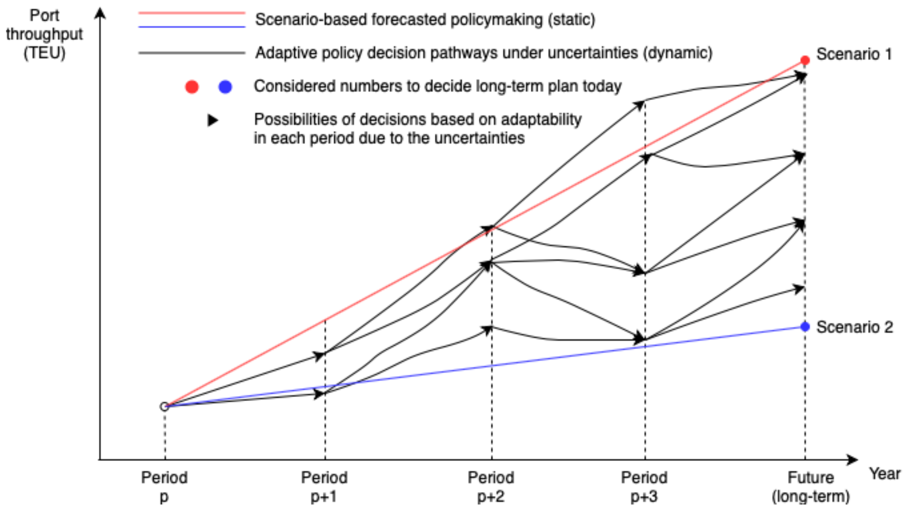

Figure 6 Adaptive policy decision pathways with possibilities due to dynamics of uncertainties

Engaging shipping network planning as a policy problem in adaptive policy decision pathways might be a potential avenue to show how well the approach being applied in a real-world problem like port investment, which requires optimality under uncertainty. Particularly in Indonesia, an archipelagic country with approximately 17,500 islands divided into 34 administrative provinces over seven main islands, where the country relies heavily on maritime trade and has a wide range of ports serving its international trading links and domestic needs. This fact is evident by what Figure 7 below which shows myriad of ports in the whole network of Indonesia. It is therefore no surprise that President Joko Widodo has highlighted the importance of the developing the country's maritime sector by stating this ambition to develop Indonesia into a strong maritime nation (Tu, Adiputranto, Fu, & Li, 2018).

In Indonesia, one of the key decisions in shipping network planning is the selection of international container gateways. International container are the commercial ports selected to handle international (export and import) flows. With regard to size, coverage, and amount of investment needed, they are bigger than any purely domestic ports. Indonesia currently has approximately 111 commercial ports that can handle international and domestic cargo (Ministry of Transportation the Republic of Indonesia, 2016). Of the 111 commercial public ports, the 2016 National Port Master Plan and BPS Statistics Indonesia[1] classify 31 as key ports[2], which have higher priority for further development. This number of ports indeed creates a huge and complex network for an archipelagic country such as Indonesia. In addition, it was estimated that a total investment of over USD 47 billion would be required up to 2030

[1] BPS Statistics Indonesia (Badan Pusat Statistik Indonesia) is a national statistics office directly under the President of the Republic of Indonesia.
[2] The list of 31 key ports is presented and elaborated more in Chapter 5.

for port development, with about USD 17.3 billion required for container facilities alone (Australia Aid, 2012).

The aforementioned facts indicate the importance of shipping network planning in Indonesia to achieve robust investment planning given that the country is not spared from the presence of future uncertainties in between the long-term policy-making process. Therefore, further research regarding the adaptive policy-making for robust shipping network investment in Indonesia is indeed necessary.

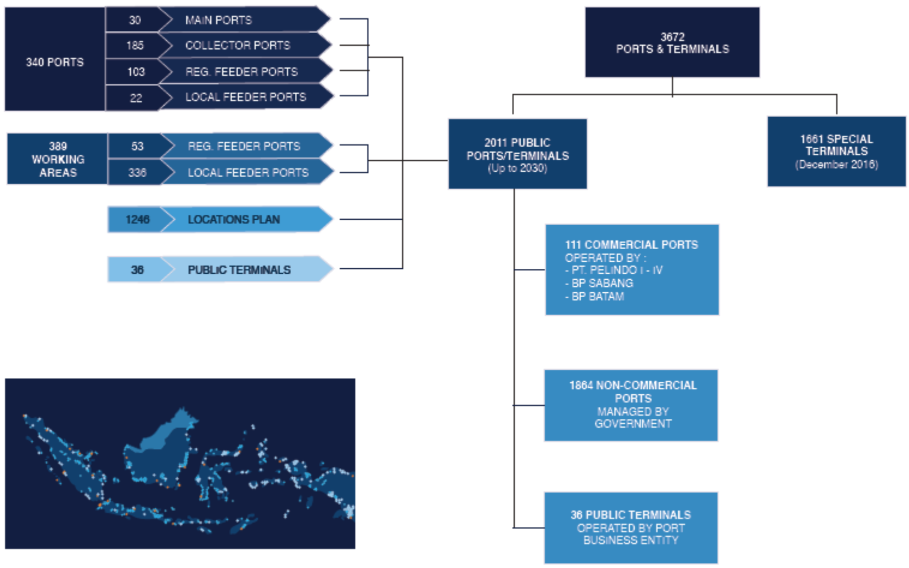

Figure 7 Indonesia's port network
(Source: World Bank based on 2016 National Port Master Plan)

2.4 MODELLING SHIPPING NETWORK PLANNING

Shipping network planning is an activity that produces masterplans for the medium- to long-term development of the ports in a determined area and can be global, regional, or local like country-level cases. There are many kinds of linear-programming models that are constructed as the solutions of network problems. Historically, the first of these structures to be analyzed was the transportation problem, which is a particular type of network problem. However, the recent researches are widening the complexity of the network problems and make the models able to solve a very complex problem from strategic, tactical, operational, and even to individual level of analysis. Selecting the appropriate model always depends on the problem to be solved. If one needs to identify the shortest-distance path through a network from a particular origin to a particular destination, the so-called Shortest-Path Problem is the appropriate model. If one needs to design a network by specifying a certain number of hub locations being installed in the network, then the P-Hub Problem is the appropriate model. Moreover, if one needs to find the most optimal transport cost given the nodes and arcs in the network, the Minimum Cost-Flow Problem is the appropriate model.

Studies done previously related to shipping network planning are focusing on model-based design or optimization maritime network for supporting policy-making process (Faisal, 2015), (Halim, Kwakkel, & Tavasszy, 2016), (Tu, Adiputranto, Fu, & Li, 2018). Those studies capturing future scenarios and projections (mostly) of the origin-destination (OD) demand or port throughput in unit of freight, for instance in TEUs. The paradigm used in this process is like what (Walker, et al., 2003) stated in the paper that is as ‘scenario uncertainty’ and the approach is often called ‘scenario planning’. They analyzed how the network that is built with the model performs in the future projection and scenarios, whether it optimizes the current network based upon *ex-ante* evaluation. The network result (i.e. optimized/designed network) considering the objectives (e.g. minimize transport cost) is then taken into account as policy recommendations. This is how the network plan is linked with the process of policy-making.

Within this research, the *shipping network* is defined as a graph consists of numbers of nodes where the ports are located and set of arcs representing the connections between ports that form a path for containers to go from the origin to the destination. The *origin* and *destination nodes* in the network are predetermined, and the scope of freight flows shipped from origins to the destinations will be limited to *export trade* of Indonesia. This implies Indonesian ports play roles as exporters and regional ports in other countries as the importers (see Figure 8).

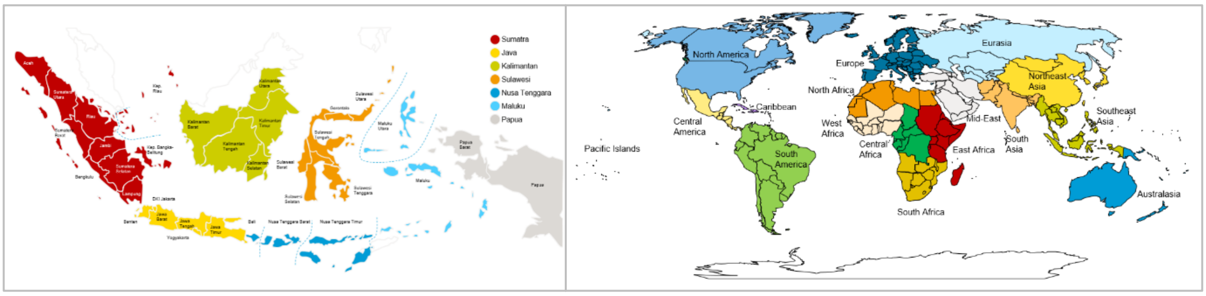

Figure 8 The seven big island regions of Indonesia (left) and sixteen worldwide regions (right) (Source: PoRInt, 2018)

Indonesia later will be divided into 34 provinces and 31 ports which will be introduced in Chapter 4.3. Meanwhile, Indonesia’s trade partners are grouped into 16 worldwide regions. The exporter is defined as the port location where the demand is originated, while the importer is defined as the port location where the demand is expected to be delivered. According to the export trade, the shipping legs (re: *arcs*) considered in this research consist of three types: (1) *domestic leg* where the demand is being shipped between two Indonesian ports, (2) *transhipment leg* where the demand is being shipped between an Indonesian port and a foreign regional port, and (3) *international leg* where the demand is being shipped between two foreign regional ports. Moreover, the focus of cargo segment considered in this research is only *containerized cargo* (expressed in TEU), given that containers account for a high percentage of the value of Indonesia’s foreign trade.

The main problem of a shipping network model considering export data is to know the flow pattern that generates the most optimal shipping network cost and fulfils demand from the origins and destinations. Given that this problem consists of transhipment legs, the container flows need not be sent directly from origin to destination but may be routed through transhipment points reflecting international gateways (subset of Indonesian ports) or transhipment hubs (subset of worldwide ports). The selected network model for this research is therefore Minimum-Cost-Flow (“MCF”) problem. The objective of MCF is to minimize the shipping network cost to meet export demand. All the ports are collectively called nodes of the network and the shipping legs connecting nodes are termed arcs. The arcs are assumed to be directed so that containers can be sent from origins within Indonesia to destinations in other countries but not vice-versa. The main concern of this model is the so-called flow conservation law meaning that the flow out of a node reduced by flow into a node equals net supply at a node. Figure 9 shows the example of the network flow from MCF problem, where the negative values in node 8 to 11 means the total number of units required at each node and the positive values in node 1 to 3 means the total units produced at each node. Furthermore, the flow capacity on each arc is presumed unlimited however, the capacity constraints come from the port capacity particularly for Indonesian ports that have connection to the worldwide ports (i.e. international gateways). Therefore, numbers of flows come to a gateway is constrained must not exceeded the determined capacity. From the result of network flow model, we can specify which ports are promising by analysing the direction of the flows and the size of the flows.

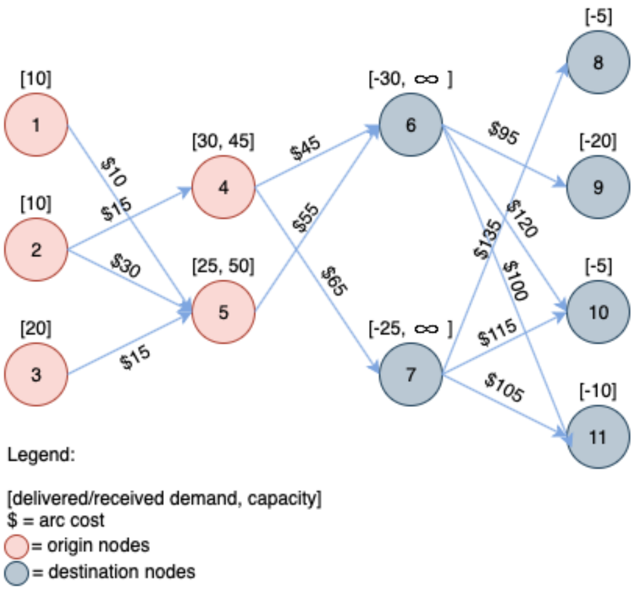

Figure 9 Example of MCF problem

2.5 THE SCIENTIFIC GAP

A concept of adaptive policy planning that is widely discussed in the existing academic literature is developed based on the presence of uncertainties combined with the needs of robust quality in policy decisions. A variety of techniques and tools, such as strategic planning, scenarios, adaptive policy pathways, sensitivity analysis, investment decision-making process, adaptive policy-making ("APM"), complex adaptive systems, assumption-based planning ("ABP"), and individual port adaptive planning have been put forward in the port and shipping literature (Frankel, 1989), (Faisal, 2015), (Lagoudis, JR, & Salminen, 2014), (Yeo, NG, Lee, & Yang, 2014), (Tu, Adiputranto, Fu, & Li, 2018) (Haasnoot, Kwakkel, Walker, & Maat, 2013) and (Taneja, Walker, Ligteringen, Van Schuylenburg, & Van Der Plas, 2010). Specifically, for the approach adaptive policy decision pathways, the focus of previous studies is more on environmental issues, water management, and global climate change. This implies that to date, there is no research available for the application of adaptive policy decision pathways on shipping network planning, whereas the decisions underlying the shipping network planning are very important decisions for the policy-makers to come up with optimal policy recommendations.

Furthermore, previous research provided broad studies regarding shipping network design and optimization. Model-based design and computational techniques were performed to find the optimal network for certain problem (Faisal, 2015), (Tu, Adiputranto, Fu, & Li, 2018) and (Halim R. , 2017). Research in network design done for Indonesia mostly studied how to design a network given future scenarios considering trends and developments that influence the network itself. A study carried out by (Faisal, 2015) clearly developed three different scenarios that capture the possibilities of different outcomes of an OD matrix due to the existence of trends and developments. The projected scenarios are set for a single year only that is 2030. Moreover, that study focused only on domestic (intra-Indonesian) trade. Another study by (Tu, Adiputranto, Fu, & Li, 2018) comes up with the results for hub selection over three different periods based on the objective minimizing total cost. Although the OD matrix used in that study is the total of both international and domestic flows, the origins and destinations are all ports in Indonesia.

The literature review therefore suggests that there is still no study which performs research focused on shipping networks that takes dynamic decisions over time and links it to adaptive policy decision pathways. Another aspect which makes this study unique is that it focuses on exports as a way to help identify which ports should become international gateways. Generally, previous studies were not focusing on exports, which typically are important for governments however has not been necessary imported in academic literature. Many governments have the ambition to promote value added exports and these are usually shipped in containers. Container exports could therefore be used in helping to designate international gateways.

To summarize, the scientific gap is that no study was found addressing the following aspects:

- Application of adaptive policy decision pathways for shipping network planning
- Assessing dynamic robustness of the policy over time
- Taking export trade that the origins are Indonesian ports and the destinations are worldwide ports.

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3 METHODOLOGY

In this chapter, we explain and substantiate the model structure of adaptive policy decision pathways for shipping network planning in Indonesia.

3.1 MODEL FLOWCHART

This sub chapter describes the steps in the model in further detail. In Figure 10, a model flowchart shows the detailed model formulation.

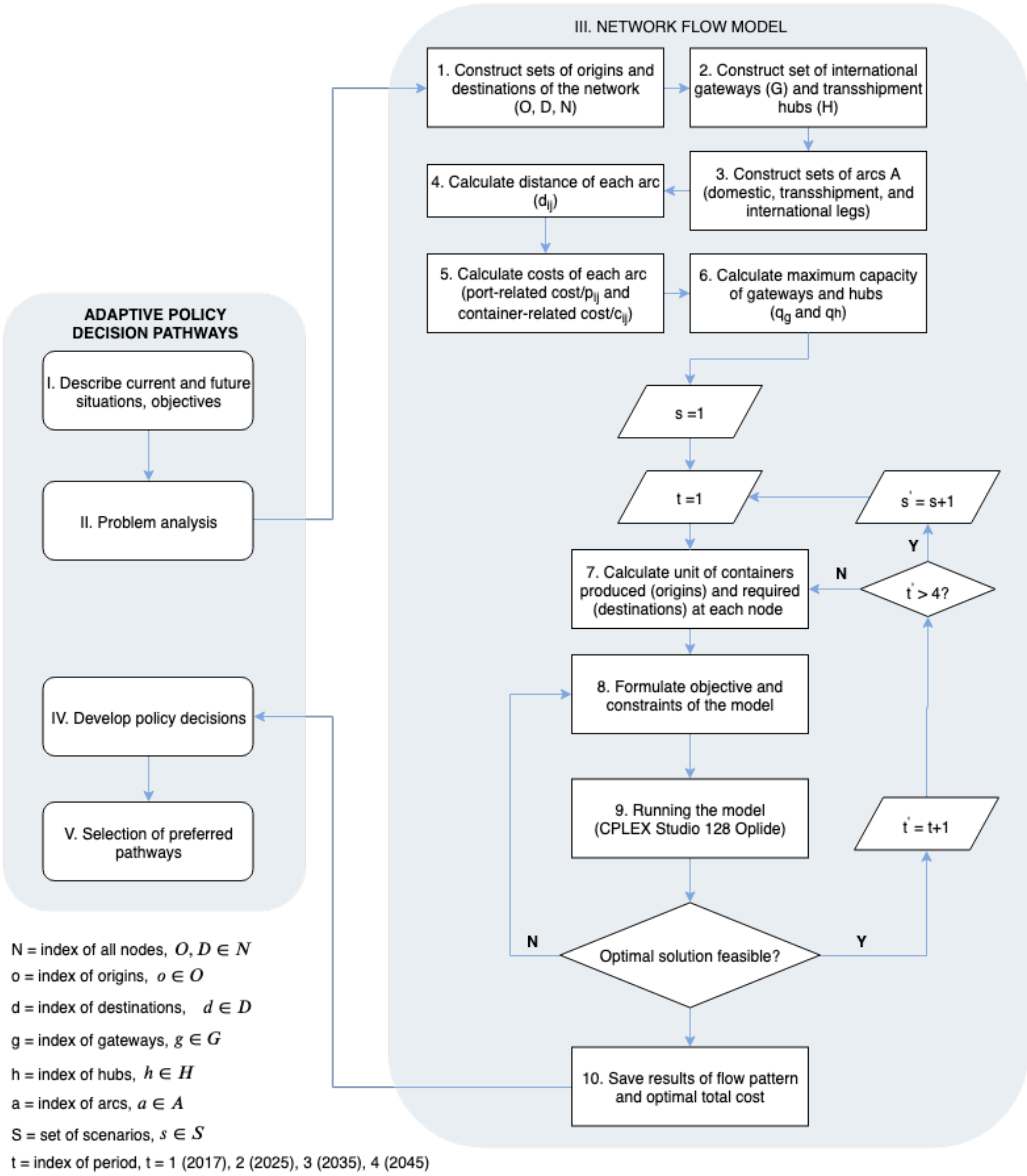

Figure 10 Model flowchart of adaptive policy decision pathways for shipping network planning

3.2 Stepwise policy analysis

The proposed approach consists of five steps, namely: (1) describe current and future situation, objectives; (2) problem analysis; (3) network flow model; (4) develop policy decisions; (5) selection of preferred pathways. The following parts describe the step by step of the model.

3.2.1 Step I & II: Describe current and future situation, objectives and problem analysis

The proposed approach is started with examining current and future situation as well as objective of the policy planning. This step involves studying the current condition of Indonesia and challenges the country currently facing, the historical information about network plans built in the past, future projection represented by constructed scenarios. From this examination, definition of success and the objectives of the policy-makers are identified. Moreover, the various constraints are also indicated by respecting the current state of policy-making, how the policy-maker implement the process and what are the drawbacks and favors of the current conditions.

The objectives of public policy are determined in this step as well. There are two key objectives of policy planning in regard to shipping network planning, those are (i) to reduce transportation costs which involves reducing economic disparity within Indonesia and (ii) to promote value added exports in terms of containerized cargo. Moreover, in this step the core problems are analyzed. As mentioned in previous chapters, the core problems are to identify the most promising ports to become international container gateways and when those intended ports should be developed based on the flow pattern resulted in different time periods. The findings encourage the policy-maker to be able to determine what are the potential policy decisions by building adaptive policy decision pathways and selecting preferred pathways to result in robust investment planning decisions.

Based on analysis of trends and developments, the future projection is performed by developing the plausible scenarios for the purpose of applying demand forecast model. We consider these scenarios as parent scenarios. Within the process of parent scenarios development, uncertainties are identified and being assessed together with the driving forces. The scenarios are constructed based on 9 different variables that can influence the export trade between Indonesia and other countries in the world. Using regression analysis, those variables are used as indicators for demand forecast model. The model for demand forecast is described as follows.

3.2.1.1 Demand forecast model for exports based on two parent scenarios

The aim of this model is to estimate and forecast Indonesian containerized volumes with its trade partners. Another objective of the forecast model is identifying the market potential (on an island basis) of ports located within the 7 island regions (e.g. Sumatra, Java, Kalimantan, Sulawesi, Nusa Tenggara, and Papua). The model has 2045 (the 100th anniversary of Indonesia's independence) as the end year with 2017 as the base year. This time period is divided into three periods of about 10-years which are: 2017-2024, 2025-2034, and 2035-2045. The reason behind the multi-period assumption is to have more reliable assumption on the variables in relation with the real-world which is facing future uncertainties.

The forecast model is based on a regression-based gravity method which is a commonly used quantitative analysis method in economic forecasting. The regression analysis involves analyzing the impact of variables on bilateral trade flows. Generally, the regression analysis has two basic formats; simple and multiple linear regressions. Simple regression relies on one independent variable whereas multiple linear regression relies on multiple independent variables. Multiple linear regression is essentially the same as simple linear regression with the only difference being that there are more variables taken into consideration (hence the name). In this forecast model we use the multiple formats, and so the equation for multiple linear regression is:

$$y = \propto + \beta 1x1 + \beta 2x2 + \beta 3x3 + \varepsilon \quad (1)$$

where:

y	= the dependent variable (e.g. container volumes expressed in TEU)
$x_{1,2,3}$	= the independent variables being used as the indicator
$\propto$	= the intercept (the value of y when x equals 0)
$\beta_{1,2,3}$	= the slope of the lines for each of the independent x variables
ε	= residual error values (the difference between the actual and predicted values)

Multiple linear regression has the additional condition that the independent x variables should have none or minimal collinearity. This means that the independent x variables used in the model should ideally not be correlated to each other. For example, if GDP and population are both used in a model, but GDP growth is driven by population growth then only one of the two independent variables should be used.

For this model, we forecast the demand with constructed parent scenarios namely optimistic (the upper bound) and pessimistic (the lower bound). In making the storyline for scenarios we consider variables those already passed through t-statistics data analysis to identify the significance of the variables towards containerized volumes both based on analysis of bilateral partner amongst 100 countries and within Indonesian trade flows only. The t-statistics analysis whether values of coefficient of each variable are significant. Here, the significance level used is 95%. Given the results from the t-statistics analysis, there are 9 variables significant for export trade flows, which are divided into 6 time-dependent variables including GDP, population, urbanization rate, the Quality of Port Infrastructure Index ("QPI"), the Liner Shipping Connectivity index ("LSCI"), and trade agreement as well as 3 non-time dependent variables which are area, distance, and whether a bilateral pair landlocked or not. The coefficients are determined for three level i.e. base, low and high.

Moreover, based on the coefficient values of variables, we do back-casting analysis to generate calculated demand volumes and compare the result with the observed data. This step is useful to ensure which level of coefficient should be used and performing in closest demand values with the observed one. The back-casting analysis is performed with similar equation for multiple linear regression as mentioned in Equation (1). Given that in this model we see Indonesia as 7 different big islands namely Java, Kalimantan, Maluku, Nusa Tenggara, Papua, Sulawesi, and Sumatra, the back-casting analysis then results in coefficient value of 9 variables specifically for each island. Table 1 below shows the coefficient value for every island identified as the most optimal result from the back-casting analysis.

Table 1 Coefficient value assumptions of nine variables per island

Variables	Java	Kalimantan	Maluku	Nusa Tenggara	Papua	Sulawesi	Sumatra
Intercept	9.12	8.09	8.00	8.00	8.00	8.09	9.12
GDP	0.61	0.55	0.55	0.55	0.55	0.61	0.61
Area	-0.09	-0.13	-0.13	-0.13	-0.13	-0.13	-0.13
Population	0.24	0.17	0.17	0.17	0.17	0.17	0.17
Urbanization Rate	-0.53	-0.71	-0.71	-0.71	-0.71	-0.53	-0.71
QPI	0.21	0.11	0.11	0.11	0.11	0.11	0.11
LSCI	0.32	0.24	0.24	0.24	0.24	0.24	0.32
Distance	-0.87	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99
Landlocked	-1.51	-1.75	-1.75	-1.75	-1.75	-1.75	-1.75
Trade Agreement	0.30	0.08	0.08	0.08	0.08	0.28	0.28

Source: Prior calculation

To develop the parent scenarios, there are calculations performed to estimate the growth of time-dependent variables. Then, we estimated different growth patterns between both parent scenarios: optimistic and pessimistic and calculate the demand projection based on the coefficient assumptions and growth of all the variables. The demand forecast is calculated and generated using Microsoft Excel spreadsheet. The expected result of this model is forecasted demand for export trade in TEU for every island in Indonesia which is detailed for each bilateral trade partner pair (e.g. Java to China, Sumatra to China, Sulawesi to China, etc.). Note that the research for this forecast model was done jointly with an expert from Port of Rotterdam Authority. The forecast model is done also for the internal objective of the company.

Having the two parent scenarios, we can capture more uncertainties by generating random values based on forecasted demand in each scenario and results in numbers of cases, then are called as branch scenarios. The method used to generate branch scenarios is explained in next part.

3.2.1.2 Random number generation for constructing branch scenarios

Given that there are two forecasted demand produced for parent scenarios, more scenarios can be generated with purpose of representing future uncertainties in demand values. These additional scenarios, called branch scenarios, are used to perform stronger analysis of adaptive policy decision pathways for shipping network planning by representing more varied cases of future demand volumes. The method used to create the branch scenarios is random numbers that follow a normal distribution theorem.

Based on forecast demand resulted for optimistic and pessimistic scenario, we generate random numbers of 100 datasets for each period. These 100 datasets are then considered as 100 different scenarios (which then we call branch scenarios) with different demand value in each period. In order to generate random numbers, we use Microsoft Excel as the software through the add-ins Analysis ToolPak. Here we need to provide input those are mean (μ) and standard deviation (σ) for normal distribution random numbers. In this model, the mean value is the average of forecast demand in optimistic, W_{s0}, and pessimistic scenario W_{s1}, for each period (t). The standard deviation is determined by firstly indicate the intended coefficient of variation (CV) for the distribution.

$$CV = \frac{\sigma}{\mu} \tag{2}$$

$$\mu = \frac{(W_{s0}^t + W_{s1}^t)}{2} \tag{3}$$

Coefficient of variation shows the extent of variability in relation to the mean of the population. The higher the coefficient of variation, the greater the level of dispersion around the mean. It is generally expressed as a percentage. Afterwards, we check whether the generated cases are distributed normally through descriptive statistics analysis done in SPSS Statistics software. For dataset small than 2000 elements, we use the Shapiro-Wilk test to test normality of the data, otherwise, the Kolmogorov-Smirnov test is used. In our case, since we have only 100 elements for each period, the Shapiro-Wilk test is used.

3.2.2 STEP III: NETWORK FLOW MODEL – MINIMUM COST FLOW (MCF) PROBLEM

For the network planning, the model is built using the so-called approach Minimum-Cost-Flow ("MCF") problem. The application of this problem is very broad, such as shipping steel from multiple mills via warehouses to customers or shipping from multiple factories via distribution centers to retail stores. Figure 11 illustrates an example of network diagram for MCF problem. The network diagram below is the example of MCF problem for special case *transshipment problem*. In this model, we pre-determined intermediate nodes (transshipment nodes) that the flows should pass through to reach the destination. Explanation about the formulation of the network is following.

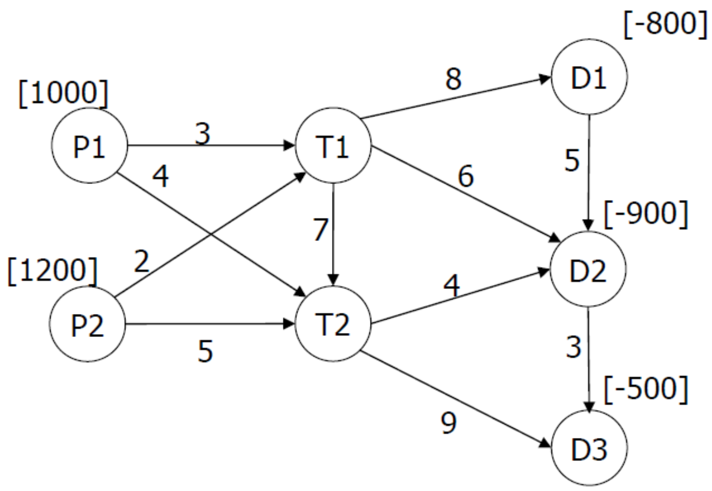

Figure 11 Network diagram of MCF problem

The objective of the problem is to minimize transport costs, which defined as the sum product of numbers of flow and container-related cost per flow and sum product of distance of each arc, numbers of flow, and shipping-related cost per flow. The decision variable in this problem is the flow from origin nodes to destination nodes through intermediate nodes. Note that transshipment problem is not the same with transportation problem, however, the solution method is similar as to solving a transportation problem. In MCF – transshipment problem, we assume that each transshipment node can be both an origin node and destination node (see Figure 9 for example). Referring to Figure 11, there are three type of nodes i.e. pure supply nodes (P1 and P2), pure demand nodes (D3), and transshipment nodes

(T1, T2, D1, D2). Supply/demand at a transshipment node should be equal with original supply/demand + *buffer* amount. Buffer means amount of flow that should be sufficient to allow the original amounts to pass through any transshipment node. To solve this problem, mathematical formulation is presented below.

3.2.2.1 Mathematical formulation

The mathematical formulation explained here is partly adjusted from the original MCF problem in order to be aligned with the problem in this research, that is adaptive policy decision pathways for shipping network problem.

Table 2 Set, parameters, and decision variables of MCF-transshipment problem

Sets	
A	Set of arcs
N	Set of all nodes
O	Set of origin nodes [O= 1,2,3…, m] – total 31 nodes
D	Set of destination nodes [D= m+1, m+2…, n] – total 16 nodes
G	Set of transshipment nodes that also origin nodes = gateways [$G \subseteq O$]
H	Set of transshipment nodes that also destination nodes = hubs [$H \subseteq D$]
S	Set of transient scenarios/cases [S = 1,2,3…, r]
T	Set of periods [T= 2017, 2025, 2035, 2045]
Parameters	
D_{ij}	Distance between i to j [nm], $i, j \in A$
P_{ij}	Shipping-related cost between i to j [USD/nm], $i, j \in A$
C_{ij}	Container-related cost between i to j [USD/TEU], $i, j \in A$
q_i	Maximum capacity of port (= gateways or hubs) [TEU]
Z_i^{st}	Amount of flow originated from origin i [TEU] in scenario/case s and period t
Y_j^{st}	Amount of flow destined to destination j [TEU] in scenario/case s and period t
Decision variable	
X_{ij}^{st}	Flows between i to j [TEU] in scenario/case s and period t, $i, j \in A$

3.2.2.2 Mathematical model

$$Minimize \sum_{i=1}^{m} \sum_{j=m+1}^{n} D_{ij} P_{ij} X_{ij}^{st} + \sum_{i=1}^{m} \sum_{j=m+1}^{n} C_{ij} X_{ij}^{st} \quad (4)$$

Subject to,

$$\sum_{j \in N} X_{ij}^{st} - \sum_{j \in N} X_{ji}^{st} = Z_i^{st} \qquad for\ i \in O, s \in S, t \in T \quad (5)$$

$$\sum_{i \in N} X_{ji}^{st} - \sum_{i \in N} X_{ij}^{st} = Y_j^{st} \qquad for\ j \in D, s \in S, t \in T \quad (6)$$

$$\sum_{j \in V \setminus \{i\}} X_{ij}^{st} + Z_i^{st} \leq q_i \qquad for \; \forall \, i \in G, s \in S, t \in T \qquad (7)$$

$$\sum_{i \in V \setminus \{j\}} X_{ij}^{st} + Y_j^{st} \leq q_j \qquad for \; \forall \, j \in H, s \in S, t \in T \qquad (8)$$

$$X_{ij}^{st} \geq 0 \qquad for \; \forall \, i \in O, j \in D, s \in S, t \in T \qquad (9)$$

Equation (4) is the objective function which to minimize total costs consisting of shipping-related cost depending on distance of arc as well as on flow variable and container-related cost which is depending on flow variable. The total cost is calculated for each scenario and each time period. Equation (5) and (6) is the so-called flow conservation constraint which ensures that all flows go out of a node reduced by flows go into a node equals net amount of flow originated or destined at a node. Both equation (7) and (8) are the maximum capacity constraints for gateways and hubs. The last constraint defines the domain of variables. The MCF model then is being applied for each scenario resulting from Step I as well as for each time period determined in this research.

The model is written and run in the OPL language of the IBM ILOG CPLEX Studio 128. For each cycle (meaning that for each scenario and period), the average time needed to have the running finished is about 2 minutes. In regard to branch scenarios, however, running the MCF model for all 100 cases each period will take much time and turns out become inefficient process. Therefore, all 100 cases per period are grouped into frequency tables and results in 13 ranges of interval. Demand value that is taken into account as the input for the MCF model is the mid-range of each interval. This will be explained further in Chapter 5.

3.2.3 Step IV & Step V: Develop policy decisions and selection of pathways

The output of previous step are flow patterns that have optimal total shipping network cost for each scenario and each period, and the amount of flow per arc. These outputs become the input for step IV and later step V.

The focus on step IV is to map the flow pattern based on certain demand and period. The same demand range can yield to different patterns. This can be caused by changes in gateway capacity throughout several periods or just because of distinct demand volumes. The same period can also have different optimal flow patterns depend on the demand that should be handled. Therefore, applying the network model to varied demand volume ranges from parent and branch scenarios may lead to different flow patterns. The real results of this application on Indonesian export trade are further described in Chapter 6. The flow pattern gives the information of which gateways are used the most in the network. For every flow pattern obtained, we can calculate the percentage of total flows (in TEUs) handled at each transshipment nodes, particularly for gateways as we focus on Indonesian ports development. This information produces insights of which ports are important in each flow pattern; thus, which ports are promising, meaning remains important throughout different cases of demand values.

The flow patterns can be translated into policy decisions consist of recommendations of which ports should be developed as international gateways and what function the port should be developed into. To establish policy decision pathways map, we can group all demand values from all periods and scenarios into several ranges, as well as their optimal flow pattern. Flow pattern is determined based on number of provincial ports that transship containers to international gateways, throughput volumes and throughput growth. Therefore, each flow pattern captures which gateways are promising as the more a gateway receives bigger flows from provincial ports, the more promising it becomes. Figure 12 is the example of policy decision pathways map based on variation of flow patterns over periods. An example from the figure, during period 3 for demand between 1.5 to 5 million TEUs, flow pattern C remains effective to be selected. Meanwhile, in period 1 flow pattern C is effective only if the demand values within the range of 1.5 to 2 million TEUs. Afterwards, we determine the optimal pathway that consists of several flow patterns. The selected pathway is then considered as policy decision for particular condition of future demand values over periods.

Definition of pathways in this research is the direction the government/policy-maker take in deciding policy through several periods within plausible distinct volumes of demand. What-if analysis approach is used to select the preferred pathways. First, from all scenarios, we identify how the demand changes in different periods. Afterwards, we can start to perform what-if analysis by delivering questions such as "what if the demand is decreased from base year to period I?" or "what if the current flow pattern is ineffective?" Therefore, in figure below there are two types of transfer points that leads to new policy decision: (1) triggered by change of range of demand and (2) triggered by ineffective flow pattern. Finally, we can complement the policy decision pathways map and selection of preferred pathways through these last two steps. This map guides policy-makers to make decision of shipping network planning under future uncertainties in terms of demand volumes.

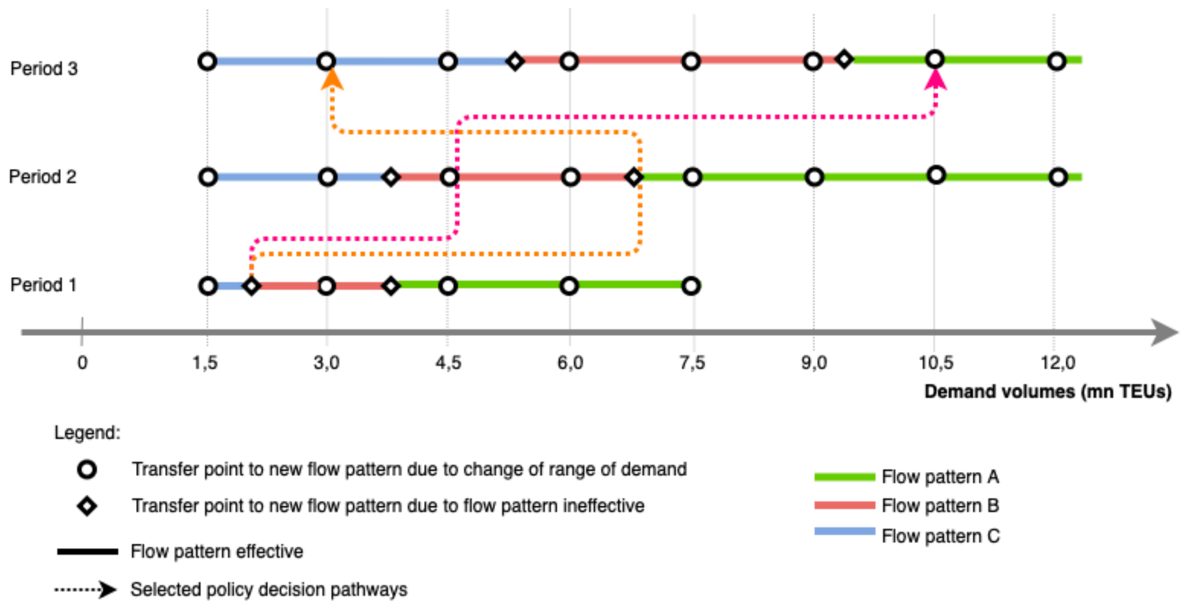

Figure 12 Example of policy decision pathways map based on flow pattern Adapted from: (Haasnoot, Kwakkel, Walker, & Maat, 2013)

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4 CURRENT, PAST AND FUTURE SITUATION OF INDONESIA

4.1 INDONESIA TODAY AND ITS CHALLENGES

Indonesia has performed impressively over the past decade with the country showing enormous efforts to develop the country. The following facts we present in the next paragraph are the research results of McKinsey Global Institute (Oberman, Dobbs, Budiman, Thompson, & Rossé, 2012) and World Bank (World Bank, 2019).

Already the 16th largest economy in the world in 2012, Indonesia is rising and is already the largest economy in Southeast Asia (World Bank, 2019). Besides being one the world's 20 largest economies and the largest in Southeast Asia, Indonesia is the world's fourth most populous nation behind the United States. Statistics in 2012 show more than 45 million people are part of the consuming class[3] with more than 50% of the population in cities and producing about 74% of GDP in 2012. Indonesia has become an emerging middle-income country by showing significant gains in poverty reduction with poverty falling from 24% in 1999 to 9.8% in 2018. The country's GDP per capita has steadily risen from US$807 in the year 2000 to US$ 3,877 in 2018. By 2030, it is estimated that there will be an additional 90 million consumers with considerable spending power. This is a signal to international business and investors of considerable new opportunities of emerging market.

Indonesia's economic planning follows a 20-year development plan called Long-term National Development Plan (RPJPN) 2005-2025 and Indonesia's Vision 2045, a vision for 100th of Indonesia independency. Those plans are segmented into 5-year Medium-term National Development Plan ("RPJMN") with different priorities and should be aligned with the programs brought by the active President in each period. Currently, Indonesia is entering the last medium-term plans in RPJPN 2005-2025 with the new President being the incumbent President Joko Widodo. In a National Development Plan Deliberation (*Musrenbangnas*) held recently in Jakarta, the President stated that in 2045 Indonesia should become the among the five biggest economies in the world, through four main pillars: (1) society, education and technology development, (2) sustainable economy development, (3) equal distribution of infrastructure development, and (4) national defense and governance system. Moreover, the ambition of turning the country into a Global Maritime Fulcrum ("GMF") which was highlighted in early 2014 by President Joko Widodo is aligned with the third pillar: infrastructure development, particularly in terms of port infrastructure. As an archipelagic country, the Indonesian government continues to target the realization of maritime and port sector development for the upcoming period (2019-2024).

Challenges: economic and infrastructure

Besides a promising economic situation and the government's focus on maritime policy, Indonesia remains at a at critical juncture. There are several challenges come from both a socio-economic and infrastructure angles. The first challenge is socio-economic. Socio-economically Indonesia faces an uneven income distribution the archipelago and rising inequality. The huge disparity between islands (e.g. Java and Sumatra compare to provinces in Maluku and Papua) can be seen in Figure 13 below in

[3] Consuming class is defined as those individuals with net income of more than US$3,600 per annum in purchasing power parity (PPP), at 2005 exchange rates (Oberman, Dobbs, Budiman, Thompson, & Rossé, 2012)

terms of GDP and number of people. Note that there are seven big islands in Indonesia: Sumatra, Java, Nusa Tenggara, Kalimantan, Sulawesi, Maluku, and Papua.

The second economic challenge is the need to boost and support value added exports. Exports are one of Indonesia's economic indicators. As a country full of natural resources those are the reliable commodities for the foreign trade, export activities become important to enhance the economic development in Indonesia. To date, however, the ratio of export of goods and services to GDP in Indonesia is only about 21% (World Bank, 2019) compare to Singapore that reaches 176.4% and Malaysia for 69.7%. It is clear that domestic trade still plays the most significant role in Indonesia's GDP, however the country should not close its 'eyes' to the fact that global trade growth is giving high influence especially when Indonesia aims to strengthen its position in the world. Moreover, due to globalization, global trade is significantly influenced by the presence of containerization that certainly gives impact to Indonesia's trade as well. Half of the value of Indonesian exports and 67% of the value of Indonesian imports are shipped in containers. In regard to economic perspective, the container segment is therefore can impact Indonesia's trade balance.

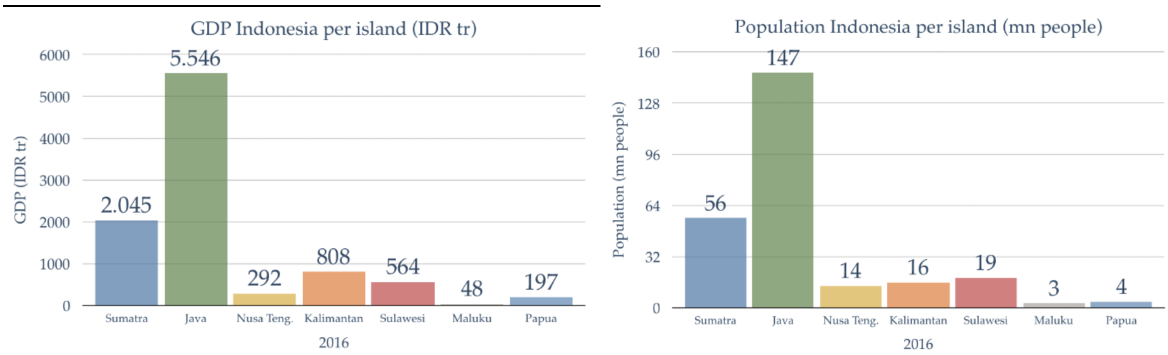

Figure 13 GDP (left) and Population (right) Indonesia per island in IDR trillion, 2016 (Source: BPS, Port of Rotterdam 2018)

The importance of port infrastructure for Indonesia is very accurately described in a line posted by the editorial board of The Jakarta Post in December 2017 (Jakarta Post, 2017) clearly emphasises the fact of Indonesia archipelagic nature.

> *"As Indonesia is an incredibly vast and diverse archipelago, sea transportation is key to facilitating the smooth distribution of goods, enhancing economic linkages between the various islands and connecting the country to global value chains."*

Talking about infrastructure, investment in port infrastructure is highly related to the output resulted from the investment itself, and one of the outputs is how good the quality of the port infrastructure is. Additionally, it is vital for developing countries to keep improving the quality of port infrastructure as it contributes to better logistics performance, leading to higher economic growth (Munim & Schramm, 2018).

Along with the economic challenges yet promising economic situation, strategic location, and very eager initiative to be Global Maritime Fulcrum, Indonesia still deals with port infrastructure challenges. The World Economic Forum's 2017-2018 Global Competitiveness Index reported that Indonesia's efficiency of port services was ranked 61/139, still below other Southeast Asia's countries. Another competitiveness indicator relevant to ports is the liner shipping connectivity index ("LSCI") where Indonesia ranks 41/107. The World Bank also assessed the logistics performance index of all countries and in 2018 Indonesia was ranked 46/160. Another port infrastructure challenge is related to the issue within the country itself. Based on historical data from several sources (Pelindos, the World Bank, Seabury, and the eeSea database), in 2016 the container throughput of Indonesia reaches more than 13.7 million TEU with about 30% being exports, 25% being imports, and 45% being domestic. This is indeed not a trivial number as it implies that the country needs special treatment on the container shipping market. Currently Java generates most of the country's container volumes (Figure 14). This big gap is due to the fact that Java accounts for more than half of the country's GDP and population plus its ports are also better quality than those in other parts of Indonesia. Therefore, ports will have limited impact in the areas it is trying to connect unless the Indonesian government boosts economic growth outside of Java and Sumatra, together with improvement on the quality of ports infrastructure.

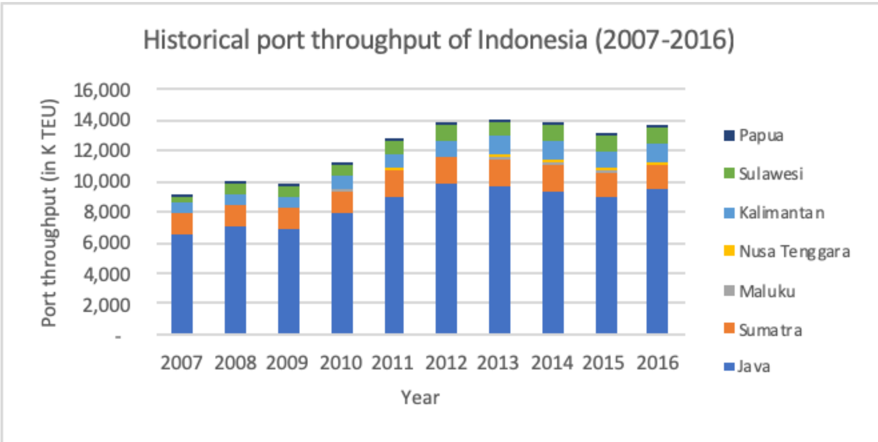

Figure 14 Port throughput of Indonesia based on islands from 2007-2016 (Source: eeSea; Pelindo(s), World Bank, Seabury 2018)

Having strong analysis for port investments is therefore a crucial task for the government to improve the robustness of shipping network plan and so the policy-making decisions. Given that the process links all governmental levels and done in multi-period time horizons makes the process more important. Moreover, the fact that port infrastructure in Indonesia is still facing many shortages while striving to realize Global Maritime Fulcrum goal drives the government to continuously focus on port infrastructure development. The big performance gap between islands proves even more the critical work to do to increase the connectivity and accessibility in Indonesia for the sake of economic development.

4.2 The current infrastructure investment planning in Indonesia

Indonesia's current infrastructure investment and policymaking process is called the National Medium-Term Infrastructure Investment Planning ("RPI2JMN"), which goes through phases with the involvement of multiple level actors such as national, provincial, local level (simplified version, see Figure 15). Basically, the RPI2JMN in Indonesia is made according to the Medium-Term Development Plan ("RPJMN/D"), which is more generally linked to the Long-Term Development Plan ("RPJPN/D"). The medium-term is established every 5 years, meanwhile the long-term is every 20 years.

The flowchart shows the process of medium and long-term development planning that leads to the RPI2JMN. Moreover, the government continues the process through annual development plan deliberation that produces an annual work plan called the Government Programs ("RKP/RKPD") as well as budgeting plan for all levels. The deliberations discuss a myriad of infrastructure projects throughout Indonesia to be assessed by the policymakers, who decide which projects are selected. Moreover, in the national level, government have to allocate the budget including funding partnership such as Public Private Partnership ("PPP"), loan, and other investment schemes to aid the limited state budget the country has.

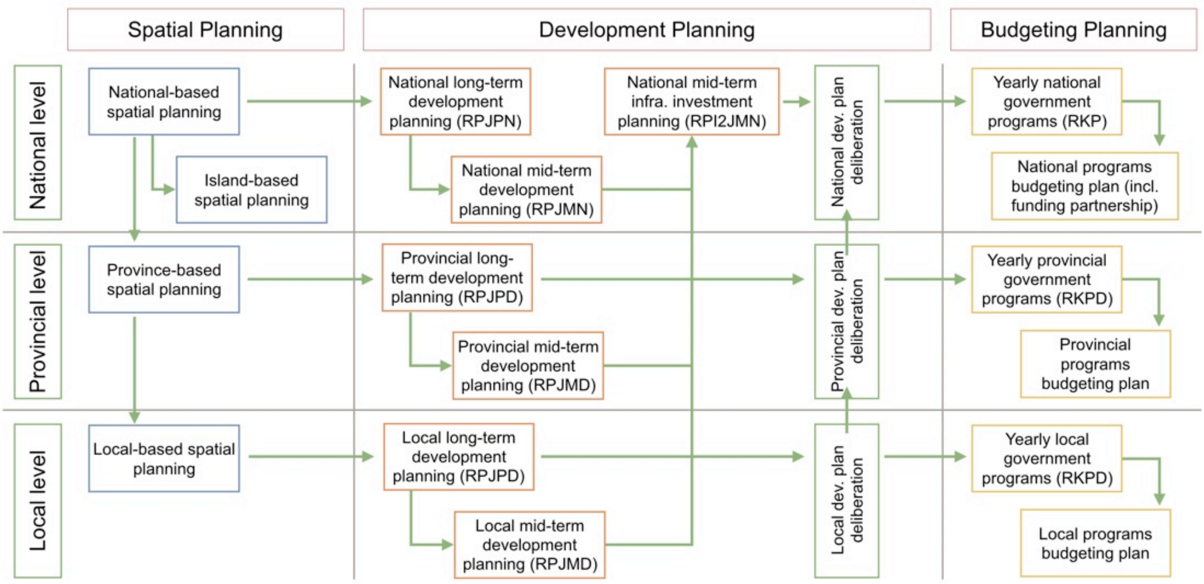

Figure 15 Simplified flowchart of infrastructure investments programs planning (RPI2JMN) in Indonesia (adapted from Bappenas, 2017)

A speech during the Infrastructure Forum in Indonesia by the Ministry of Finance ("MoF") of Indonesia stressed the fact that the private sector holds a very important role in supporting Indonesia's infrastructure development. The challenge in the infrastructure investment planning process is then to generate robust investment decisions with solid analysis that results in selected infrastructure projects with the most benefits and significant value for money invested in them under future uncertainties. As we believe in business perspective there is no one party (esp. private sectors) want to experience loss, promising infrastructures in terms of performance followed by deep analysis for the upcoming future are highly anticipated.

In the case of policy-making for ports development generally made in the form of shipping network plans. The government examining the condition of ports infrastructure comprehensively in national level. Several indicators such as logistic performance index is also taken into account as one of the considerations to building the policy. Moreover, global challenges and analysis on the pattern of relations between national and global trade which are vital for the port's infrastructure development planning in the country are also taken into account. Based on these assessments, the government drafts policy that is aligned with the higher level of planning (i.e. RPJMN and RPJPN). The policy for the shipping network plan is therefore made to support the goals and targets in the RPJMN and/or RPJPN.

The two network plans (Figure 1) mentioned in Chapter 1 are the examples of developed policy in recent years. The *Maritime Highway* network plan in 2014 was built based on specific assumptions about the future. There are two main vulnerable assumptions: the *potential demand* to be handled at the ports that is related to the *economic size* of port's hinterland[4], which is expected generates promising captive cargo for the port. Unfortunately, turns out that the future is different from what had been expected due to circumstances happen as the uncertainties. One of the examples is that the constructed ports infrastructure operates with an overcapacity condition. That means the investment which is provided to the port development does not meet strong trend of ports revenue. It might be due to relying only on the overrated demand projection in the beginning of policy decision-making process without monitoring system in between the implementation, or the sluggish of industrialization zones near the port. In regard to that, there is still no robust yet structured way to deal with those future unexpected uncertainties. Next part elaborates the previous network plans have ever developed in Indonesia from time to time to provide clearer picture of what happened in the past as well as the alternatives that popped up as the ideas from the government.

4.3 Previous network plans of Indonesia

There have been several government port development policies over the last few years emphasizing development of different ports. The changes of network configuration between one plan and another capture the uncertainties within the process of network design for Indonesia's maritime transport. Table 3 below shows the summary of differences of international gateway hub candidates between all network plans.

Table 3 International gateway hub candidates determined in four network plans

MP3EI (2011)	Nusantara Pendulum (2012)	Maritime Highway (2014)	Integrated Port Network (2018)
Kuala Tanjung	Belawan	Belawan	Kuala Tanjung
Bitung	Tanjung Priok	Kuala Tanjung	Tanjung Priok
Makassar	Tanjung Perak	Tanjung Priok	Tanjung Perak
Sorong	Makassar	Tanjung Perak	Kijing
	Sorong	Makassar	Makassar
		Bitung	Bitung
		Sorong	Sorong

Source: (MP3EI, 2011), IPC, Bappenas, Kemenko Maritim

Flashback to the policy commenced under President Susilo Bambang Yudhoyono (2009-2014), there was the *Blueprint of National Logistics System Development* that is included in Master Plan for the Acceleration and Expansion of Indonesia's Economic Development (**MP3EI**). In this policy, the government defined the foreland (*"Wilayah Depan"*) and hinterland *("Wilayah Dalam"*) which means that the foreland will connect Indonesia to world outside and hinterland is dedicated to domestic network

[4] Mostly are expected from the development of Special Economic Zones or SEZs. For instance, captive cargo of Kuala Tanjung Port that is expected to be generated also from SEZ Sei Mangkei which the location is relatively close to the port.

(Figure 16Figure 16). There are several action plans related to port infrastructure stated in the blueprint, such as building global connectivity of the country by developing dedicated ports for export and import trade as well as international gateway hubs.

Indicators of that action plan: the government determined the international gateway hubs for eastern part of Indonesia namely Bitung (North Sulawesi), Makassar (South Sulawesi), Sorong (West Papua) and for western part of Indonesia that is Kuala Tanjung (North Sumatra) (see Figure 17). Another characteristic is to have a detailed interconnection plan linking international gateway hubs and main and/or feeder ports throughout the provinces. Moreover, this network is connected with the next network plan called Nusantara Pendulum (second plan).

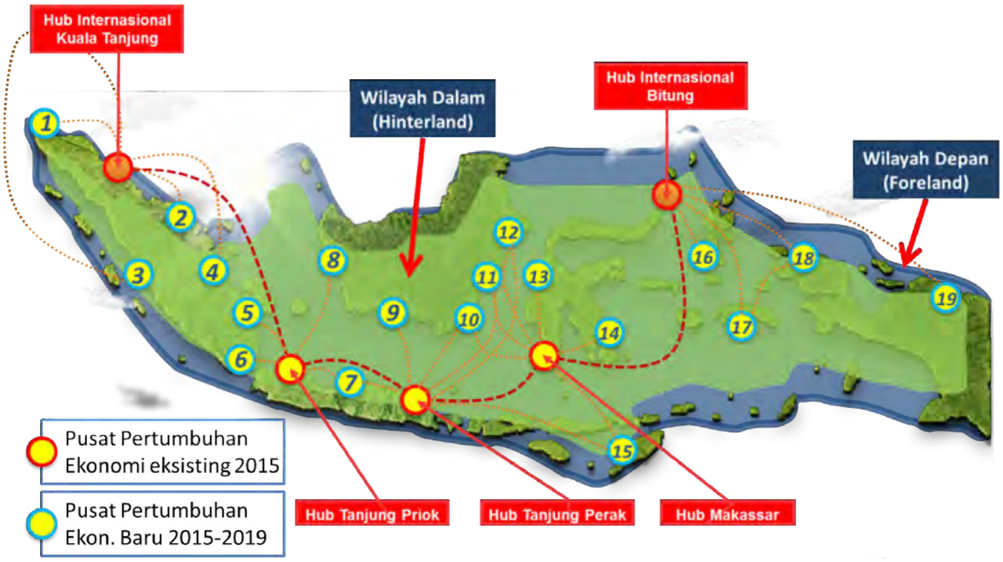

Figure 16 Foreland and Hinterland of Indonesian shipping network (Source: (Presidential Decree No 26/2012, 2012))

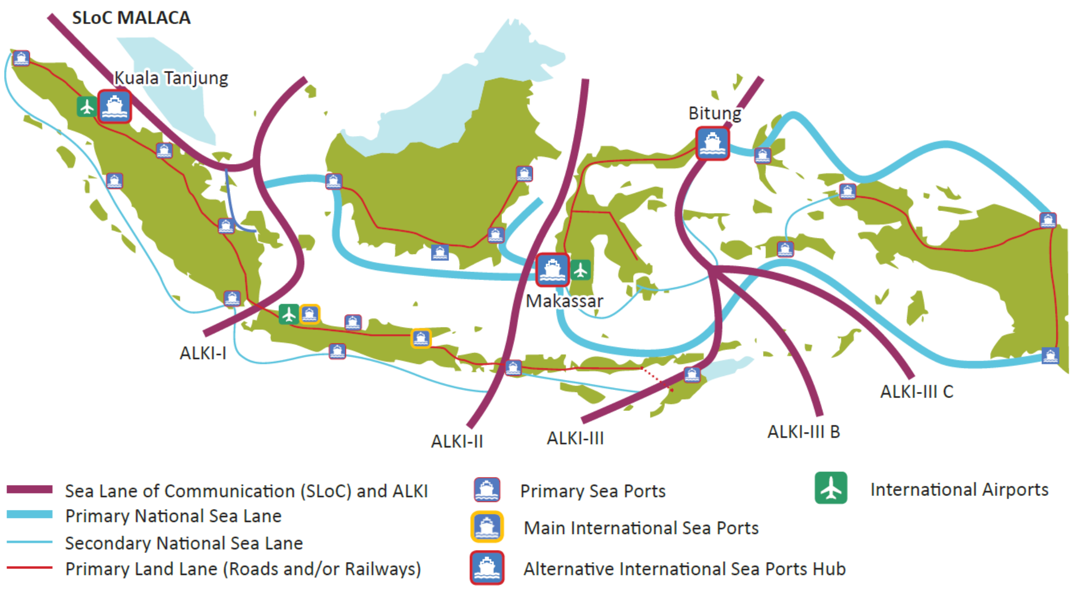

Figure 17 Shipping Network Plan in Blueprint of National Logistics System Development (MP3EI) (Source: (Presidential Decree No 26/2012, 2012))

The second network plan is called **Nusantara Pendulum**. This policy is designed with the objective increasing Indonesian container shipping flow from west to east and vice versa like a pendulum (Fahmiasari, 2015). The objective is based on an idea taken from MP3EI which is to balance the economy by designing the economic corridors in Indonesia. Nusantara Pendulum was formed to connect the eastern and western part of Indonesia. The shape of network of international gateway hubs is like a 'pendulum' represents a concept to swing the container as pendulum. This type of shape is similar with what is called as 'corridor network' (Woxenius, 2007). Under the network plan, there are five main ports determined as priority for the development, namely Belawan, Tanjung Priok (Jakarta), Tanjung Perak (East Java), Makassar, and Bitung (see Figure 18). Along the pendulum, there are numbers of loops as main service zone for each of the ports.

These loops are aligned with six corridors set in the MP3EI network plan: Sumatra economic corridor (centre of natural resources production and processing and as nation's reserves energy), Java economic corridor (driver for national industry and service provision), Kalimantan economic corridor (centre for national mining and reserves energy production and processing), Sulawesi economic corridor (centre for production and processing of natural agricultural plantation, fishery, oil & gas, and mining), Bali-Nusa Tenggara economic corridor (tourism gateway and national food support), Papua-Maluku Islands economic corridor (centre for food, fishery, energy, and national mining development). The network plan of Nusantara Pendulum is shown in figure below.

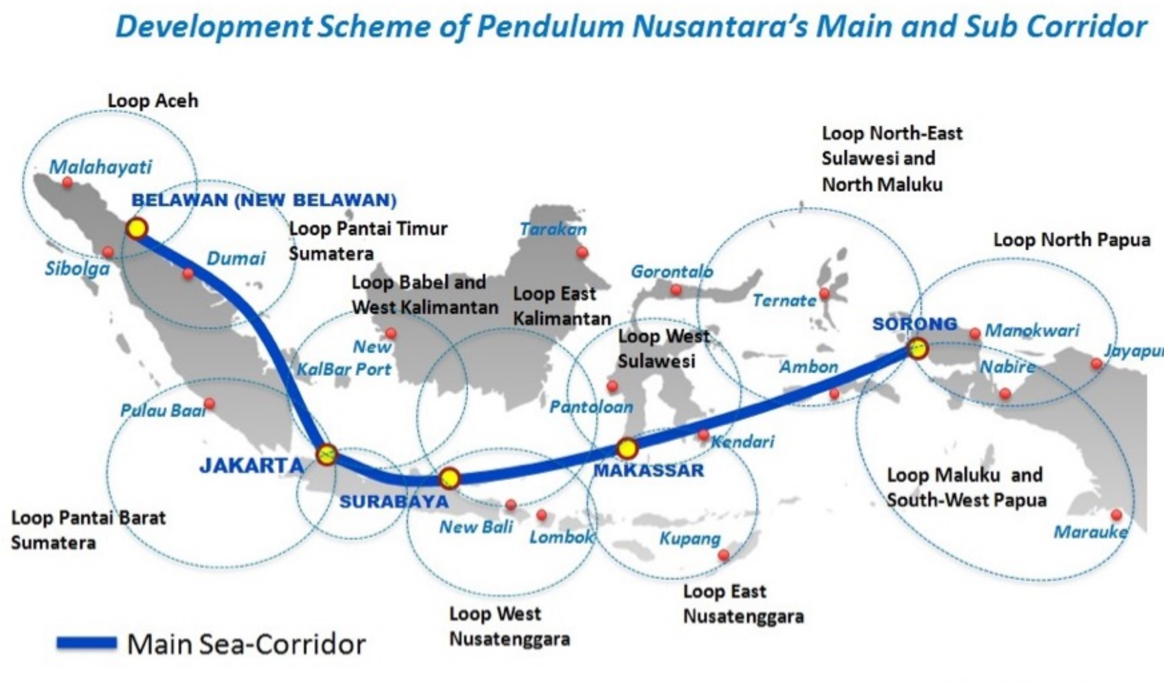

Figure 18 Nusantara Pendulum Network Plan (IPC)
(Source: Indonesia Port Corporation, 2012)

The third network plan refers to the national development strategic plan by Indonesia's current President, Joko Widodo, that is known as *Nawacita* 2014-2019 as well as what is in National Mid-term Development Planning *(RPJMN)* 2015-2019, one of the focus points is the so-called **Maritime Highway/*Tol Laut*** policy. Through this policy the Indonesian government planned to develop 24 existing and new main ports across the archipelago which evolved in port development plans on 61 locations in 2017. Amongst the 24 main ports, six of them are planned to be hubs: Belawan/Kuala Tanjung, Tanjung Priok, Tanjung Perak, Makassar, Bitung and Sorong (Figure 19).

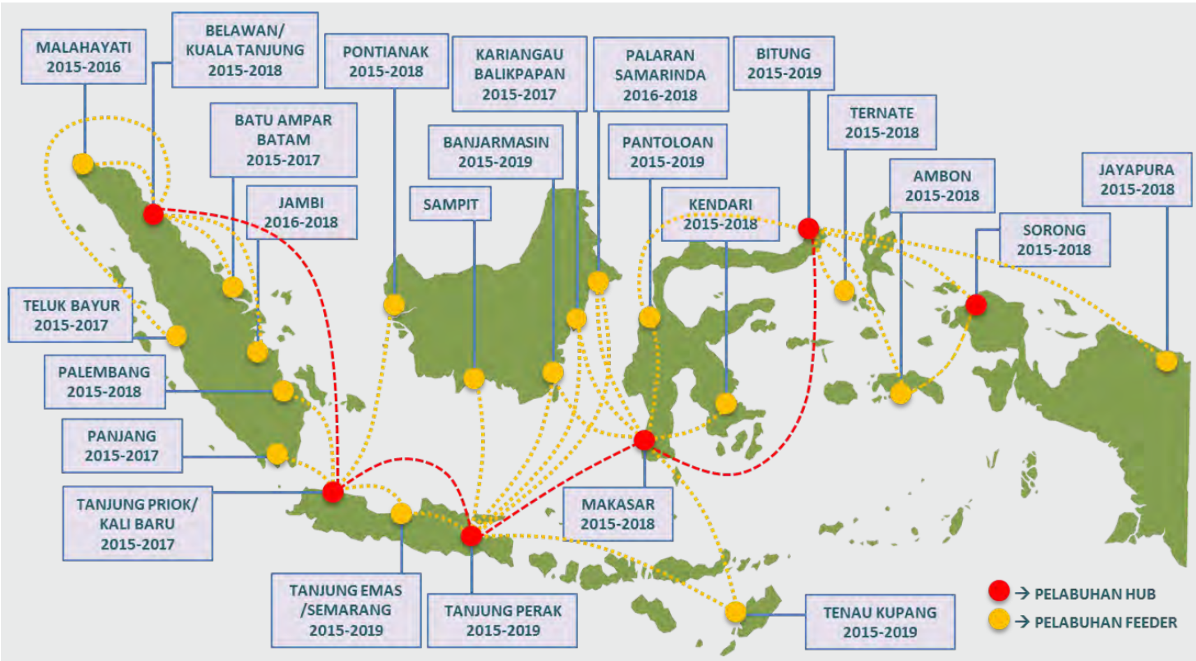

Figure 19 Maritime Highway ("Tol Laut") Network Plan (RPJMN 2014-2019)
(Source: National Planning and Development Agency (Bappenas), 2015)

Late 2018, the government initiated a so-called plan *Integrated Port Network*. This plan has been being discussed and studied by several ministries and institutions such as Coordinating Ministry for Maritime Affairs, National Development and Planning Agency, Coordinating Ministry for Economy, Ministry of State-Owned Enterprises, Ministry of Transportation, Pelindo(s), and other institutions. The most recent network plan was addressed by the Coordinating Ministry for Maritime Affairs (*Kemenko Maritim*) of Indonesia that there are 7 international hubs that are prioritized: Kuala Tanjung, Tanjung Priok, Kijing (West Kalimantan), Tanjung Perak, Makassar, Bitung, and Sorong (Figure 20).

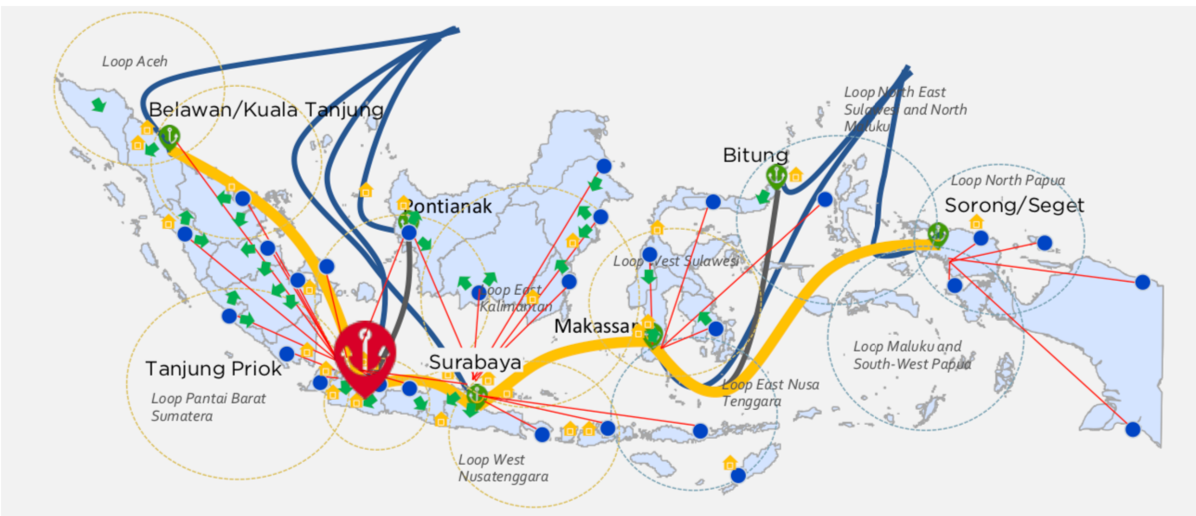

Figure 20 Integrated Port Network by 4 Pelindo(s), 2018
(Source: IPC, 2018)

Overall, there are eight ports nominated as international gateway hubs in four network plans from time to time (Figure 21). Those eight ports are Belawan (North Sumatra), Kuala Tanjung (North Sumatra), Tanjung Priok (Jakarta), Tanjung Perak (East Java), Kijing (West Kalimantan), Makassar (South Sulawesi), Bitung (North Sulawesi), and Sorong (West Papua).

Figure 21 Eight ports nominated as international gateway hubs in four network plans

4.4 HISTORICAL FACTS OF INDONESIAN EXPORT TRADE

The scope of this research is taking export trade as the data for the model. Generally, export and import are two aspects those are regularly evaluated as economic indicators of a country. Specifically, export is very important and has been one of the pivotal development agenda points in Indonesian economic development due to the wave of globalization since the 1980s that implies rapid growth of global trade (Presidential Decree No 26/2012, 2012).

The Observatory of Economic Complexity ("OEC") built by Alexander Simoes from MIT visualises the export and import of 221 countries, the destinations, the origins, types of commodities, the values, rank of each country, etc. In the visualization, it is shown that Indonesia is the 25th largest export economy in the world with the export values of $188 billion, import values of $153 billion resulting in a positive trade balance of $35.1 billion. Compared to the countries in the world, Indonesia is slightly below Thailand that exported $215 billion in 2017 and ranked 23rd. On the other hand, Turkey's rank is slightly under Indonesia which is 27th with export values of $166 billion. Figure 22 below illustrates the export values of countries around the globe that shows China as the country with biggest export values, which is described by the darkest blue, and followed by the US and Germany. Exports contributed approximately 21% of Indonesia's GDP in 2019 based on data from the World Bank and the Organization for Economic Co-operation and Development ("OECD"). Historical export trade data over 17 years from 2000 to 2016 is shown in

Table 4 below. The table shows both net weight and value of exports from year to year as well as the growth (y-0-y) which is showing fluctuate numbers over the years. In 2000, the growth of export values was positive that is 27.66%, however decreased in the next year for about 9.34%. Furthermore, starting from 2002 to 2008, Indonesian exports kept raising positively in terms of export values which in 2002 the value was US$57,158.8 million and in 2008 increased significantly to US$137,020.4 million. However, in 2009 the value fell down again for about 14.97% to the value of US$116.510.0 million. Global financial crisis was the reason behind the declination in 2009. Two years after, which are 2010 and 2011, export values increased by 35.42% and 28.98% respectively. Then, during the time period from 2012 to 2016, its value experienced decreasing trend.

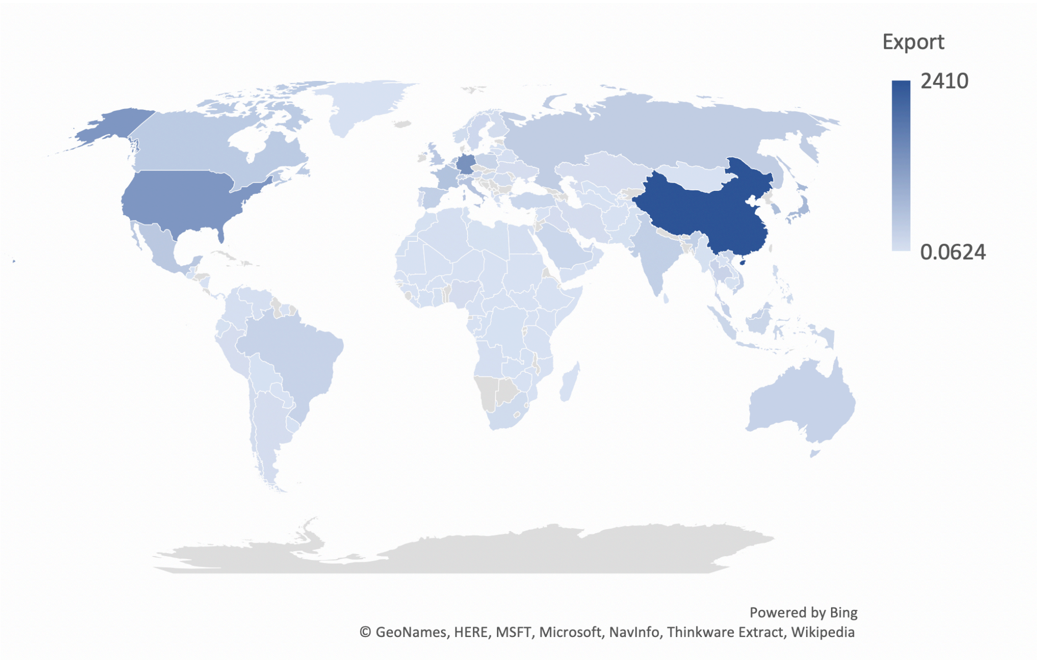

Figure 22 Export values of worldwide countries (in Billion USD) (Source: OEC)

Table 4 Net Weight and FOB Value of Indonesian Exports, 2000-2016

Year	Net weight (000 tons)	FOB Value (US$ million)	Growth of FOB Value
2000	225.102,80	$ 62.124,00	
2001	272.456,60	$ 56.320,90	
2002	223.270,10	$ 57.158,80	
2003	219.566,80	$ 61.058,20	
2004	232.317,40	$ 71.584,60	
2005	258.731,50	$ 85.660,00	
2006	327.172,30	$100.798,60	
2007	342.773,50	$114.100,90	
2008	355.054,00	$137.020,40	
2009	378.999,10	$116.510,00	
2010	478.846,80	$157.779,10	
2011	582.220,00	$203.496,60	
2012	600.136,60	$190.020,30	
2013	700.005,00	$182.551,80	
2014	549.465,50	$175.980,00	
2015	509.661,80	$150.366,30	
2016	514.784,60	$145.186,20	

Source: (BPS, Indonesian Foreign Trade Statistics Exports 2016 Volume I, 2017)

Generally, Indonesian exports are divided into two types of commodities: oil and gas and non-oil and gas commodities. Based on the same data source, the decrease of Indonesian exports in 2016 mostly caused by the drop of oil and gas both in terms of net weight and value of exports. Meanwhile, value of exports of non-oil and gas increased for about 0.22% in 2016 compare to the previous year. From Table 5 it can be seen that the average growth of non-oil and gas is higher than oil and gas, and so does its average contribution to the whole export values.

Figure 23 shows that non-oil and gas is dominating Indonesian export value and moreover based on the same source, the net weight of non-oil and gas reached 92% of total exports weight. In terms of non-oil and gas commodities, agricultural and industrial products, which mostly are containerized commodity, shared more than 85% of total export values in 2016 (BPS, Indonesian Foreign Trade Statistics Exports 2016 Volume I, 2017). This fact might be influenced by the improvement of containerization concept in the global maritime freight transport. Thus, container export flows are increasingly important for the country. Some of the main export commodity types namely palm oil, garment (convection) of textiles, electrical apparatus, coffee, medicinal plants, aromatics, and spices, and annual fruits.

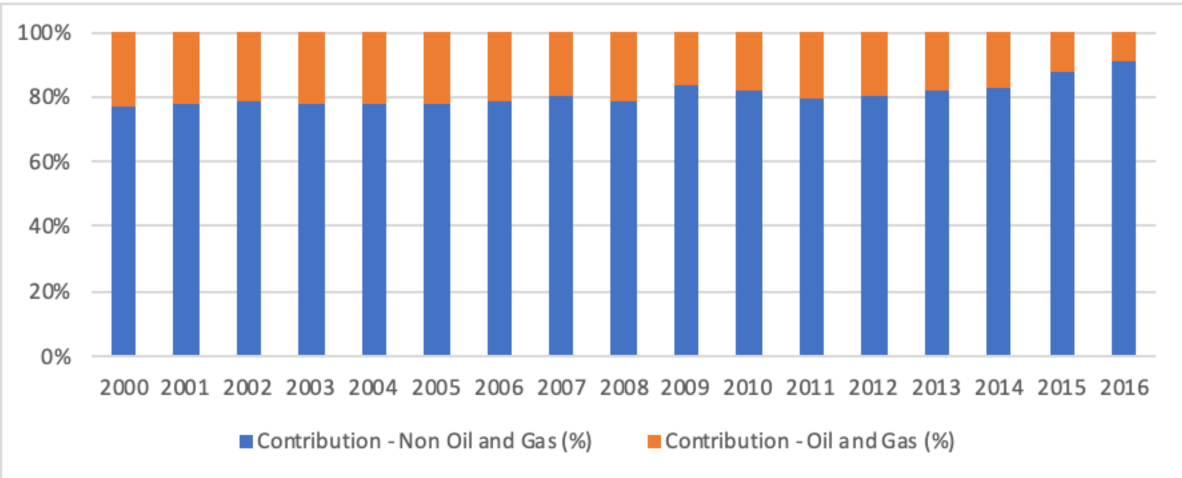

Figure 23 Contribution of Oil and Gas and Non-Oil and Gas Exports, 2000-2016
(Source: (BPS, Indonesian Foreign Trade Statistics Exports 2016 Volume I, 2017)

Table 5 FOB Value, Growth and Share of Indonesian Exports of Oil & Gas and Non-Oil & Gas, 2000-2016

Year	Non-Oil and Gas (US$ million)	Oil and Gas (US$ million)	Growth - Non Oil and Gas (%)	Growth - Oil and Gas (%)	Contribution - Non Oil and Gas (%)	Contribution - Oil and Gas (%)
2000	$ 47.757,40	$ 14.366,60	22,85%	46,71%	76,87%	23,13%
2001	$ 43.684,60	$ 12.636,30	-8,53%	-12,04%	77,56%	22,44%
2002	$ 45.046,10	$ 12.112,70	3,12%	-4,14%	78,81%	21,19%
2003	$ 47.406,80	$ 13.651,40	5,24%	12,70%	77,64%	22,36%
2004	$ 55.939,30	$ 15.645,30	18,00%	14,61%	78,14%	21,86%
2005	$ 66.428,40	$ 19.231,60	18,75%	22,92%	77,55%	22,45%
2006	$ 79.589,10	$ 21.209,50	19,81%	10,28%	78,96%	21,04%
2007	$ 92.012,30	$ 22.088,60	15,61%	4,14%	80,64%	19,36%
2008	$ 107.894,20	$ 29.126,20	17,26%	31,86%	78,74%	21,26%
2009	$ 97.491,70	$ 19.018,30	-9,64%	-34,70%	83,68%	16,32%
2010	$ 129.739,50	$ 28.039,60	33,08%	47,43%	82,23%	17,77%
2011	$ 162.019,60	$ 41.477,00	24,88%	47,92%	79,62%	20,38%
2012	$ 153.043,00	$ 36.977,30	-5,54%	-10,85%	80,54%	19,46%
2013	$ 149.918,80	$ 32.633,00	-2,04%	-11,75%	82,12%	17,88%
2014	$ 145.961,20	$ 30.018,80	-2,64%	-8,01%	82,94%	17,06%
2015	$ 131.791,90	$ 18.574,40	-9,71%	-38,12%	87,65%	12,35%
2016	$ 132.080,80	$ 13.105,50	0,22%	-29,44%	90,97%	9,03%
Average			**8,28%**	**5,27%**	**80,86%**	**19,14%**

Source: (BPS, Indonesian Foreign Trade Statistics Exports 2016 Volume I, 2017)

The Observatory of Economic Complexity developed by MIT Media Lab, showing Indonesia's top export markets shows that 68% of Indonesian exported within Asia, 13% to Europe, 12% to North America, 2.8% to Africa, 2.1% to Oceania, and 1.4% to South America. More about the data of destination of export trade from Indonesia is illustrated in Figure 24 below. The figure shows a pareto chart that plots the distribution of Indonesian exported containers based on worldwide regions of destination in descending order of frequency. The graph is complemented with a cumulative line on a secondary axis as a percentage of the total exported containers. It is shown that Northeast Asia, Southeast Asia, and South Asia are in the top three destinations of export trade of Indonesia with the percentage of about 70%. Then, those regions are followed by Europe and North America.

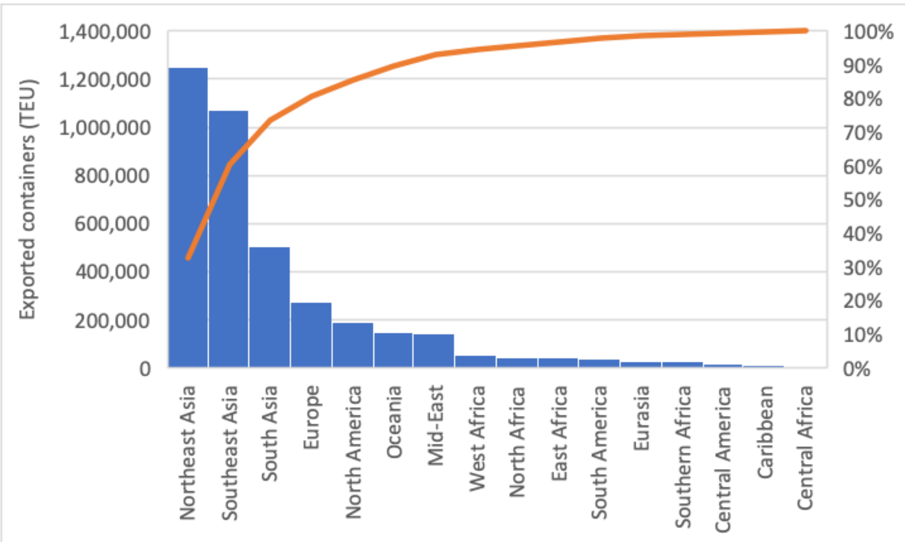

Figure 24 Distribution of Indonesian exported containers based on destinations

In order to complement the understanding of container cargo in export trade, based on Seabury[5] database we can identify the numbers of containers (in TEU) of Indonesian export from 2016-2018 as well as the list of types of commodity inside the container (Table 6). Moreover, from the database we can also identify how many TEUs are exported to destination regions (Table 7). Appendix A shows the table of Indonesian export values based on both types of commodities and regions of destinations.

Table 6 Indonesian export volume by types of commodities from 2016-2018 (in TEU)

Ocean volume (TEU)		2016	2017	2018
Indonesia	Capital Equipment & Machinery	44.157	47.823	51.278
	Chemicals & Products	234.798	260.044	270.743
	Consumer Fashion Goods	185.148	182.089	182.222
	Consumer personal & household goods	281.452	285.687	289.714
	High Technology	42.761	36.134	30.205
	Land Vehicles & Parts	273.436	321.430	303.027
	Live Animals	7	6	3
	Machinery parts. Components, supplies & manufactures n.e.s.	245.341	249.432	233.997
	Raw Materials, Industrial consumables & Foods	1.977.259	2.149.053	2.288.502
	Secure or Special Handling	6.631	1.994	2.316
	Temperature or Climate Control	69.197	70.211	79.089
	Waste Products	0	1	7

Table 7 Indonesian export volume by regions of destinations from 2016-2018 (in TEU)

Ocean volume (TEU)		2016	2017	2018
Indonesia	Africa	103.542	115.489	116.986
	Asia Pacific	1.905.898	2.073.481	2.159.611
	Europe	378.517	387.889	361.442
	Latin America	85.569	92.973	101.166
	Middle East & South Asia	439.014	483.430	533.412
	North America	447.645	450.643	458.486
	Special Categories & Errors	1	0	0
	All partner countries	3.360.186	3.603.905	3.731.102

4.5 Trends and Developments Influencing Future Indonesian Export Trade

Looking towards the future there are a number of trends and developments that need to be analyzed as those have significant influence for future Indonesia's shipping network planning. In this part, we describe the trends and developments divided into four categories: (1) macroeconomic dynamics, (2) demographic trends, (3) globalization and technology and (4) geopolitical issues.

4.5.1 Macroeconomic Dynamics

Macroeconomic dynamics is one of the key trends for the port sector in dealing with demand and supply concept. (Rashed, Meersman, Sys, Van de Voorde, & Vanelslander, 2018) discussed that a cointegration relationship between the economic indicators (GDP). Their study concluded that GDP growth in Europe has a positive relation with container throughput growth, but that GDP is not the only factor influencing GDP growth. In the case of Indonesia, Figure 25 shows the historical GDP data and Indonesian container export flows from 2010-2016 that indicates how both numbers relate to each other.

[5] https://seaburycargo.com

Figure 25 Historical data between GDP and container throughput of Indonesia

Furthermore, there are several uncertainties in macroeconomic situation both globally and in national scope. The normalization of US monetary policy, recent trade wars between the US and several of its trade partners, the rebalancing of China's economy, fluctuations of energy prices and geopolitical tensions have all had an impact on the global trade landscape. Future uncertainties such as continued slowdown of China's economy and challenges caused by trade wars are adding even more complexities in global growth. In addition, the impact of trade war between China and US potentially generates a benefit to Southeast Asia countries from production shifting from China.

Indonesia has experienced very steady consistent GDP growth over the last 20 years. In 2018, Indonesia maintained strong economic development with the real GDP growth of 5.17% year-on-year (World Bank, 2018). Indonesia, the 8th biggest market size in the globe based on the combination of country size and foreign markets (World Economic Forum, 2018), is currently experiencing remarkable economic growth. It is projected that Indonesia's GDP average growth will be maintained above 6% from 2020-2030 (Indrawati, 2019). In 2045, moreover, Indonesia has economic transformation target to become the five strongest economy in the world.

Given the economic transformation target, Indonesia's government through MoF is alert to the urgency of investment initiative especially in financing infrastructure development. Accordingly, one of the key success for ports investment in developing countries is the ability to gain private sectors participate in it given not all of these infrastructure developments can be funded by the State Budget. As part of its efforts to address the national infrastructure deficit, the current government has increasingly promoted PPPs, provides taxation incentives to encourage investment and foreign direct investment (FD). The government believes that investment will be the fuel to drive productivity and provide job opportunities for our people, especially the young generation. In addition to that, Asia and particularly Southeast Asia countries, such as India and Indonesia, is forecasted remain as a promising destination to invest (Indrawati, 2019).

4.5.2 DEMOGRAPHIC TRENDS

In the coming years, Indonesia is undergoing a demographic transition. The portion of Indonesia's productive age is increasing while the dependency ratio continues to decline and is expected to experience a peak demographic bonus in 2030. To be estimated, numbers of middle-income class will increase to 49% of total population by 2030 from 19% in 2010. This growing middle-income class with higher income will translate into increasing demand numbers, numbers of middle classes and so the per capita incomes are raising. The demographic bonus provides an abundant workforce and a large market potential, boosts income and consumption among the population and thus increases economic activities. Therefore, Indonesia must be able to harness this potential. In relation to port infrastructure, it is required for Indonesia during years of demographic bonus to accelerate infrastructure development to boost and maintain higher economic growth.

Besides the demographic bonus that influence composition of the population, there is urbanization rate that is also a major driver for Indonesian container growth. Urbanization often drives where container ports are developed as the ports are demand driven. Based on report by (Oberman, Dobbs, Budiman, Thompson, & Rossé, 2012), the proportion of Indonesians living in urban areas could reach 71% in 2030, up from 53% in 2012, as an estimated 32 million people move from rural to urban areas. It is also estimated that overall share of GDP generated by urban areas will increase from 74% in 2012 to 86% in 2030. The majority of growth is highly influenced by small middleweight cities such as Pekanbaru, Pontianak, Karawang, Makassar, and Balikpapan, which each is expected having annual growth rates of more than 7% for the GDP. Small middleweight cities are defined as cities with number of inhabitants between 150,000 to 2 million. This applies similarly to 20 mid-sized and large middleweight cities, which are between 2 million and 10 million inhabitants. All those cities are projected to contribute roughly 25% of GDP in 2030. On the other hand, Jakarta's contribution to GDP is estimated to remain relatively constant about 20%.

4.5.3 GLOBALIZATION AND TECHNOLOGY IMPROVEMENT

Economies of scale continues playing a key role in the maritime, ports, and logistics sector (Halim, Kwakkel, & Tavasszy, 2016) as carriers aim to minimize operational costs. The utilization of economies of scale in the maritime sector is mainly represented by deployment of larger ships, particularly in container shipping. The existence of larger ships needs deeper draft, new advanced cranes, yard cranes, expansion of berth and yard area, etc. The investment needed to cope with the emerging economies of scale is therefore not trivial as these technological developments are highly capital intensive. More to the supply chain point of view, the bigger ships could generate a constraint to the customer which is higher inventory levels due to lower frequency of port of call. Another recent issue that might be the answer for that constraint is the new generation of container ships which are smaller and faster, designed in order to achieve greater flexibility. Figure 26 shows the evolution of container ships.

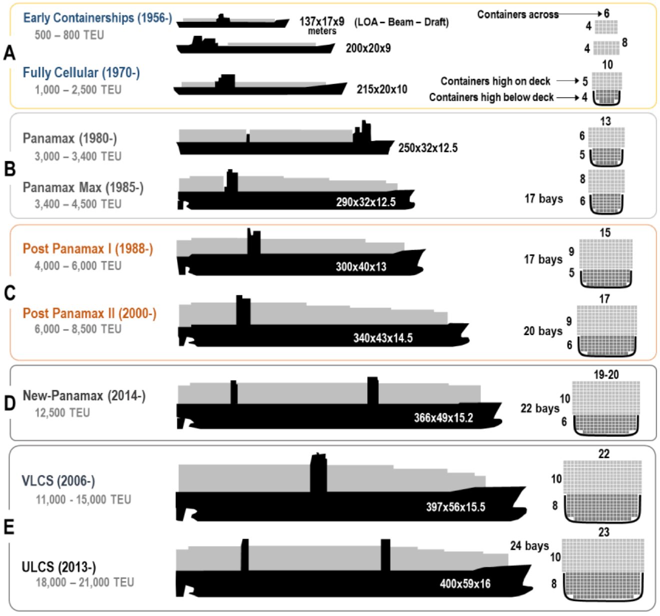

Figure 26 The evolution of container ships
(Source: (Rodrigue J.-P. , 2017)

Over a long period of history, the significance role of maritime and ports sector remained unchanged yet continuously rising especially in the process of economic development in a country. It is strongly supported by the fact from an article of UNCTAD in 2018 that as much as 80% of the volume of goods in the world are transported by ship. The globalization and technology improvement enter the maritime trade and continuously change the value of sea from economic value to strategic value. This improvement pulls developing countries, such as Indonesia, to do action by switching or adding their priority to the infrastructure development, in particular ports infrastructure. Within the globalization and technology improvement, there are several points that need to be concerned: intelligent ports (UNCTAD, 2018), advanced information technology (Jussila, Lehtonen, Laitinen, Makkonen, & Frank, 2018) (Zaman, Pazouki, Norman, Younessi, & Coleman, 2017), development of big data and e-commerce in shipping (Midoro & Pitto, 2000) (Rodrigue, Comtois, & Slack, 2016), the liner shipping consolidation, and containerization (Bernhofe, El-Sahli, & Kneller, 2016).

Besides the evolution of ship size, containerization is also one of the products of globalization. Containerization yields the shift of type of cargo in freight transport in the globe as more and more shippers using container to transfer their freight. This big shift also means changes in the way port infrastructure, superstructure, and supporting equipment being developed. The impact for Indonesian ports is real as the direction of port development recently tends to make the ports being able to handle containerized cargo more attractive. The fact that bigger players in the global trade utilize containers more than ever pushes smaller players to do the same in order to keep their market position in global trade.

All the trends and developments in globalization and technology are related with two assessment indicators for ports and logistics sector in the world. World Economic Forum in its Global Competitiveness Report indicates Quality of Port Infrastructure ("QPI") as an indicator for ports assessment. Moreover, World Bank indicates Liner Shipping Connectivity Index ("LSCI") for logistics related assessment.

4.5.4 (GEO)POLITICAL ISSUES

Besides, geopolitics situation is also influenced by the globalization. There are several major trends describe the recent concerns on geopolitics situation around the globe those are relevant for maritime sector (Jakarta Post, 2017). One of them is the changing nature and value of the sea which is from economic values (that emphasize the sea as a public good) to strategic values (which emphasize control of the sea). The changing value impacts the more difficult problem solving for maritime disputes (e.g. South China Sea, East China Sea).

Moreover, Free Trade Agreements ("FTA") and cabotage rules are rising issues nowadays related to the geopolitical aspect. In the growing atmosphere of trade, countries in the world are increasing participation in many platforms for maritime cooperation and one of them is through FTA (Quansah et al., 2017). It is studied that in relation to maritime trade, the FTAs can affect tariff reductions and the elimination of some nontariff barriers (Stoke, 1989). Currently, there are several countries that already have free trade agreements with Indonesia, namely Australia, China, India, Japan, Korea, New Zealand, Pakistan, and all ASEAN countries.

Another issue is cabotage rules that Indonesia sets activities relating to domestic sea transportation must be performed by an Indonesian Sea carriage company using an Indonesian flagged vessel which are manned by Indonesian crews. Conversely, non-Indonesian sea flagged vessels are prohibited from carrying passengers and/or good between island or ports in Indonesian waters. These rules could imply two opposite impacts: the rules will limit the participation of foreign shipping liners that may potentially also bring international flows and the rules will encourage the development of the Indonesian shipbuilding industry to improve the capability. The rule is stated in Article 8 of the Maritime Law No 17 of 2008. However, historical evidence shows that cabotage rules do not bring the country to more advanced shipbuilding industries, for instance US and Brazil. Neither country is home to major shipping lines, and neither is a major shipbuilder as both countries account for less than 10% of global shipbuilding orders. The country needs to be internationally competitive in order to have a successful shipbuilding industry and on the contrary cabotage rules weaken the country in this matter.

More to the national issue, recently in April 2019 the current President of Indonesia Joko Widodo decided to relocate the capital city of Indonesia from Java to another island in Indonesia which is planned to be fully shifted in 2024. The idea is to keep or even enhance the current capital city, Jakarta, as the center of business and the new capital city as the center of governance for the country. We understand that Jakarta is the most developed and populated city in Indonesia where the economy activities growing in a high speed. Not to mention as well for its port infrastructure, Tanjung Priok Port Jakarta, which has the biggest market share in Indonesia compare to all other ports in the country. Thus, aiming to keep Jakarta as the center of business implies the likeliness this issue might not (or not significant) influence the shipping network planning in Indonesia.

Moreover, the case of relocating capital city of Indonesia is not the first one in the world. Beforehand, the movement of Brazil's capital from Rio de Janeiro to Brasilia in 1960 did not change the economic or demographic concentration of the country. Most of Brazil's economy and by extension container trade volumes are still generated by the area between São Paulo and Rio de Janeiro. Likewise, the shifting Australia's capital city to Canberra, is irrelevant for the country with regards to container volumes as Sydney and Melbourne continue account for most of Australian container volumes. The same might be true for Indonesia.

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5 DATA ANALYSIS

This chapter is divided into five big parts essential for the network model used in this research. The first part is about province-port and region-port pairs that represent the nodes in the network, the second port deals with the distance between nodes. Third is the container export volumes by origin and destination nodes. The fourth part deals with shipping cost analysis based on collected data from academic literature reviews and official government data, and fifth is the capacity for selected port nodes.

5.1 PROVINCE-PORT AND REGION-PORT PAIRS

The export flows in this analysis have 34 origins based on the 34 provinces in Indonesia. For the destinations, we consider there are 16 worldwide regions as follows: the Caribbean, Central Africa, Central America, East Africa, Eurasia, Europe, Mid-East, North Africa, North America, Northeast Asia, Oceania, South America, South Asia, Southeast Asia, Southern Africa, and West Africa. These 16 regions match the regions in the forecast model. Furthermore, to obtain the port-level OD (origin-destination) matrix, each Indonesian province and worldwide region is assigned one main strategic port in that particular province or region. As result, there are 31 province-port pairs for Indonesian ports and 16 region-port pairs for worldwide ports. The representative ports are presented in Table 8.

There are three special cases in the province-port pairs: Jakarta and West Java are assumed to be served by Tanjung Priok, Central Java and Yogyakarta are assumed to be served by Tanjung Emas while Central Sulawesi and West Sulawesi are assigned to Pantoloan. These are cases in which a province does not have a main strategic port given the list provided by governmental data, therefore it is allocated to the closest strategic port from its capital. Moreover, the allocation of the aforementioned ports is based on actual market circumstances; it is known that Tanjung Priok's hinterland is Jakarta and West Java. This is clearly a simplification because there are many factors in addition to distance that determine hinterland choice, such as specialized facilities in relation to the type of commodity and hinterland connection (e.g. road, railway) that implies multimodal transport once we want to consider them.

There are four types of ports considered in this export trade model:

1. *Provincial ports*: a set of small-scale Indonesian ports with no international connections serving their immediate hinterland. Export demand volumes originate from these ports.
2. *International gateway hubs (gateways)*: a set of ports in Indonesia that have been designated to serve as international gateways to foreign markets. These ports tend to be bigger and play a more pivotal role in the network; this is why these ports are considered in the policy strategies. This type of port can be origin node, but it is not end destination.
3. *Transshipment hubs (hubs)*: set of ports outside Indonesia where Indonesian cargoes only have to pass through these ports if Indonesian ports don't already have direct connections to regional ports. This type of port can be the end destinations however not origin nodes.
4. *Regional ports*: set of ports outside Indonesia that play role as end destination nodes.

Table 8 Indonesian province-port pairs and worldwide region-port pairs

Code	Indonesia Provinces	Representative Port	Code	Worldwide Region	Representative Port
1	Aceh	Lhokseumawe	32	Caribbean	Caucedo
2	North Sumatra	Belawan	33	Central Africa	Pointe Noire
3	West Sumatra	Teluk Bayur	34	Central America	Panama Canal
4	Riau	Dumai	35	East Africa	Mombasa
5	Jambi	Jambi	36	Eurasia	Vladivostok
6	South Sumatra	Palembang	37	Europe	Rotterdam
7	Bengkulu	Bengkulu	38	Mid-East	Dubai
8	Lampung	Panjang	39	North Africa	Port Said
9	Bangka Belitung Islands	Tanjung Pandan	40	North America	Los Angeles
10	Riau Islands	Batu Ampar	41	Northeast Asia	Shanghai
11	Jakarta	Tanjung Priok	42	Oceania	Melbourne
11	West Java	Tanjung Priok	43	South America	Santos
12	Central Java	Tanjung Emas	44	South Asia	Colombo
12	Yogyakarta	Tanjung Emas	45	Southeast Asia	Singapore
13	East Java	Tanjung Perak	46	Southern Africa	Cape Town
14	Banten	Banten	47	West Africa	Tin Can Island
15	Bali	Benoa			
16	West Nusa Tenggara	Benete			
17	East Nusa Tenggara	Tenau			
18	West Kalimantan	Pontianak			
19	Central Kalimantan	Sampit			
20	South Kalimantan	Banjarmasin			
21	East Kalimantan	Samarinda			
22	North Kalimantan	Tarakan			
23	North Sulawesi	Bitung			
24	Central Sulawesi	Pantoloan			
24	West Sulawesi	Pantoloan			
25	South Sulawesi	Makassar			
26	Southeast Sulawesi	Kendari			
27	Gorontalo	Gorontalo			
28	Maluku	Ambon			
29	North Maluku	Ternate			
30	West Papua	Sorong			
31	Papua	Jayapura			

According to BPS and eeSea data there are seven Indonesian ports which serve as export gateways. These are Belawan (2), Palembang (6), Panjang (8), Tanjung Priok (11), Tanjung Emas (12), Tanjung Perak (13), Makassar (25). In addition, there are two more ports candidate as gateways: Bitung (23) and Sorong (30) which currently don't have connections to foreign markets, but which have been identified as potential future gateways in government plans. Therefore, we take all 9 ports as international container gateways. Meanwhile, Port Said, North Africa (39), Shanghai, Northeast Asia (41), Colombo, South Asia (44), and Singapore, Southeast Asia (45) are considered transshipment hubs. Obviously, those are not the only ports that have direct connection with Indonesian international gateways. Indonesian ports indeed have direct connections to other ports such as Busan, Laem Chabang, Port Klang, Tokyo, New York, Sydney, Hong Kong, etc. This is a simplification in order to have a consistent region-port pair. Afterall, there are 47 port nodes in total considered in this network. See Table 9 for list of ports and the port ID codes.

Table 9 List of provincial ports, international gateway hubs, transshipment hubs and regional ports

Provincial ports		Int. gateway hubs		Transshipment hubs		Regional ports	
1	Lhokseumawe	2	Belawan	39	Port Said	32	Caucedo
3	Teluk Bayur	6	Palembang	41	Shanghai	33	Pointe Noire
4	Dumai	8	Panjang	44	Colombo	34	Panama Canal
5	Jambi	11	Tanjung Priok	45	Singapore	35	Mombasa
7	Bengkulu	12	Tanjung Emas			36	Vladivostok
9	Tanjung Pandan	13	Tanjung Perak			37	Rotterdam
10	Batu Ampar	23	Bitung			38	Dubai
14	Banten	25	Makassar			40	Los Angeles
15	Benoa	30	Sorong			42	Melbourne
16	Benete					43	Santos
17	Tenau					46	Cape Town
18	Pontianak					47	Tin Can Island
19	Sampit						
20	Banjarmasin						
21	Samarinda						
22	Tarakan						
24	Pantoloan						
26	Kendari						
27	Gorontalo						
28	Ambon						
29	Ternate						
31	Jayapura						

5.1.1 SETTING INITIAL NETWORK

To set up the initial network, we analyze how the current ports and connections perform in terms of export trade flows. The first step is to identify which ports have connections to each other and that connection is defined as an arc. There are three types of arcs: domestic, transshipment, and international. Domestic arcs are the connection between two Indonesian ports (e.g. Ambon and Tanjung Perak), transshipment arcs are the connections between Indonesian international gateways and transhipment hubs (e.g. Tanjung Perak and Singapore), and international arcs are connections between two foreign international regional ports (e.g. Singapore and Rotterdam).

Moreover, to recall the types of ports considered in this network and the port names, see Table 9. From the table, there are two types of hubs: international gateway hubs (Indonesia) and transshipment hubs (worldwide). International gateway hubs (re: gateways) are ports that link Indonesia with foreign markets. It is possible that a gateway is also an origin node. Transshipment hubs (re: hubs) are worldwide regional ports that have direct connection with Indonesia's gateways. It is also possible in this network that hubs are the destination nodes. Furthermore, we presume that all Indonesian provincial ports have connections to all Indonesian gateways, thus there are 279 domestic arcs. Similar with transshipment arcs that all gateways have connections with all hubs meaning that there are 36 transshipment arcs in total.

Lastly there are the international arcs which are the connections based on information from eeSea database. Table 10 below shows 64 connections between two worldwide ports as not all transshipment hubs have connections with all regional ports in terms of export trade. In other words, we can also note that international legs are not fully connected. These international arcs are represented by binary variable that equals 1 if the connection exists and otherwise 0. For arcs with the same origin and destination the binary variable is indicated as 1 (e.g. Port Said to Port Said) as well. However, note that for arcs that connect same port nodes, we set the distance and cost to 0, this applies as well for domestic arcs. Further details about distance and cost are given in the following sections. There are a total of 379 available arcs in the network for domestic, transshipment, and international.

Table 10 Binary variable showing connection between hubs and regional ports

O\D	Caucedo	Pointe Noire	Panama Canal	Mombasa	Vladivostok	Rotterdam	Dubai	Port Said
Port Said	0	0	0	1	0	0	1	1
Shanghai	1	1	1	1	1	1	1	1
Colombo	0	1	0	1	0	1	1	1
Singapore	1	1	1	1	0	1	1	1

O\D	Los Angeles	Shanghai	Melbourne	Santos	Colombo	Singapore	Cape Town	Tin Can Island
Port Said	0	1	0	0	0	1	0	0
Shanghai	1	1	1	1	1	1	1	1
Colombo	1	1	0	0	1	1	1	1
Singapore	1	1	1	1	1	1	1	1

The network is set hierarchically with directed graph. In this hierarchical network, hubs and gateways are forming the top layer and origin and destination nodes (provincial ports, international regional ports) construct the lower layer. It is possible to see origins and/or destinations also as gateways and/or hubs, respectively. In this structure, the demand from origin to destination may visit up to two transshipment nodes, namely gateways and hubs, on its way. Moreover, the demand may pass through up to three arcs to go from origin to destination. The schematic description of this network structure is presented in Figure 27. In this figure, we have a network with 47 nodes where nodes 2, 6, 8, 11, 12, 13, 23, 25, 30 are gateways and nodes 39, 41, 44, 45 are hubs.

The demand from node 24 to node 46 may follow the path 24 → 11 → 41 → 46 traversing a gateway and a hub. This path is going through three different arcs those are domestic, transshipment, and international arc. The demand from node 24 to node 39 may follow the path 24 → 2 → 39. This path visits a gateway and going through 2 arcs, domestic arc and transshipment arc. Demand from node 11 to node 34 may go through a hub, taking the path 11 → 45 → 34 which contains of two arcs. Finally, the demand from node 23 to node 44 goes directly as in this case node 23 acts as gateway as well as an origin node. Moreover node 44 acts as hub as well as a destination node. Therefore, it is possible to have the route with only one arc as we have mentioned before that the origin and destination nodes can be also the gateways and hubs, respectively.

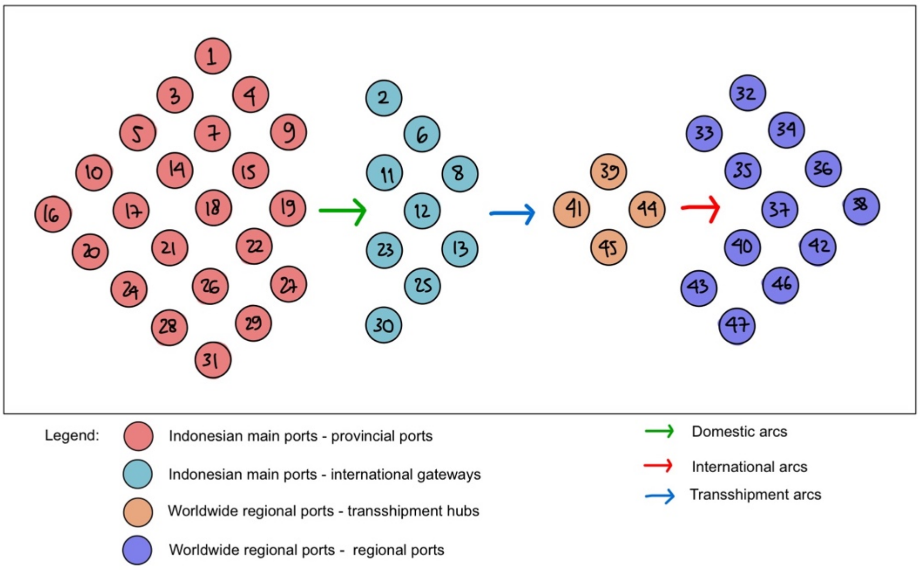

Figure 27 A hierarchical structure for a network with 47 nodes and 14 hubs (7 transshipment, 7 international gateway)

Figure 28 below shows the location of 31 port nodes in Indonesia which the blue dots represent gateways and red dots represent provincial ports. Meanwhile, Figure 29 illustrates the regional port locations in the world which the orange dots represent hubs and purple nodes represent regional ports. As this research focus on the port development in Indonesia, we illustrate all domestic arcs amongst Indonesian ports considered in this research, which are the arcs that connect origins (all Indonesian ports) and gateways (see Figure 30). Note that these arcs are part of assumption in the research, which we assume that all Indonesian ports considered in this research have connection with all nine gateways mentioned in advance.

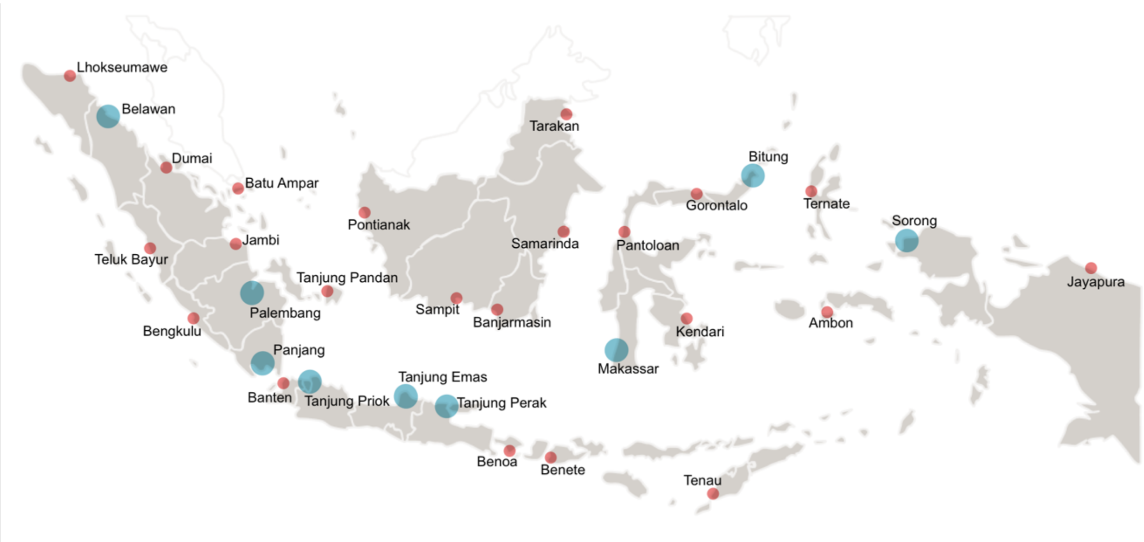

Figure 28 Location of 31 main ports in Indonesia

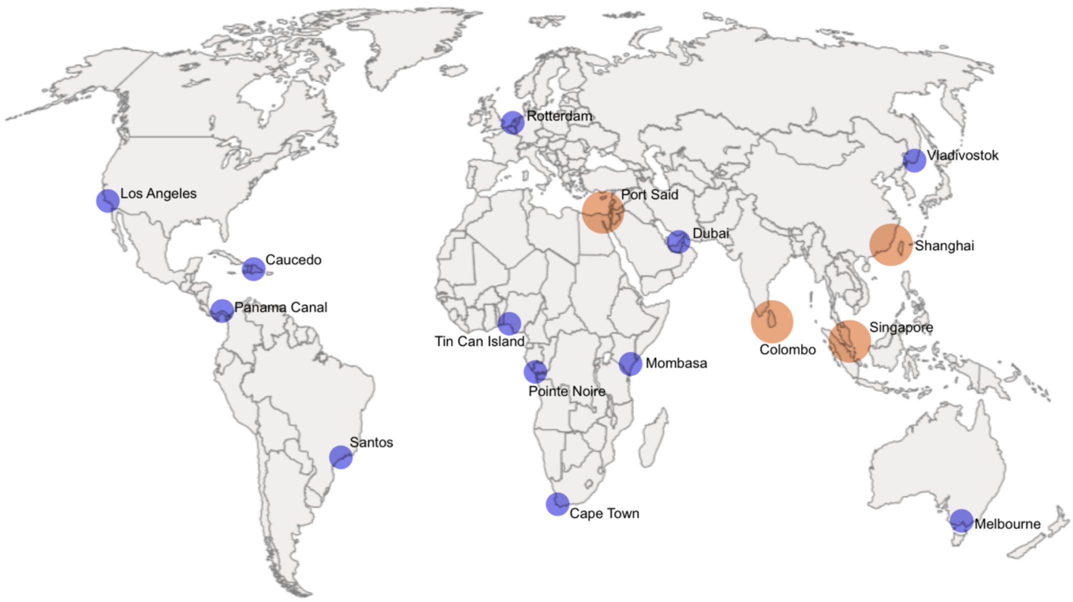

Figure 29 Location of 16 regional ports in the world

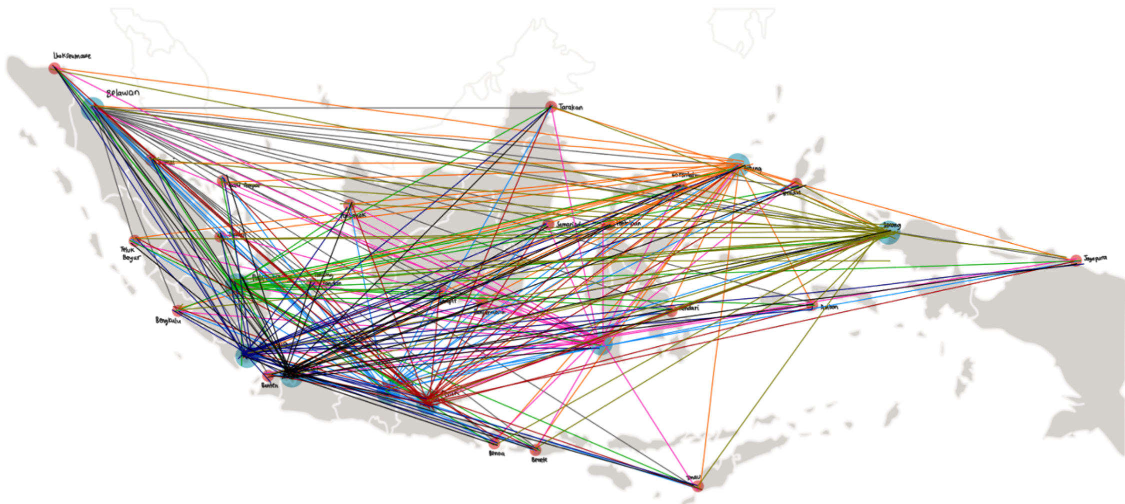

Figure 30 Domestic arcs amongst Indonesian ports

Based on data gathered from BPS Statistics Indonesia, particularly the report of Indonesian Foreign Statistics – Exports, we can collect export volume flows per port in each province. In this research, we take the same database of 2016 (i.e. base year) to identify the flow pattern between Indonesian ports. This database gives information about the unit value of cargoes being transferred from origin province to the ports where the cargoes are shipped. Then, we take this observed flow pattern as the base data for further analysis. The flow pattern in the network can be schematized by having extensive collection of databases from BPS statistics data, and the flow pattern is shown in Figure 31. Moreover, based on the information of international arcs (Table 10), which are the connections between hubs and regional worldwide ports, we can also schematize the flow pattern for worldwide scope. Figure 32 describes the flow pattern for international arcs. Note that the available connections in the last flow pattern for international arcs are fixed as the scope is beyond Indonesian shipping network policy.

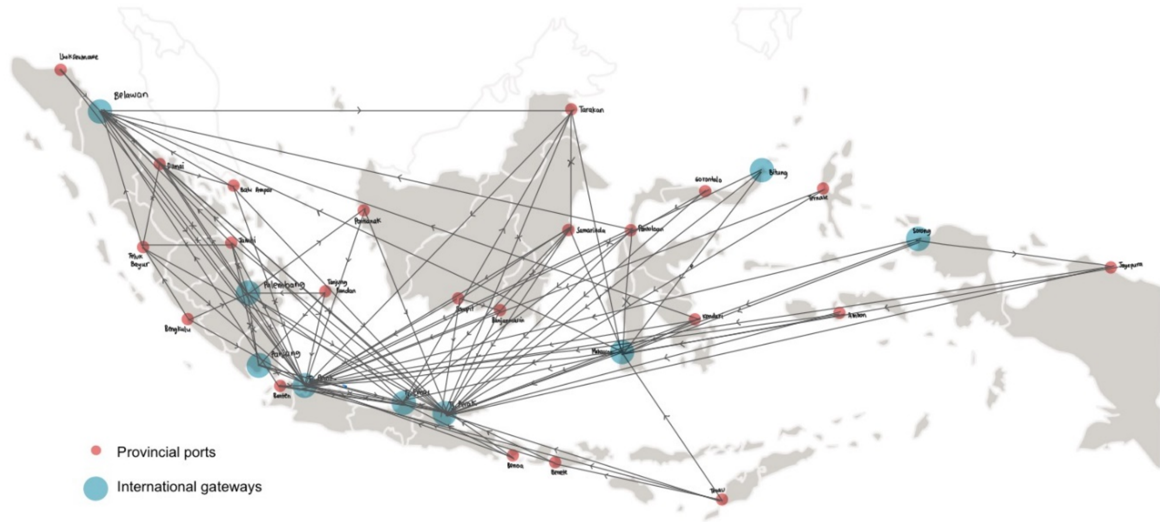

Figure 31 Flow pattern for export trade – domestic arcs (within Indonesian scope) in base year (Source: BPS Statistics Indonesia)

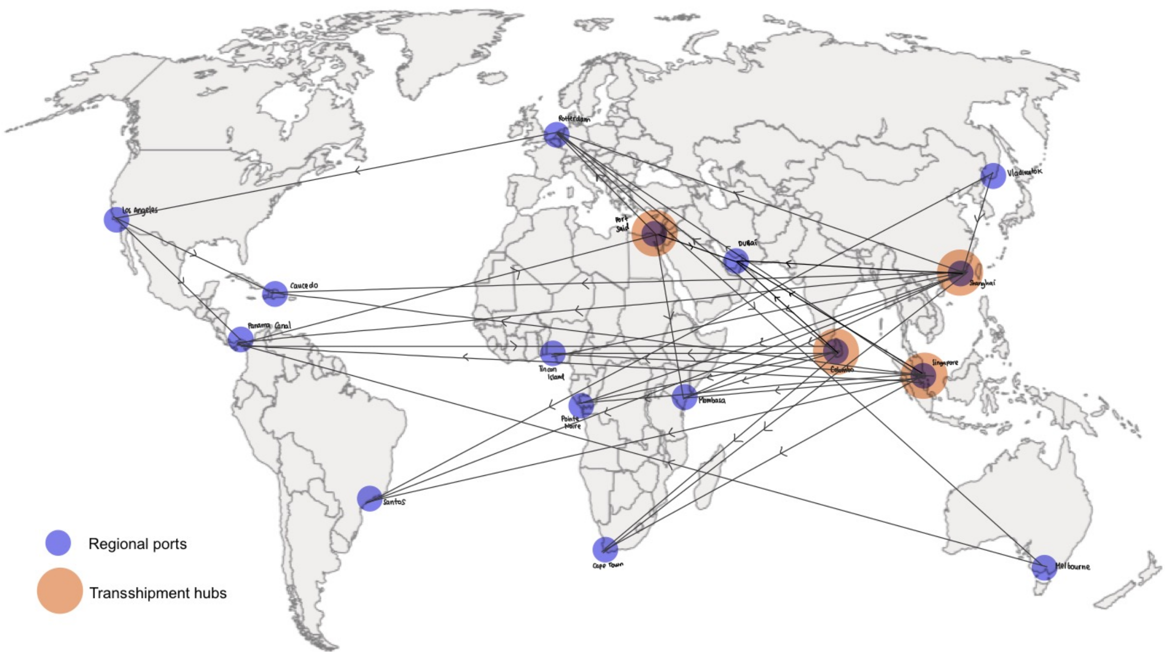

Figure 32 Flow pattern for export trade – international arcs (within worldwide scope) in base year (Source: eeSea database)

5.2 OBSERVED EXPORT VOLUME

In this sub chapter we analyze export volumes data taken from (BPS, 2018) and (BPS, 2017) which show export volumes by origin provinces, loading ports in Indonesia, and foreign destinations. All data is from 2016 and take into account all types of export commodities (e.g. dry bulk, liquid bulk, container). From that data set, we analyzed and determined the OD matrix where origins are Indonesian ports and destinations are foreign ports. Table 13 shows part of OD matrix provides container volumes representing demand expressed in TEUs. To result in OD demand matrix in TEUs, there are several calculations need to be done. Originally, the data from BPS are in kilograms (see Table 11) as it represents all export commodities. Moreover, the data are also for all transport modes and not only via sea transportation (BPS, 2018). Full export data (all commodities and all transport modes) shows total number of export flows of 512 billion kilograms. In addition, to come up with OD demand matrix in TEU, BPS data were also cross referenced against Indonesian container export data from Seabury[6]. Full OD matrices, see Appendix B and C.

Firstly, we estimate percentage of container share of total export flows for each Indonesian port. Due to the fact that available data is at provincial level, we use province-pair in Table 8. Data for estimating percentage of exports that are containerized comes from the Seabury database. In Seabury, we can generate matrix data by determine columns, rows, and filters. Here we set the columns with years, rows with Indonesian provinces, and filters with export trade as well as container type of commodity. Based on that set, we can calculate the average percentage of container share of total export flows for each province. Note that in order to be in line with ports-level analysis, we take the average of represented provinces for the special cases (Tanjung Priok, Tanjung Emas, and Pantoloan). Table 14 below describes the calculation results of containerization rate of exports of each port. Based on that calculation we apply the percentage to the actual OD matrix, and we get the OD matrix in TEUs like presented in Table 13. One variable needed to convert the numbers from kilograms to TEU is the assumption of how many tonnes of one TEU is (Table 12). Based on the Seabury Database, we can calculate and convert from kilograms to tonnes to TEUs.

Table 11 Part of OD demand of all commodities from Indonesian ports to worldwide ports – in kilograms

O\D	32	33	34	35	36	37	38	39	40
1	-	-	-	-	-	535,431	123,023	26,003	1,613,854
2	128,501,939	35,370,153	43,930,993	217,470,878	393,899,201	1,300,521,145	431,577,302	250,472,628	489,877,184
3	701,090	-	331,356	-	351,122	193,051,135	14,757,216	22,265,376	188,118,848
4	3,252,672	9,158,004	32,956,347	147,608,006	270,694,573	3,267,696,303	848,569,845	756,996,553	2,285,958,179
5	10,709,817	215,430	2,050,591	837,011	439,789	46,090,685	34,524,190	1,731,598	124,189,385
6	-	9,600	14,718,572	3,733,225	13,341,107	232,592,702	193,230,914	13,470,471	274,182,830
7	-	-	607,040	5	2	82,702,522	-	-	12,590,013
8	749,038	20,982	4,007,743	117,667,924	24,015,778	1,325,583,767	44,900,665	68,019,798	262,772,256
9	-	-	2,499,840	-	-	28,437,170	245,063	-	3,763,623
10	251,213	389,005	3,426,780	16,703,344	43,927,891	418,262,519	119,849,288	187,128,704	267,435,908

Table 12 Assumption of container weight per TEU (Source: Author's calculation based on Seabury)

Kilograms	Tonnes	TEUs
11.168,38	11,17	1

Table 13 Part of OD container demand matrix from Indonesian ports to worldwide ports – in TEUs

Origin\Dest	32	33	34	35	36	37	38	39	40
1	-	-	-	-	-	1	0	0	3
2	4,945	1,361	1,690	8,368	15,156	50,042	16,606	9,638	18,850
3	15	-	7	-	8	4,210	322	486	4,103
4	62	175	630	2,822	5,174	62,462	16,221	14,470	43,696
5	187	4	36	15	8	805	603	30	2,169
6	-	0	241	61	218	3,804	3,160	220	4,484
7	-	-	2	0	0	274	-	-	42
8	9	0	47	1,366	279	15,384	521	789	3,050
9	-	-	30	-	-	340	3	-	45
10	2	3	29	141	370	3,521	1,009	1,575	2,251

[6] (Seabury Cargo, n.d.)

Table 14 Containerisation rate of exports of each Indonesian port

Representative Province	Ports name	Container %
Aceh	Lhokseumawe	2,248%
North Sumatra	Belawan	42,974%
West Sumatra	Teluk Bayur	24,357%
Riau	Dumai	21,349%
Jambi	Jambi	19,504%
South Sumatra	Palembang	18,266%
Bengkulu	Bengkulu	3,696%
Lampung	Panjang	12,961%
Bangka Belitung Islands	Tanjung Pandan	13,334%
Riau Islands	Batu Ampar	9,401%
Jakarta & West Java	Tanjung Priok	77,491%
Central Java & Yogyakarta	Tanjung Emas	59,545%
East Java	Tanjung Perak	77,388%
Banten	Banten	15,948%
Bali	Benoa	52,159%
West Nusa Tenggara	Benete	10,002%
East Nusa Tenggara	Tenau	0,088%
West Kalimantan	Pontianak	39,372%
Central Kalimantan	Sampit	15,122%
South Kalimantan	Banjarmasin	0,415%
East Kalimantan	Samarinda	0,349%
North Kalimantan	Tarakan	0,885%
North Sulawesi	Bitung	27,233%
Central Sulawesi & West Sulawesi	Pantoloan	11,906%
South Sulawesi	Makassar	47,157%
Southeast Sulawesi	Kendari	18,249%
Gorontalo	Gorontalo	17,536%
Maluku	Ambon	15,128%
North Maluku	Ternate	56,327%
West Papua	Sorong	13,619%
Papua	Jayapura	0,403%

(Source: Author's calculation)

5.3 DISTANCE BETWEEN NODES

Data for distance between all arcs are also taken into account in order to calculate and analyze the shipping costs (later in the next part). The distance data is generated through database from website called http://ports.com/sea-route/. In the website we can type in two ports that we want to calculate the distance between those, and the result will appear together with the map illustration and itinerary of routes those are taken from origin to destination. Another approach is by indicating the latitude and longitude of each port location and calculate the distance through a solver. However, the result will be then point-to-point distance. As the decision, this research then uses website-based database to calculate the distance as the results are giving more reliable routes that the vessel will go through in the real situation. This is due to the objective of the network flow model is to have minimum shipping cost, therefore the more reliable distance the more relevant the results will be. The full distance data is presented in Appendix E. Table 15 to Table 17 below shows part of the OD distance matrix for each arc which the data is in nautical miles (nm).

Table 15 Part of OD distance matrix – domestic arcs (in nm)

Domestic arc	Belawan	Palembang	Panjang	Tanjung Priok	Tanjung Emas	Tanjung Perak	Bitung	Makassar	Sorong
Lhokseumawe	311	933	1127	1263	1470	1687	2544	1907	2973
Belawan	0	734	1137	1064	1271	1130	2347	1708	2687
Teluk Bayur	903	824	507	674	884	932	2144	1433	2729
Dumai	291	459	732	689	862	951	1690	1299	2069
Jambi	608	126	529	456	664	762	1739	1100	2324
Palembang	734	0	404	330	506	635	1660	1015	2245
Bengkulu	1092	623	306	473	683	911	1943	1232	2527
Panjang	1137	404	0	214	337	495	1723	1012	2308
Tanjung Pandan	921	234	422	216	401	604	1463	824	2048
Batu Ampar	483	261	665	591	799	761	1874	1235	2327
Tanjung Priok	1064	330	214	0	234	384	1517	806	2102
Tanjung Emas	1271	538	424	210	0	194	1382	671	1967
Tanjung Perak	1488	761	652	438	194	0	1231	520	1815

Table 16 OD distance matrix – transshipment arc (in nm)

Transshipment arc	Port Said	Shanghai	Colombo	Singapore
Belawan	5075	3171	1324	483
Palembang	5696	2812	1945	261
Panjang	5599	3101	1961	665
Tanjung Priok	5766	2909	2129	591
Tanjung Emas	5975	2902	2338	799
Tanjung Perak	6204	2976	2567	1016
Bitung	7235	2004	3557	1874
Makassar	6524	2540	2887	1235
Sorong	7736	2319	3986	2327

Table 17 Part of OD distance matrix – international arcs (in nm)

International arc	Caucedo	Pointe Noire	Panama Canal	Mombasa	Vladivostok	Rotterdam	Dubai
Port Said	0	0	0	3222	0	0	3132
Shanghai	14694	11099	15827	6981	1118	11999	6627
Colombo	0	7214	0	2742	0	7673	2276
Singapore	12038	8757	13171	4325	0	9343	3971

5.4 SHIPPING COST ANALYSIS

After having the OD container demand and distance matrix, another data needed is cost. Here, costs are defined as generalized cost that is calculated by considering two types of costs: shipping-related costs and container-related costs. Shipping-related costs are the costs that depend on the location of the ports as it is calculated with the distance and depend on the vessel size thus it is calculated with container volumes (in TEUs) as well. Meanwhile, container-related costs are the costs that depend on the number of TEUs being handled as it is calculated with the container volumes.

5.4.1 SHIPPING-RELATED COST

Shipping-related costs consist of two types of costs namely vessel chartering costs and fuel consumption cost. These costs vary depending on vessel size used in each arc, be it domestic, transshipment, or international arc. Therefore, we firstly need to determine size of vessel used in every arc. A report by Mercator Transport Group provided extensive analysis on vessel specifications for the case study within San Pedro Bay in 2005. The fact that this research considers international trade flows, we therefore use vessel specifications in this report as the assumptions of vessel characteristics per arc. Note that the vessel size taken into account here is part of the assumptions of average vessel size, as in reality there might be bigger or smaller vessel size used in particular port for certain arc. For example, Tanjung Priok was recorded to have international vessel calling with the size of 9,000 TEUs, which is bigger than what we assume in Table 18 below (i.e. 5,060 TEUs).

Table 18 Vessel specifications for each arc

Arc Type	From	To	Vessel Size (TEU)	Draft design (m)	Vessel Speed (Knot)
Domestic	Provincial	Gateway	1050	8.8	19
Transshipment	Gateway	Hub	5060	12	23
International	Hub	Regional	12000	16	25

Source: (Mercator Transport Group, 2005)

Table 18 above shows vessel type used for particular arc type, including vessel size in TEUs, draft design in meters and vessel speed in knot. Moreover, we identify the fuel cost in USD/day by multiplying fuel consumption (mt/day) with fuel price (USD/mt). Fuel price assumption is determined from (Brancaccio, Kalouptsidi, & Papageorgiou, 2018) in which the authors mention as much as 470 USD/mt is the average fuel cost and this is the assumption we use for all vessel types. The vessel chartering cost is determined from (Mercator Transport Group, 2005) and it is specific for each vessel. Table 19 shows vessel fuel cost and vessel chartering cost in USD/day for each arc type.

Table 19 Vessel fuel cost and vessel chartering cost

Arc Type	Vessel Size (TEU)	Fuel Consumption (mt/day)	Fuel Cost (USD/day)	Vessel Hire Cost (USD/day)
Domestic	1050	44	$ 20,680	$ 16,972
Transshipment	5060	153.632	$ 72,207	$ 46,644
International	12000	348.3	$ 163,701	$ 85,526

Source: (Mercator Transport Group, 2005) and (Brancaccio, Kalouptsidi, & Papageorgiou, 2018)

After we gathered all the vessel specification data, we continue calculating the unit cost for shipping-related cost which should be in USD/TEU.nm. Besides depending on distance, the unit cost is also per TEU because each arc has specific vessel size therefore shipping-related cost per TEU is also specific per arc. Equation 11 below shows the calculation of unit cost for shipping-related cost. Later, the unit cost is multiplied by distance and container volumes then we can determine the shipping-related cost in USD (Equation 12).

$$F_{C,ij} = Fuel\ consumption\ \times\ Fuel\ Price \qquad \forall i \in O, j \in D \qquad (10)$$

$$P_{ij} = \frac{\frac{V_{C,ij}}{S_S\ \times 24} + \frac{F_{C,ij}}{S_S\ \times\ 24}}{\gamma_S} \qquad \forall i \in O, j \in D \qquad (11)$$

$$C_{P,ij} = P_{ij}\ \times\ D_{ij} \times\ X_{ij} \qquad \forall i \in O, j \in D \qquad (12)$$

Where P_{ij} is the unit cost for shipping-related cost (USD/TEU.nm), $C_{P,ij}$ is the shipping-related cost (USD) from node i to node j, S_s is the vessel speed (knot), γ_S is vessel size (TEUs), D_{ij} is the distance between node i and node j (nm), and X_{ij} is container flows on arc (TEUs). Index i and j here are representing two ports between each arc. The vessel chartering cost $V_{C,ij}$ for each arc is fixed, and fuel cost $F_{C,ij}$ is calculated by Equation 10. Dividing D_{ij} with S_s results in shipping time in hours, therefore, to calculate in daily basis, we divide shipping time with 24 to get shipping time in days. O and D denote origins and destinations where the vessel starts and ends the trip respectively. Finally, Table 20 shows the calculation results of unit cost of generalized shipping-related cost for each arc type.

Table 20 Unit cost for shipping-related cost in USD/TEU.nm

Arc Type	Vessel Size (TEU)	Cost per vessel (USD/nm)	P_{ij} $(USD/TEU \cdot nm)$
Domestic	1050	$ 82.57	$ 0.08
Transshipment	5060	$ 215.31	$ 0.04
International	12000	$ 415.38	$ 0.03

(Source: Author's calculation)

5.4.2 CONTAINER-RELATED COST

Container related costs consist of two types of handling costs those are container handling charges and container handling time cost. Handling cost is the stevedoring costs which is paid for container handling activities at ports. For container handling, ports do two types of activity be it loading, unloading or both. In this network configuration with directed graph, we can determine which port does loading, unloading, or both activities. This implies that when the container is at gateway or hub, the container is being unloaded and loaded, otherwise when the container is at origin or destination nodes. Figure 33 illustrates this handling activity.

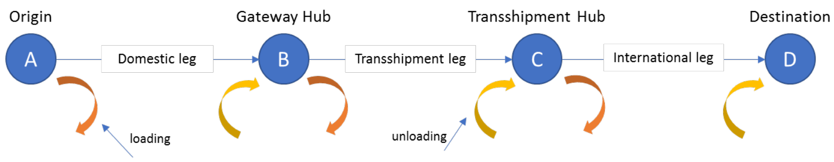

Figure 33 Illustration of container handling activity: loading and unloading from/to port to/from vessel

Table 21 Container handling specifications based on port in Indonesia

Port nodes	Port names	Type	Class	Pelindo	Cont. handling charges (USD/TEU)	Loading rate (TEU/crane/hour)	Unloading rate (TEU/crane/hour)	Number of cranes
1	Lhokseumawe	Provincial	II	Pelindo 1	$ 30.00	16	18	2
2	Belawan	Gateway	Main	Pelindo 1	$ 25.93	20	22	4
3	Teluk Bayur	Provincial	III	Pelindo 2	$ 30.00	14	16	1
4	Dumai	Provincial	I	Pelindo 1	$ 30.00	18	20	3
5	Jambi	Provincial	I	Pelindo 2	$ 30.00	18	20	3
6	Palembang	Gateway	Main	Pelindo 2	$ 27.43	20	22	4
7	Bengkulu	Provincial	I	Pelindo 2	$ 30.00	18	20	3
8	Panjang	Gateway	Main	Pelindo 2	$ 27.43	20	22	4
9	Tanjung Pandan	Provincial	III	Pelindo 2	$ 30.00	14	16	1
10	Batu Ampar	Provincial	I	Pelindo 1	$ 30.00	18	20	3
11	Tanjung Priok	Gateway	Main	Pelindo 2	$ 25.59	20	22	4
12	Tanjung Emas	Gateway	I	Pelindo 3	$ 27.43	18	20	3
13	Tanjung Perak	Gateway	Main	Pelindo 3	$ 25.59	20	22	4
14	Banten	Provincial	I	Pelindo 2	$ 30.00	18	20	3
15	Benoa	Provincial	II	Pelindo 3	$ 30.00	16	18	2
16	Benete	Provincial	III	Pelindo 3	$ 30.00	14	16	1
17	Tenau	Provincial	II	Pelindo 3	$ 30.00	16	18	2
18	Pontianak	Provincial	II	Pelindo 2	$ 27.43	16	18	2
19	Sampit	Provincial	II	Pelindo 3	$ 30.00	16	18	2
20	Banjarmasin	Provincial	I	Pelindo 3	$ 30.00	18	20	3
21	Samarinda	Provincial	I	Pelindo 4	$ 30.00	18	20	3
22	Tarakan	Provincial	II	Pelindo 4	$ 30.00	16	18	2
23	Bitung	Gateway	I	Pelindo 4	$ 32.59	18	20	3
24	Pantoloan	Provincial	I	Pelindo 4	$ 30.00	18	20	3
25	Makassar	Gateway	Main	Pelindo 4	$ 29.63	20	22	4
26	Kendari	Provincial	II	Pelindo 4	$ 30.00	16	18	2
27	Gorontalo	Provincial	II	Pelindo 4	$ 30.00	16	18	2
28	Ambon	Provincial	I	Pelindo 4	$ 30.00	18	20	3
29	Ternate	Provincial	I	Pelindo 4	$ 30.00	18	20	3
30	Sorong	Gateway	Main	Pelindo 4	$ 30.74	20	22	4
31	Jayapura	Provincial	I	Pelindo 4	$ 30.00	18	20	3

Source: extended from (Lazuardi, 2015)

In order to calculate container-related costs, we need to identify first container handling charges, loading-unloading rate, and number of cranes for each port. Container handling charges (USD/TEU) is the parameter that here is presumed to be fixed per container based on reviews done over several literatures. Loading-unloading rate in TEU/crane/hour are used to calculate handling time per TEU and therefore we need number of cranes data as well. The container handling specification data of Indonesian ports are based on The Standard of Port Operational Services Performance – Ministry of Transportation 2013 that reviewed from (Lazuardi, 2015). These data consist of container handling charges, loading-unloading rate, and number of cranes for all 31 ports in Indonesia. Table 21 shows the details for container handling in 31 Indonesian ports.

Furthermore, for regional worldwide ports, data needed are similar with Indonesian ports. Container handling charges for ports in the world are generated from several sources (see Table 22). Moreover, loading-unloading rate for worldwide ports are reviewed from (Ducruet, Itoh, & Merk, 2014), while the number of cranes data are from (UNCTAD, 2018). In Table 22 there are also the details for container handling specifications in 16 worldwide ports. Remember that the Indonesian ports are the origin nodes and worldwide ports are the destination nodes.

Table 22 Container handling specifications based on port in the world (regional ports)

Port nodes	Port names	Type	Cont. handling charges (USD/TEU)	Loading rate (TEU/crane/hour)	Unloading rate (TEU/crane/hour)	Number of cranes
32	Caucedo	Regional	175.00	33	33	7
33	Pointe Noire	Regional	150.00	33	33	7
34	Panama Canal	Regional	210.00	33	33	7
35	Mombasa	Regional	99.00	33	33	7
36	Vladivostok	Regional	150.00	33	33	7
37	Rotterdam	Regional	150.87	33	33	7
38	Dubai	Regional	139.67	33	33	7
39	Port Said	Hub	150.00	40	40	8
40	Los Angeles	Regional	150.00	33	33	7
41	Shanghai	Hub	136.59	40	40	8
42	Melbourne	Regional	148.28	33	33	7
43	Santos	Regional	111.37	33	33	7
44	Colombo	Hub	140.00	40	40	8
45	Singapore	Hub	133.81	40	40	8
46	Cape Town	Regional	129.25	33	33	7
47	Tin Can Island	Regional	100.12	33	33	7

Sources	
(orange)	Terminal handling charges during and after the liner conference era, European Commission, 2009
(light salmon)	https://www.kpa.co.ke/InforCenter/Documents/Tariff%202012%20Book%20for%20Website.pdf
(pale pink)	http://nigerianports.gov.ng/wp-content/uploads/2017/06/TICTTariff.pdf
(salmon)	http://saaff.org.za/wp-content/uploads/2017/11/standard-container-terminal-tariffs-1-april-18.pdf
(light blue)	https://portcom.slpa.lk/Tariff/Tariff%20-%202015.pdf
(blue)	https://www.cma-cgm.com/local/dominican-republic/tariffs-local-charges
(green)	https://www.cma-cgm.com/static/PA/attachments/LOCAL%20CHARGES.pdf
(grey)	Vergaeghe et al., 2018

Source: (UNCTAD, 2018), (Ducruet, Itoh, & Merk, 2014), list mentioned above

To estimate the total container-related costs, we need to calculate first unit cost of container-related costs in USD/TEU. For the first type of container-related costs, container handling charges E_{ij}, the unit is already in USD/TEU so that the value can be directly used in the calculation. Meanwhile, for the second type of container-related costs, container handling time costs, a calculation for unit cost is performed through the Equation 14 elaborated below.

$$T_{H,ij} = \frac{1}{R_{L,i} \times Cr_i \times 24} + \frac{1}{R_{U,j} \times Cr_j \times 24} \qquad \forall i \in O, j \in D \qquad (13)$$

$$C_{ij} = E_{ij} + (T_{H,ij} \times V_{C,ij}) \qquad \forall i \in O, j \in D \qquad (14)$$

$$C_{C,ij} = C_{ij} \times X_{ij} \qquad \forall i \in O, j \in D \qquad (15)$$

Equation 13 is used to calculate handling time ($T_{H,ij}$) for each arc based on loading rate of ($R_{L,i}$) and unloading rate ($R_{U,j}$) in a particular arc, and number of cranes for certain port, Cr_i and Cr_j. To have the handling time in days, we need to divide with 24. This handling time is then multiplied by vessel chartering cost ($V_{C,ij}$). Equation 14 is used to find the unit cost, C_{ij}, in USD/TEU of container-related costs which is the sum of two types of costs: container handling charges E_{ij} and container handling time cost. Finally, to find the container-related costs, we need to multiply the unit cost with the number of TEUs handled in each arc (X_{ij}). O denotes origins where the inflows being loaded, while D denotes destinations where the outflows being unloaded. Remember that index i and j here are the two ports in each arc. In domestic and international arcs, there are some arcs that have the same port nodes between i and j. Regarding that, the cost calculation set both the costs to zero. After having all the inputs required to calculate the total cost of the shipping network, we identify the total cost by the following Equation 16:

$$TC = \sum_{i \in O} \sum_{j \in D} C_{P,ij} + \sum_{i \in O} \sum_{j \in D} C_{C,ij} \qquad (16)$$

Where the total shipping network cost TC (USD) is the sum of total shipping-related cost and total container-related cost of all arcs used in the network. Further, the total shipping network cost will be calculated for all scenarios and different periods.

5.5 PORT CAPACITY

Next data is port capacity. Given that two of the constraints in the network flow model, which are Equation 7 and 8, we need to estimate the port capacity. As this research focuses on the development of international container gateways in Indonesia, the gateways capacity should be identified for future estimation as well. For this part, Table 23 shows the gateway capacity details considered only for base year. Later in Chapter 6 the estimation of future capacity of gateways will be provided. Note that port capacity here implies total capacity for all types of container flows i.e. domestic, import, and export flow. However, to address recommendation for gateways development in the policy decision-making, port capacity remains important to be included in this analysis.

Table 23 Gateways capacity for base year

Port ID	Port names	Location	Island Region	Area (ha)	Berth (m)	Capacity (TEU)
2	Belawan	Belawan, Sumatera Utara	Sumatra	36	950	1,100,000
6	Palembang	Palembang, South Sumatra	Sumatra	5	1,200	55,000
8	Panjang	Panjang, Lampung	Sumatra	8	1,860	80,000
11	Tg. Priok	Jakarta, DKI Jakarta	Java	164	3,140	8,600,000
12	Tg. Emas	Semarang, Jawa Tengah	Java	27	631	700,000
13	Tg. Perak	Suarabaya, Jawa Timur	Java	80	2,675	3,700,000
23	Bitung	Bitung, Sulawesi Utara	Sulawesi	10	607	500,000
25	Makassar	Makassar, Sulawesi Selatan	Sulawesi	18	1,000	800,000
30	Sorong	Sorong, Papua Barat	Papua	3	340	45,000

Source: Pelindo I-IV

5.6 Parent scenarios: Optimistic and Pessimistic

Based on the trends and developments, we can build assumptions on represented variables and develop scenarios for the forecast model which is explained in this sub chapter. The scenarios developed herein are based on high-level analysis as the aim of the scenario analysis is not to predict the future, rather to identify the differences in future evolutions under assumed conditions (Chermack, Lynham, & Ruona, 2001). The level of uncertainties in this scenario development is only limited to the assumptions on the variables without taking into account vulnerabilities and opportunities which are not directly influencing demand projection. These scenarios are used to observe different likely events for the independent variables and accounting for the qualitative factors, hence, to determine the underlying drivers, trends, and developments for the preparation of future plausible adjustments on the policy/planning.

These scenarios are based on variable assumptions for long-term planning which are split into three periods: 2017-2024, 2025-2034, 2035-2045. The splitting into three periods allows assigning various growth rates and updating changes to the model at different periods according to the changes in economic growth and other trends and developments. Moreover, by having the periods differentiation later the forecast model can be adjusted by adding sensitivities which make changes in specific period for specific variables. Two scenarios are made: optimistic and pessimistic. Each scenario is determined by the coefficient assumptions of the 9 variables, of which six are time-dependent variables and the other three are non-time-dependent variables. The time-dependent variables are the ones that represent the four categories of trends and developments, namely GDP, population, urbanization rate, QPI, LSCI, and trade agreement. Meanwhile, the non-time dependent variables are area, distance, and landlocked. Table 24 shows the variable assumptions for both scenarios.

Table 24 Time-dependent variable assumptions for both scenarios

Variable	Optimistic	Pessimistic
GDP	• Indonesia grows at CAGR 7% over the coming decades with world GDP growing at just over CAGR 3% over the coming years • Java only accounts for 50% of the GDP	• Indonesia grows at CAGR 5% over the coming decades with world GDP growing at CAGR 2,5% over the coming decades

	• China, the US, India, Indonesia and Japan are the 5 biggest economies	• Java continues to be the centre of the Indonesia economy accounting for more than 50% of the total GDP • China, the EU, the US, India, and Japan are the 5 biggest economies
Population	• Indonesia's population grows CAGR 0,7% over the coming decades reaching just over 320 million by 2045 • The world population grows at CAGR 0,8% with the world population reaching 8,5 billion people by 2045 with India, China, the EU, the US, and Nigeria being the most populous countries on the planet	• Indonesia's population grows CAGR 0,7% over the coming years with Indonesia's population reaching approximately 315 million people by 2045 • The world population grows CAGR 0,6% with the world population reaching just over 8 billion by 2045 with India, China, the EU, the US, and Nigeria being the 5 most populous nations on the planet
Urbanization rate	• The average urbanisation for the 7 island regions rises from 43% in 2017 to 62% in 2045 • Urbanisation projections for the other countries are based on UNCTAD projections	• The average urbanisation for the 7 island regions rises from 43% in 2017 to 60% in 2045 • Urbanisation projections for other countries based on rounded down figures based on UNCTAD projections
QPI	• Indonesia's ports rank among the world's best with QPI scores for Java, Sumatra, and Sulawesi either being 7 or very close to 7	• Indonesia's QPI improves slightly in the short-term before stagnating an eventually declining • Java continues to have the best ports of all the islands
LSCI	• Strong improvement with Java, Sumatra, and Sulawesi all having similar connectivity.	• Mild improvement in connectivity with Java continuing to have the best overall connectivity by far
Trade Agreements	• Agreements currently under negotiation or discussion are all signed – these include agreements with the EU, the US, Peru, Chile, etc.	• No new trade agreements are signed

(Source: developed by authors)

5.7 Forecasted demand

The container export projection of Indonesia up to 2045 from the forecast model built in this research is shown in Figure 34. The green line showing the optimistic scenario and the grey line is the pessimistic scenario. This result is used as one of the elements in developing policy decisions as well as when applying network flow model.

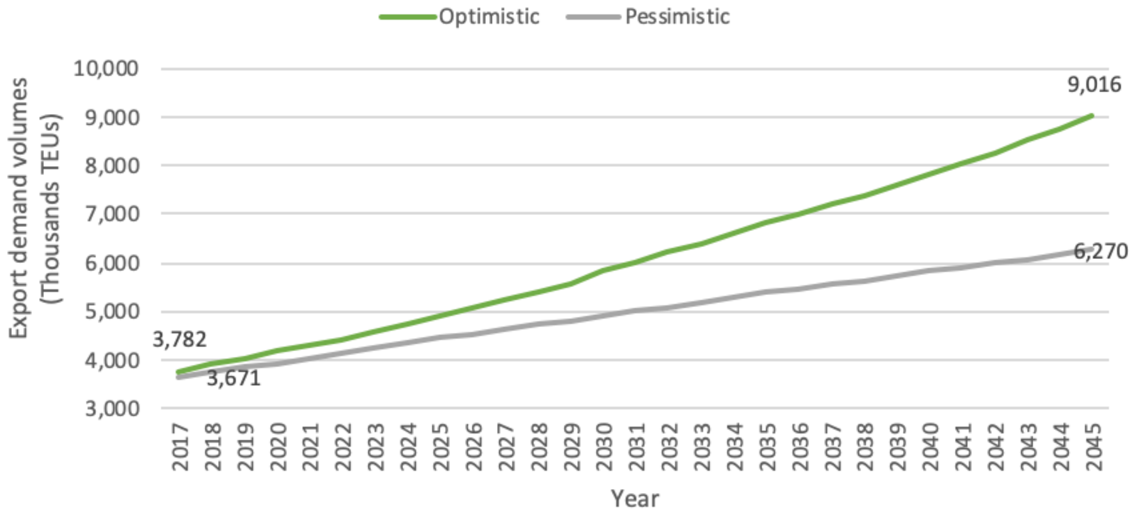

Figure 34 Graph of container export volume projection for Indonesia – parent scenarios (Source: Author's calculation)

Besides the forecast result of country-level, the model also generates the projection of export flows on an island basis. To recall, there are seven big islands considered in the forecast model, namely Java, Kalimantan, Maluku, Nusa Tenggara, Papua, Sulawesi, and Sumatra. The island-based projection illustrated in Figure 35 is in the form of CAGR (Compound Annual Growth Rate) that is calculated for start year 2017 and end year 2045. From the figure below, it can be seen that Java remains dominating in optimistic scenario, followed by Sulawesi showing the motivation of strengthening the eastern part of Indonesia. Sumatra also has similar CAGR with Sulawesi in the optimistic scenario. However, in the pessimistic scenario, Java, Sulawesi, and Sumatra about having the same CAGR that is about 1.8% with Sumatra being the highest one. Kalimantan, Maluku, Nusa Tenggara and Papua growing for about 2% in optimistic scenario, and about 1.5% in the pessimistic scenario.

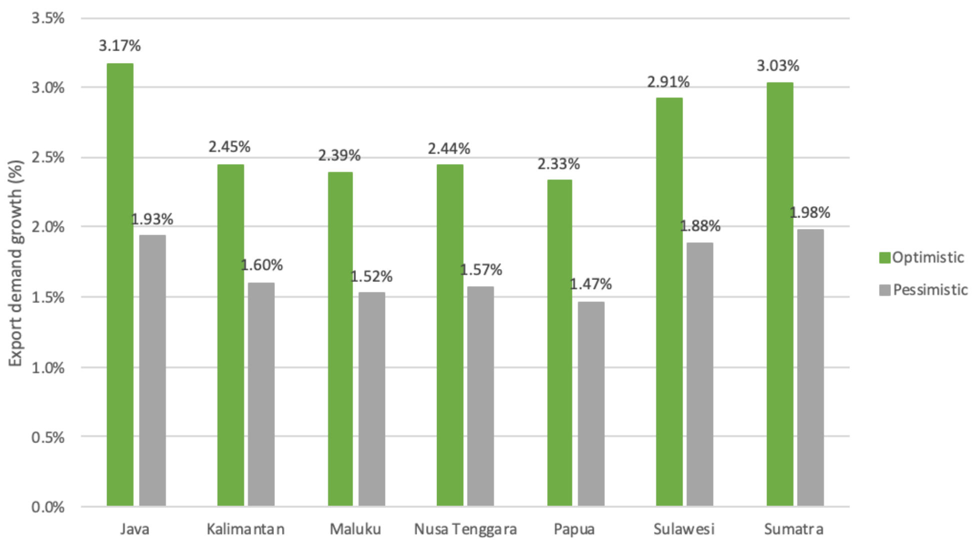

Figure 35 Graph of island-based container export growth projection (CAGR) (Source: Author's calculation)

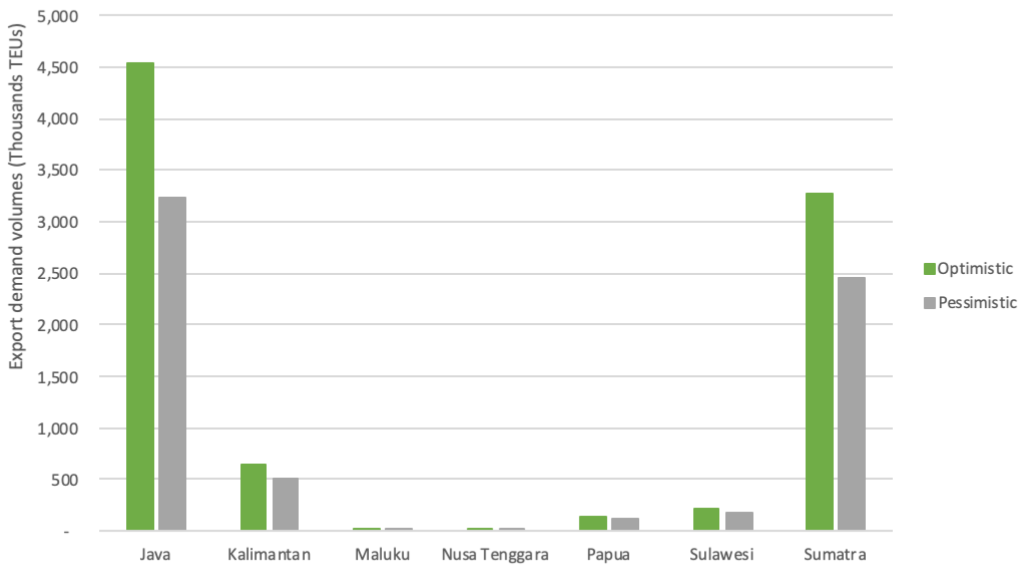

Figure 36 Graph of island-based container export volumes projection in 2045 (Source: Author's calculation)

5.7.1 Demand forecast analysis based on parent scenarios

In this part, the developed parent scenarios are further elaborated. To recall, there are two parent scenarios that result in different forecasted demand i.e. optimistic and pessimistic.

5.7.1.1 Optimistic scenario

In the optimistic scenario, Indonesia's GDP (at constant 2010 prices) grows at an average annual rate of 6.6% up to 2045 with Indonesia's GDP growing from roughly USD 1 trillion today USD 6.6 trillion by 2045. Among the island regions, Sulawesi experiences the highest GDP growth with an average annual growth rate of 8.8% followed by Papua, Nusa Tenggara, Maluku and Sumatra. Java continues dominates the country's economy followed by Sumatra in the 2nd position and Sulawesi in 3rd position. The historical and projected GDP for each island in the optimistic scenario is presented in Figure 37 below.

Figure 38 shows other variables projected for each island in Indonesia and compare the value between current state and future (2045). Looking at the variable of population, Java continues to be the most populated island followed by Sumatra and Sulawesi. That also applies to the variable of quality of port infrastructure and liner shipping connectivity index. However, for the urbanization rate Kalimantan and Nusa Tenggara have higher rate in 2045 than Sumatra and Sulawesi. Note that the range of score for quality of port infrastructure is 1 for the lowest quality and 7 for highest quality.

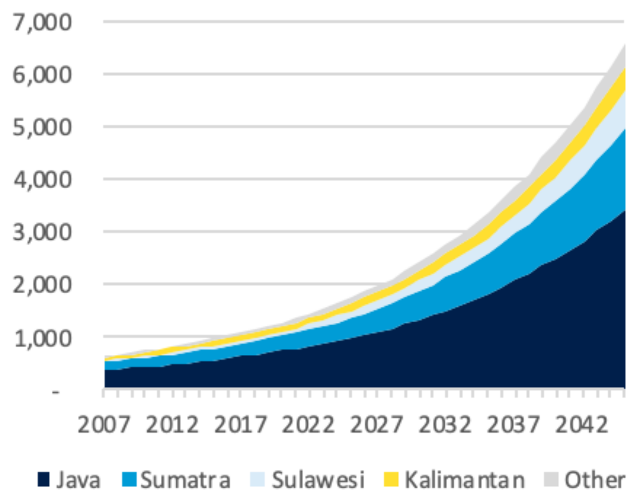

Figure 37 Historical and Projected GDP in USD billion – Optimistic scenario (Source: Authors calculation)

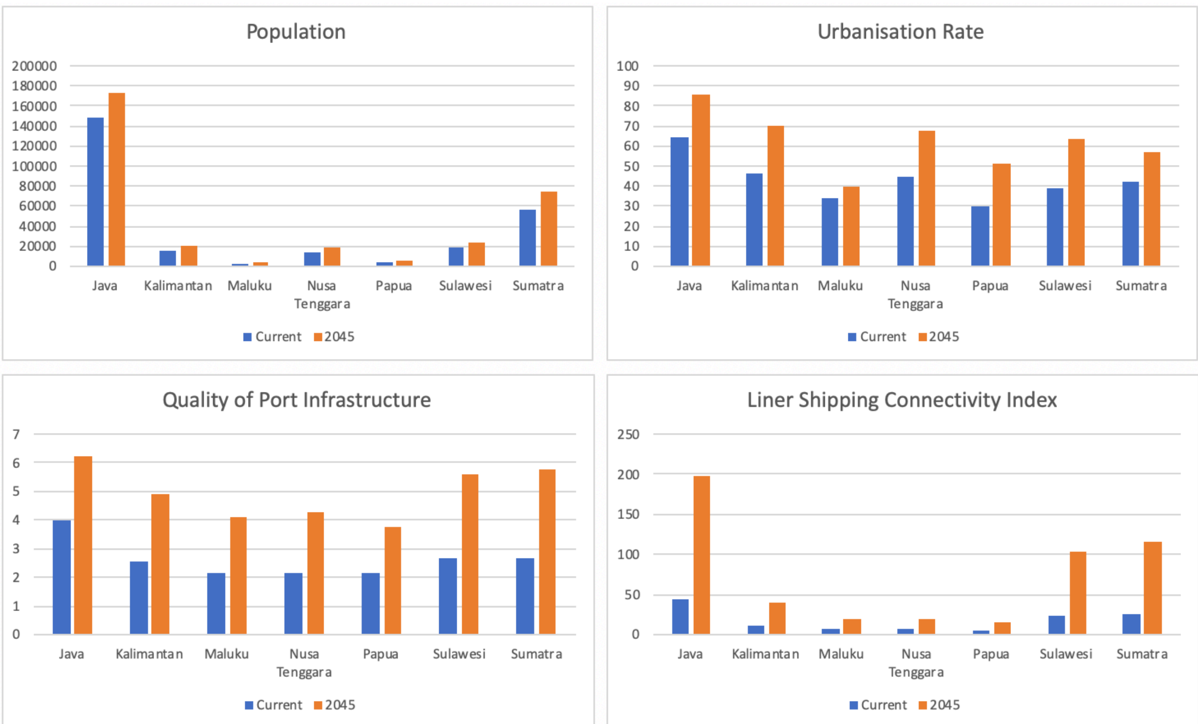

Figure 38 Projected values for Population, Urbanization Rate, QPI, LSCI – Optimistic Scenario (Source: Author's calculation)

From the base year demand (current) and future optimistic demand (2045) for export trade from Indonesia to the worldwide regional ports around the globe, the top half destinations of all 16 regions are shown in Table 25 below. Moreover, the projected demand for export trade the origin node is still highly dominated by provinces in Java island, followed by Sumatra and Sulawesi. The total demand projection in optimistic scenario for export trade in TEUs is about 9 million TEUs in 2045.

Table 25 Top half region destinations of Indonesian exports between 2016 and 2045 (optimistic)

Ranks	Current (2016)	#TEUs (2016)	Projection (2045)	#TEUs (2045)
1st	Northeast Asia	1.249.998	Northeast Asia	3.033.903
2nd	Southeast Asia	1.070.347	Southeast Asia	1.636.957
3rd	South Asia	505.351	South Asia	1.343.937
4th	Europe	271.511	North America	390.823
5th	North America	191.429	Europe	380.578
6th	Oceania	149.163	Mid-East	344.212
7th	Mid-East	140.014	South America	133.063
8th	West Africa	53.599	Oceania	111.613

Source: Authors calculation

5.7.1.2 Pessimistic scenario

In the pessimistic scenario, Indonesia's average annual GDP growth slows gradually due to a combination of both external and internal factors (e.g. protectionist policies at home and abroad, lower world GDP growth, etc.). In 2045, the country is projected to have GDP (at constant 2010 prices) of $4.2 trillion with the economy growing at a CAGR of only 4.95%. As in the optimistic scenario, Sulawesi experiences the highest average annual GDP growth among the islands with an average annual GDP growth of 6.5%. Papua, Nusa Tenggara, and Maluku are in the second, third, and fourth place respectively, in terms of GDP growth. Java still dominates the country's economy; accounting for half of the country's GDP with Sumatra, Sulawesi, and Kalimantan in second, third, and fourth place respectively. Figure 39 below shows the historical and projected GDP of all 7 islands in Indonesia for pessimistic scenario up to 2045.

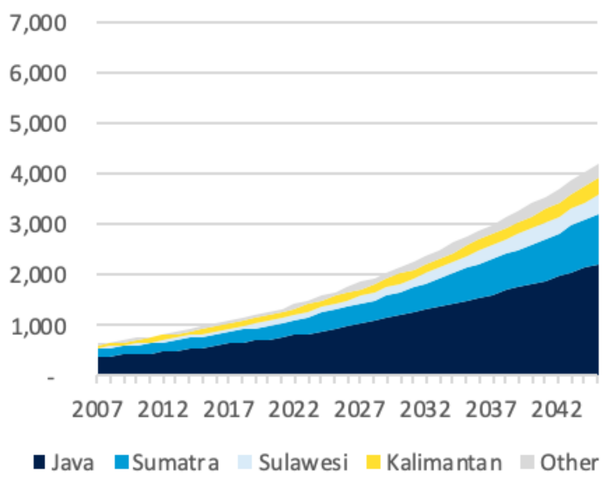

Figure 39 Historical and Projected GDP in USD billion (constant 2010 prices) – Pessimistic scenario (Source: Authors calculation)

Reflecting on other variables such as population, urbanization rate, QPI and LSCI, Figure 40 below shows the projected values for those variables in current state and 2045. For population projection, the difference between optimistic and pessimistic scenario is not significant. Java remains the most populated island in the country with a population of 170 million, followed by Sumatra, Sulawesi, Kalimantan, and Nusa Tenggara. The urbanization rate of all the islands in the pessimistic scenario is also similar to the optimistic scenario. The projection for QPI in 2045, however, shows an extreme value compare to optimistic scenario, with Indonesia having a projected QPI of 2.57. This is of course, a scenario where we assume that the Indonesian government does not increase investment in infrastructure, makes ineffective investments, or fails to reform its port sector. The same thing goes to LSCI which decreases dramatically from optimistic scenario.

From the base year demand (current) and future pessimistic demand (2045) for export trade from Indonesia to foreign markets, the top half destinations of all 16 regions are shown in Table 26 below. The difference between optimistic and pessimistic scenario is that the destinations do not vary too much from the current situation. Moreover, Java, Sumatra, and Sulawesi continue to generate most export volumes. Compared with the optimistic scenario, the demand projection in the pessimistic scenario for export trade in 2045 is about 6.3 million TEUs or around 2.3 million TEUs lower than optimistic scenario.

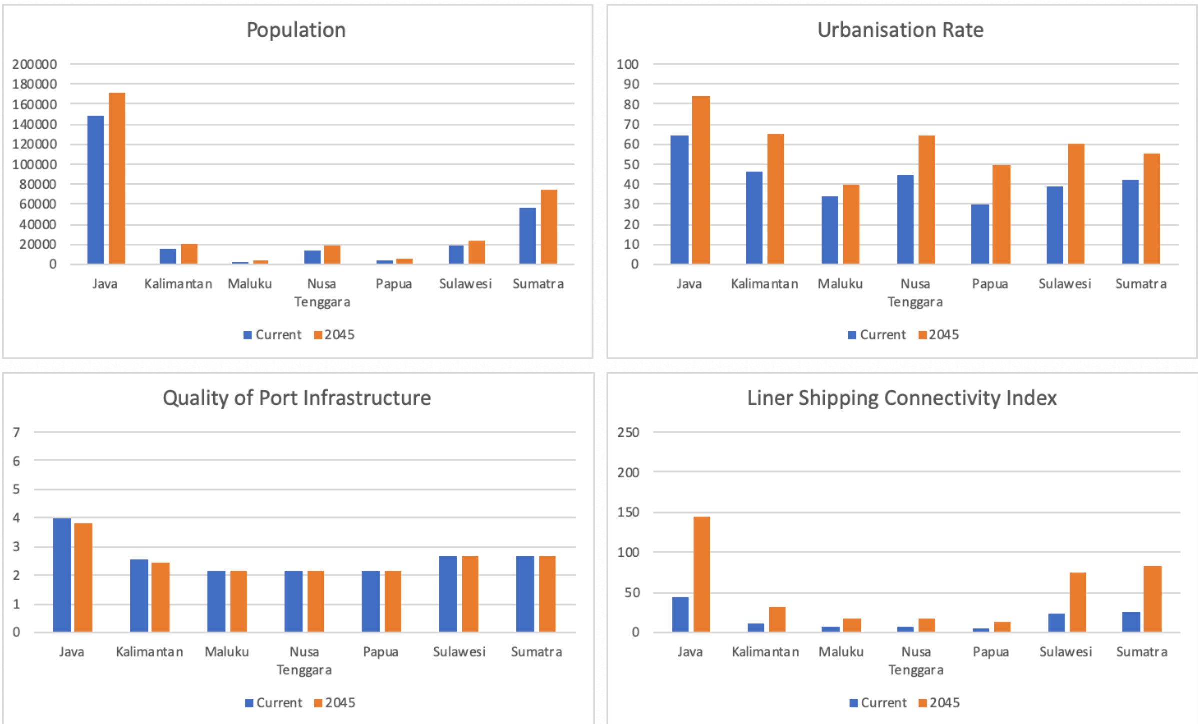

Figure 40 Projected values for Population, Urbanization Rate, QPI, LSCI Index – Pessimistic Scenario (Source: Author's calculation)

Table 26 Top half region destination of Indonesian exports between 2016 and 2045 (Pessimistic)

Ranks	Current (2016)	#TEUs (2016)	Projection (2045)	#TEUs (2045)
1st	Northeast Asia	1.249.998	Northeast Asia	2.430.256
2nd	Southeast Asia	1.070.347	Southeast Asia	1.410.835
3rd	South Asia	505.351	South Asia	939.060
4th	Europe	271.511	Europe	314.442
5th	North America	191.429	North America	257.276
6th	Oceania	149.163	Mid-East	253.854
7th	Mid-East	140.014	Oceania	94.368
8th	West Africa	53.599	South America	92.967

Source: Authors calculation

Looking at the GDP, population, urbanization rate, QPI, LSCI, and container export projections shows that Java continues to be the center of development. This is a scenario where the government largely fails to promote trade growth outside of Java.

5.7.2 DEMAND FORECAST ANALYSIS BASED ON BRANCH SCENARIOS

Branch scenarios are required for the adaptive policy decision pathways model to capture more uncertainties that may happen in the future with regards to export volumes. The branch scenarios are randomly developed based on the forecasted demand in two previous parent scenarios: optimistic and pessimistic. To generate random numbers those are normally distributed we need two inputs namely mean and standard deviation. As the model will be applied in three different periods, random values are generated for a particular period. Figure 41 shows the forecasted demand in optimistic and pessimistic scenario as well as the mean for each period.

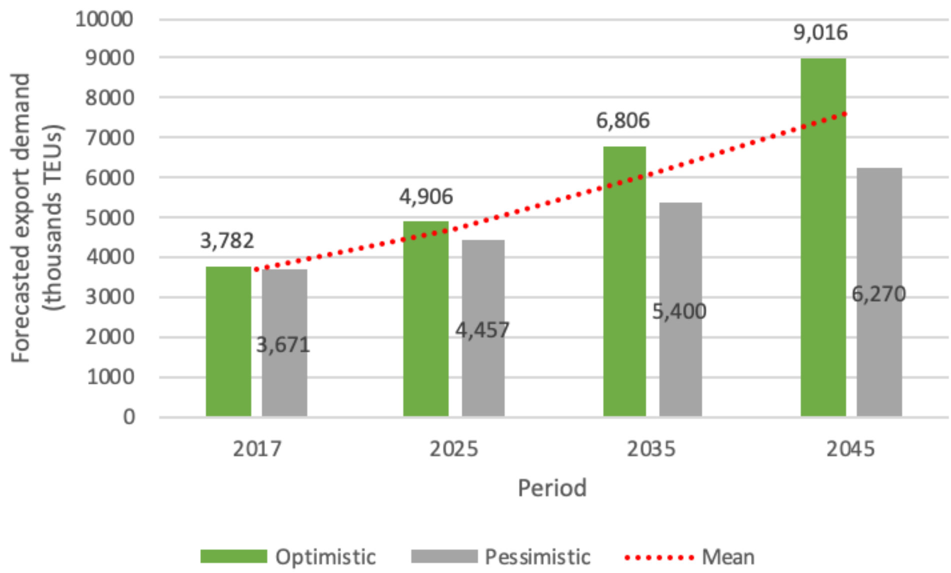

Figure 41 Forecasted export demand values – optimistic, pessimistic, mean
Source: Authors calculation

After identifying the mean, we calculate standard deviation. As explained in Chapter 3.2.1.2 particularly Equation (2), a coefficient of variation (CV) is needed to determine standard deviation. For the sake of logicality of the demand values and intended extent of uncertainties, we bound the CV from 10% to 50%. After some iterations, the most optimal CV is 30% as lower number provides less uncertain values amongst 100 cases and higher number provides less likely values as it gives negative numbers which are not likely for future demand volumes. Furthermore, normality tests are performed for datasets of each period using Shapiro-Wilk theorem and done in SPSS Statistics software. Table 27 shows the descriptive statistics result of 100 numbers randomly generated for each period. Moreover, Table 28 describes the results of normality tests taken for each period that showing all datasets are distributed normally. Figure 42, Figure 43, and Figure 44 give the normal Q-Q plot of 100 cases for each period.

Table 27   Descriptive statistics of 100 numbers generated for each period

Descriptive Statistics

Period	Year	N	Minimum	Maximum	Mean	Std. Deviation
I	2017-2024	100	1,692,520	7,518,604	4,629,750	1,347,772
II	2025-2034	100	1,698,006	11,907,300	6,266,686	1,759,375
III	2035-2045	100	1,228,510	14,013,945	7,523,360	2,244,344

Table 28   Normality test for 100 numbers generated for each period

Tests of Normality (Shapiro-Wilk)

Period	Year	Statistic	df	Sig.
I	2017-2024	0.988	100	0.529
II	2025-2034	0.987	100	0.412
III	2035-3045	0.995	100	0.982

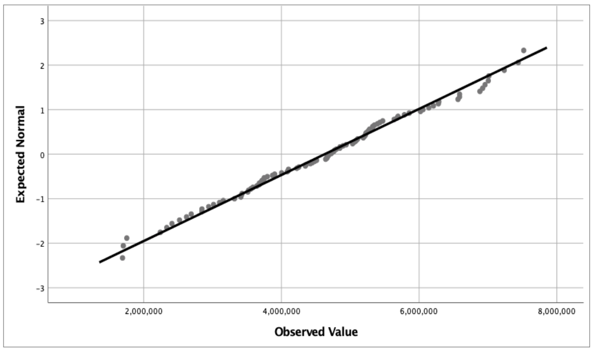

Figure 42   Normal Q-Q Plot of 100 cases - Period 1

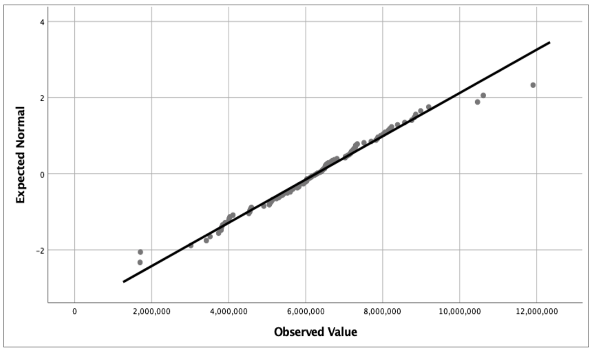

Figure 43   Normal Q-Q Plot of 100 cases - Period 2

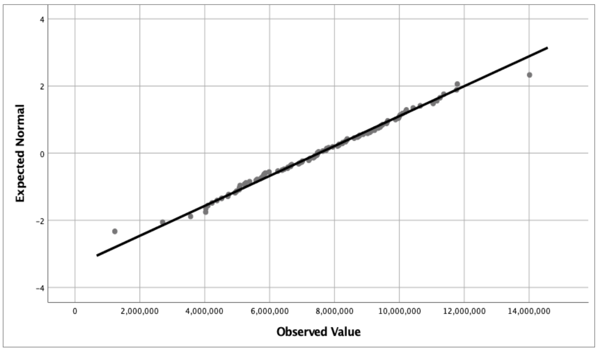

Figure 44   Normal Q-Q Plot of 100 cases - Period 3

Since there are 100 demand values for each period, it is more efficient to binning the numbers into several intervals then used in the network flow model. Visual binning resulted from SPSS Statistics software gives 15 intervals for period 1, 13 intervals for period 2, and 15 intervals for period 3. Thus, we take only 13 intervals to generate 13 cases of demand values that each consists of three different periods. Furthermore, the midpoint for each interval is then considered as the demand value for certain case in a particular period. Table 29 shows the random number generation results for 13 cases for all periods that represents total export demand values in each period. In the table, we can see that each period is represented by the last year of every period, that is 2024 for Period 1, 2034 for Period 2 and 2045 for Period 3.

From the table we can see that by generating random numbers and take them as branch scenarios, we capture different evolution of demand throughout periods which are different with the ones in parent scenarios. In parent scenarios, the demand is always increasing from period to period though in pessimistic the demand is smaller than optimistic; thus, the flow pattern will remain similar. Meanwhile, in branch scenarios, we can analyze network flow patterns when the network dealing with demand uncertainties from period to period. Bear in mind that total export demand values per each period here are *yearly* values.

Table 29 Total yearly export demand values for 13 scenarios in TEUs

	Export demand values in thousand TEUs		
	2024	2034	2045
Case 1	4,033	8,418	5,629
Case 2	6,733	4,578	4,829
Case 3	4,393	10,338	11,229
Case 4	3,313	7,778	4,029
Case 5	1,873	3,938	9,629
Case 6	2,233	9,058	3,229
Case 7	2,953	5,218	6,429
Case 8	4,753	10,658	8,829
Case 9	5,473	3,298	2,429
Case 10	5,833	7,138	8,029
Case 11	6,193	5,858	12,029
Case 12	5,113	6,498	7,229
Case 13	3,673	2,018	10,429

Source: Authors calculation

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6 MODEL APPLICATION AND RESULTS

6.1 OUTLINE

In this chapter, we focus answering the research question "*what are the promising policy decisions over ranges of demand and periods?*" After the outline, the chapter continues with sub chapter 6.2 that provides the results from application of network model to all scenarios constructed in particular period of time. In sub chapter 6.3, we are mapping the results from network model in order to identify the promising ports for certain range of demand and period. The output is the policy pathways map that becomes input for elaborating and identifying policy decisions, which are explained in sub chapter 6.4. The policy decisions are indicated for specific period and range of demand. Finally, in sub chapter 6.5 we test the policy decisions that results in the recommendations of promising policy decision pathways for shipping network planning in Indonesia.

Given the historical and current situation of Indonesia, data on nodes and arcs, and variation of export demand volumes from parent and branch scenarios, we start the network model application.

6.2 APPLYING THE NETWORK MODEL

Based on the demand forecast model, there are two parent scenarios constructed: optimistic and pessimistic. Demand values projected in each scenario are then used to generate random numbers to capture other export volume possibilities, that we call branch scenarios. From random number generation process, we generated 100 cases for every period then are represented in 13 branch scenarios. Figure 45 shows demand growth between period for both parent and branch scenarios. Moreover, to have clear understanding of periodization used in this research, Table 30 presents the details of period range and year of analysis considered in each period.

Table 30 Details of periodization

Period	Range	Year of analysis
I	2017-2024	2024
II	2025-2034	2034
III	2035-2045	2045

To produce policy decisions on shipping network planning, the analysis is done with a network flow model called Minimum Cost-Flow problem. Shipping network planning is a process that encourages policy-makers to efficiently and robustly decide policy recommendations for ports development to deal with future uncertainties. This problem is real as recent planning is done with the estimation set for only single year in the future. Trends and developments that may exist in the future should be anticipated by planning the policy pathways adaptively. Therefore, two problems underlying the shipping network planning are, (1) identifying which ports are promising that cope with uncertainties and when the port should be developed and (2) identifying the preferred policy decision pathways taking constructed scenarios into account. The following explanations tell about the model results and analysis based on flow patterns, optimal solution cost, and selection of promising ports.

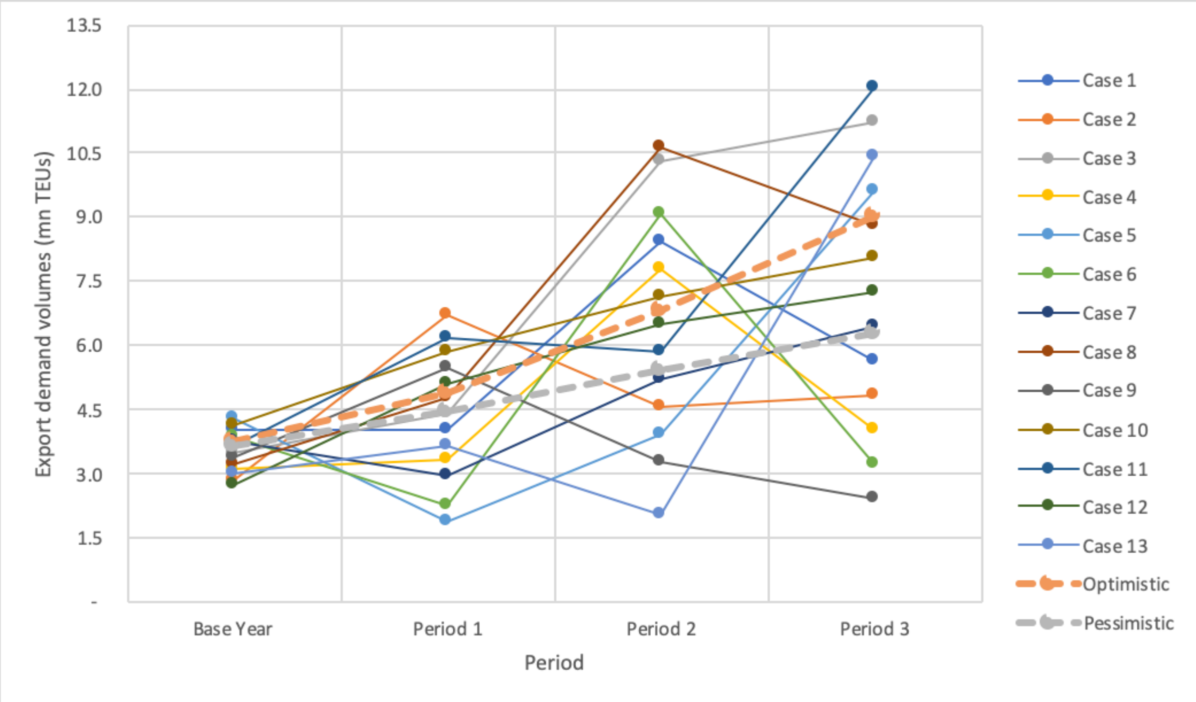

Figure 45 Projected demand of optimistic, pessimistic, and branch scenarios (Source: Author's calculation)

The network flow model is applied to variation of demand values resulted from different scenarios. As the generated demand value is the yearly container volume in total for the whole Indonesian exports, then it should be broken-down into port-level demand to fit the model formulation. In other words, we need to identify how many containers originated from Indonesian ports and how many containers destined to worldwide ports. Using the percentage of share of total container volume in base year (BPS Statistics), we could generate port-level demand for all scenarios. Indeed, for future condition these percentage numbers should be further estimated. Therefore, from the demand forecast model, we use island-based CAGR (see Figure 35) to calculate the percentage of exports share of each port in the future. Table 31 lists percentage of share of total export demand values for each port in initial condition as well as future condition both optimistic and pessimistic scenario. Appendix E and F show details of port-level demand for all scenarios (parent and branch) and for all periods.

Moreover, in order to have more reliable model results, we need to estimate future gateway capacity. Here, the estimation is based on several sources such as Pelindo's, *Bappenas* and other information recently announced by the government (see Table 32). Moreover, the capacity is estimated based on period. As mentioned before in Chapter 5.5, gateway capacity is not only dedicated for export flows but also all types of containers both international and domestic flows. In shipping network planning, future growth of capacity is important as it gives policymaker insights in deciding ports development planning in the policy. This will help policymakers to indicate for example the required development scale of the gateways. Finally, having port-level demand, gateway capacity estimation, as well as nodes and arcs those are already determined beforehand in Chapter 5, the Minimum Cost-Flow problem model is ready to run in CPLEX software. Transcript of code for MCF model in CPLEX software is described in

Appendix H. The results of network flow model are described separately between parent scenarios and branch scenarios, those we further explain in the following parts.

Table 31 Percentage of share of total export demand values for Indonesian and worldwide ports

Port Name	Nodes	Initial	Optimistic	Pessimistic
Lhokseumawe	1	0.02%	0.02%	0.02%
Belawan	2	8.25%	8.16%	8.38%
Teluk Bayur	3	1.70%	1.68%	1.73%
Dumai	4	13.39%	13.24%	13.59%
Jambi	5	2.92%	2.89%	2.96%
Palembang	6	3.32%	3.28%	3.37%
Bengkulu	7	0.16%	0.16%	0.16%
Panjang	8	2.83%	2.80%	2.87%
Tanjung Pandan	9	0.27%	0.27%	0.28%
Batu Ampar	10	4.20%	4.15%	4.26%
Tanjung Priok	11	20.43%	21.18%	20.56%
Tanjung Emas	12	4.85%	5.03%	4.88%
Tanjung Perak	13	21.96%	22.77%	22.10%
Banten	14	2.19%	2.27%	2.21%
Benoa	15	0.13%	0.11%	0.12%
Benete	16	0.19%	0.16%	0.17%
Tenau	17	0.00%	0.00%	0.00%
Pontianak	18	1.01%	0.89%	0.94%
Sampit	19	4.10%	3.59%	3.79%
Banjarmasin	20	1.17%	1.03%	1.09%
Samarinda	21	1.87%	1.64%	1.73%
Tarakan	22	0.34%	0.30%	0.31%
Bitung	23	0.61%	0.61%	0.61%
Pantoloan	24	0.98%	0.98%	0.98%
Makassar	25	0.91%	0.92%	0.92%
Kendari	26	0.08%	0.08%	0.08%
Gorontalo	27	0.01%	0.01%	0.01%
Ambon	28	0.07%	0.06%	0.07%
Ternate	29	0.06%	0.05%	0.05%
Sorong	30	1.94%	1.66%	1.74%
Jayapura	31	0.01%	0.01%	0.01%
		100.00%	100.00%	100.00%

Port Name	Nodes	Initial	Optimistic	Pessimistic
Caucedo	32	0.28%	0.28%	0.28%
Pointe Noire	33	0.15%	0.15%	0.15%
Panama Canal	34	0.42%	0.42%	0.42%
Mombasa	35	1.08%	1.10%	1.09%
Vladivostok	36	0.73%	0.73%	0.74%
Rotterdam	37	7.07%	7.12%	7.13%
Dubai	38	3.65%	3.71%	3.67%
Port Said	39	1.15%	1.16%	1.17%
Los Angeles	40	4.98%	5.05%	5.03%
Shanghai	41	32.55%	32.04%	32.19%
Melbourne	42	3.88%	3.98%	3.91%
Santos	43	0.96%	0.97%	0.96%
Colombo	44	13.16%	12.97%	13.13%
Singapore	45	27.87%	28.19%	28.04%
Cape Town	46	0.68%	0.69%	0.69%
Tin Can Island	47	1.40%	1.43%	1.41%
		100.00%	100.00%	100.00%

(Source: BPS Statistics and author's calculation)

Table 32 Gateway capacity estimation in TEUs

Port ID	Port names	Location	Island Region	Capacity (TEUs)			
				Base year	2024	2034	2045
2	Belawan	Belawan, Sumatera Utara	Sumatra	1,100,000	1,500,000	2,000,000	2,000,000
6	Palembang	Palembang, South Sumatra	Sumatra	150,000	250,000	400,000	650,000
8	Panjang	Panjang, Lampung	Sumatra	125,000	200,000	350,000	500,000
11	Tg. Priok	Jakarta, DKI Jakarta	Java	7,100,000	8,600,000	15,500,000	22,500,000
12	Tg. Emas	Semarang, Jawa Tengah	Java	700,000	700,000	700,000	1,000,000
13	Tg. Perak	Suarabaya, Jawa Timur	Java	3,700,000	3,700,000	5,000,000	5,000,000
23	Bitung	Bitung, Sulawesi Utara	Sulawesi	500,000	900,000	1,200,000	1,500,000
25	Makassar	Makassar, Sulawesi Selatan	Sulawesi	800,000	1,800,000	3,000,000	3,000,000
30	Sorong	Sorong, Papua Barat	Papua	95,000	500,000	1,500,000	1,500,000

(Source: Bappenas and Pelindo(s))

6.2.1 NETWORK FLOW ANALYSIS – PARENT SCENARIOS

The model is first applied to parent scenarios: optimistic and pessimistic. Based on the forecast model, total flows in TEUs are calculated and therefore the MCF model can be processed. The model generates two things. First is optimal solution of total cost (in USD) in the network given certain amount of demand. Second is amount of flow pass selected arcs in TEUs. Optimal solutions obtained from the model are specific for certain scenario in certain period, and these results are shown in Table 33 below.

The optimal solution of total cost is transformed to USD/TEU which means cost needed for 1 TEU container (see Table 33). Note that those solutions are specific for certain demand value and period. Moreover, the flow pattern results for the two parent scenarios show vary number of total arcs used which are between 47 to 49 out of 379 available arcs. In regard to domestic arc between Indonesian ports, Table 34 provides number of provincial ports that use domestic arcs to go to a particular gateway. This figure is part of the results from network flow model as well. For example, in period 1 of optimistic scenario, as many as 7 provincial ports in Indonesia transshipped their containerized exports via Tanjung Priok. Or in period 3 of pessimistic scenario, as many as 2 provincial ports in Indonesia transshipped via Panjang. However, these figures should be complemented with other aspects to lead us identify clearly the promising ports. Therefore, we also analyze the throughput of exports as well as percentage of exports being handled for each gateway. Throughput volumes are obtained from flow decision variables resulted from the model.

Table 33 Optimal solution of cost per TEU for parent scenarios from CPLEX

Scenario		Year	Total Flow (TEUs)	Cost (USD/TEU)	#arcs used
Parent	Optimistic	2024	4,906,313	$ 433.68	48
		2034	6,805,822	$ 433.32	48
		2045	9,016,066	$ 433.37	49
	Pessimistic	2024	4,456,661	$ 433.79	48
		2034	5,400,007	$ 433.18	48
		2045	6,269,597	$ 432.57	47

Table 34 Number of provincial ports that transshipped their containers to gateway – parent scenarios

Gateway	Optimistic			Pessimistic		
	2024	2034	2045	2024	2034	2045
Belawan	3	3	3	3	3	3
Palembang	1	1	2	1	2	2
Panjang	1	2	3	1	3	3
Tanjung Priok	7	6	5	7	4	3
Tanjung Emas	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2
Bitung	4	4	4	4	4	4
Makassar	5	5	5	5	5	5
Sorong	2	2	2	2	2	2

Figure 46 and Figure 47 show the export throughput volume and growth (CAGR) of each gateway in certain period for optimistic and pessimistic scenario, respectively. To calculate throughput growth, we compare the throughput volume between two consecutive periods, which throughput growth for first period is compared with base year. In optimistic scenario, Tanjung Priok starts the throughput with 1.3 million TEUs in period 1 then grows to 1.7 million TEUs in period 2 and reaches 2.5 million TEUs in the last period. Meanwhile in pessimistic scenario, export throughput of Tanjung Priok grows slower only within range 1.2 to 1.4 million TEUs over three periods. Moreover, its growth of export throughput increases between 2% to 3% in optimistic scenario, while in pessimistic scenario it increases between 0.5% to 1% over periods. In regard to throughput volume in TEUs, Tanjung Perak and Belawan remains having significant amount of TEUs in both scenarios though the growth not always increasing. The throughput of Makassar in optimistic scenario reaches more than half of million TEUs only in period 3, while in pessimistic scenario the max throughput is about 480 thousand TEUs in last period. Furthermore, the significant growth comes from Palembang and Panjang that reach more than 6%.

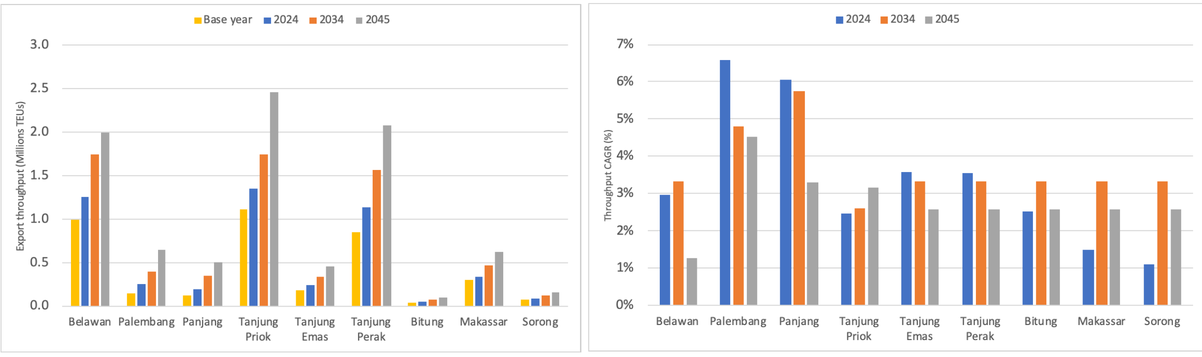

Figure 46 Export throughput volume (mn TEUs) and growth of gateway per period – optimistic scenario

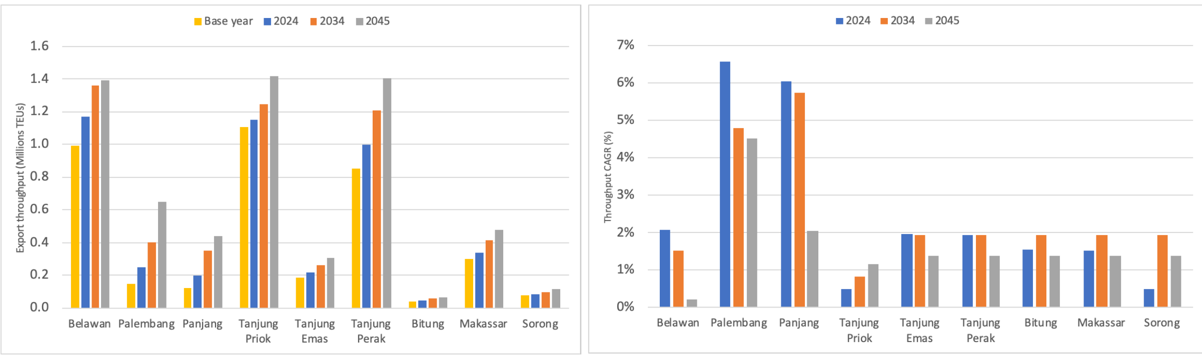

Figure 47 Export throughput volume (mn TEUs) and growth of gateway per period – pessimistic scenario

Next factor we analyze is the percentage of exports being handled per gateway over periods. Since the export throughput volume per gateway is known, the percentage is then the ratio between throughput volume and total export flows in that particular period and scenario. The percentage of export being handled in each gateway also varied from period to period. The graphs in Figure 48 and Figure 49 show the average percentage of export being handled per gateway over periods in optimistic and pessimistic scenario, respectively. The results show that Tanjung Priok (11), Belawan (2), Tanjung Perak (13), Makassar (25), and Palembang (6) are the top five international gateways in both the optimistic and pessimistic scenarios that count for about **87%** of total export flows.

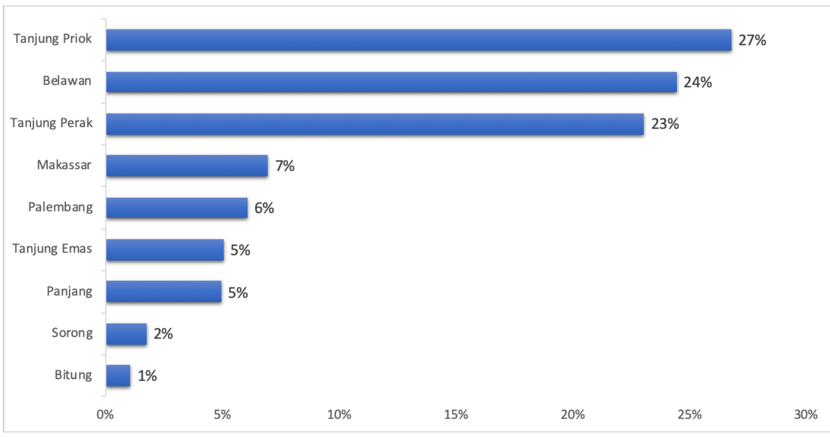

Figure 48 Average percentage of export being handled per gateway over periods – optimistic scenario

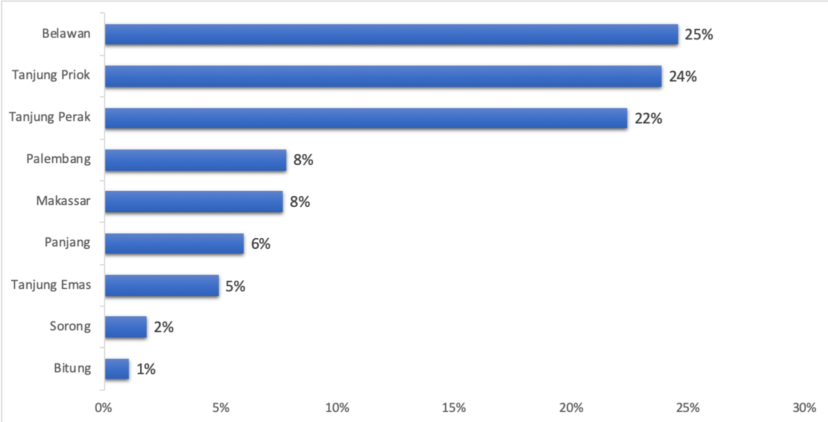

Figure 49 Average percentage of export being handled per gateway over periods – pessimistic scenario

The flow pattern from origins to destinations of each scenario also differ depending on factors involved in the total cost. To see to which direction the flows go from all origins to all destinations in particular scenario and period, Sankey Diagram is used to visualize the flow diagram. This visualization tool shows clear illustration of the flows in the network by having origin nodes, destination nodes and bandwidth that could represents flows between the OD pair or even costs between the OD pair. Figure 50 and Figure 51 respectively illustrate the samples of flow pattern of period 1 in optimistic scenario and period 1 in pessimistic scenario using Sankey diagram. Appendix K provides all Sankey Diagram of flow patterns of parent scenarios in all periods.

From both figures of Sankey diagram, we can see that in period 1 of optimistic scenario and period 1 of pessimistic scenario the flow patterns are similar not only for domestic arcs but also transshipment and international arcs. Both parent scenarios in first period result in similar flow pattern though the demand is different. Moreover, Tanjung Perak (13), Makassar (25), Bitung (23), and Sorong (30) are always be the optimal gateways for flows that go to Shanghai (41). Meanwhile, Belawan (2) is always chosen to connect Indonesia to Colombo (44) and little amount of flows from Belawan go to Port Said (39). In these parent scenarios, Tanjung Priok (11) remains important especially for shipment to Singapore (45), which also receive flow from Palembang (6), Panjang (8), and Tanjung Emas (12). In regard to domestic arcs, Tanjung Priok is important especially for provincial ports in parts of Sumatra, Java, and Kalimantan. Meanwhile, Makassar takes role as gateway for Central Sulawesi, East Nusa Tenggara, some provincial ports in eastern part of Kalimantan, Maluku, and Papua. Belawan receives flows from northern part of Sumatra, while Palembang and Panjang only receives from one port each. Despite of significant amount of flows originated from Tanjung Perak itself, it only receives flows from Benoa and Benete, two small provincial ports in Nusa Tenggara. Sorong becomes the only gateway candidate in Papua island that receives flow from Ambon and Jayapura. Regardless, in both flow patterns the model results in direct connection of Sorong to Shanghai, but still in a small amount of flow. So does Bitung, the other gateway candidate in northern part of Sulawesi. Bitung receives flow from several ports in Sulawesi as well as Ternate, however the total of those flows destined to Bitung remains very small even compare to Sorong. Note that here, the gateways also take role as origin nodes that implies their representing provinces generate export demand which being handled at the gateways.

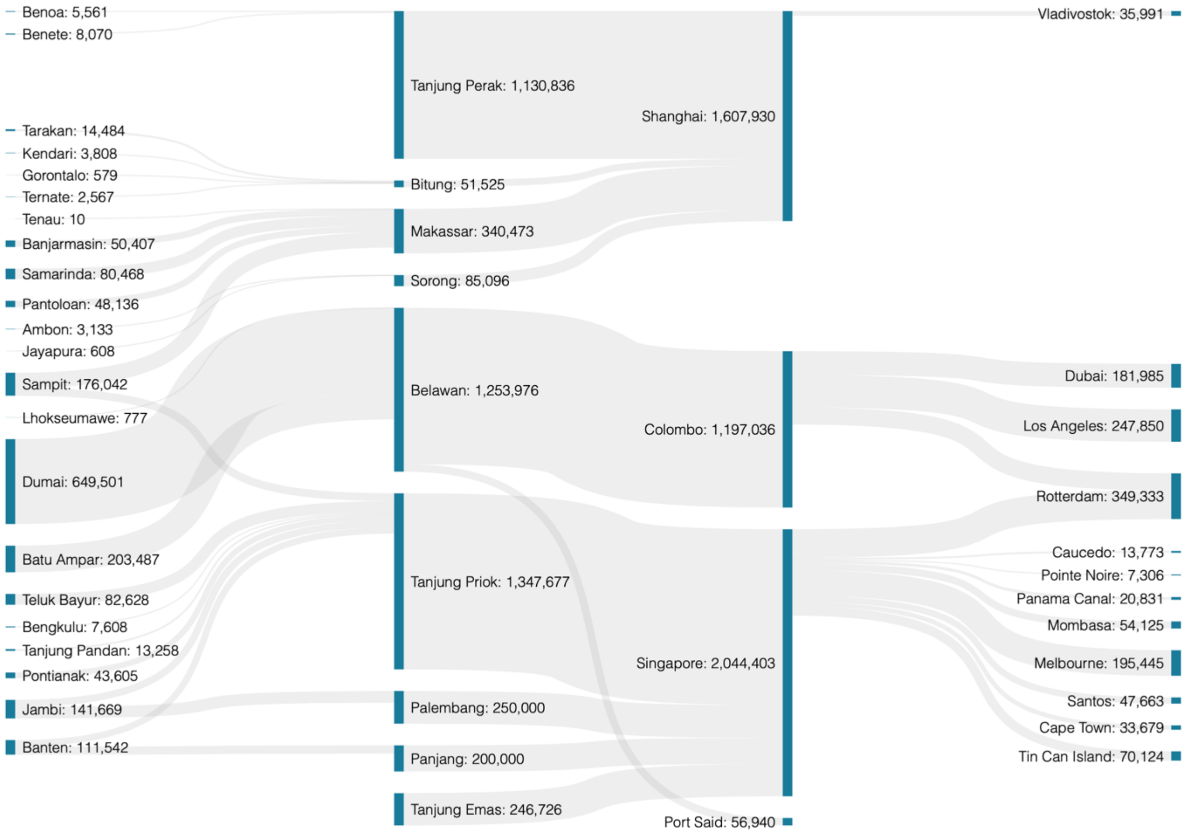

Figure 50 Sankey diagram showing flow pattern for period 1 – optimistic scenario

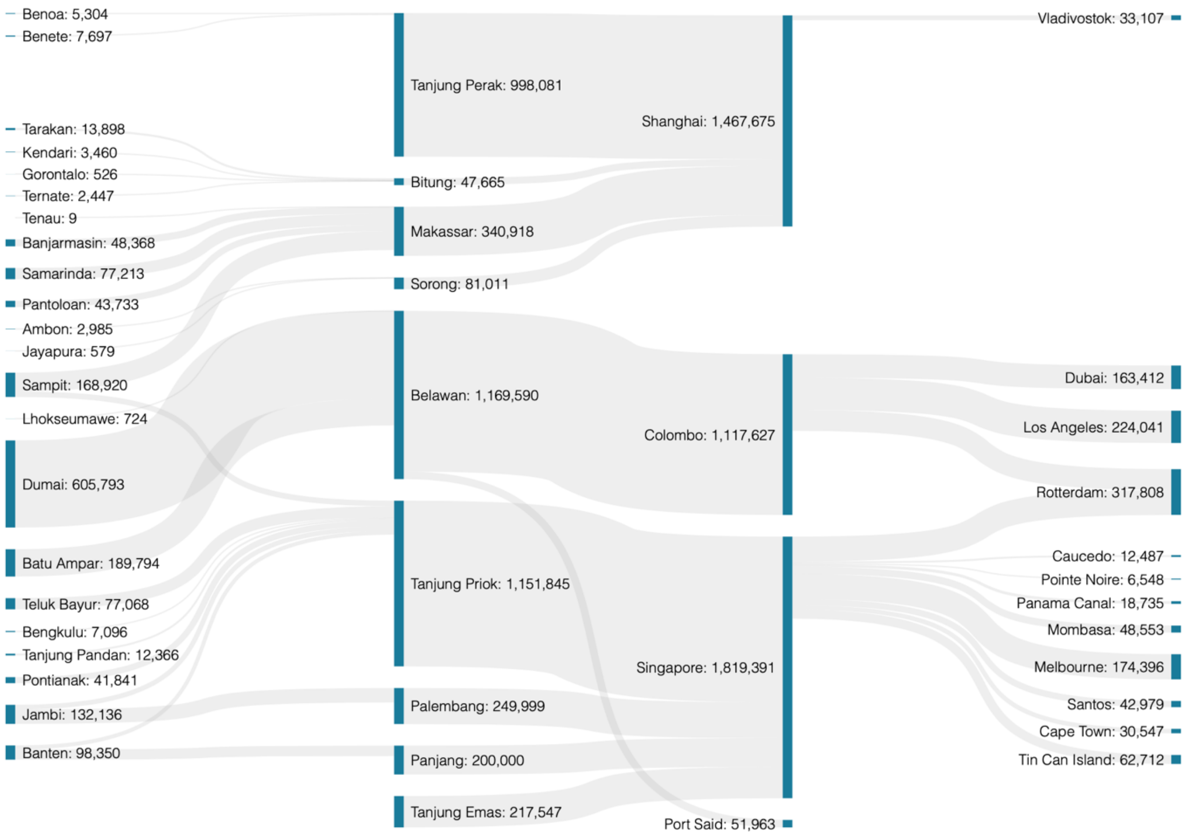

Figure 51 Sankey diagram showing flow pattern for period 1 – pessimistic scenario

6.2.2 NETWORK FLOW ANALYSIS – BRANCH SCENARIOS

As mentioned in previous part, the demand growth in parent scenarios is always increasing over periods. In order to capture more uncertainties that may exist in the future, branch scenarios are generated based on the average values of parent scenarios per period. These scenarios have more fluctuate demand values over periods. From 100 numbers generated per period that follow normal distribution rule, 13 scenarios representing 13 interval/range of demand are obtained. Note that now we call 13 cases mentioned in previous chapter as 13 scenarios. Each of demand from specific scenario and period is modelled in MCF to result in flow patterns and optimal total cost. Having 13 scenarios with 3 periods each, in total the process takes 39 times of model run. Figure 52 shows the optimal solution of cost in USD/TEU from MCF model run for 13 branch scenarios in certain period. Each dot represents a particular scenario in particular period given the demand values of each scenario. From this graph we can see that dots in first period tends to be more linear than others. Meanwhile, in third period is less linear. From this figure we also can see that the maximum yearly demand in period 1 is about 6.5 million TEUs, period 2 reaches about 10.5 million TEUs in maximum and period 3 up to 12 million TEUs.

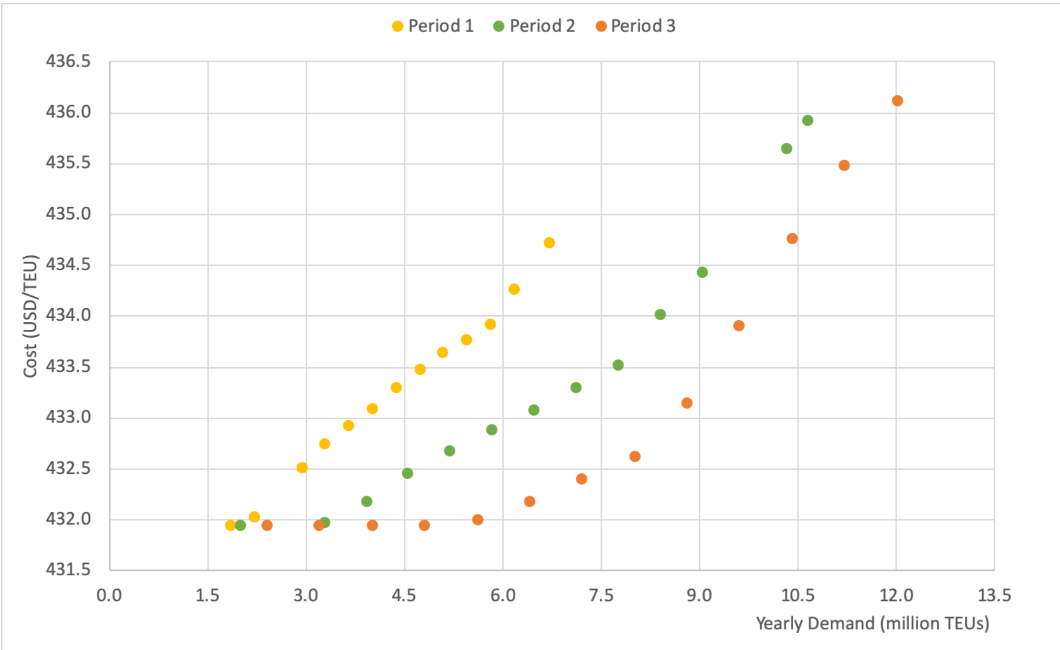

Figure 52 Cost for certain demand value and period as optimal solutions from network model

Table 35 provides number of provincial ports that transshipped amount of export flows to a particular gateway for Scenario 2 and 4. As the examples of analysis, scenario 2 and scenario 4 are taken into account, as these two cases have quite distinct results of flow patterns. The two scenarios taken here as samples (scenario 2 and 4) have different demand growth. In scenario 2 (see Figure 53), demand in period 1 increases from the base year quite significantly, however it drops down for around 2 million TEUs and stays stable until period 3. Meanwhile in scenario 4, demand goes down from base year then rises significantly in period 2. Moreover, in period 3 scenario 4 experiences decreasing on its demand for about 3.7 million TEUs from period 2.

Table 35 Number of provincial ports that transshipped their containers to gateway – Scenario 2 and 4

Gateway	Scenario 2			Scenario 4		
	2024	2034	2045	2024	2034	2045
Belawan	3	3	2	3	3	2
Palembang	1	2	5	2	2	5
Panjang	1	3	3	3	1	3
Tanjung Priok	8	3	0	4	7	0
Tanjung Emas	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2
Bitung	4	4	4	4	4	4
Makassar	5	5	5	5	5	5
Sorong	2	2	2	2	2	2

Total number of arcs used in this branch scenarios is between 46 to 49 arcs out of 379 available arcs. Next is we analyze the export throughput volume and growth of each gateway from both scenarios. In Scenario 2, Tanjung Priok, Belawan, and Tanjung Perak show their significant throughput volumes over periods, or in other words are higher than any other gateways. However, those three gateways experiencing decreasing from period 1 to period 2 and continue to decrease until period 3 except for Tanjung Perak. The big drop happens between period 1 and 2 due to the fact that the total demand also has decreased significantly for about 2 million TEUs. Meanwhile, this decrease in throughput volume is not experienced by Palembang and Panjang. Although the volume is relatively small compare to three prior gateways, the growth of throughput in Palembang and Panjang is always positive over periods. Other gateways except Palembang and Panjang have their throughput volume decreased in period 2, even in period 3 as well for Tanjung Priok and Belawan.

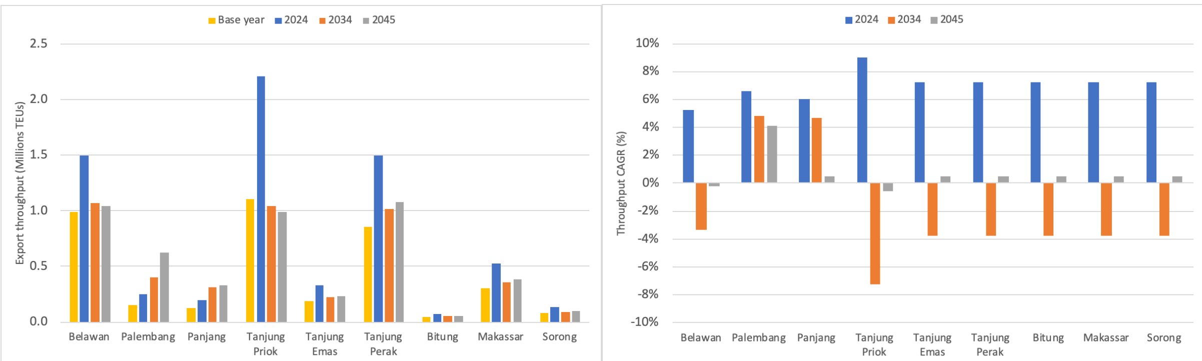

Figure 53 Export throughput volume (mn TEUs) and growth of gateway per period – scenario 2

On the other hand, scenario 4 experiencing different situation (see Figure 54). The big drop of throughput volumes happens between period 2 to period 3 which is significantly seen from Belawan, Tanjung Priok and Tanjung Perak. This might be related to the fact that total demand in Scenario 4 is significantly decreased for about 3.7 million TEUs from period 2 to period 3. Moreover, in this scenario 4, Palembang does not experience declination in its throughput volumes. This is also supported by the fact that throughput growth of Palembang is always positive over periods in scenario 4. The top two highest throughput volume over periods in this scenario 4 hold by Belawan and Tanjung Priok that reach about 2 million TEUs in period 2 (orange bar).

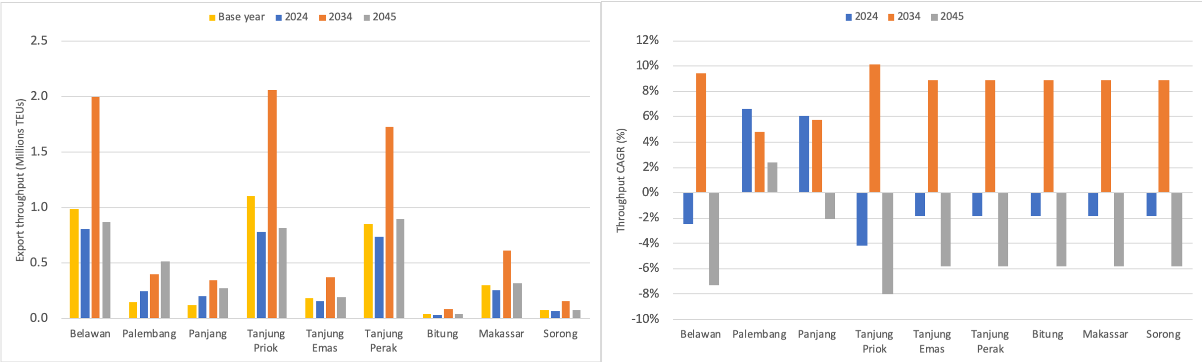

Figure 54 Export throughput volume (mn TEUs) and growth of gateway per period – scenario 4

Beside the number of arcs, export throughput volume and throughput growth, the analysis continue with average percentage of export being handled in particular gateway. With similar analysis approach from parent scenarios, we can learn from Figure 55 and Figure 56 about the average percentage of exports being handled in each gateway out of total export demand in scenario 2 and scenario 4, respectively. Note that the percentage is average value over all three periods. In scenario 2, Tanjung Priok, Belawan, Tanjung Perak, Palembang and Makassar becoming the top five gateways with regards to the percentage. If we sum all percentage values of those five gateways, they handle in average 85% of total export demand. Moreover, scenario 4 arrives in different results that Belawan becomes the gateways with highest average percentage of export being handled at that gateway. Then it is followed by Tanjung Priok, Tanjung Perak, Palembang and Makassar. Those five ports in average then handle 87% of total export demand.

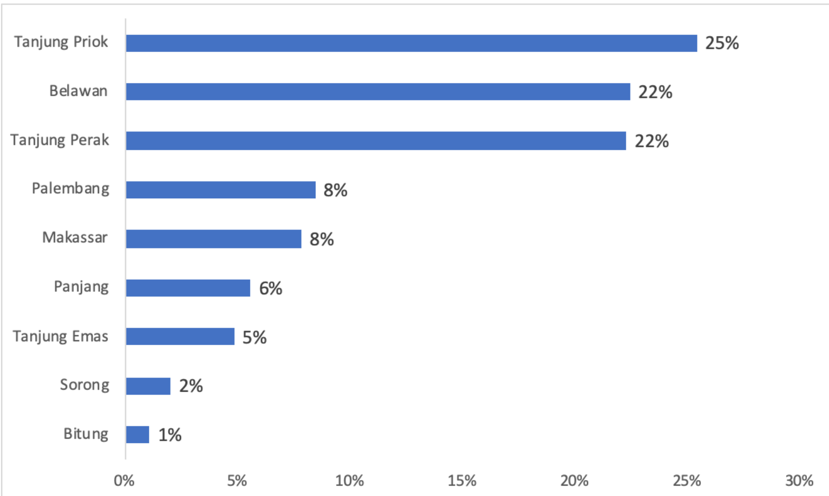

Figure 55 Average percentage of export being handled per gateway – Scenario 2

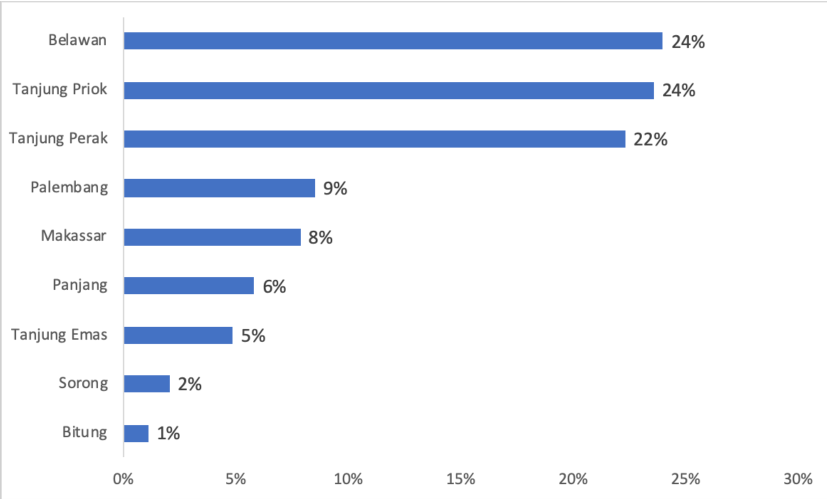

Figure 56 Average percentage of export being handled per gateway – Scenario 4

Next is we present flow patterns visualized with Sankey diagram of period 2 in scenario 2 and period 3 in scenario 4. We specifically selected these two cases as both have quite different result of flow pattern. For period 2 in scenario 2, Palembang and Panjang receive flows from more provincial ports if we compare to the flow pattern of parent scenarios. Palembang receives from Batu Ampar and Jambi, while Panjang receives from Teluk Bayur, Bengkulu, and Banten. This leads to the result that Palembang handles container volumes 400 thousand TEUs and Panjang handles for about 315 thousand TEUs.

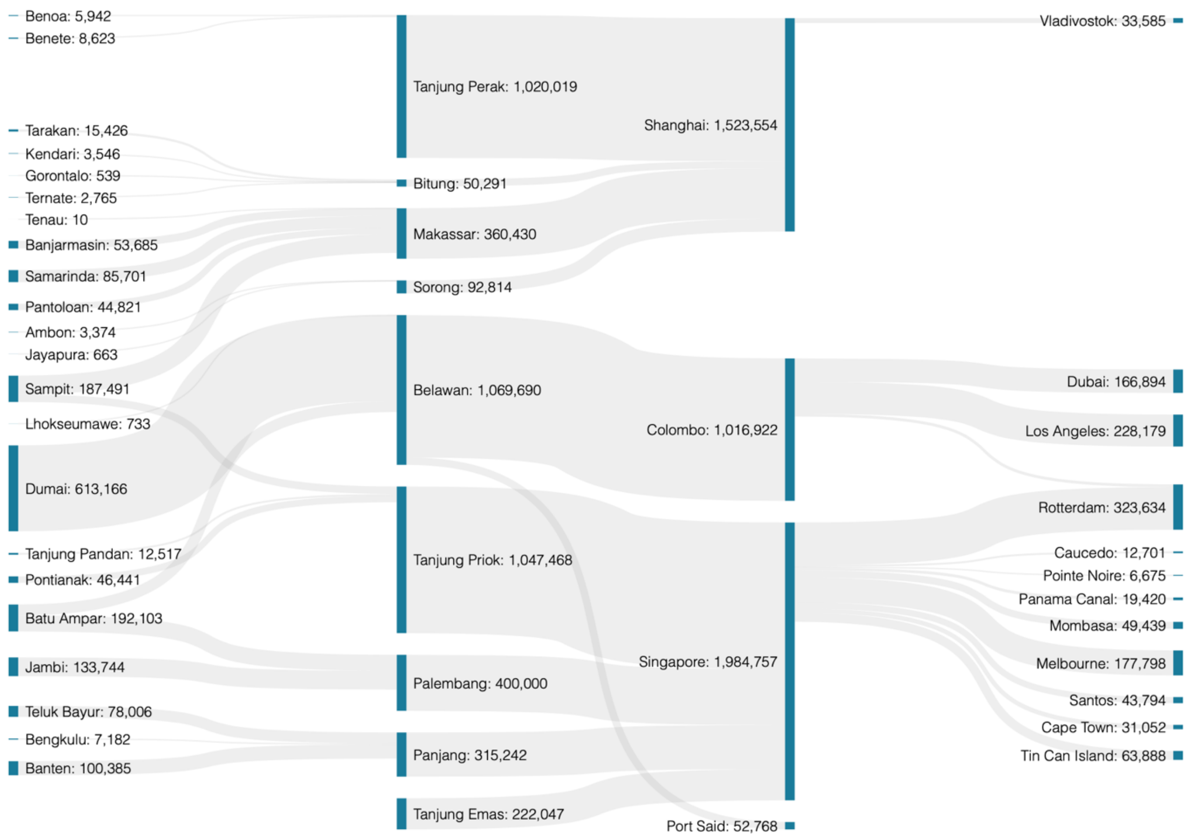

Figure 57 Sankey diagram showing flow pattern for period 2 – Scenario 2

On the other hand, period 3 in scenario 4 arrives in another different pattern. The significant result comes from Tanjung Priok that in this pattern, this gateway does not receive any container volumes from provincial port. Containers those in previous flow patterns (re: parent scenarios and scenario 2) go to Tanjung Priok such as Bengkulu, Teluk Bayur, Banten, Jambi, Pontianak, Tanjung Pandan, and Sampit, in this pattern go to Palembang and Panjang. Moreover, in this flow pattern, Belawan does not receive containers from Batu Ampar anymore, as they shift to Palembang. These results quite interesting given that Tanjung Priok is currently a big main international port in Indonesia and Palembang has feeder connection to Singapore and the port size is relatively small.

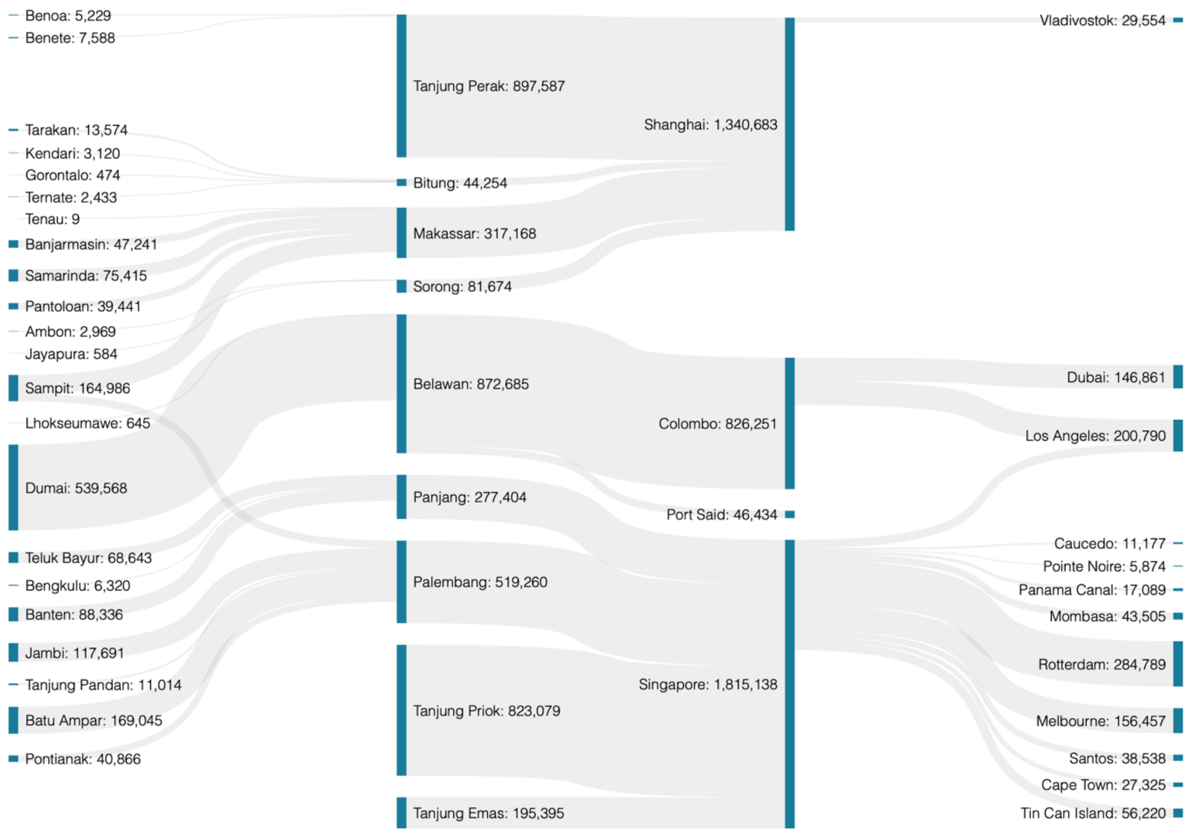

Figure 58 Sankey diagram showing flow pattern for period 3 – Scenario 4

6.3 POLICY PATHWAYS MAP

Policy pathway map is the output of a step which we do mapping the promising ports in each period and certain demand value based on flow pattern generated from network flow model. This step is done in order to have a clearer picture of how ports function in a scenario and therefore we can translate this into policy decision pathways. Therefore, policy pathways map is an intermediary step before making policy decisions.

To develop a policy pathways map, there are several things required to be complete first. The example of policy pathways map in Figure 12 shows that x-axis in the map represents demand values in TEUs. Since this research aims to generate policy decisions that deal with uncertainties, which are captured by changeable demand, therefore demand volumes of all scenarios (i.e. parent and branch) are divided into several ranges/intervals. In that, mapping the promising ports becomes more clustered with regard to particular range of demand. There are 7 ranges of demand from 1.5 to 12 million TEUs with length of each range is 1.5 million TEUs. Note that in this case we use all scenarios both parent and branch as the illustration of variation of future demand uncertainties. Afterwards, we can set x-axis by the range of demand and determine which flow pattern that fit appropriately for certain range and certain period eventually. To perform this, first we need to obtain the probability of a period has total flows within a certain range of demand. In this case, two parent scenarios and 13 branch scenarios are taken into account which the results are presented in Figure 59. Period 1 does not appear in the demand range of 7,5 up to 9 million TEUs and beyond. The random number generation process therefore estimates that it is unlikely to have very high demand in period 1. Period 2 is more likely to have demand value within range 4,5 to 6,0 million TEUs. Moreover, period 3 has same probability to have demand value in range 3,0 to 12,0 million TEUs, which is 15%. In other words, amongst scenarios we have, demand value of period 3 might be more uncertain. In addition, Period 2 and 3 have probability in each range of demand which implies the scenarios constructed in this research have fluctuate demand volumes over periods.

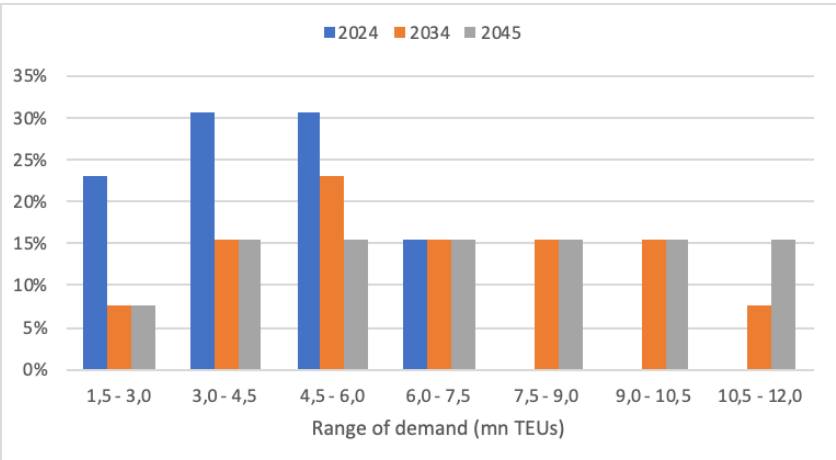

Figure 59 Range of demand volumes and probability each period has total flows within the range

After identifying the range, we assess the flow pattern of all scenarios in all periods. In this stage, we only take into account Period 1, Period 2, and Period 3 since the base year is presumed to be fixed in the range 3,0 to 4,5 million TEUs. This is due to the fact that if we generate random numbers for the base year, they are mostly converged in that range.

Assessing flow pattern is done based on number of provincial ports that transshipped their containers to particular gateway, throughput volume as well as throughput growth per gateway. Since each iteration from network flow model generates flow decision variables as well, therefore flow pattern assessment is done for each scenario and each period. Flow pattern indicates how promising a port is. For example, the more a gateway received flows from provincial port, the more important it is to the Indonesian export trade, and thus the more promising. For this analysis, we only look at the flow variables of gateways as our focus in this research is on international gateways development. Moreover, it is possible that different scenarios or different period has similar flow pattern. On the other hand, for some scenarios in different period but within same range of demand, the flow pattern can be different.

Table 36 shows number of provincial ports that transshipped their containers to particular gateway of all scenarios.

Table 36 Number of provincial ports that transshipped their containers to gateway – all scenarios

Gateway	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045
Belawan	3	3	2	3	3	2	3	2	2	3	3	2	2	3	2
Palembang	1	1	4	1	2	5	1	1	1	2	2	5	5	2	1
Panjang	1	1	3	1	3	3	1	1	1	3	1	3	3	3	3
Tanjung Priok	7	8	2	8	3	0	7	9	9	4	7	0	0	3	7
Tanjung Emas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bitung	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Makassar	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sorong	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Gateway	Scenario 6			Scenario 7			Scenario 8			Scenario 9			Scenario 10		
	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045
Belawan	2	3	2	3	3	3	3	2	3	3	2	2	3	3	3
Palembang	3	1	5	2	2	2	1	1	2	1	5	5	2	1	2
Panjang	3	1	3	3	3	3	1	1	3	1	3	3	1	1	3
Tanjung Priok	3	8	0	4	4	3	7	9	5	7	1	0	7	7	4
Tanjung Emas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bitung	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Makassar	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sorong	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Gateway	Scenario 11			Scenario 12			Scenario 13			Optimistic			Pessimistic		
	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045
Belawan	3	3	2	3	3	3	3	2	2	3	3	3	3	3	3
Palembang	1	2	1	1	1	2	2	5	1	1	1	2	1	2	2
Panjang	1	3	1	1	3	3	3	3	1	1	2	3	1	3	3
Tanjung Priok	8	4	9	7	5	3	4	0	9	7	6	5	7	4	3
Tanjung Emas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bitung	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Makassar	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sorong	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Moreover, Figure 60 to Figure 67 below are the graphs showing throughput TEU for each gateway in different scenarios. We present them starts from parent scenarios (optimistic and pessimistic) and branch scenarios (Scenario 1 to 13). From these figures, we can notice that the gateway throughput between period is changing following the fact that yearly total demand for that specific period does also change. Thus, the growth of throughput per gateway is identified.

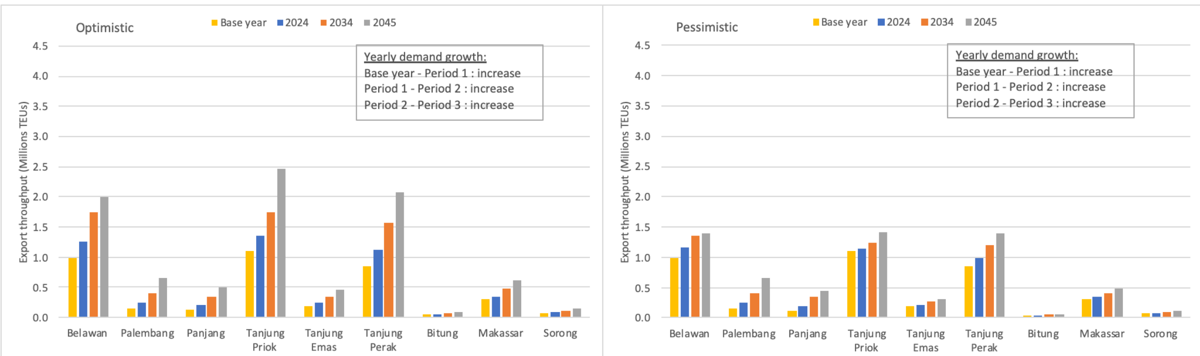

Figure 60 Throughput per gateway over periods – Parent scenarios

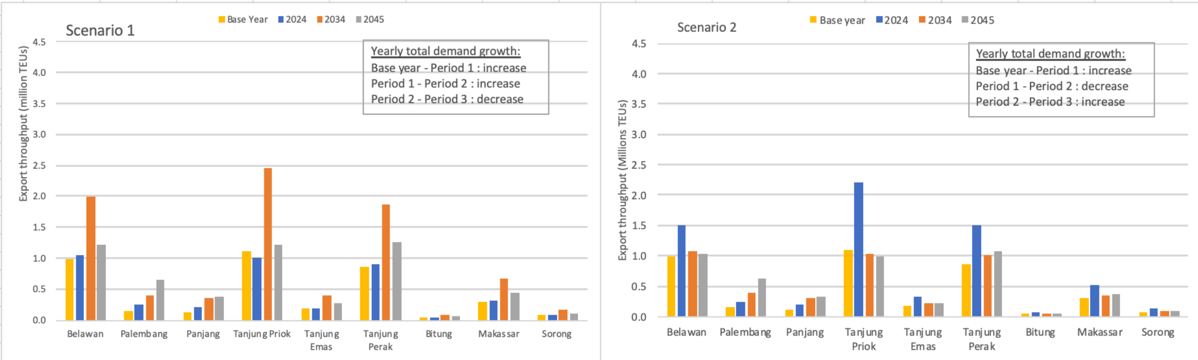

Figure 61 Throughput per gateway over periods – Scenario 1 and Scenario 2

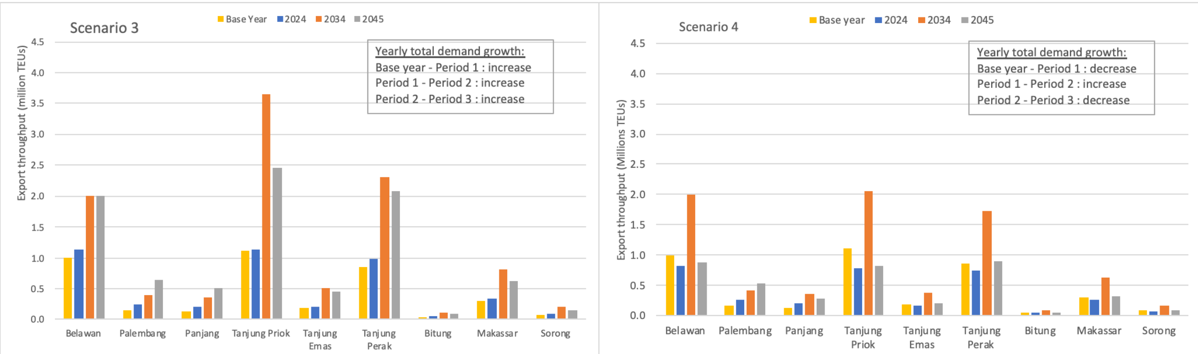

Figure 62 Throughput per gateway over periods – Scenario 3 and Scenario 4

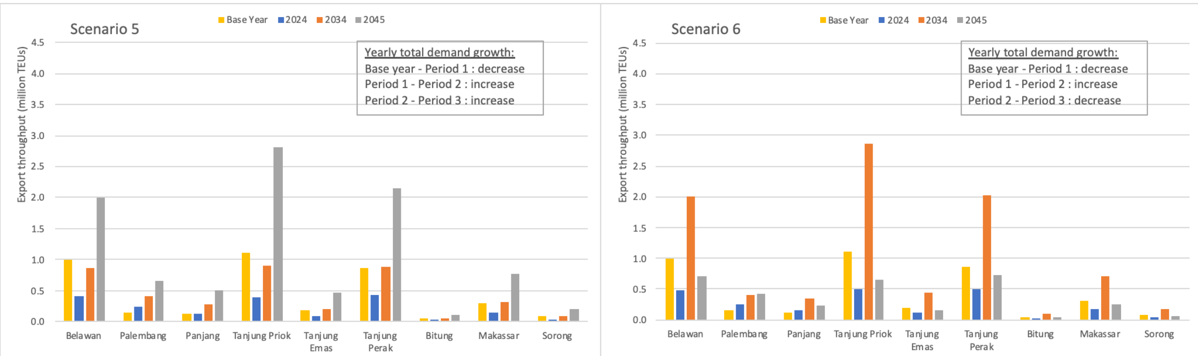

Figure 63 Throughput per gateway over periods – Scenario 5 and Scenario 6

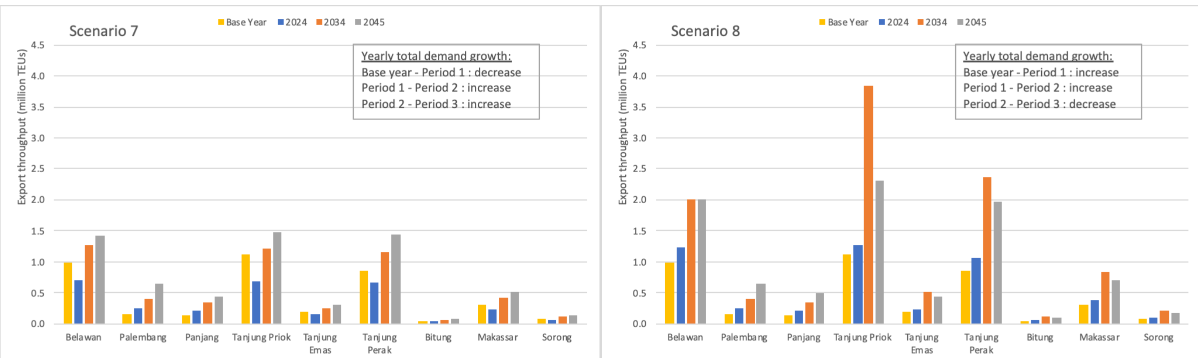

Figure 64 Throughput per gateway over periods – Scenario 7 and Scenario 8

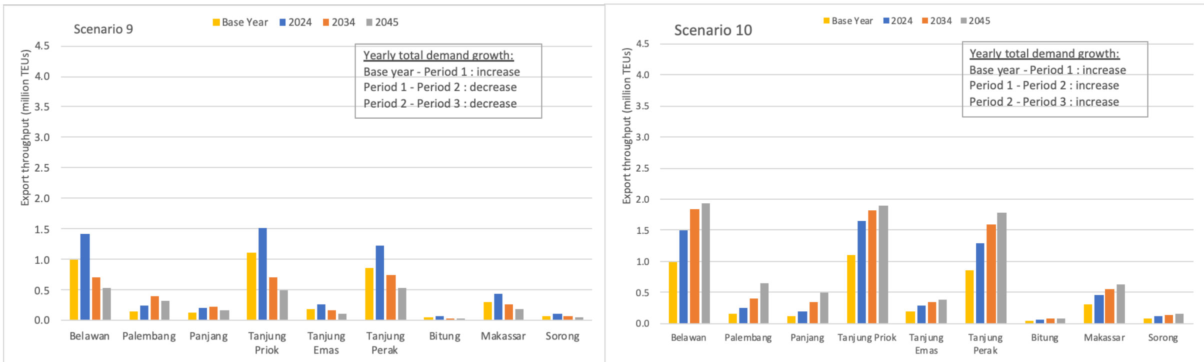

Figure 65 Throughput per gateway over periods – Scenario 9 and Scenario 10

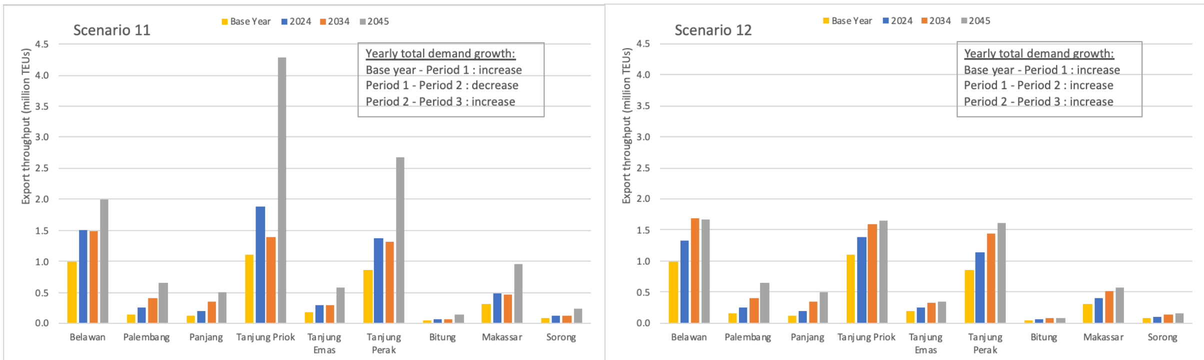

Figure 66 Throughput per gateway over periods – Scenario 11 and Scenario 12

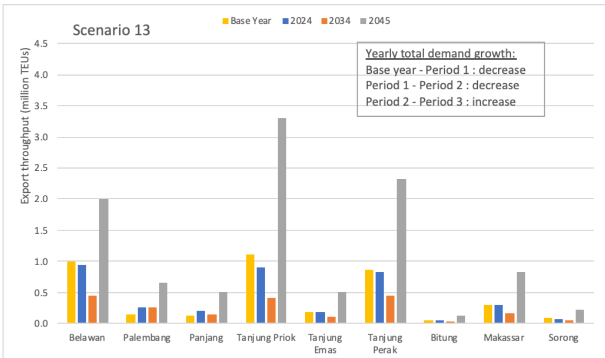

Figure 67 Throughput per gateway over periods – Scenario 13

From throughput per gateway and numbers of provincial ports that transshipped containers to particular gateway, we identify that there are some scenarios that have identical flow pattern, and some are significantly distinct with each other. In each flow pattern, there may be gateways that either have high number of throughputs in TEUs but fluctuate over periods or increasing throughput growth though the yearly total demand values drops at the same time. These flow pattern analyses lead us to several findings, as follow:

1. Tanjung Priok, Tanjung Perak, and Belawan are the top three gateways that have higher throughput in TEUs.
2. Compare to Bitung and Sorong, which gateways are located in eastern part of Indonesia, export throughput of Makassar remains higher.
3. In most of scenarios, throughput growth of Palembang steadily growing with amount of TEUs that is comparable with Makassar, even though the yearly total demand tends to fluctuate from year to year.

4. Though some yearly total demands are in the same range, and in the same period, the flow pattern possibly result differently.
5. There are several scenarios that have identical flow pattern in particular period. We classify that and come up with three different flow patterns, those are explained as follow.

From all scenarios, there are three different flow patterns determined yet identically used in different scenarios and periods. For example, in scenario 1 period 1 and 2 the flow patterns are identical which those periods have more provincial ports going to Tanjung Priok to transship their export flows (see Table 36). Another example, in scenario 2 period 3 and scenario 5 period 1 the flow patterns are identical which none of provincial ports transship their export flow to Tanjung Priok though its throughput still has share of export that is high compare to Belawan and Tanjung Perak. In the following explanation, we elaborate each of three flow patterns.

Flow pattern A

In this flow pattern (see Figure 68), more provincial ports come to Tanjung Priok to transship their export flows, such as Dumai, Batu Ampar, Teluk Bayur, Bengkulu, Banten, Jambi, Tanjung Pandan, Pontianak, and Sampit. Belawan only receives flows from Lhokseumawe and Dumai. Palembang only receives flows from Batu Ampar, while Panjang only receives flows from Banten. Thus, Batu Ampar and Banten split their flows into two gateways. Tanjung Perak handles flows from Benoa and Benete, provincial ports within Nusa Tenggara island. Tanjung Emas does not receive flows from any provincial ports. Sampit, Banjarmasin, Tenau, Samarinda, and Pantoloan transship their flows to Makassar. Bitung receives from four ports, namely Tarakan, Gorontalo, Kendari and Ternate. Finally, Sorong receives flows from Jayapura and Ambon. The last five gateways have always the same flow pattern in all scenarios.

In regard to throughput volumes per gateway, Figure 69 shows the average percentage of export being handled per gateway. The sum of average percentage of Tanjung Priok, Belawan, Tanjung Perak, and Makassar already exceeds 80% of total export flows.

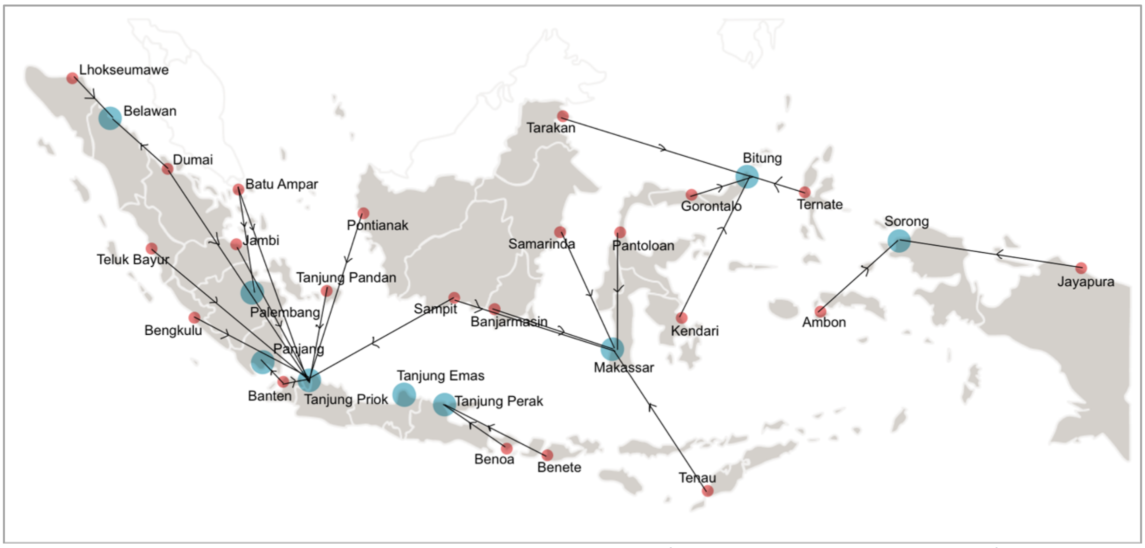

Figure 68 Network with Flow Pattern A – (only domestic arcs considered)

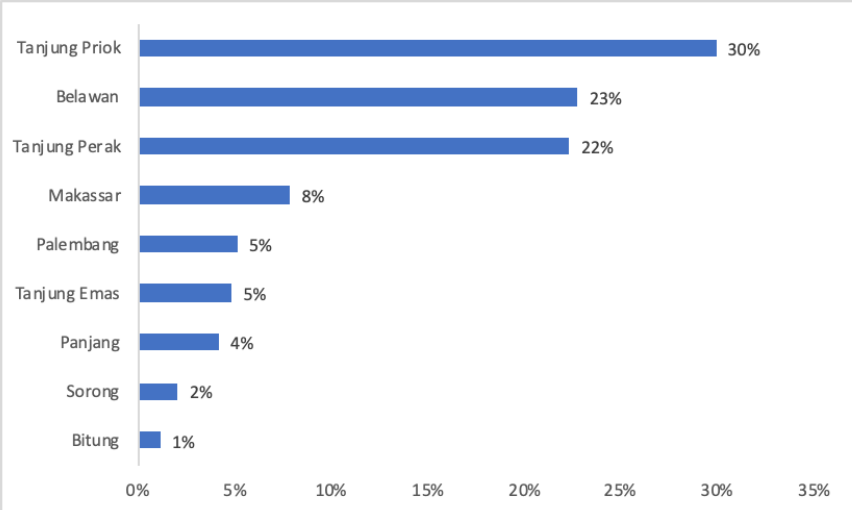

Figure 69 Average percentage of export being handled per gateway – Flow pattern A

<u>Flow pattern B</u>

In this flow pattern (see Figure 70), Tanjung Priok has lower number of provincial ports that transship export flows compare to previous pattern. Those are only Teluk Bayur, Tanjung Pandan, Pontianak, and Sampit. Belawan receives from Lhokseumawe, Dumai and Batu Ampar. Palembang receives from Jambi and Batu Ampar, which implies Batu Ampar splits its flows to two gateways. So does Teluk Bayur that also transships amount of flows to Panjang together with Bengkulu. The rest of gateways have similar flow pattern with flow pattern A.

In regard to throughput volumes per gateway, Figure 71 shows the average percentage of export being handled per gateway and we sort from largest to smallest. The graph shows different results compare to flow pattern A. Here, Belawan is being in the first place that means having largest share of export flows those are handled at that gateway. It is followed by Tanjung Priok, Tanjung Perak, Palembang, and Makassar. Palembang in this pattern handles more flows than Makassar. The sum of average percentage of the top five gateways surpasses 80% of total export flows.

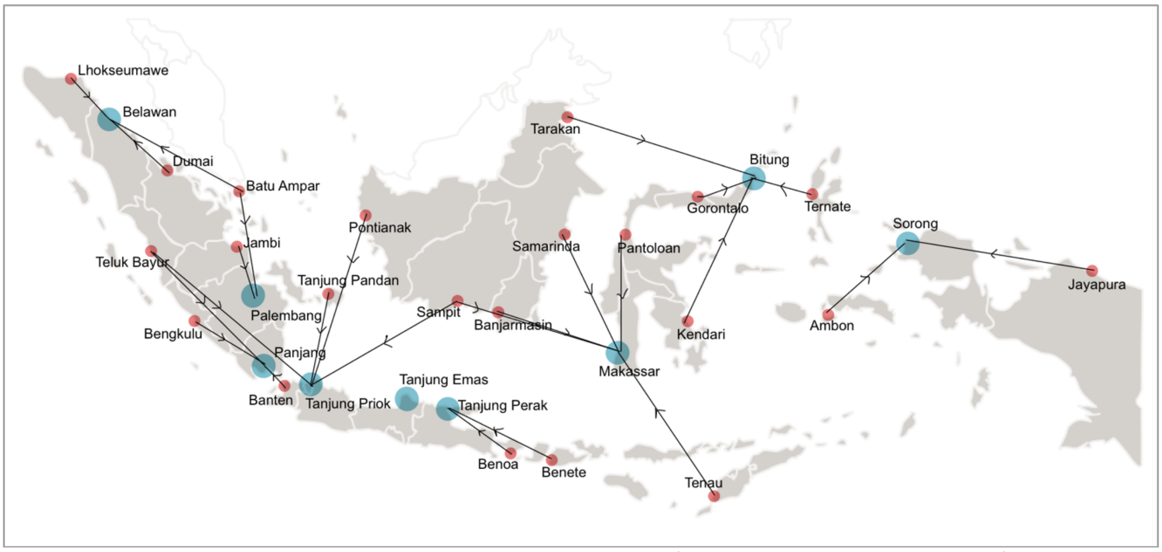

Figure 70 Network with Flow Pattern B – (only domestic arcs considered)

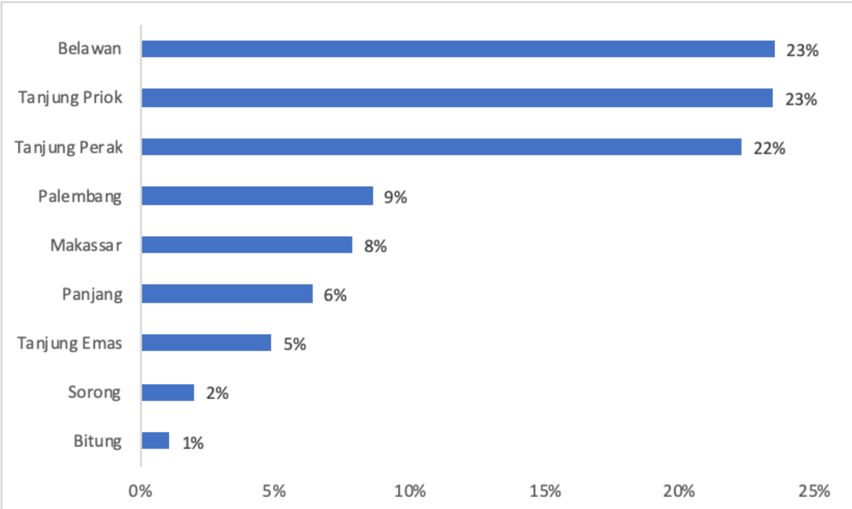

Figure 71 Average percentage of export being handled per gateway – Flow pattern B

<u>Flow pattern C</u>

Flow pattern C shows very different configuration (see Figure 72). Here, there is no provincial ports coming to Tanjung Priok to transship their export flows. Note that gateways are also generates export flows and therefore Tanjung Priok only handles containers those are produced in its pair of provinces (Jakarta and West Java). Moreover, Belawan receives from Lhokseumawe and Dumai. Palembang receives from Batu Ampar, Jambi, Tanjung Pandan, Pontianak, and Sampit, which go to Tanjung Priok in previous flow patterns. Thus, Palembang is likely to be the second option of those ports to transship their flows. Panjang receives flows from Teluk Bayur, Bengkulu and Banten. The rest of gateways have the same flow pattern.

The average percentage of export being handled also results in different ranks. Tanjung Perak becomes in the first position. As Tanjung Perak is a pair of East Java province, which is one of the key provinces that generate export containerized commodities. Then, the second place is Belawan that is followed by Tanjung Priok, Palembang and Makassar. The sum of average percentage of the top five gateways are exceeding 80% of total exports.

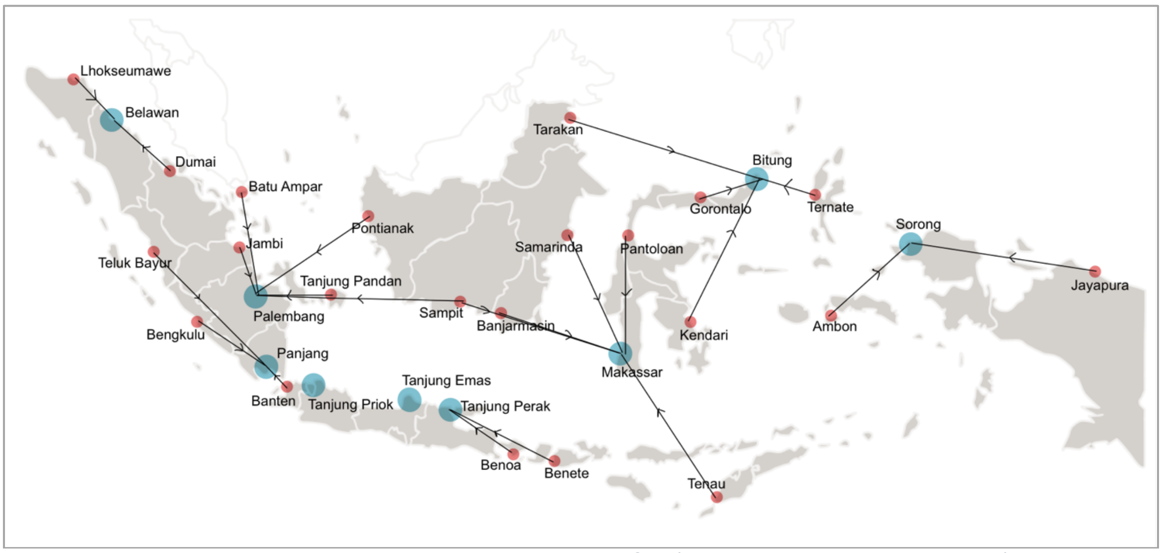

Figure 72 Network with Flow Pattern C – (only domestic arcs considered)

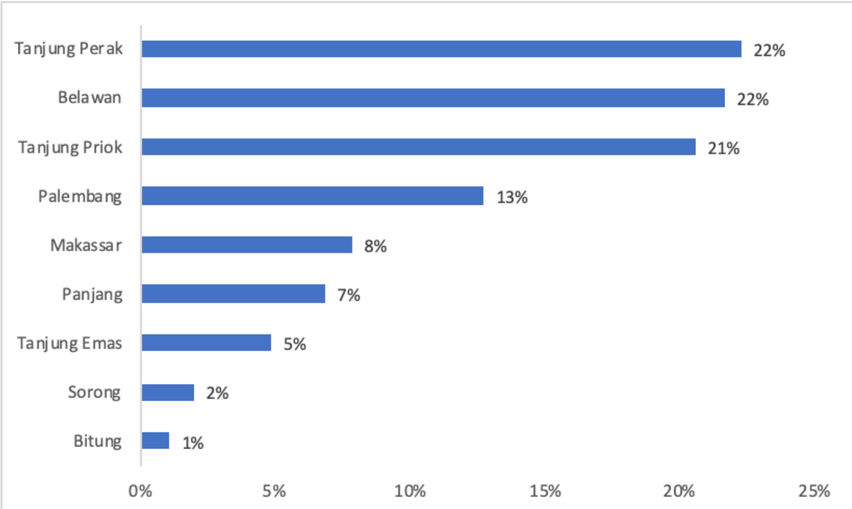

Figure 73 Average percentage of export being handled per gateway – Flow pattern C

Given the demand values of each scenario, ranges of demand, and flow pattern of each scenario, we continue the step by mapping the flow pattern into policy pathways map. First, we identify how the flow pattern changes in each period for particular range of demand. Here, we say that moving from one range of demand to another range of demand means passing a point that may require policymaker to transfer to new flow pattern. For some scenarios, it is also possible even in the same range of demand and period, the flow pattern changes. This implies there are some specialties that a flow pattern is being ineffective to cope with certain amount of demand and thus, there are some points that the policymaker should also transfer to new flow pattern. Therefore, there are two factors that become the references for policymaker to adapt with the network: the change of range of demand and the existence of ineffective flow pattern. Figure 74 is the policy pathways map that is constructed based on flow pattern assessment of all scenarios in this research.

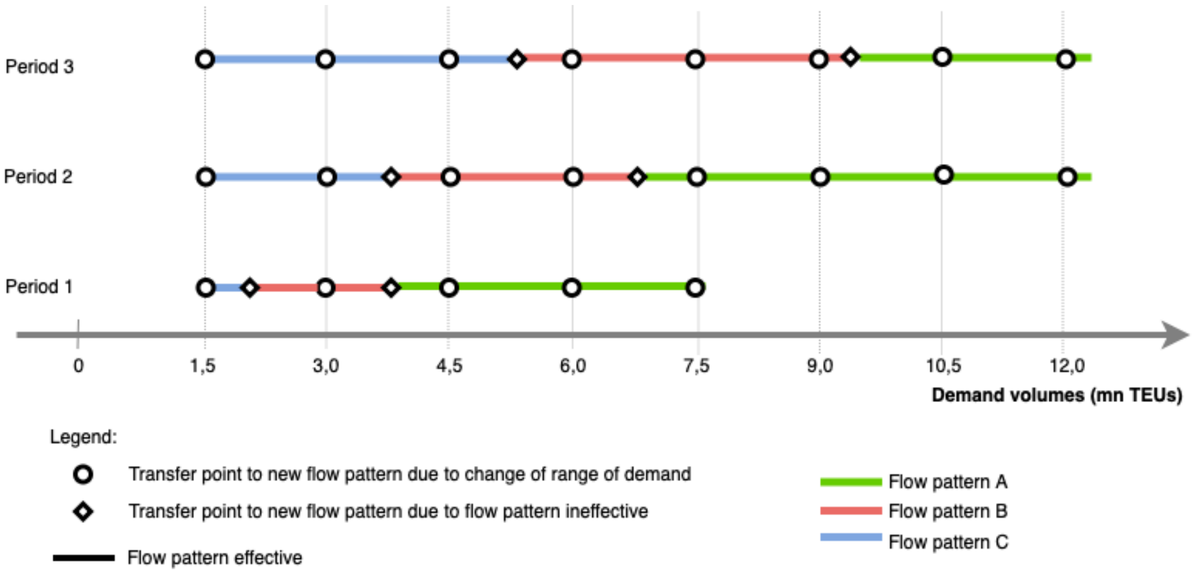

Figure 74 Policy pathways map based on flow pattern assessment of all scenarios

6.4 Policy decision description

In this part, the description of policy decisions is provided. Policy decisions are the recommendations for policymakers in regard to international container gateways development. We consider the previous three flow patterns and policy pathways map as basis in constructing policy decisions. These policy decisions are therefore linked to the periods and ranges of demand. By having these policy decisions, the government can plan and make policy for shipping network planning under future uncertainties. The three policy decisions are Policy Decision A (linked to flow pattern A), Policy Decision B (linked to flow pattern B), and Policy Decision C (linked to flow pattern C). Each policy decision has recommendations for which gateways should be developed, when they should be developed, and what is the function of the gateway. The function of gateway can be two types: main and feeder gateway. Main gateways are gateways that have more connection to worldwide transshipment hubs and ports, otherwise feeder gateways have less connection.

Policy decision A

The focus in this policy is the development of Tanjung Priok. Tanjung Priok is developed to cope with big yearly demand volume in the future. In other words, it is developed to be the main international container gateway in the country. When the demand goes significantly higher, the existence and expansion of Tanjung Priok make the network more optimal. However, once the expansion takes place, but the demand does not follow to increase then the investment for the expansion becomes not efficient. Belawan and Tanjung Perak become other main gateways with smaller scale than Tanjung Priok. Moreover, Makassar become feeder gateway. The most optimal condition to implement this policy decision is when the flow pattern A is effective.

Policy decision B

The focus in this policy is the development of Belawan, Tanjung Priok, and Tanjung Perak as main gateways. They are developed with similar scale to cope with mid-range of yearly demand volumes. Belawan becomes the gateway that is significantly important for direct connection with Port Said and Colombo. Moreover, Palembang and Makassar become feeder gateways. Palembang transfers smaller number of containers to Singapore compare to Tanjung Priok, so does Makassar to Shanghai with smaller flows compare to Tanjung Perak. In Period 3, this policy remains optimal in longer range of demand than others. The most optimal condition to implement this policy decision is when the flow pattern B is effective.

Policy decision C

The highlight in this policy is the development of Palembang to function as feeder gateway. Palembang is developed to deal with small yearly demand volume in the future that results in more optimal shipping network cost for that range of demand. Tanjung Perak, Belawan, and Tanjung Priok still become the main gateway, however Tanjung Priok is not receiving flows from other provincial ports. Focus of main gateway development is to Belawan and Tanjung Perak. This policy is more efficient to be implemented when unexpected drop of demand is happened, for example due to economy crisis. The most optimal condition to implement this policy decision is when the flow pattern C is effective.

After describing the policy decisions, we can conclude that over three policy decisions, there are **3 main gateways** remain important for the export trade in Indonesia: ***Belawan, Tanjung Priok, and Tanjung Perak***. Moreover, there are 2 gateways those are likely to become **feeder gateways: *Palembang and Makassar***. In the next sub chapter, we are going to simulate how to select policy decision pathways given the adaptive policy decision pathways map.

6.5 SIMULATION OF SELECTING POLICY DECISION PATHWAYS

In shipping network planning and policy decision-making, policy-makers need to have reliable predictive pathways to cope with future uncertainties. Thus, the last step in the adaptive policy decision pathways for shipping network planning is the selection of pathways that guide policymaker to make decision over periods under certain conditions. To assume the conditions, What-If Analysis approach is used. The condition is based on yearly total demand growth between periods. The growth is whether increase, decrease, or stable. For the sake of simplicity of this research, we presume three different conditions: (1) yearly demand from period 1 to period 3 remains increasing; (2) yearly demand from period 1 to period 2 increases, but then decreases from period 2 to period 3; (3) yearly demand from period 1 to period 2 is stable, but then increases from period 2 to period 3. The result of policy decision map with selected adaptive pathways for those three different conditions is in Figure 75 below.

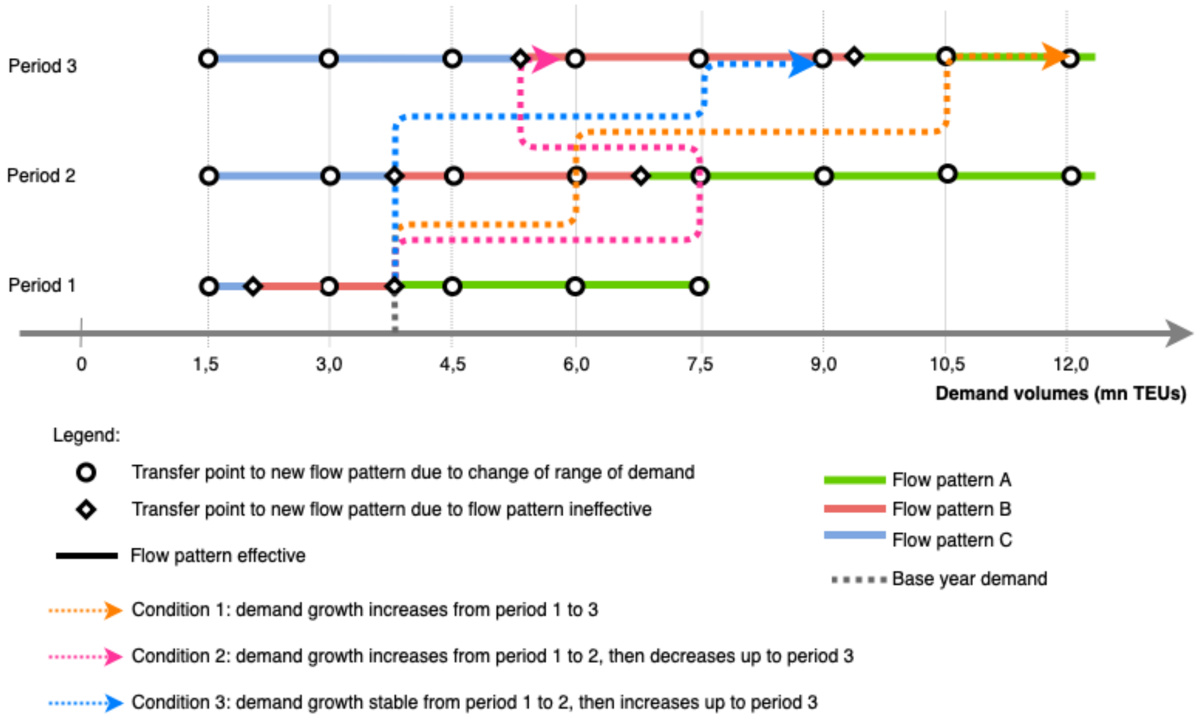

Figure 75 Preferred adaptive policy decision pathways for three different conditions

Figure above illustrates the pathways selected for three different conditions. The first condition indicates rising demand from base year demand to 6 million TEUs between period 1 to period 2, then increases again to 10.5 million TEUs in period 3. The effective flow pattern between period 1 and 2 is flow pattern B and between period 2 and period 3 is flow pattern A. Therefore, in this condition the policy decision is to develop Belawan, Tanjung Priok, Tanjung Perak as main gateways as well as Makassar and Palembang as feeder gateways, with more concentrated on Tanjung Priok during period 3. In condition

2, demand is increasing from base year demand to 7.5 million TEUs, then goes down to around 5 million TEUs. Flow pattern that is optimal in between period 1 and 2 is flow pattern A. However, as the demand decreases, flow pattern A becomes ineffective. Thus, in this condition the policy decision is to primarily develop Tanjung Priok but with smaller scale of expansion in the first two periods and develop Belawan and Tanjung Perak in the next period. For the condition 3, demand remains stable between two first periods and rising up to about 7.5 million in period 3. The flow pattern that is optimal in this condition is flow pattern B throughout all periods. Therefore, policy decision B is considered to be implemented if the demand growth aligned with the amount of values as just set in condition 3.

Having this approach in shipping network planning will help policymaker to have several predictive pathways based on projected demand that lies under different ranges. As what the model resulted in previous parts, the flow pattern is very sensitive to demand volumes that it tends to change given the demand value and capacity of a port in a particular period. In the real application, it is strongly recommended that policymaker further identifying what triggers likely to happen during certain period that can influence the demand.

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7 VALIDATION AND SENSITIVITY ANALYSIS

7.1 VALIDATION

Mirroring to the current condition of shipping network planning in Indonesia, there are several network masterplans those were regularly announced by the government to be implemented. One of the plans is involving Kuala Tanjung, a greenfield port project in North Sumatra that is planned to become international gateway in Indonesia. Related with that, there is also a network plan that designs Kuala Tanjung and Bitung as the only two international gateways in the country. Therefore, the objective of this validation is to test how well the approach is able to reproduce adaptive policy decision pathways while considering greenfield port project such as Kuala Tanjung. For this validation, we use two cases that are explained below. Moreover, the originated and destined demand used in both cases are based on optimistic scenario from parent scenario.

1. 50:50 case. Kuala Tanjung is functioning as support gateway for Belawan in dealing with limited space to expand capacity in Belawan. Demand estimation: Kuala Tanjung takes 50% of total demand volumes of Belawan.
2. Extreme case. Only Kuala Tanjung and Bitung those are planned to be developed as international container gateways

Before showing the result, some assumptions need to be done first. Kuala Tanjung and Belawan are treated as different gateways though has same pair-province that is North Sumatra. We assume that quality of port infrastructure between Belawan and Kuala Tanjung is not differing. Factors involved in port-related cost and container-related cost of Kuala Tanjung are assumed to be the same as Belawan, such as vessel size, number of cranes, and loading-unloading rate. Moreover, the distance between Belawan and Kuala Tanjung is 49 nm. Capacity of Kuala Tanjung over periods is set as mentioned in Table 37.

Table 37 Capacity assumption for Kuala Tanjung over periods

Port ID	Port names	Location	Island Region	Capacity (TEUs)			
				Base year	2024	2034	2045
48	Kuala Tanjung	Kuala Tanjung, North Sumatra	Sumatra	600,000	600,000	1,200,000	2,500,000

<u>50:50 case – Kuala Tanjung takes 50% of demand volumes of Belawan</u>

After running the MCF model on this new added data, the results show that Kuala Tanjung has higher export throughput than Belawan (see Figure 76). The fact that Kuala Tanjung has closer distance[7] to some transshipment hubs and provincial ports is the reason why Kuala Tanjung has more throughput volumes though both gateways have equal demand originated. The growth of export throughput in Belawan is decreasing from period to period as the capacity of Kuala Tanjung is increased. Moreover, the average percentage of exports being handled in Kuala Tanjung is also higher than in Belawan (Figure 77). Therefore, for this 50:50 event, Tanjung Priok, Tanjung Perak, Kuala Tanjung are likely to become main gateways, while Belawan, Makassar, and Palembang become the feeder gateways.

[7] http://ports.com/sea-route/

Moreover, having Kuala Tanjung in the network also makes the shipping network cost lower than if the network does not have Kuala Tanjung.

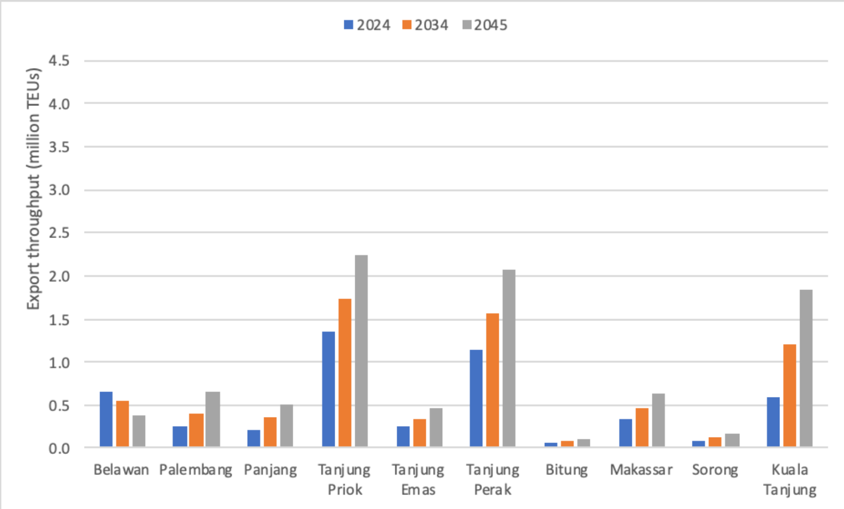

Figure 76 Throughput per gateway over periods – 50:50 case

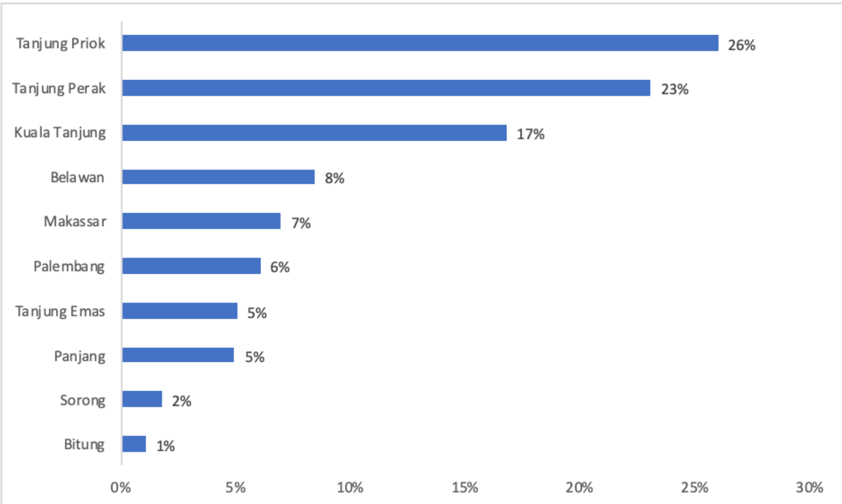

Figure 77 Average percentage of export being handled per gateway – 50:50 case

<u>Extreme case – Kuala Tanjung and Bitung are the only two international gateways</u>

In this case, we assume that Kuala Tanjung and Bitung has big capacity to deal with all export flows transshipped to both gateways from all other provincial ports. The results from MCF model shows that Bitung becomes the main gateway for 15 provincial ports those are located in eastern part of Indonesia and Kuala Tanjung the main gateway for other 16 provincial ports those are located in western part of Indonesia. This flow pattern remains the same for all periods. Moreover, the average cost per TEU over periods resulted from this flow pattern is 22% higher than the original flow pattern resulted in optimistic scenario. For the transshipment arc, Kuala Tanjung is connected with three of four hubs: Singapore, Port Said, and Colombo, meanwhile Bitung only transships export flows to Shanghai. The average percentage of exports being handled in Kuala Tanjung is 67% of total exports and Bitung is 33%. This also leads to the fact that demand originated from provinces in western part of Indonesia is higher than eastern part of Indonesia. The network consists of flow pattern (within Indonesian ports) for this case is illustrated in Figure 78. To this degree of analysis, considering the cost per TEU resulted from the network flow model, this extreme plan for international container gateways is not recommended for the implementation. On the other hand, considering this extreme plan might be potential to significantly promote eastern part of Indonesia. Since the flow pattern shows that Kuala Tanjung be the dedicated gateway for western part and so is Bitung for eastern part of Indonesia. By focusing only on two international container gateways may lead to efficient and effective spending of investment and thus the quality of both gateways become stronger and significantly improved.

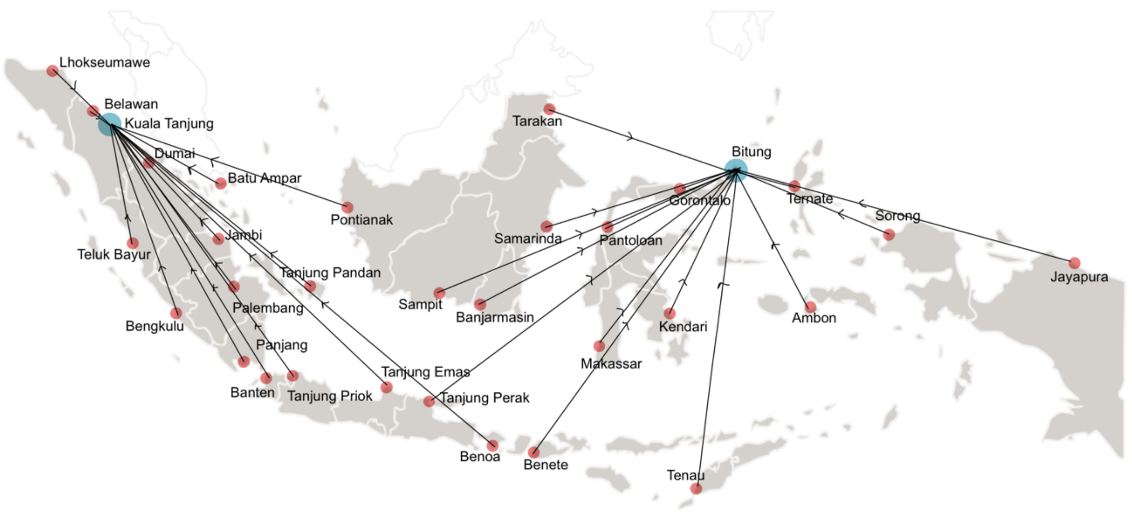

Figure 78 Network with Flow Pattern Extreme Case – (only domestic arcs considered)

7.2 SENSITIVITY ANALYSIS

In this chapter, a sensitivity analysis is reported in order to further understand and test how sensitive the policy decisions resulted with this model towards parameters underlying the model. The parameter analyzed for the sensitivity analysis is related to cost parameter, which is number and type of cranes.

As the main objective of the policy decision is to reduce total shipping network cost, cost parameter then becomes the key parameter in the model. As mentioned in Chapter 5.4, there are two types of costs considered: shipping-related costs and container-related costs with several factors involved. A study published in 2018 about operational system of container loading/unloading in two big ports in Indonesia concluded that handling activities in berth are one of the key process business in the port (Sitorus & Nahry, 2018). These are the activities where containers being loaded/unloaded from vessel to berth and vice versa. In the study, there are two types of quay crane (re: crane) currently used in both ports, Tanjung Priok and Tanjung Perak, namely single-lift crane and twin-lift crane. Twin-lift crane is basically able to handle container two times more than single-lift, or in other words using twin-lift crane 2 TEUs of containers can be handled at one time while only 1 TEU with single-lift.

As shown in Table 21, specifications on container handling such as loading/unloading rate and number of cranes are listed down. We assume that the crane type used in our main calculation of this research is single-lift. For the sensitivity analysis, we define simple scenarios with varying number of cranes and type of cranes which can influence the loading/unloading rate. These scenarios are only applied for Indonesian ports as the focus of this research is Indonesian ports development. Variation number of cranes is set from 0 (initial number of cranes), +1, +2, and +3. In this sensitivity analysis we do not take into account decreasing number of cranes as for some Indonesian ports the initial number of cranes is only 1. Then, we apply the variation number of cranes to three scenarios: (1) all cranes are *single-lift*; (2) all cranes are twin-lift (*all twin-lift*); and (3) only new additional cranes are twin-lift (*new twin-lift*). The sensitivity analysis is done with sampling of demand values from optimistic scenario in period 2.

The results from this sensitivity analysis are illustrated by two figures below. Figure 79 shows the effects of variation of number of additional cranes on shipping network cost per TEU. The horizontal axis represents the increasing number of cranes at Indonesian ports at the same time, and the value of zero denotes that the number of cranes at each Indonesian port takes the initial value of Table 21. The graph tells us that as the number of cranes increased, the cost gets lower. Moreover, change all cranes into twin-lift type makes the cost per TEU the lowest no matter how many additional cranes is. The single-lift and new twin-lift have the same cost per TEU for zero additional crane indeed because in the later scenario twin-lift type of crane is used only for additional cranes.

Related to this result, if number of cranes is increased for all gateways in Indonesia to same degree of improvements this will not change the result of flow pattern because all container-related cost for gateways lowered proportionally. Therefore, this will affect when the improvement applies differently in some gateways.

It is likely for the policymaker to have optimal network by improving the operational cost in the future. Quality of cranes are one of the factors involved in the operational cost of a port and therefore affect the total cost if the cranes are being improved. In the main calculation of this research we set the container-related cost to be fixed throughout period, implies that no improvement in cranes or loading-unloading rate. However, in the real case, the expansion of port capacity tends to be followed by the enhancement of port equipment to avoid the experience of bottlenecking in the terminal.

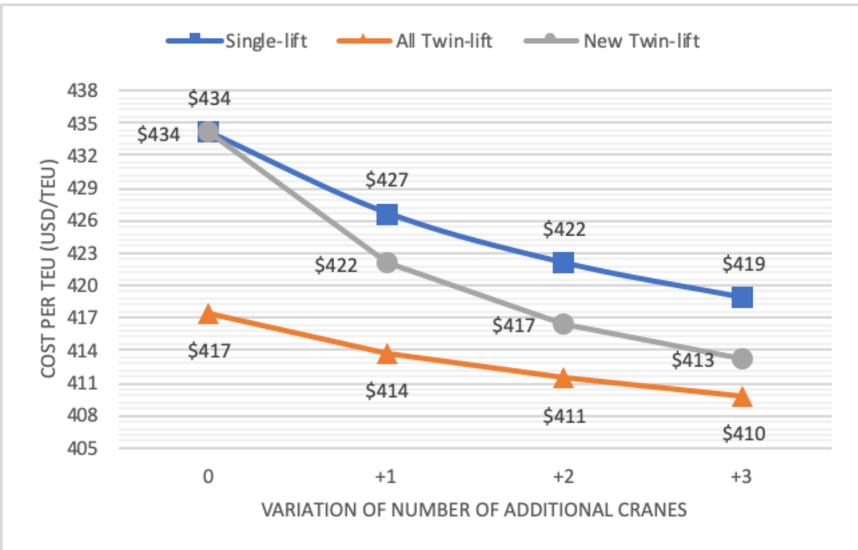

Figure 79 Effects of variation of number of cranes on cost per TEU

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8 CONCLUSION AND RECOMMENDATIONS

The main research question and sub questions are as follows:

How to build adaptive policy decision pathways for shipping network planning in Indonesia that supports robust investment decisions under future uncertainties?

1. *What are the characteristics and stepwise policy analysis of adaptive policy decision pathways for shipping network planning?*
2. *What is the model involved in adaptive policy for shipping network planning and to what extent is the model useful in analyzing the policy based on Indonesian export trade data?*
3. *What is Indonesia's containerized export volume potential under ensembles of scenarios?*
4. *How to map policy pathways and select preferred policy pathways?*
5. *What are the promising policy decisions over ranges of demand and periods?*
6. *How sensitive do the adaptive policy decision pathways perform towards other factors?*

In this final chapter, we answer these research questions, after which we give recommendations for further improvement of the model, future research, policymakers, and data collection.

8.1 CONCLUSION

SUB QUESTION 1

The characteristics of adaptive policy decision pathways for shipping network planning are identified from several aspects such as focus of the approach, planning process, and types of actions that can be taken. The focus of this approach is to explore actions for achieving objectives over time by including dynamic interaction between the network infrastructure and market. The dynamic interaction comes from the difference future scenarios represented by different demand values over specified periods of time. In the planning process, a short stepwise approach consisted of 5 steps for designing adaptive pathways is taken. The steps involved are: (1) describe current, future situations and objectives; (2) problem analysis; (3) network flow model; (4) develop policy decisions; (5) selection of preferred policy decision pathways.

The approach actions used in this research will be mainly based on two key decisions: which ports should be the focus of development based on potential and when should these ports be developed. Therefore, the actions are in the form of development policy options in the preferred pathways. In generating a desirable plan, this approach presents several preferred pathways with focus on how to identify promising pathways as in this case where the model is confronted with a limited number of possible actions. In terms of types of uncertainties, this approach explicitly concentrates on uncertainties in demand values which is the core decision variable in modelling shipping network flow. Other factors related to parameters such as cost and capacity, however, can also be performed to test the desirable policy. The last characteristic is in regard to dynamic robustness of resulting plan. This approach results in clear pathways showing when a policy should be changed and what the next decision should be. The dynamic robustness is produced by involving certain periods as the timeline of policy realization.

SUB QUESTION 2

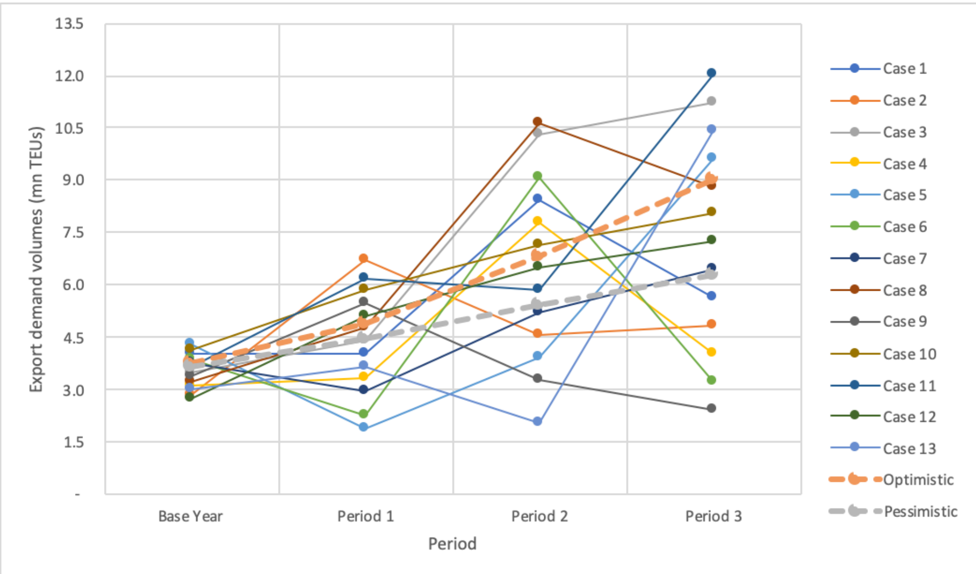
The model involved in building adaptive policy for shipping network planning is Minimum Cost-Flow (MCF) problem. The objective of MCF is to minimize the shipping network cost to meet export demand. All the ports are collectively called nodes of the network and the shipping legs connecting nodes are termed arcs. The arcs are assumed to be directed so that containers can be sent from origins within Indonesia to destinations in other countries but not vice-versa. Here, costs are defined as generalized cost that is calculated by considering two types of costs: shipping-related costs and container-related costs. Shipping-related costs are the costs that depend on the location of the ports as it is calculated with the distance and depend on the vessel size thus it is calculated with container volumes (in TEUs) as well. Meanwhile, container-related costs are the costs that depend on the number of TEUs being handled as it is calculated with the container volumes. Moreover, the main concern of this model is the so-called flow conservation law meaning that the flow out of a node reduced by flow into a node equals net supply or demand at a node.

The model is useful to analyse flow pattern resulted from certain condition that is the input for the model. The policy made for Indonesian export trade aims to focus on development of international container gateways. Given that currently Indonesia has list of ports those are already gateways or planned to be developed as gateways, this model can support the analysis of how the flows go to each of that gateways. Moreover, the flow pattern resulted from this model is satisfying the objective of minimizing shipping network cost, thus the results come from the model are the optimal flow pattern for certain input. From this flow pattern we can see the throughput volumes handled in each gateway, number of provincial ports that tranship their export flows to each gateway, and the growth of throughput over periods once the development of gateway capacity and changes of demand take place. This model is useful to see which gateways are promising to be developed as international container gateways given that through this model, we can also consider worldwide ports (i.e. transhipment hubs and regional ports) as the input to this model. We can analyse the connection of one gateway to another hub or a hub to a regional port.

There are several interesting findings in regard to connection between ports. Flow pattern in relation with Palembang provides interesting insight that this gateway remains having increased throughput over periods even though the yearly demand volume goes fluctuate. Moreover, number of flows originated from a node is also important to determine the function of a port. For example, even though Makassar connects to more provincial ports than Belawan, the fact that Makassar as well as its connected provincial ports generate smaller demand yields to smaller throughput of Makassar compare to Belawan. More to international side, from the MCF model applied in this research, Belawan is the most optimal gateway for exporting containers to Port Said and Colombo. Overall, the model helps us to indicate how the network will look like when certain flow pattern is implemented.

SUB QUESTION 3

The potential container volume of Indonesia for export trade is forecasted by two approaches. First is using demand forecast model and second is by generating random numbers with respect to results from demand forecast model. Note that the research for this forecast model was done jointly with an expert from Port of Rotterdam Authority. The forecast model is done also for the internal objective of the company. Moreover, the random number generation follows the rule of normal distribution. The first approach results in two scenarios: optimistic and pessimistic. Both scenarios are categorized as parent scenarios. Moreover, the second approach results in 13 scenarios, which originally come from 100 cases randomly generated, those are categorized as branch scenarios. Branch scenarios are required for the adaptive policy decision pathways to capture more uncertainties that may happen in the future with regards to export volumes. The branch scenarios are randomly developed based on the forecasted demand in two previous parent scenarios. To generate random numbers those are normally distributed we need two inputs namely mean and standard deviation. The mean is obtained from demand volumes of parent scenarios, while the standard deviation is obtained by firstly determined coefficient of variation (CV) that is set to 30% in this research. Figure below shows the parent scenarios and 13 cases/scenarios of branch scenarios. These scenarios then become the potential demand volumes used further in this research. Note that in forecasting potential demand, we assume three different periods those are Period 1 from 2017-2024, Period 2 from 2025-2034 and Period 3 from 2035-2045. The last year of each period represents the year of analysis of each period.



Sub question 4

To develop policy pathways map, we first need to analyze the optimal flow pattern resulted from MCF model (sub question 2) for each scenario for certain period (sub question 3). The flow pattern is analyzed focus on gateways and assessed from several aspects such as number of provincial ports that transship flows to each gateway, throughput volumes and growth of each gateway as well as percentage of exports handled in each gateway. We analyze flow pattern for each period and certain demand volume based on developed scenarios. Some of scenarios have identical flow pattern in certain period. Therefore, we categorize those identical flow patterns and result in three types of flow pattern.

- Flow pattern A: in average 30% of exports are handled by Tanjung Priok, Belawan and Tanjung Perak are followed in second and third highest percentage of handling exports.

- Flow pattern B: Tanjung Priok, Belawan and Tanjung Perak having similar average percentage in handling exports, yet Belawan has the highest percentage. Smaller number of provincial ports come to Tanjung Priok
- Flow pattern C: No provincial ports come to Tanjung Priok, though it still handles export flows originated from its pair-province (Jakarta and West Java). Palembang shows more significant average percentage of handling exports and provincial ports that are used to transship via Tanjung Priok, shift to Palembang.

Based in these flow patterns, we analyze how each of them being effective in certain period and range of demand. For example, in optimistic scenario period 1, flow pattern A remains effective to be implemented as the model gives results that flow pattern A is the optimal solution under that particular condition. Then, we can build policy pathways map with x-axis represents demand volumes and mapping the flow pattern for each period.

Moreover, to select preferred pathways, we use the approach “What-if Analysis”. Through this approach, we estimate the possibility of future demand volumes based on types of demand growth over periods. Three types of demand growth are increase, decrease or stable. Here, we apply “What-if Analysis” in three different conditions: (1) yearly demand from period 1 to period 3 remains increasing; (2) yearly demand from period 1 to period 2 increases, but then decreases from period 2 to period 3; (3) yearly demand from period 1 to period 2 is stable, but then increases from period 2 to period 3. By applying this approach, we can analyze how the flow pattern changes from period to another period and therefore may lead to different policy decisions. Having this approach in shipping network planning will help policymaker to have several predictive pathways and thus can support policy decision-making. As what the model results, the flow pattern is very sensitive to demand volumes that it tends to change given the demand value and capacity of a port in a particular period.

Sub question 5

The promising policy decisions generated in this research are Policy Decision A, Policy Decision B, and Policy Decision C those are linked to flow pattern explained in previous sub question. Those three policy decisions are as follow:

Policy Decision A

The focus in this policy is the development of Tanjung Priok. Tanjung Priok is developed to cope with big yearly demand volume in the future. In other words, it is developed to be the main international container gateway in the country. Belawan and Tanjung Perak become other main gateways with smaller scale than Tanjung Priok. Moreover, Makassar become feeder gateway. The most optimal condition to implement this policy decision is when the flow pattern A is effective.

Policy Decision B

The focus in this policy is the development of Belawan, Tanjung Priok, and Tanjung Perak as main gateways with relatively same scale in handling the exports. They are developed with similar scale to deal with mid-range of yearly demand volumes. Moreover, Palembang and Makassar become feeder gateways. The most optimal condition to implement this policy decision is when the flow pattern B is effective.

Policy Decision C

The highlight in this policy is the development of Palembang to function as feeder gateway. Palembang is developed to deal with small yearly demand volume in the future that results in more optimal shipping network cost for that range of demand. Tanjung Perak, Belawan, and Tanjung Priok still become the main gateway. The most optimal condition to implement this policy decision is when the flow pattern C is effective.

We can conclude that over three policy decisions, there are **3 main gateways** remain important for the export trade in Indonesia: ***Belawan, Tanjung Priok, and Tanjung Perak***. Moreover, there are 2 gateways those are likely to become **feeder gateways: *Palembang and Makassar***.

SUB QUESTION 6

To answer this sub question, we firstly do validation of the model in two cases. This validation is related to an additional gateway candidate namely Kuala Tanjung, which is currently still a greenfield port project in Indonesia. Related with that, there is also a network plan that designs Kuala Tanjung and Bitung as the only two international gateways in the country. Therefore, the objective of this validation is to test how well the approach is able to reproduce adaptive policy decision pathways while considering greenfield port project such as Kuala Tanjung. For this validation, we use two cases:

1. 50:50 case. Demand estimation: Kuala Tanjung takes 50% of total demand volumes of Belawan.
2. Extreme case. Only Kuala Tanjung and Bitung developed as international container gateways

The first case leads to conclusion that Kuala Tanjung is more optimal to be developed as international container gateways compare to Belawan. Having Kuala Tanjung in the network also makes the shipping network cost lower than if the network does not have Kuala Tanjung. Moreover, the second case leads to conclusion that it is not efficient to invest only on Kuala Tanjung and Bitung as gateways since the shipping cost per TEU for the resulted flow pattern is 22% higher compare to the initial flow pattern under the same scenario.

Furthermore, we perform sensitivity analysis with respect to changes in number and type of cranes. A study done previously on two big ports in Indonesia Tanjung Priok and Tanjung Perak, there are two types of crane (re: crane) currently used in both ports, namely single-lift crane and twin-lift crane. Besides varying the type of crane, we also set variation of number of cranes which is set from 0 (initial number of cranes), +1, +2, and +3. The first finding of this sensitivity analysis is that as the number of cranes increased, the cost gets lower. Moreover, change all cranes into twin-lift type makes the cost per TEU the lowest no matter how many additional cranes is. This will lead to different flow pattern once the improvement of cranes applies differently for some ports/gateways.

MAIN QUESTION

To answer this main question, firstly, general findings are provided. After running several scenarios in the network model, the main finding from the model is that flow pattern is very sensitive to demand volumes. That is why there are some scenarios even in the same range of demand but not exactly have the same demand values, may lead to different flow pattern. Second general finding is that MCF model is able to identify the flow pattern so that is very useful to come up with the first finding. In regard to this, during policy decision-making process it is therefore very important to deal with future uncertainties which considering variation of demand volumes. By applying adaptive policy decisions for shipping network planning, the results show that there could be more than one plausible policy decision for a single period. Given that shipping network planning is future long-term plan with full of uncertainties, using the approach of adaptive policy decision pathways with integration of network flow model is one of the solutions. The key factor in this model is thus demand volumes which results in flow variables for each of ports. Then, these flow variables create a pattern which we can further analyse to identify under which condition the flow pattern is being effective. Since each of flow pattern gives the information about flows in each port and how ports connect to each other, we can determine the promising ports within each flow pattern. Based on this, policy decision pathways are able to be built, thus supports more robust investment planning for ports development in Indonesia under future uncertainties.

8.2 Recommendations

This research is built on several assumptions and simplifications that may lead to imperfect results. However, it does not deny the fact some important insights can still be inferred as a learning points for future research and practices.

Model improvement: Network design/optimization problem

The problem considered in this research for network optimization is the classic Minimum Cost Flow problem for special case transshipment problem. This means that the nodes of hubs and links are pre-determined. Since the model is used the very classic one, nodes and arcs are predetermined, which imply the model used in this research is not yet designing a network. Therefore, it is recommended to taking the model to the higher level of computational model. This network design problem can be further studied by using the network design approach such as Hub-Location problem, P-Hub Problem, etc. This implies that the model is done without any pre-determined hubs locations.

Further research: considering other type of commodities

Export trade analyzed in this research is only for container cargo. In the case of Indonesia, big amount of exports is also from dry bulk cargos. The recommendation for further research therefore to take types of commodities as one additional variable in the shipping network problem, which may result in more detailed policy recommendations. Such as, what types of ports need to be developed in particular areas, how the industrialization could be improved to support the business at that port, or which ports generate more dry bulk and to which destinations the flows go to. This might be potential to have shipping network plan or port development plan which ports are industrially clustered based on the analysis of different types of commodities.

Insights for policymaker: From strategic to tactical and operational level

In regard to the approach used in this research, it is done in strategic level. Therefore, further analysis once the results want to be applied in tactical and operational level are required. In this level of approach, we do not take into consideration how the hinterland connects to each port, how the intermodal accessibility performs between the port and its hinterland, etc. Moreover, in terms of port nodes, we are considering a node as one single port, though in fact each port may consists of several terminals. Further analysis on tactical and operational level, for example taking into account several terminals in a port may lead to different policy decisions. For example, in Tanjung Perak there are several terminals operate for international container flows. To determine and decide terminal should be further developed needs more analysis on the terminal level such as business case, feasibility study of the terminal, hinterland connection of the terminal, etc. Moreover, in the real application, it is also strongly recommended that policymaker further identifying what triggers likely to happen during certain period that can influence the demand. This will improve the level of details of analysis.

Data collection: intermodal transport

In both of the cases of adaptive policy decision-making and shipping network planning, data is key input materials. Availability of data only is not enough to indicate that the analysis is solid. The data must be sufficient enough especially in generating the input of trends and developments. In current data collection, we only consider shipping arcs which connect ports with sea transport mode. However, in a hierarchical network structure which is considered in this research, it might be potential to improve the system to capture multimodal transport. That is due to some results from the model show that there are domestic arcs (from provincial port to gateway) used inefficiently in the network. For example, flows from Teluk Bayur, West Sumatra is more likely to be transferred via road transport to Palembang or Belawan rather than using sea transport. The arcs are used to connect two ports which actually are located in the same island. Therefore, if more detailed data collected, especially in related to hinterland connection, the analysis will be more reliable, and the policy decisions will touch cross-sector recommendations.

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Appendix

A. Indonesian export data by type of commodities and regions of destinations

Data is from 2016-2018 in TEU (Seabury Database) – highlighted rows are the highest volume.

Export volume (TEU)		2016	2017	2018
Capital Equipment & Machinery	Africa	2.130	2.946	3.270
	Asia Pacific	26.062	27.060	27.794
	Europe	7.005	7.222	8.743
	Latin America	1.447	1.662	1.902
	Middle East & South Asia	5.053	6.063	6.198
	North America	2.461	2.871	3.372
	Special Categories & Errors	0	0	0
	All partner countries	44.157	47.823	51.278
Chemicals & Products	Africa	22.678	23.100	22.102
	Asia Pacific	140.118	154.817	161.101
	Europe	19.425	26.666	32.233
	Latin America	6.193	6.141	5.862
	Middle East & South Asia	38.545	39.854	38.644
	North America	7.839	9.465	10.802
	Special Categories & Errors	0	0	0
	All partner countries	234.798	260.044	270.743
Consumer Fashion Goods	Africa	2.905	3.104	2.859
	Asia Pacific	37.263	37.375	39.721
	Europe	36.860	36.190	34.551
	Latin America	5.497	6.444	6.295
	Middle East & South Asia	7.025	6.773	6.773
	North America	95.598	92.202	92.022
	Special Categories & Errors	0	0	0
	All partner countries	185.148	182.089	182.222
Consumer personal & household goods	Africa	7.184	7.422	7.083
	Asia Pacific	113.544	115.479	116.157
	Europe	56.954	56.133	55.142
	Latin America	8.067	9.055	9.795
	Middle East & South Asia	20.201	19.932	19.340
	North America	75.502	77.666	82.198
	Special Categories & Errors	0	0	0
	All partner countries	281.452	285.687	289.714
High Technology	Africa	197	207	184
	Asia Pacific	20.742	17.837	15.444
	Europe	4.924	5.589	5.512
	Latin America	1.186	1.180	1.072
	Middle East & South Asia	1.602	1.664	1.546
	North America	14.110	9.658	6.448
	Special Categories & Errors	0	0	0
	All partner countries	42.761	36.134	30.205

Export volume (TEU)		2016	2017	2018
Land Vehicles & Parts	Africa	2.766	2.963	3.002
	Asia Pacific	159.088	195.825	188.732
	Europe	14.923	16.135	18.209
	Latin America	6.959	9.871	11.146
	Middle East & South Asia	27.345	32.999	26.711
	North America	62.354	63.637	55.226
	Special Categories & Errors	0	0	0
	All partner countries	273.436	321.430	303.027
Live Animals	Africa	0	0	0
	Asia Pacific	7	5	1
	Europe	0	0	0
	Latin America	0	0	0
	Middle East & South Asia	0	1	1
	North America	0	0	0
	Special Categories & Errors	0	0	0
	All partner countries	7	6	3
Machinery parts. Components, supplies & manufactures n.e.s.	Africa	6.750	7.318	8.039
	Asia Pacific	185.222	187.067	163.754
	Europe	13.771	13.713	14.986
	Latin America	4.063	4.273	5.264
	Middle East & South Asia	18.379	21.079	23.767
	North America	17.155	15.982	18.187
	Special Categories & Errors	0	0	0
	All partner countries	245.341	249.432	233.997
Raw Materials, Industrial consumables & Foods	Africa	57.788	67.126	69.167
	Asia Pacific	1.174.500	1.293.229	1.394.698
	Europe	220.836	222.632	188.413
	Latin America	51.755	53.826	59.270
	Middle East & South Asia	319.344	353.629	408.959
	North America	153.035	158.611	167.997
	Special Categories & Errors	1	0	0
	All partner countries	1.977.259	2.149.053	2.288.502
Secure or Special Handling	Africa	823	902	845
	Asia Pacific	5.291	464	918
	Europe	145	134	114
	Latin America	33	34	28
	Middle East & South Asia	170	241	250
	North America	168	220	161
	Special Categories & Errors	0	0	0
	All partner countries	6.631	1.994	2.316

Export volume (TEU)		2016	2017	2018
Temperature or Climate Control	Africa	321	399	435
	Asia Pacific	44.061	44.321	51.284
	Europe	3.676	3.476	3.539
	Latin America	368	487	532
	Middle East & South Asia	1.348	1.196	1.223
	North America	19.423	20.332	22.074
	Special Categories & Errors	0	0	0
	All partner countries	69.197	70.211	79.089
Waste Products	Africa	0	0	0
	Asia Pacific	0	1	7
	Europe	0	0	0
	Latin America	0	0	0
	Middle East & South Asia	0	0	0
	North America	0	0	0
	Special Categories & Errors	0	0	0
	All partner countries	0	1	7
All commodity groups	Africa	103.542	115.489	116.986
	Asia Pacific	1.905.898	2.073.481	2.159.611
	Europe	378.517	387.889	361.442
	Latin America	85.569	92.973	101.166
	Middle East & South Asia	439.014	483.430	533.412
	North America	447.645	450.643	458.486
	Special Categories & Errors	1	0	0
	All partner countries	3.360.186	3.603.905	3.731.102

B. Base year OD Demand Matrix for export flows between Indonesian ports (1-31) and worldwide ports (32-47) in TEUs

Origin\Dest	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	Total
1	-	-	-	-	-	1	0	0	3	148	0	0	402	61	-	-	615
2	4,945	1,361	1,690	8,368	15,156	50,042	16,606	9,638	18,850	61,124	9,109	8,638	58,229	31,550	10,680	10,984	316,971
3	15	-	7	-	8	4,210	322	486	4,103	8,631	3,079	1,349	34,391	8,776	66	1	65,443
4	62	175	630	2,822	5,174	62,462	16,221	14,470	43,696	185,066	7,040	1,966	95,383	75,948	1,173	2,122	514,410
5	187	4	36	15	8	805	603	30	2,169	15,059	895	134	14,311	77,865	59	25	112,204
6	-	0	241	61	218	3,804	3,160	220	4,484	25,075	12	801	38,403	50,989	146	4	127,620
7	-	-	2	0	0	274	-	-	42	488	0	2	1,670	3,548	-	-	6,026
8	9	0	47	1,366	279	15,384	521	789	3,050	56,558	4,093	586	15,460	9,468	1,008	167	108,784
9	-	-	30	-	-	340	3	-	45	2,689	2,449	47	825	4,074	-	-	10,501
10	2	3	29	141	370	3,521	1,009	1,575	2,251	6,261	3,993	74	2,567	139,202	21	146	161,164
11	3,235	1,517	6,837	8,281	2,724	45,673	52,397	6,258	51,621	211,302	52,472	11,951	49,183	263,175	6,382	11,693	784,703
12	408	108	702	3,888	430	15,356	7,845	3,233	13,983	56,976	32,139	4,010	9,462	32,451	475	4,820	186,285
13	1,632	2,344	2,984	16,197	3,317	53,638	31,575	6,685	33,549	262,432	30,188	5,194	88,172	278,589	4,053	22,970	843,517
14	69	14	514	248	367	4,834	3,584	730	4,673	23,264	2,499	641	7,765	32,723	1,915	378	84,218
15	81	10	62	68	12	977	97	13	981	1,353	493	134	148	409	33	114	4,986
16	-	-	0	0	-	0	0	-	2	5,236	0	0	214	1,783	-	0	7,234
17	-	-	-	0	-	0	0	-	0	0	0	0	0	9	0	-	9
18	-	4	0	16	35	756	105	5	284	29,236	1	415	1,946	6,152	3	5	38,961
19	-	61	16	-	13	2,350	4,678	1	1,141	94,501	3	54	43,105	11,363	8	0	157,295
20	0	-	1	-	-	1,702	35	1	26	27,660	21	5	9,282	6,308	0	0	45,039
21	-	0	16	9	0	716	79	0	192	40,337	414	0	18,635	11,495	5	1	71,899
22	-	-	-	-	-	57	0	-	0	5,162	74	-	6,040	1,607	0	-	12,942
23	0	-	1	0	32	3,770	164	104	5,512	8,988	65	512	2,472	1,872	6	3	23,501
24	-	-	0	0	4	7	247	0	8	31,234	4	0	2,347	3,590	1	160	37,603
25	10	-	41	0	29	789	749	31	741	15,399	111	228	4,310	12,675	17	5	35,135
26	0	-	-	0	0	7	-	0	14	2,562	1	-	367	25	0	1	2,975
27	-	-	0	-	-	0	-	-	0	102	-	-	130	220	-	-	453
28	0	-	-	-	-	20	-	0	5	1,769	3	-	11	1,023	-	-	2,831
29	-	-	-	-	-	1	-	0	-	2,276	0	-	1	43	-	-	2,320
30	0	-	2,409	-	-	3	14	-	0	68,753	5	-	-	3,294	-	-	74,478
31	-	-	-	-	-	14	-	-	5	356	1	-	121	60	-	0	557
Total	10,656	5,600	16,293	41,477	28,177	271,511	140,014	44,269	191,429	1,249,998	149,163	36,741	505,351	1,070,347	26,051	53,599	3,840,677

C. Base year OD Demand Matrix for export flows between Indonesian ports (1-31) and worldwide ports (32-47) in kilograms

O\D	32	33	34	35	36	37	38	39	40
1	-	-	-	-	-	535,431.00	123,023.00	26,003.00	1,613,854.00
2	128,501,939.00	35,370,153.00	43,930,993.00	217,470,878.00	393,899,201.00	1,300,521,145.00	431,577,302.00	250,472,628.00	489,877,184.00
3	701,090.00	-	331,356.00	-	351,122.00	193,051,135.00	14,757,216.00	22,265,376.00	188,118,848.00
4	3,252,672.00	9,158,004.00	32,956,347.00	147,608,006.00	270,694,573.00	3,267,696,303.00	848,569,845.00	756,996,553.00	2,285,958,179.00
5	10,709,817.00	215,430.00	2,050,591.00	837,011.00	439,789.00	46,090,685.00	34,524,190.00	1,731,598.00	124,189,385.00
6	-	9,600.00	14,718,572.00	3,733,225.00	13,341,107.00	232,592,702.00	193,230,914.00	13,470,471.00	274,182,830.00
7	-	-	607,040.00	5.00	2.00	82,702,522.00	-	-	12,590,013.00
8	749,038.00	20,982.00	4,007,743.00	117,667,924.00	24,015,778.00	1,325,583,767.00	44,900,665.00	68,019,798.00	262,772,256.00
9	-	-	2,499,840.00	-	-	28,437,170.00	245,063.00	-	3,763,623.00
10	251,213.00	389,005.00	3,426,780.00	16,703,344.00	43,927,891.00	418,262,519.00	119,849,288.00	187,128,704.00	267,435,908.00
11	46,628,713.00	21,860,154.00	98,538,086.00	119,342,680.00	39,266,077.00	658,264,172.00	755,161,551.00	90,190,570.00	743,991,079.00
12	7,658,273.00	2,018,388.00	13,162,500.00	72,916,654.00	8,057,904.00	288,017,349.00	147,146,781.00	60,639,793.00	262,258,585.00
13	23,553,269.00	33,821,137.00	43,057,040.00	233,743,304.00	47,868,566.00	774,075,511.00	455,672,448.00	96,479,242.00	484,160,725.00
14	4,815,752.00	954,511.00	35,997,056.00	17,334,126.00	25,725,750.00	338,538,812.00	250,992,337.00	51,105,963.00	327,265,100.00
15	1,727,050.00	224,065.00	1,328,088.00	1,453,812.00	267,439.00	20,913,131.00	2,082,792.00	268,621.00	21,004,740.00
16	-	-	4.00	4.00	-	42,072.00	554.00	-	197,301.00
17	-	-	-	32.00	-	174,368.00	26,006.00	-	180,622.00
18	-	111,202.00	4.00	458,502.00	989,044.00	21,432,492.00	2,965,781.00	147,011.00	8,058,610.00
19	-	4,500,500.00	1,169,280.00	-	966,949.00	173,595,318.00	345,527,288.00	100,801.00	84,275,956.00
20	138,600.00	-	2,039,615.00	-	-	4,579,720,358.00	93,586,612.00	1,649,814.00	69,475,025.00
21	-	7,279.00	49,936,147.00	30,199,286.00	1,981.00	2,293,171,008.00	252,829,479.00	21,755.00	614,697,411.00
22	-	-	-	-	-	72,376,835.00	210,946.00	-	476,659.00
23	20,000.00	-	23,001.00	5.00	1,315,414.00	154,595,921.00	6,735,243.00	4,256,898.00	226,050,588.00
24	-	-	20,001.00	320.00	395,300.00	617,995.00	23,190,803.00	19,991.00	786,150.00
25	239,946.00	-	978,488.00	2.00	677,284.00	18,690,627.00	17,739,852.00	729,786.00	17,556,492.00
26	20,412.00	-	-	4.00	2.00	402,503.00	-	2.00	827,998.00
27	-	-	2.00	-	-	58.00	-	-	13,736.00
28	15,000.00	-	-	-	-	1,474,453.00	-	19,370.00	367,300.00
29	-	-	-	-	-	10,017.00	-	1.00	-
30	2.00	-	197,549,857.00	-	-	224,844.00	1,165,990.00	-	2.00
31	-	-	-	-	-	38,461,500.00	-	-	12,619,758.00
Grand Total	**228,982,786.00**	**108,660,410.00**	**548,328,431.00**	**979,469,124.00**	**872,201,173.00**	**16,330,272,723.00**	**4,042,811,969.00**	**1,605,740,749.00**	**6,784,765,917.00**

O\D	41	42	43	44	45	46	47	Grand Total
1	73,766,543.00	94,867.00	2.00	199,494,943.00	30,116,474.00	-	-	**305,771,140.00**
2	1,588,550,333.00	236,723,239.00	224,504,534.00	1,513,302,371.00	819,952,838.00	277,570,425.00	285,471,237.00	**8,237,696,400.00**
3	395,730,638.00	141,170,021.00	61,871,334.00	1,576,896,610.00	402,420,317.00	3,005,972.00	31,000.00	**3,000,702,035.00**
4	9,681,671,700.00	368,292,675.00	102,825,871.00	4,989,934,832.00	3,973,172,659.00	61,378,595.00	110,989,922.00	**26,911,156,736.00**
5	862,321,232.00	51,226,316.00	7,652,757.00	819,504,265.00	4,458,704,399.00	3,389,697.00	1,459,139.00	**6,425,046,301.00**
6	1,533,182,145.00	731,361.00	48,988,021.00	2,348,106,192.00	3,117,641,129.00	8,899,674.00	272,434.00	**7,803,100,377.00**
7	147,483,814.00	141,377.00	496,440.00	504,668,361.00	1,072,275,297.00	-	-	**1,820,964,871.00**
8	4,873,471,851.00	352,685,949.00	50,475,405.00	1,332,119,081.00	815,856,434.00	86,870,424.00	14,347,949.00	**9,373,565,044.00**
9	225,231,630.00	205,089,497.00	3,951,200.00	69,080,738.00	341,268,286.00	-	-	**879,567,047.00**
10	743,804,561.00	474,336,550.00	8,810,173.00	304,946,574.00	16,537,043,979.00	2,440,754.00	17,384,363.00	**19,146,141,606.00**
11	3,045,379,368.00	756,256,154.00	172,245,954.00	708,852,636.00	3,792,993,678.00	91,979,715.00	168,522,432.00	**11,309,473,019.00**
12	1,068,640,829.00	602,806,757.00	75,214,880.00	177,464,037.00	608,663,525.00	8,911,096.00	90,399,912.00	**3,493,977,263.00**
13	3,787,306,243.00	435,662,120.00	74,956,366.00	1,272,461,035.00	4,020,483,367.00	58,498,030.00	331,490,578.00	**12,173,288,981.00**
14	1,629,139,277.00	175,033,332.00	44,903,855.00	543,751,574.00	2,291,523,229.00	134,087,013.00	26,462,555.00	**5,897,630,242.00**
15	28,972,809.00	10,550,208.00	2,863,753.00	3,171,706.00	8,765,127.00	713,661.00	2,445,138.00	**106,752,140.00**
16	584,634,386.00	7,032.00	485.00	23,903,544.00	199,060,081.00	-	5.00	**807,845,468.00**
17	3,159,471.00	1,087,889.00	2.00	706,052.00	111,289,856.00	218.00	-	**116,624,516.00**
18	829,299,300.00	18,947.00	11,768,971.00	55,200,803.00	174,516,022.00	86,681.00	131,000.00	**1,105,184,370.00**
19	6,979,407,451.00	207,668.00	3,978,496.00	3,183,489,469.00	839,220,358.00	573,808.00	1.00	**11,617,013,343.00**
20	74,426,887,281.00	56,020,320.00	12,479,961.00	24,975,259,369.00	16,974,110,622.00	1,219,978.00	1.00	**121,192,587,556.00**
21	129,160,657,472.00	1,324,380,819.00	12,549.00	59,671,904,589.00	36,808,445,687.00	14,448,063.00	3,967,640.00	**230,224,681,165.00**
22	6,517,440,653.00	93,416,064.00	-	7,626,174,991.00	2,028,934,046.00	15,141.00	-	**16,339,045,335.00**
23	368,583,016.00	2,665,344.00	21,011,380.00	101,367,890.00	76,782,943.00	253,000.00	143,157.00	**963,803,800.00**
24	2,929,789,581.00	378,682.00	1.00	220,145,812.00	336,713,083.00	120,000.00	15,000,000.00	**3,527,177,719.00**
25	364,699,808.00	2,626,633.00	5,409,938.00	102,064,896.00	300,178,120.00	398,245.00	116,228.00	**832,106,345.00**
26	156,768,020.00	75,716.00	-	22,440,095.00	1,513,455.00	1.00	40,005.00	**182,088,213.00**
27	6,517,808.00	-	-	8,300,000.00	13,999,141.00	-	-	**28,830,745.00**
28	130,634,559.00	194,705.00	-	807,934.00	75,517,809.00	-	-	**209,031,130.00**
29	45,133,700.00	233.00	-	14,013.00	850,406.00	-	-	**46,008,370.00**
30	5,638,224,048.00	379886	-	-	270,149,626.00	-	-	**6,107,694,255.00**
31	986,335,272.00	4,040,488.00	-	336,646,543.00	165,388,426.00	-	2.00	**1,543,491,989.00**
Grand Total	**258,812,824,799.00**	**5,296,300,849.00**	**934,422,328.00**	**112,692,180,955.00**	**100,667,550,419.00**	**754,860,191.00**	**1,068,674,698.00**	**511,728,047,521.00**

D. Calculation of container percentage of export flows for each Indonesian province

SUMATRA

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	All dates
Aceh	C	19.909	2,743%	8.936	0,752%	9.421	3,249%	2,248%	**38.265**
	All modes	725.706		1.188.428		289.985			**2.204.119**
Bengkulu	C	53.068	3,198%	72.488	5,093%	36.331	2,797%	3,696%	**161.887**
	All modes	1.659.333		1.423.289		1.299.130			**4.381.751**
Jambi	C	537.781	12,184%	719.857	20,245%	726.503	26,082%	19,504%	**1.984.141**
	All modes	4.413.702		3.555.742		2.785.406			**10.754.850**
Lampung	C	1.218.830	12,563%	1.314.685	11,610%	1.382.213	14,711%	12,961%	**3.915.729**
	All modes	9.701.792		11.323.908		9.395.705			**30.421.404**
North Sumatra	C	3.608.093	37,620%	5.400.105	47,059%	3.885.425	44,242%	42,974%	**12.893.623**
	All modes	9.590.796		11.475.246		8.782.187			**29.848.229**
Riau	C	5.073.757	19,510%	5.147.185	18,478%	7.064.943	26,058%	21,349%	**17.285.885**
	All modes	26.006.225		27.855.709		27.112.687			**80.974.621**
South Sumatra	C	1.367.877	16,845%	1.555.258	19,173%	1.475.144	18,780%	18,266%	**4.398.279**
	All modes	8.120.260		8.111.796		7.855.018			**24.087.075**
West Sumatra	C	616.078	15,037%	759.482	20,205%	1.387.720	37,830%	24,357%	**2.763.280**
	All modes	4.097.150		3.758.897		3.668.307			**11.524.354**
Bangka Belitung	C	141.839	14,374%	102.366	10,948%	125.291	14,680%	13,334%	**369.496**
	All modes	986.784		935.049		853.467			**2.775.300**
Riau Islands	C	2.322.698	13,072%	1.332.976	7,917%	1.324.183	7,214%	9,401%	**4.979.857**
	All modes	17.767.956		16.837.799		18.355.225			**52.960.980**
Sumatra	**C**	**14.959.929**	**18,009%**	**16.413.338**	**18,982%**	**17.417.175**	**21,664%**	**19,552%**	**48.790.442**
	All modes	**83.069.704**		**86.465.863**		**80.397.116**			**249.932.684**

JAVA

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	All dates
Banten	C	445.496	18,935%	319.984	15,922%	479.242	12,988%	15,948%	**1.244.722**
	All modes	2.352.777		2.009.635		3.689.986			**8.052.398**
Central Java	C	2.004.177	55,499%	2.273.936	54,819%	4.208.065	68,359%	59,559%	**8.486.178**
	All modes	3.611.164		4.148.061		6.155.816			**13.915.040**
East Java	C	6.828.441	58,442%	20.582.129	79,614%	111.675.385	94,109%	77,388%	**139.085.955**
	All modes	11.684.097		25.852.363		118.666.234			**156.202.694**
Jakarta	C	12.087.659	83,644%	12.544.077	84,924%	17.785.278	86,394%	84,988%	**42.417.014**
	All modes	14.451.247		14.770.940		20.586.125			**49.808.312**
West Java	C	38.619	2,392%	112.823	6,247%	294.243	16,050%	8,230%	**445.685**
	All modes	1.614.536		1.805.927		1.833.335			**5.253.798**
Yogyakarta	C	1.743	88,145%	43	100,000%	768	11,656%	66,600%	**2.554**
	All modes	1.978		43		6.587			**8.608**
Java	**C**	**21.406.135**	**63,490%**	**35.832.992**	**73,750%**	**134.442.981**	**89,072%**	**75,437%**	**191.682.108**
	All modes	**33.715.798**		**48.586.968**		**150.938.084**			**233.240.850**

Jakarta & West Java	C	12.126.278	75,479%	12.656.899	76,353%	18.079.521	80,642%	77,491%	**42.862.699**
	All modes	16.065.782		16.576.867		22.419.460			**55.062.110**
Central Java & Yogyakarta	C	2.005.920	55,517%	2.273.979	54,820%	4.208.833	68,299%	59,545%	**8.488.732**
	All modes	3.613.141		4.148.104		6.162.403			**13.923.648**

BALI & NTT

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	All dates
Bali	C	14.476	85,774%	59.228	35,024%	192.143	35,678%	52,159%	**265.847**
	All modes	16.877		169.108		538.543			**724.528**
East Nusa Tenggara	C	32	0,052%	180	0,211%	0	0,000%	0,088%	**212**
	All modes	61.197		85.446		123.236			**269.879**
West Nusa Tenggara	C	30.214	15,969%	40.065	4,921%	72.778	9,114%	10,002%	**143.057**
	All modes	189.204		814.130		798.488			**1.801.822**
Bali & NTT	**C**	**44.722**	**16,732%**	**99.473**	**9,308%**	**264.921**	**18,142%**	**14,727%**	**409.116**
	All modes	**267.278**		**1.068.684**		**1.460.267**			**2.796.229**

KALIMANTAN

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	All dates
West Kalimantan	C	333.377	24,805%	377.238	57,107%	390.641	36,205%	39,372%	**1.101.256**
	All modes	1.344.015		660.576		1.078.975			**3.083.566**
Central Kalimantan	C	245.461	10,477%	367.447	21,805%	219.339	13,083%	15,122%	**832.248**
	All modes	2.342.794		1.685.122		1.676.474			**5.704.389**
South Kalimantan	C	423.974	0,287%	501.278	0,408%	719.800	0,550%	0,415%	**1.645.052**
	All modes	147.615.589		122.939.482		130.823.634			**401.378.705**
East Kalimantan	C	1.164.693	0,347%	1.014.921	0,130%	1.306.485	0,570%	0,349%	**3.486.099**
	All modes	335.997.168		781.120.450		229.291.537			**1.346.409.155**
North Kalimantan	C	61.864	0,080%	93.467	0,390%	367.006	2,184%	0,885%	**522.337**
	All modes	77.485.618		23.947.093		16.806.582			**118.239.293**
Kalimantan	**C**	**2.229.369**	**0,395%**	**2.354.351**	**0,253%**	**3.003.272**	**0,791%**	**0,480%**	**7.586.991**
	All modes	**564.785.184**		**930.352.723**		**379.677.201**			**1.874.815.108**

SULAWESI

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	**All dates**
North Sulawesi	C	264.935	24,046%	251.687	23,403%	324.905	34,251%	27,233%	**841.527**
	All modes	1.101.800		1.075.446		948.611			**3.125.857**
Central Sulawesi	C	33.536	2,408%	190.697	13,813%	623.879	17,890%	11,371%	**848.111**
	All modes	1.392.785		1.380.511		3.487.232			**6.260.528**
West Sulawesi	C	35.827	18,050%	0	0,000%	0	#DIV/0!	#DIV/0!	**35.827**
	All modes	198.490		35.200		0			**233.690**
South Sulawesi	C	350.964	46,998%	353.988	44,288%	552.383	50,185%	47,157%	**1.257.336**
	All modes	746.764		799.279		1.100.691			**2.646.734**
Southeast Sulawesi	C	68.346	2,753%	30.701	37,921%	19.015	14,072%	18,249%	**118.061**
	All modes	2.482.797		80.960		135.122			**2.698.880**
Gorontalo	C	31.933	28,346%	14.384	9,959%	4.063	14,304%	17,536%	**50.380**
	All modes	112.653		144.430		28.407			**285.490**
Sulawesi	**C**	**785.540**	**13,016%**	**841.457**	**23,933%**	**1.524.245**	**26,741%**	**21,230%**	**3.151.242**
	All modes	**6.035.290**		**3.515.826**		**5.700.063**			**15.251.179**
Central Sulawesi & West Sulawesi	C	69.362	4,359%	190.697	13,470%	623.879	17,890%	11,906%	**883.938**
	All modes	1.591.275		1.415.711		3.487.232			**6.494.217**

MALUKU

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	**All dates**
Maluku	C	153.840	42,349%	5.196	2,853%	368	0,181%	15,128%	**159.404**
	All modes	363.267		182.138		203.338			**748.743**
North Maluku	C	14.563	2,106%	20.749	100,000%	25.354	66,876%	56,327%	**60.666**
	All modes	691.469		20.749		37.912			**750.130**
Maluku	**C**	**168.403**	**15,966%**	**25.945**	**12,788%**	**25.722**	**10,662%**	**13,139%**	**220.070**
	All modes	**1.054.736**		**202.887**		**241.250**			**1.498.873**

PAPUA

Ocean weight (metric tons)		2014	%	2015	%	2016	%	Average %	**All dates**
Papua	C	148.662	19,179%	150.816	11,777%	136.621	9,901%	13,619%	**436.099**
	All modes	775.116		1.280.652		1.379.928			**3.435.696**
West Papua	C	63.698	0,234%	26.886	0,396%	36.942	0,580%	0,403%	**127.526**
	All modes	27.229.597		6.796.162		6.374.163			**40.399.922**
Papua	**C**	**212.360**	**0,758%**	**177.702**	**2,200%**	**173.563**	**2,238%**	**1,732%**	**563.625**
	All modes	**28.004.713**		**8.076.814**		**7.754.091**			**43.835.618**

E. Port-level demand originated from Indonesian ports and destined to worldwide ports for parent scenarios: optimistic and pessimistic

Case	Start year period	Lhokseumawe	Belawan	Teluk Bayur	Dumai	Jambi	Palembang	Bengkulu	Panjang	Tanjung Pandan	Batu Ampar	Tanjung Priok	Tanjung Emas	Tanjung Perak	Banten	Benoa	Benete
Optimistic	Base Year	598.96	308,477.41	63,689.09	500,626.97	109,197.49	124,200.24	5,864.57	105,868.69	10,219.77	156,845.62	801,083.83	190,173.42	861,125.58	85,975.78	4,287.05	6,220.89
	Period 1	777.08	400,211.06	82,628.67	649,501.20	141,670.16	161,134.36	7,608.56	137,351.46	13,258.89	203,487.68	1,039,306.59	246,726.35	1,117,203.29	111,542.88	5,561.92	8,070.84
	Period 2	1,077.93	555,155.25	114,618.87	900,959.61	196,518.63	223,518.53	10,554.25	190,527.93	18,392.15	282,269.19	1,441,680.58	342,247.98	1,549,735.47	154,727.39	7,715.25	11,195.51
	Period 3	1,428.00	735,446.22	151,842.23	1,193,553.23	260,339.58	296,107.90	13,981.83	252,403.35	24,365.14	373,938.30	1,909,877.53	453,395.67	2,053,024.07	204,976.31	10,220.83	14,831.34
Pessimistic	Base Year	597.02	307,475.43	63,482.22	499,000.85	108,842.80	123,796.82	5,845.53	105,524.82	10,186.58	156,336.16	754,847.58	179,197.16	811,423.89	81,013.50	4,369.77	6,340.92
	Period 1	724.79	373,279.09	77,068.22	605,793.40	132,136.55	150,290.92	7,096.54	128,108.47	12,366.64	189,794.09	916,394.59	217,547.63	985,078.95	98,351.43	5,304.95	7,697.96
	Period 2	878.20	452,291.49	93,381.34	734,022.36	160,106.04	182,103.17	8,598.67	155,225.34	14,984.30	229,968.02	1,110,368.86	263,596.18	1,193,591.71	119,169.59	6,427.86	9,327.39
	Period 3	1,019.63	525,126.23	108,418.99	852,225.62	185,888.70	211,428.14	9,983.36	180,222.04	17,397.29	267,000.91	1,289,177.06	306,044.38	1,385,801.70	138,360.05	7,462.97	10,829.43

Case	Start year period	Tenau	Pontianak	Sampit	Banjarmasin	Samarinda	Tarakan	Bitung	Pantoloan	Makassar	Kendari	Gorontalo	Ambon	Ternate	Sorong	Jayapura
Optimistic	Base Year	7.87	33,610.51	135,691.85	38,853.61	62,024.31	11,164.30	23,189.22	37,103.06	34,667.89	2,935.69	446.68	2,415.03	1,979.24	62,707.61	468.97
	Period 1	10.21	43,605.46	176,043.29	50,407.72	80,468.83	14,484.29	30,085.13	48,136.61	44,977.28	3,808.70	579.51	3,133.21	2,567.82	81,355.32	608.43
	Period 2	14.16	60,487.58	244,199.53	69,923.38	111,622.83	20,091.98	41,732.78	66,773.00	62,390.51	5,283.26	803.88	4,346.25	3,561.96	112,852.54	843.99
	Period 3	18.76	80,131.39	323,505.23	92,631.55	147,873.21	26,617.00	55,285.82	88,458.04	82,652.31	6,999.03	1,064.94	5,757.72	4,718.74	149,502.28	1,118.08
Pessimistic	Base Year	8.02	34,465.25	139,142.60	39,841.69	63,601.64	11,448.22	22,514.70	36,023.82	33,659.49	2,850.30	433.69	2,459.45	2,015.65	63,793.84	477.10
	Period 1	9.74	41,841.26	168,920.89	48,368.32	77,213.20	13,898.29	27,333.14	43,733.38	40,863.05	3,460.30	526.50	2,985.81	2,447.02	77,446.54	579.20
	Period 2	11.80	50,697.84	204,676.56	58,606.49	93,557.00	16,840.15	33,118.77	52,990.48	49,512.57	4,192.75	637.95	3,617.82	2,964.98	93,839.74	701.80
	Period 3	13.70	58,861.97	237,636.64	68,044.18	108,622.95	19,552.00	38,452.05	61,523.80	57,485.83	4,867.93	740.68	4,200.41	3,442.45	108,951.22	814.81

Case	Start year period	Caribbean	Central Africa	Central America	East Africa	Eurasia	Europe	Mid-East	North Africa	North America	Northeast Asia	Oceania	South America	South Asia	Southeast Asia	Southern Africa	West Africa	Total Flow
Optimistic	Base Year	- 10,616.35	- 5,631.73	- 16,056.28	- 41,719.15	- 27,741.71	- 269,261.98	- 140,272.04	- 43,888.62	- 191,040.05	- 1,211,630.94	- 150,646.70	- 36,738.50	- 490,517.03	- 1,065,949.26	- 25,959.49	- 54,051.40	**3,781,721.23**
	Period 1	- 13,773.39	- 7,306.46	- 20,831.03	- 54,125.40	- 35,991.42	- 349,333.91	- 181,985.52	- 56,940.02	- 247,850.70	- 1,571,940.39	- 195,445.35	- 47,663.63	- 636,384.81	- 1,382,936.53	- 33,679.21	- 70,124.97	**4,906,312.76**
	Period 2	- 19,105.84	- 10,135.21	- 28,895.89	- 75,080.39	- 49,925.72	- 484,580.70	- 252,442.35	- 78,984.71	- 343,807.64	- 2,180,526.86	- 271,113.23	- 66,116.90	- 882,765.13	- 1,918,348.98	- 46,718.32	- 97,274.28	**6,805,822.15**
	Period 3	- 25,310.61	- 13,426.69	- 38,280.05	- 99,463.33	- 66,139.49	- 641,952.05	- 334,424.96	- 104,635.60	- 455,461.83	- 2,888,669.86	- 359,159.35	- 87,588.87	- 1,169,449.96	- 2,541,347.68	- 61,890.46	- 128,864.86	**9,016,065.66**
Pessimistic	Base Year	- 10,285.97	- 5,393.84	- 15,433.09	- 39,994.57	- 27,271.12	- 261,783.51	- 134,605.26	- 42,802.98	- 184,546.05	- 1,181,675.65	- 143,652.59	- 35,402.57	- 482,046.69	- 1,029,302.77	- 25,162.42	- 51,657.41	**3,671,016.49**
	Period 1	- 12,487.30	- 6,548.19	- 18,735.96	- 48,553.92	- 33,107.49	- 317,808.52	- 163,412.51	- 51,963.36	- 224,041.26	- 1,434,569.31	- 174,396.07	- 42,979.17	- 585,210.82	- 1,249,586.69	- 30,547.50	- 62,712.76	**4,456,660.84**
	Period 2	- 15,130.50	- 7,934.26	- 22,701.83	- 58,831.38	- 40,115.39	- 385,079.41	- 198,002.21	- 62,962.50	- 271,464.32	- 1,738,226.20	- 211,310.68	- 52,076.61	- 709,083.05	- 1,514,088.11	- 37,013.53	- 75,987.24	**5,400,007.23**
	Period 3	- 17,567.04	- 9,211.95	- 26,357.61	- 68,305.29	- 46,575.37	- 447,090.65	- 229,887.49	- 73,101.67	- 315,179.57	- 2,018,141.38	- 245,339.09	- 60,462.77	- 823,270.21	- 1,757,909.22	- 42,974.00	- 88,223.84	**6,269,597.15**

*Negative value represents amount of demand that is destined to a port.

F. Port-level demand originated from Indonesian ports and destined to worldwide ports for branch scenarios: Scenario/Case 1 - 13

Case	Start year period	Lhokseumawe	Belawan	Teluk Bayur	Dumai	Jambi	Palembang	Bengkulu	Panjang	Tanjung Pandan	Batu Ampar	Tanjung Priok	Tanjung Emas	Tanjung Perak	Banten	Benoa	Benete
Case 1	Base Year	643.92	331,631.48	68,469.54	538,203.63	117,393.77	133,522.62	6,304.76	113,815.12	10,986.86	168,618.33	820,997.72	194,900.88	882,532.02	88,113.02	5,216.14	7,569.08
	Period 1	646.20	332,803.28	68,711.47	540,105.34	117,808.57	133,994.41	6,327.04	114,217.27	11,025.68	169,214.13	823,898.66	195,589.55	885,650.39	88,424.36	5,234.57	7,595.82
	Period 2	1,348.95	694,736.77	143,437.25	1,127,485.99	245,928.90	279,717.32	13,207.89	238,431.96	23,016.44	353,239.54	1,719,912.99	408,299.01	1,848,821.57	184,588.50	10,927.31	15,856.51
	Period 3	901.95	464,520.07	95,906.08	753,868.08	164,434.81	187,026.68	8,831.16	159,422.15	15,389.43	236,185.65	1,149,981.03	272,999.92	1,236,172.84	123,420.93	7,306.30	10,602.10
Case 2	Base Year	456.43	235,071.56	48,533.51	381,496.85	83,212.65	94,645.32	4,469.03	80,675.98	7,787.86	119,522.35	581,950.81	138,152.30	625,568.40	62,457.48	3,697.37	5,365.22
	Period 1	1,078.86	555,633.88	114,717.69	901,736.39	196,688.06	223,711.24	10,563.35	190,692.19	18,408.00	282,512.55	1,375,545.36	326,547.80	1,478,643.37	147,629.47	8,739.40	12,681.66
	Period 2	733.61	377,822.13	78,006.19	613,166.28	133,744.73	152,120.05	7,182.91	129,667.63	12,517.15	192,104.01	935,348.79	222,047.27	1,005,453.78	100,385.68	5,942.65	8,623.32
	Period 3	773.75	398,496.19	82,274.61	646,718.14	141,063.11	160,443.91	7,575.95	136,762.92	13,202.07	202,615.75	986,530.15	234,197.47	1,060,471.22	105,878.68	6,267.83	9,095.18
Case 3	Base Year	560.59	288,715.96	59,609.08	468,556.17	102,202.16	116,243.82	5,488.88	99,086.61	9,565.08	146,797.89	714,754.65	169,679.29	768,325.96	76,710.56	4,541.13	6,589.58
	Period 1	703.89	362,514.03	74,845.63	588,322.81	128,325.84	145,956.65	6,891.88	124,413.93	12,009.99	184,320.59	897,451.55	213,050.65	964,716.12	96,318.38	5,701.88	8,273.93
	Period 2	1,656.63	853,194.08	176,152.78	1,384,645.84	302,020.98	343,515.95	16,220.38	292,814.13	28,266.09	433,807.30	2,112,195.09	501,424.87	2,270,505.47	226,689.91	13,419.64	19,473.10
	Period 3	1,799.33	926,687.24	191,326.37	1,503,917.65	328,036.73	373,106.02	17,617.58	318,036.80	30,700.90	471,174.97	2,294,137.15	544,617.04	2,466,084.20	246,216.72	14,575.59	21,150.49
Case 4	Base Year	498.10	256,529.32	52,963.74	416,320.58	90,808.46	103,284.72	4,876.97	88,040.24	8,498.75	130,432.56	635,072.34	150,763.10	682,671.42	68,158.71	4,034.88	5,854.96
	Period 1	530.82	273,381.79	56,443.15	443,670.40	96,774.04	110,069.92	5,197.36	93,823.96	9,057.07	139,001.22	676,792.87	160,667.35	727,518.93	72,636.34	4,299.94	6,239.60
	Period 2	1,246.40	641,917.66	132,532.07	1,041,766.04	227,231.54	258,451.11	12,203.73	220,304.57	21,266.56	326,383.62	1,589,152.29	377,257.05	1,708,260.27	170,554.69	10,096.54	14,650.98
	Period 3	645.55	332,472.30	68,643.14	539,568.20	117,691.41	133,861.15	6,320.75	114,103.68	11,014.72	169,045.84	823,079.28	195,395.03	884,769.59	88,336.43	5,229.36	7,588.27
Case 5	Base Year	685.59	353,089.24	72,899.77	573,027.36	124,989.57	142,162.01	6,712.71	121,179.37	11,697.75	179,528.55	874,119.25	207,511.67	939,635.05	93,814.26	5,553.64	8,058.83
	Period 1	300.06	154,538.80	31,906.50	250,800.51	54,704.97	62,220.95	2,937.99	53,037.34	5,119.83	78,575.39	382,581.29	90,822.94	411,256.01	41,060.28	2,430.70	3,527.16
	Period 2	631.05	325,003.03	67,101.01	527,446.33	115,047.37	130,853.84	6,178.75	111,540.25	10,767.26	165,248.08	804,588.09	191,005.31	864,892.48	86,351.87	5,111.88	7,417.79
	Period 3	1,542.93	794,639.48	164,063.43	1,289,617.77	281,293.32	319,940.50	15,107.17	272,718.33	26,326.20	404,035.16	1,967,235.40	467,012.15	2,114,680.96	211,132.21	12,498.65	18,136.66
Case 6	Base Year	623.09	320,902.60	66,254.43	520,791.77	113,595.87	129,202.92	6,100.79	110,132.99	10,631.42	163,163.22	794,436.95	188,595.48	853,980.51	85,262.41	5,047.38	7,324.20
	Period 1	357.75	184,249.55	38,040.66	299,017.98	65,222.24	74,183.19	3,502.83	63,234.00	6,104.14	93,681.85	456,134.19	108,284.04	490,321.74	48,954.29	2,898.01	4,205.27
	Period 2	1,451.51	747,555.87	154,342.42	1,213,205.94	264,626.26	300,983.53	14,212.05	256,559.35	24,766.33	380,095.46	1,850,673.69	439,340.96	1,989,382.87	198,622.30	11,758.09	17,062.04
	Period 3	517.36	266,448.42	55,011.67	432,418.26	94,319.71	107,278.39	5,065.55	91,444.45	8,827.37	135,475.94	659,628.40	156,592.58	709,067.97	70,794.17	4,190.89	6,081.36
Case 7	Base Year	602.26	310,173.72	64,039.31	503,379.90	109,797.96	124,883.22	5,896.82	106,450.86	10,275.97	157,708.11	767,876.18	182,290.08	825,428.99	82,411.79	4,878.63	7,079.33
	Period 1	473.13	243,671.04	50,308.99	395,452.92	86,256.77	98,107.68	4,632.52	83,627.31	8,072.76	123,894.76	603,239.98	143,206.25	648,453.20	64,742.32	3,832.63	5,561.49
	Period 2	836.17	430,641.24	88,911.36	698,886.24	152,442.09	173,386.27	8,187.07	147,795.02	14,267.03	218,959.93	1,066,109.49	253,089.22	1,146,015.08	114,419.48	6,773.43	9,828.85
	Period 3	1,030.15	530,543.95	109,537.55	861,018.01	187,806.51	213,609.44	10,086.36	182,081.39	17,576.78	269,755.55	1,313,431.90	311,802.37	1,411,874.46	140,963.19	8,344.77	12,109.01
Case 8	Base Year	518.93	267,258.20	55,178.86	433,732.44	94,606.36	107,604.42	5,080.94	91,722.36	8,854.19	135,887.67	661,633.11	157,068.49	711,222.94	71,009.33	4,203.63	6,099.84
	Period 1	761.57	392,224.78	80,979.80	636,540.29	138,843.10	157,918.90	7,456.73	134,610.59	12,994.30	199,427.04	971,004.45	230,511.75	1,043,781.85	104,212.39	6,169.19	8,952.05
	Period 2	1,707.91	879,603.64	181,605.37	1,427,505.82	311,369.67	354,149.06	16,722.46	301,877.82	29,141.04	447,235.27	2,177,575.44	516,945.85	2,340,786.12	233,706.81	13,835.03	20,075.86
	Period 3	1,414.74	728,615.59	150,431.96	1,182,467.83	257,921.62	293,357.73	13,851.97	250,059.09	24,138.84	370,465.26	1,803,784.53	428,209.70	1,938,979.33	193,589.95	11,460.18	16,629.75
Case 9	Base Year	539.76	277,987.08	57,393.97	451,144.31	98,404.26	111,924.12	5,284.91	95,404.49	9,209.64	141,342.78	688,193.88	163,373.89	739,774.45	73,859.94	4,372.38	6,344.71
	Period 1	876.95	451,646.27	93,248.12	732,975.23	159,877.63	181,843.38	8,586.41	155,003.90	14,962.92	229,639.95	1,118,110.23	265,433.95	1,201,913.31	120,000.42	7,103.81	10,308.27
	Period 2	528.49	272,183.92	56,195.83	441,726.38	96,350.01	109,587.63	5,174.59	93,412.86	9,017.38	138,392.16	673,827.39	159,963.36	724,331.18	72,318.07	4,281.10	6,212.26
	Period 3	389.16	200,424.54	41,380.20	325,268.32	70,948.00	80,695.62	3,810.34	68,785.21	6,640.01	101,906.04	496,177.53	117,790.14	533,366.35	53,251.92	3,152.42	4,574.44
Case 10	Base Year	664.75	342,360.36	70,684.65	555,615.50	121,191.67	137,842.31	6,508.74	117,497.24	11,342.31	174,073.44	847,558.48	201,206.27	911,083.53	90,963.64	5,384.89	7,813.95
	Period 1	934.64	481,357.02	99,382.28	781,192.70	170,394.90	193,805.63	9,151.25	165,200.55	15,947.23	244,746.41	1,191,663.13	282,895.05	1,280,979.04	127,894.44	7,571.12	10,986.38
	Period 2	1,143.84	589,098.55	121,626.89	956,046.09	208,534.18	237,184.90	11,199.56	202,177.19	19,516.68	299,527.69	1,458,391.59	346,215.09	1,567,698.97	156,520.89	9,265.76	13,445.45
	Period 3	1,286.54	662,591.71	136,800.49	1,075,317.89	234,549.92	266,774.97	12,596.77	227,399.86	21,951.49	336,895.36	1,640,333.65	389,407.26	1,763,277.71	176,047.70	10,421.71	15,122.84
Case 11	Base Year	581.43	299,444.84	61,824.20	485,968.04	106,000.06	120,563.52	5,692.85	102,768.74	9,920.53	152,253.00	741,315.41	175,984.68	796,877.48	79,561.17	4,709.88	6,834.46
	Period 1	992.33	511,067.76	105,516.44	829,410.18	180,912.17	205,767.87	9,716.09	175,397.21	16,931.54	259,852.87	1,265,216.02	300,356.15	1,360,044.77	135,788.45	8,038.44	11,664.49
	Period 2	938.72	483,460.34	99,816.54	784,606.19	171,139.45	194,652.48	9,191.24	165,922.41	16,016.91	245,815.85	1,196,870.19	284,131.18	1,286,576.38	128,453.28	7,604.21	11,034.38
	Period 3	1,927.53	992,711.12	204,957.85	1,611,067.59	351,408.43	399,688.79	18,872.79	340,696.03	32,888.26	504,744.87	2,457,588.03	583,419.48	2,641,785.82	263,758.97	15,614.06	22,657.40
Case 12	Base Year	435.60	224,342.68	46,318.40	364,084.98	79,414.75	90,325.62	4,265.06	76,993.86	7,432.41	114,067.24	555,390.04	131,846.90	597,016.88	59,606.86	3,528.62	5,120.34
	Period 1	819.26	421,935.52	87,113.96	684,757.76	149,360.37	169,881.14	8,021.57	144,807.24	13,978.61	214,533.50	1,044,557.34	247,972.85	1,122,847.58	112,106.41	6,636.50	9,630.16
	Period 2	1,041.28	536,279.45	110,721.72	870,326.14	189,836.82	215,918.69	10,195.40	184,049.80	17,766.80	272,671.77	1,327,630.89	315,173.14	1,427,137.68	142,487.09	8,434.98	12,239.91
	Period 3	1,158.34	596,567.83	123,169.02	968,167.95	211,178.22	240,192.21	11,341.56	204,740.62	19,764.13	303,325.45	1,476,882.78	350,604.81	1,587,576.09	158,505.44	9,383.24	13,615.92
Case 13	Base Year	477.27	245,800.44	50,748.63	398,908.71	87,010.55	98,965.02	4,673.00	84,358.11	8,143.30	124,977.45	608,511.58	144,457.70	654,119.91	65,308.09	3,866.12	5,610.09
	Period 1	588.51	303,092.53	62,577.31	491,887.87	107,291.30	122,032.17	5,762.20	104,020.62	10,041.38	154,107.67	750,345.76	178,128.45	806,584.66	80,530.35	4,767.25	6,917.71
	Period 2	323.38	166,545.71	34,385.48	270,286.48	58,955.28	67,055.21	3,166.26	57,158.08	5,517.62	84,680.32	412,305.99	97,879.44	443,208.59	44,250.46	2,619.55	3,801.20
	Period 3	1,671.13	860,663.36	177,694.90	1,396,767.71	304,665.02	346,523.26	16,362.38	295,377.56	28,513.55	437,605.06	2,130,686.28	505,814.59	2,290,382.58	228,674.46	13,537.12	19,643.58

Case	Start year period	Tenau	Pontianak	Sampit	Banjarmasin	Samarinda	Tarakan	Bitung	Pantoloan	Makassar	Kendari	Gorontalo	Ambon	Ternate	Sorong	Jayapura
Case 1	Base Year	9.58	40,763.58	164,570.09	47,122.52	75,224.46	13,540.31	24,588.52	39,341.95	36,759.84	3,112.84	473.64	2,962.29	2,427.74	77,922.54	582.76
	Period 1	9.61	40,907.61	165,151.58	47,289.02	75,490.26	13,588.16	24,675.40	39,480.96	36,889.73	3,123.84	475.31	2,972.76	2,436.32	78,197.88	584.82
	Period 2	20.06	85,395.86	344,758.85	98,717.25	157,588.18	28,365.69	51,510.63	82,417.69	77,008.40	6,521.11	992.22	6,205.72	5,085.90	163,240.40	1,220.83
	Period 3	13.41	57,098.01	230,515.23	66,005.06	105,367.78	18,966.08	34,441.42	55,106.73	51,489.93	4,360.19	663.43	4,149.31	3,400.57	109,147.01	816.28
Case 2	Base Year	6.79	28,894.59	116,652.81	33,402.03	53,321.63	9,597.83	17,429.17	27,886.90	26,056.61	2,206.49	335.73	2,099.77	1,720.87	55,234.12	413.08
	Period 1	16.04	68,297.57	275,729.90	78,951.70	126,035.26	22,686.20	41,196.97	65,915.70	61,589.48	5,215.42	793.55	4,963.19	4,067.58	130,555.78	976.39
	Period 2	10.91	46,441.25	187,491.91	53,685.89	85,701.96	15,426.25	28,013.28	44,821.62	41,879.86	3,546.40	539.60	3,374.89	2,765.89	88,775.83	663.93
	Period 3	11.51	48,982.47	197,751.28	56,623.53	90,391.48	16,270.36	29,546.14	47,274.21	44,171.48	3,740.46	569.13	3,559.56	2,917.23	93,633.56	700.26
Case 3	Base Year	8.34	35,488.47	143,273.52	41,024.52	65,489.87	11,788.10	21,406.58	34,250.82	32,002.85	2,710.02	412.34	2,578.95	2,113.58	67,838.80	507.35
	Period 1	10.47	44,559.61	179,895.36	51,510.71	82,229.60	14,801.23	26,878.28	43,005.60	40,183.03	3,402.72	517.74	3,238.15	2,653.82	85,178.93	637.03
	Period 2	24.64	104,873.16	423,392.32	121,232.93	193,531.28	34,835.40	63,259.31	101,215.72	94,572.67	8,008.46	1,218.53	7,621.14	6,245.90	200,472.68	1,499.28
	Period 3	26.76	113,906.81	459,862.85	131,675.79	210,201.85	37,836.09	68,708.39	109,934.33	102,719.05	8,698.29	1,323.49	8,277.61	6,783.91	217,741.17	1,628.42
Case 4	Base Year	7.41	31,532.15	127,301.10	36,451.03	58,188.93	10,473.94	19,020.14	30,432.47	28,435.10	2,407.90	366.37	2,291.44	1,877.95	60,275.99	450.79
	Period 1	7.89	33,603.62	135,664.03	38,845.64	62,011.60	11,162.01	20,269.65	32,431.70	30,303.12	2,566.08	390.44	2,441.98	2,001.32	64,235.77	480.40
	Period 2	18.54	78,903.42	318,547.69	91,212.02	145,607.14	26,209.11	47,594.41	76,151.68	71,153.64	6,025.32	916.78	5,733.91	4,699.23	150,829.64	1,128.01
	Period 3	9.60	40,866.93	164,987.34	47,241.99	75,415.19	13,574.65	24,650.86	39,441.70	36,853.04	3,120.73	474.84	2,969.80	2,433.90	78,120.11	584.24
Case 5	Base Year	10.20	43,401.13	175,218.37	50,171.52	80,091.76	14,416.42	26,179.48	41,887.52	39,138.33	3,314.25	504.28	3,153.96	2,584.83	82,964.42	620.47
	Period 1	4.46	18,995.65	76,688.93	21,958.89	35,054.27	6,309.73	11,458.14	18,333.18	17,129.92	1,450.57	220.71	1,380.41	1,131.32	36,311.56	271.56
	Period 2	9.38	39,948.82	161,280.75	46,180.66	73,720.92	13,269.68	24,097.06	38,555.61	36,025.10	3,050.62	464.17	2,903.08	2,379.22	76,365.07	571.11
	Period 3	22.95	97,675.73	394,334.96	112,912.72	180,249.26	32,444.65	58,917.83	94,269.30	88,082.16	7,458.84	1,134.90	7,098.10	5,817.24	186,714.27	1,396.38
Case 6	Base Year	9.27	39,444.80	159,245.94	45,598.02	72,790.82	13,102.26	23,793.03	38,069.17	35,570.59	3,012.13	458.31	2,866.45	2,349.20	75,401.61	563.91
	Period 1	5.32	22,647.64	91,432.71	26,180.58	41,793.60	7,522.80	13,661.02	21,857.81	20,423.22	1,729.45	263.14	1,645.80	1,348.82	43,292.61	323.77
	Period 2	21.59	91,888.29	370,970.01	106,222.47	169,569.21	30,522.26	55,426.86	88,683.70	82,863.16	7,016.89	1,067.66	6,677.53	5,472.56	175,651.16	1,313.64
	Period 3	7.69	32,751.39	132,223.39	37,860.46	60,438.89	10,878.93	19,755.58	31,609.19	29,534.59	2,501.00	380.54	2,380.04	1,950.56	62,606.66	468.22
Case 7	Base Year	8.96	38,126.02	153,921.80	44,073.52	70,357.17	12,664.21	22,997.55	36,796.39	34,381.34	2,911.43	442.99	2,770.62	2,270.66	72,880.67	545.05
	Period 1	7.04	29,951.63	120,920.26	34,623.95	55,272.27	9,948.94	18,066.77	28,907.07	27,009.82	2,287.20	348.01	2,176.59	1,783.82	57,254.72	428.19
	Period 2	12.44	52,933.69	213,703.07	61,191.12	97,682.99	17,582.82	31,929.51	51,087.63	47,734.62	4,042.19	615.04	3,846.69	3,152.56	101,186.59	756.75
	Period 3	15.32	65,213.56	263,279.17	75,386.59	120,344.07	21,661.79	39,336.70	62,939.24	58,808.38	4,979.92	757.72	4,739.07	3,883.90	124,660.46	932.30
Case 8	Base Year	7.72	32,850.92	132,625.24	37,975.53	60,622.58	10,911.99	19,815.62	31,705.25	29,624.35	2,508.60	381.70	2,387.28	1,956.49	62,796.93	469.64
	Period 1	11.33	48,211.60	194,639.13	55,732.40	88,968.93	16,014.30	29,081.15	46,530.23	43,476.33	3,681.59	560.17	3,503.54	2,871.32	92,159.98	689.24
	Period 2	25.40	108,119.38	436,497.90	124,985.54	199,521.80	35,913.69	65,217.42	104,348.73	97,500.05	8,256.35	1,256.25	7,857.04	6,439.23	206,678.06	1,545.69
	Period 3	21.04	89,560.19	361,571.01	103,531.19	165,272.96	29,748.94	54,022.55	86,436.79	80,763.71	6,839.11	1,040.61	6,508.34	5,333.91	171,200.82	1,280.36
Case 9	Base Year	8.03	34,169.70	137,949.38	39,500.02	63,056.22	11,350.05	20,611.10	32,978.03	30,813.60	2,609.31	397.02	2,483.11	2,035.03	65,317.86	488.49
	Period 1	13.04	55,515.59	224,126.69	64,175.78	102,447.60	18,440.45	33,486.91	53,579.49	50,062.93	4,239.35	645.04	4,034.32	3,306.33	106,122.09	793.66
	Period 2	7.86	33,456.38	135,069.60	38,675.44	61,739.88	11,113.11	20,180.83	32,289.60	30,170.35	2,554.84	388.73	2,431.28	1,992.55	63,954.31	478.30
	Period 3	5.79	24,635.84	99,459.45	28,478.93	45,462.60	8,183.21	14,860.30	23,776.67	22,216.15	1,881.27	286.25	1,790.29	1,467.23	47,093.21	352.20
Case 10	Base Year	9.89	42,082.35	169,894.23	48,647.02	77,658.11	13,978.37	25,384.00	40,614.74	37,949.08	3,213.55	488.96	3,058.13	2,506.29	80,443.48	601.61
	Period 1	13.90	59,167.58	238,870.46	68,397.47	109,186.93	19,653.52	35,689.78	57,104.12	53,356.23	4,518.23	687.47	4,299.71	3,523.83	113,103.14	845.87
	Period 2	17.01	72,410.99	292,336.54	83,706.79	133,626.10	24,052.54	43,678.18	69,885.67	65,298.89	5,529.54	841.35	5,262.11	4,312.56	138,418.88	1,035.19
	Period 3	19.13	81,444.64	328,807.07	94,149.66	150,296.67	27,053.22	49,127.27	78,604.27	73,445.27	6,219.38	946.31	5,918.58	4,850.57	155,687.36	1,164.34
Case 11	Base Year	8.65	36,807.25	148,597.66	42,549.02	67,923.52	12,226.15	22,202.07	35,523.60	33,192.09	2,810.72	427.67	2,674.78	2,192.12	70,359.74	526.20
	Period 1	14.76	62,819.58	253,614.24	72,619.16	115,926.26	20,866.59	37,892.66	60,628.75	56,649.53	4,797.11	729.91	4,565.10	3,741.33	120,084.20	898.07
	Period 2	13.96	59,426.12	239,914.22	68,696.34	109,664.03	19,739.40	35,845.73	57,353.64	53,589.37	4,537.97	690.48	4,318.50	3,539.22	113,597.36	849.56
	Period 3	28.67	122,022.36	492,626.79	141,057.32	225,178.14	40,531.80	73,603.67	117,766.85	110,037.50	9,318.02	1,417.79	8,867.37	7,267.25	233,254.62	1,744.44
Case 12	Base Year	6.48	27,575.82	111,328.67	31,877.53	50,887.98	9,159.78	16,633.69	26,614.12	24,867.36	2,105.78	320.41	2,003.94	1,642.32	52,713.19	394.23
	Period 1	12.18	51,863.59	209,382.91	59,954.09	95,708.26	17,227.37	31,284.03	50,054.86	46,769.63	3,960.47	602.61	3,768.93	3,088.82	99,141.04	741.45
	Period 2	15.49	65,918.55	266,125.38	76,201.57	121,645.07	21,895.97	39,761.96	63,619.65	59,444.13	5,033.75	765.91	4,790.30	3,925.89	126,008.12	942.38
	Period 3	17.23	73,329.10	296,043.12	84,768.13	135,320.37	24,357.51	44,231.98	70,771.76	66,126.82	5,599.65	852.02	5,328.83	4,367.24	140,173.91	1,048.32
Case 13	Base Year	7.10	30,213.37	121,976.96	34,926.53	55,755.28	10,035.88	18,224.65	29,159.68	27,245.86	2,307.19	351.05	2,195.61	1,799.41	57,755.06	431.93
	Period 1	8.75	37,255.62	150,407.81	43,067.33	68,750.93	12,375.09	22,472.52	35,956.33	33,596.42	2,844.96	432.88	2,707.37	2,218.82	71,216.82	532.61
	Period 2	4.81	20,471.51	82,647.28	23,664.98	37,777.81	6,799.96	12,348.38	19,757.57	18,460.83	1,563.27	237.86	1,487.67	1,219.22	39,132.79	292.66
	Period 3	24.85	105,791.27	427,098.90	122,294.26	195,225.55	35,140.37	63,813.11	102,101.82	95,400.61	8,078.57	1,229.20	7,687.86	6,300.58	202,227.72	1,512.40

Case	Start year period	Caribbean	Central Africa	Central America	East Africa	Eurasia	Europe	Mid-East	North Africa	North America	Northeast Asia	Oceania	South America	South Asia	Southeast Asia	Southern Africa	West Africa	Total Flow
Case 1	Base Year	-11,149.01	-5,859.37	-17,046.51	-43,395.53	-29,479.81	-284,069.26	-146,490.58	-46,316.92	-200,283.61	-1,307,814.16	-156,062.16	-38,440.82	-528,725.31	-1,119,854.38	-27,256.30	-56,077.83	**4,018,321.54**
	Period 1	-11,188.40	-5,880.08	-17,106.74	-43,548.86	-29,583.97	-285,073.00	-147,008.20	-46,480.57	-200,991.30	-1,312,435.23	-156,613.59	-38,576.65	-530,593.53	-1,123,811.31	-27,352.61	-56,275.98	**4,032,520.02**
	Period 2	-23,356.12	-12,274.84	-35,710.83	-90,909.55	-61,757.43	-595,098.38	-306,883.99	-97,029.58	-419,575.33	-2,739,747.65	-326,935.54	-80,529.90	-1,107,629.79	-2,345,989.59	-57,099.38	-117,477.78	**8,418,005.67**
	Period 3	-15,616.54	-8,207.29	-23,877.24	-60,784.62	-41,292.71	-397,899.11	-205,191.06	-64,876.64	-280,539.58	-1,831,870.47	-218,598.08	-53,844.50	-740,591.68	-1,568,593.02	-38,178.21	-78,548.87	**5,628,509.61**
Case 2	Base Year	-7,902.79	-4,153.32	-12,083.14	-30,760.21	-20,896.28	-201,357.85	-103,837.45	-32,830.99	-141,967.76	-927,022.69	-110,622.11	-27,248.15	-374,778.29	-793,790.47	-19,320.18	-39,749.85	**2,848,321.54**
	Period 1	-18,679.67	-9,817.12	-28,560.67	-72,707.29	-49,392.12	-475,945.48	-245,438.49	-77,601.94	-335,566.33	-2,191,184.78	-261,475.24	-64,405.89	-885,855.87	-1,876,266.48	-45,666.72	-93,955.93	**6,732,520.02**
	Period 2	-12,701.87	-6,675.49	-19,420.79	-49,439.79	-33,585.85	-323,635.30	-166,894.24	-52,768.08	-228,179.73	-1,489,970.52	-177,798.97	-43,794.97	-602,367.79	-1,275,831.12	-31,052.64	-63,888.52	**4,578,005.67**
	Period 3	-13,396.91	-7,040.76	-20,483.48	-52,145.09	-35,423.63	-341,344.30	-176,026.53	-55,655.50	-240,665.50	-1,571,500.23	-187,527.96	-46,191.39	-635,328.76	-1,345,643.34	-32,751.81	-67,384.44	**4,828,509.61**
Case 3	Base Year	-9,706.24	-5,101.13	-14,840.56	-37,779.83	-25,664.91	-247,308.63	-127,533.64	-40,323.17	-174,365.46	-1,138,573.50	-135,866.58	-33,466.30	-460,304.41	-974,937.09	-23,729.13	-48,820.95	**3,498,321.54**
	Period 1	-12,187.23	-6,405.02	-18,633.93	-47,436.65	-32,225.06	-310,522.66	-160,132.23	-50,630.09	-218,934.64	-1,429,601.84	-170,595.15	-42,020.54	-577,961.84	-1,224,138.67	-29,794.49	-61,299.97	**4,392,520.02**
	Period 2	-28,683.24	-15,074.51	-43,855.84	-111,644.43	-75,843.22	-730,829.92	-376,878.86	-119,160.34	-515,273.13	-3,364,636.22	-401,503.83	-98,897.36	-1,360,260.79	-2,881,068.82	-70,122.75	-144,272.41	**10,338,005.67**
	Period 3	-31,153.98	-16,373.01	-47,633.53	-121,261.35	-82,376.26	-793,782.77	-409,342.78	-129,424.67	-559,658.17	-3,654,462.12	-436,088.90	-107,416.26	-1,477,432.10	-3,129,240.78	-76,163.04	-156,699.87	**11,228,509.61**
Case 4	Base Year	-8,624.17	-4,532.44	-13,186.11	-33,568.06	-22,803.73	-219,738.16	-113,315.93	-35,827.86	-154,926.84	-1,011,643.01	-120,719.90	-29,735.41	-408,988.74	-866,249.12	-21,083.76	-43,378.29	**3,108,321.54**
	Period 1	-9,190.73	-4,830.20	-14,052.36	-35,773.28	-24,301.80	-234,173.67	-120,760.12	-38,181.54	-165,104.63	-1,078,102.02	-128,650.49	-31,688.85	-435,856.90	-923,156.60	-22,468.84	-46,227.99	**3,312,520.02**
	Period 2	-21,580.41	-11,341.61	-32,995.82	-83,997.92	-57,062.16	-549,854.53	-283,552.36	-89,652.67	-387,676.06	-2,531,451.46	-302,079.45	-74,407.41	-1,023,419.46	-2,167,629.85	-52,758.26	-108,546.24	**7,778,005.67**
	Period 3	-11,177.27	-5,874.23	-17,089.73	-43,505.55	-29,554.55	-284,789.49	-146,861.99	-46,434.35	-200,791.41	-1,311,129.99	-156,457.84	-38,538.28	-530,065.84	-1,122,693.66	-27,325.40	-56,220.01	**4,028,509.61**
Case 5	Base Year	-11,870.39	-6,238.50	-18,149.48	-46,203.38	-31,387.26	-302,449.57	-155,969.05	-49,313.79	-213,242.69	-1,392,434.48	-166,159.95	-40,928.08	-562,935.76	-1,192,313.02	-29,019.88	-59,706.27	**4,278,321.54**
	Period 1	-5,195.39	-2,730.44	-7,943.60	-20,222.12	-13,737.46	-132,375.01	-68,263.96	-21,583.48	-93,331.27	-609,435.60	-72,724.27	-17,913.25	-246,383.65	-521,847.17	-12,701.31	-26,132.02	**1,872,520.02**
	Period 2	-10,926.17	-5,742.26	-16,705.79	-42,528.16	-28,890.58	-278,391.45	-143,562.61	-45,391.16	-196,280.46	-1,281,674.33	-152,942.88	-37,672.48	-518,157.46	-1,097,471.38	-26,711.51	-54,956.98	**3,938,005.67**
	Period 3	-26,714.71	-14,039.95	-40,846.02	-103,982.28	-70,638.10	-680,673.15	-351,013.71	-110,982.38	-479,910.00	-3,133,721.65	-373,948.67	-92,110.05	-1,266,906.26	-2,683,341.42	-65,310.23	-134,371.01	**9,628,509.61**
Case 6	Base Year	-10,788.31	-5,669.81	-16,495.02	-41,991.60	-28,526.08	-274,879.10	-141,751.34	-44,818.48	-193,804.07	-1,265,503.99	-151,013.26	-37,197.19	-511,620.09	-1,083,625.05	-26,374.51	-54,263.61	**3,888,321.54**
	Period 1	-6,194.22	-3,255.38	-9,470.79	-24,109.91	-16,378.55	-157,824.68	-81,388.00	-25,732.99	-111,274.61	-726,602.20	-86,705.83	-21,357.15	-293,751.96	-622,174.53	-15,143.20	-31,156.01	**2,232,520.02**
	Period 2	-25,131.82	-13,208.06	-38,425.83	-97,821.17	-66,452.69	-640,342.23	-330,215.61	-104,406.50	-451,474.60	-2,948,043.84	-351,791.64	-86,652.38	-1,191,840.13	-2,524,349.33	-61,440.50	-126,409.32	**9,058,005.67**
	Period 3	-8,957.64	-4,707.70	-13,695.97	-34,866.02	-23,685.47	-228,234.68	-117,697.46	-37,213.20	-160,917.33	-1,050,759.76	-125,387.72	-30,885.17	-424,802.92	-899,743.98	-21,899.00	-45,055.58	**3,228,509.61**
Case 7	Base Year	-10,427.62	-5,480.25	-15,943.53	-40,587.68	-27,572.36	-265,688.95	-137,012.11	-43,320.04	-187,324.53	-1,223,193.83	-145,964.37	-35,953.56	-494,514.86	-1,047,395.73	-25,492.72	-52,449.39	**3,758,321.54**
	Period 1	-8,191.89	-4,305.26	-12,525.17	-31,885.49	-21,660.72	-208,724.01	-107,636.08	-34,032.03	-147,161.29	-960,935.42	-114,668.93	-28,244.95	-388,488.59	-822,829.24	-20,026.96	-41,204.00	**2,952,520.02**
	Period 2	-14,477.58	-7,608.71	-22,135.80	-56,351.42	-38,281.11	-368,879.14	-190,225.86	-60,145.00	-260,078.99	-1,698,266.71	-202,655.07	-49,917.46	-686,578.12	-1,454,190.87	-35,393.76	-72,820.07	**5,218,005.67**
	Period 3	-17,836.18	-9,373.82	-27,270.99	-69,424.15	-47,161.79	-454,453.92	-234,355.59	-74,097.79	-320,413.66	-2,092,240.70	-249,668.19	-61,497.61	-845,854.59	-1,791,542.70	-43,604.62	-89,713.30	**6,428,509.61**
Case 8	Base Year	-8,984.86	-4,722.01	-13,737.59	-34,971.98	-23,757.46	-228,928.32	-118,055.16	-37,326.30	-161,406.38	-1,053,953.18	-125,768.79	-30,979.04	-426,093.96	-902,478.44	-21,965.55	-45,192.51	**3,238,321.54**
	Period 1	-13,186.07	-6,929.96	-20,161.12	-51,324.44	-34,866.14	-335,972.33	-173,256.27	-54,779.61	-236,877.98	-1,546,768.45	-184,576.70	-45,464.44	-625,330.15	-1,324,466.02	-32,236.37	-66,323.96	**4,752,520.02**
	Period 2	-29,571.09	-15,541.13	-45,213.34	-115,100.24	-78,190.85	-753,451.84	-388,544.68	-122,848.79	-531,222.76	-3,468,784.31	-413,931.87	-101,958.60	-1,402,365.96	-2,970,248.70	-72,293.31	-148,738.18	**10,658,005.67**
	Period 3	-24,495.08	-12,873.42	-37,452.26	-95,342.75	-64,769.03	-624,118.34	-321,849.18	-101,761.23	-440,035.91	-2,873,351.41	-342,878.55	-84,456.94	-1,161,643.35	-2,460,391.74	-59,883.83	-123,206.58	**8,828,509.61**
Case 9	Base Year	-9,345.55	-4,911.57	-14,289.08	-36,375.91	-24,711.18	-238,118.48	-122,794.40	-38,824.73	-167,885.92	-1,096,263.34	-130,817.69	-32,222.67	-443,199.19	-938,707.76	-22,847.34	-47,006.73	**3,368,321.54**
	Period 1	-15,183.74	-7,979.83	-23,215.50	-59,100.02	-40,148.32	-386,871.66	-199,504.35	-63,078.64	-272,764.65	-1,781,101.66	-212,539.81	-52,352.24	-720,066.78	-1,525,120.74	-37,120.13	-76,371.95	**5,472,520.02**
	Period 2	-9,150.46	-4,809.03	-13,990.78	-35,616.54	-24,195.32	-233,147.60	-120,230.99	-38,014.24	-164,381.19	-1,073,378.14	-128,086.78	-31,550.00	-433,947.12	-919,111.64	-22,370.39	-46,025.44	**3,298,005.67**
	Period 3	-6,738.00	-3,541.17	-10,302.21	-26,226.49	-17,816.39	-171,679.87	-88,532.93	-27,992.05	-121,043.24	-790,389.52	-94,317.60	-23,232.06	-319,540.01	-676,794.30	-16,472.59	-33,891.15	**2,428,509.61**
Case 10	Base Year	-11,509.70	-6,048.94	-17,597.99	-44,799.45	-30,433.53	-293,259.42	-151,229.82	-47,815.35	-206,763.15	-1,350,124.32	-161,111.05	-39,684.45	-545,830.53	-1,156,083.70	-28,138.09	-57,892.05	**4,148,321.54**
	Period 1	-16,182.58	-8,504.77	-24,742.69	-62,987.81	-42,789.40	-412,321.32	-212,628.39	-67,228.15	-290,707.99	-1,898,268.26	-226,521.36	-55,796.14	-767,435.09	-1,625,448.09	-39,562.02	-81,395.94	**5,832,520.02**
	Period 2	-19,804.70	-10,408.39	-30,280.82	-77,086.29	-52,366.90	-504,610.68	-260,220.74	-82,275.75	-355,776.79	-2,323,155.27	-277,223.35	-68,284.92	-939,209.13	-1,989,270.10	-48,417.13	-99,614.70	**7,138,005.67**
	Period 3	-22,275.44	-11,706.89	-34,058.51	-86,703.22	-58,899.95	-567,563.54	-292,684.65	-92,540.08	-400,161.83	-2,612,981.17	-311,808.43	-76,803.83	-1,056,380.43	-2,237,442.06	-54,457.43	-112,042.15	**8,028,509.61**
Case 11	Base Year	-10,066.93	-5,290.69	-15,392.05	-39,183.75	-26,618.63	-256,498.79	-132,272.87	-41,821.61	-180,845.00	-1,180,883.67	-140,915.47	-34,709.93	-477,409.64	-1,011,166.41	-24,610.93	-50,635.17	**3,628,321.54**
	Period 1	-17,181.41	-9,029.71	-26,269.88	-66,875.60	-45,430.49	-437,770.98	-225,752.43	-71,377.67	-308,651.33	-2,015,434.87	-240,502.91	-59,240.04	-814,803.40	-1,725,775.45	-42,003.90	-86,419.94	**6,192,520.02**
	Period 2	-16,253.29	-8,541.94	-24,850.80	-63,263.04	-42,976.37	-414,122.99	-213,557.49	-67,521.91	-291,978.26	-1,906,562.90	-227,511.16	-56,039.95	-770,788.46	-1,632,550.61	-39,734.88	-81,751.61	**5,858,005.67**
	Period 3	-33,373.61	-17,539.55	-51,027.29	-129,900.88	-88,245.34	-850,337.58	-438,507.31	-138,645.82	-599,532.25	-3,914,832.35	-467,159.02	-115,069.37	-1,582,695.01	-3,352,190.46	-81,589.45	-167,864.30	**12,028,509.61**
Case 12	Base Year	-7,542.10	-3,963.76	-11,531.65	-29,356.29	-19,942.55	-192,167.69	-99,098.22	-31,332.55	-135,488.23	-884,712.52	-105,573.22	-26,004.51	-357,673.07	-757,561.15	-18,438.39	-37,935.63	**2,718,321.54**
	Period 1	-14,184.91	-7,454.90	-21,688.31	-55,212.23	-37,507.23	-361,421.99	-186,380.31	-58,929.12	-254,821.31	-1,663,935.05	-198,558.25	-48,908.34	-672,698.46	-1,424,793.38	-34,678.25	-71,347.96	**5,112,520.02**
	Period 2	-18,028.99	-9,475.16	-27,565.81	-70,174.67	-47,671.64	-459,366.84	-236,889.11	-74,898.83	-323,877.53	-2,114,859.08	-252,367.26	-62,162.43	-854,998.79	-1,810,910.36	-44,076.01	-90,683.15	**6,498,005.67**
	Period 3	-20,055.81	-10,540.36	-30,664.75	-78,063.68	-53,030.87	-511,008.73	-263,520.12	-83,318.94	-360,287.75	-2,352,610.94	-280,738.31	-69,150.72	-951,117.51	-2,014,492.38	-49,031.02	-100,877.73	**7,228,509.61**
Case 13	Base Year	-8,263.48	-4,342.88	-12,634.62	-32,164.13	-21,850.01	-210,548.01	-108,576.69	-34,329.43	-148,447.30	-969,332.85	-115,671.00	-28,491.78	-391,883.52	-830,019.79	-20,201.97	-41,564.07	**2,978,321.54**
	Period 1	-10,189.56	-5,355.14	-15,579.55	-39,661.07	-26,942.89	-259,623.34	-133,884.16	-42,331.06	-183,047.96	-1,195,268.63	-142,632.04	-35,132.75	-483,225.21	-1,023,483.95	-24,910.72	-51,251.99	**3,672,520.02**
	Period 2	-5,599.04	-2,942.58	-8,560.77	-21,793.28	-14,804.79	-142,659.91	-73,567.74	-23,260.41	-100,582.66	-656,785.76	-78,374.59	-19,305.02	-265,526.45	-562,392.15	-13,688.14	-28,162.35	**2,018,005.67**
	Period 3	-28,934.35	-15,206.48	-44,239.78	-112,621.82	-76,507.18	-737,227.96	-380,178.25	-120,203.52	-519,784.08	-3,394,091.88	-405,018.79	-99,763.16	-1,372,169.18	-2,906,291.10	-70,736.64	-145,535.44	**10,428,509.61**

*Negative value represents amount of demand that is destined to a port.

G. Flow decisions for selected arcs based on results from MCF model – Base year, optimistic and pessimistic scenario

Scenario	Base year			Optimistic									Pessimistic								
Year	2016			2024			2034			2045			2024			2034			2045		
Total Flow (TEUs)			3,840,677			4,906,313			6,805,822			9,016,066			4,456,661			5,400,007			6,269,597
Total Cost (USD)	$		1,664,048,580	$		2,127,782,236	$		2,949,096,793	$		3,907,262,125	$		1,933,273,798	$		2,339,193,436	$		2,712,050,967
USD/TEU	$		433.27	$		433.68	$		433.32	$		433.37	$		433.79	$		433.18	$		432.57
#arcs	From	To	Flow	From	To	Flow	From	To	Flow	From	To	Flow	From	To	Flow	From	To	Flow	From	To	Flow
1	1	2	615	1	2	777	1	2	1,078	1	2	1,428	1	2	725	1	2	878	1	2	1,020
2	3	11	65,443	3	11	82,629	3	11	114,619	3	8	28,639	3	11	77,068	3	8	67,006	3	8	108,419
3	4	2	514,410	4	2	649,501	4	2	900,960	3	11	123,204	4	2	605,793	3	11	26,375	4	2	852,226
4	5	6	22,380	5	6	88,866	5	6	176,481	4	2	1,193,553	5	6	99,709	4	2	734,022	5	6	185,889
5	5	11	89,824	5	11	52,805	5	11	20,037	5	6	49,526	5	11	32,427	5	6	160,106	7	8	9,983
6	7	11	6,026	7	11	7,609	7	8	4,745	5	11	210,813	7	11	7,097	7	8	8,599	9	11	17,397
7	9	11	10,501	9	11	13,259	7	11	5,810	7	8	13,982	9	11	12,367	9	11	14,984	10	2	14,318
8	10	2	161,164	10	2	203,488	9	11	18,392	9	11	24,365	10	2	189,794	10	2	172,177	10	6	252,683
9	14	8	16,216	14	8	62,649	10	2	282,269	10	2	69,573	14	8	71,892	10	6	57,791	14	8	138,360
10	14	11	68,001	14	11	48,894	14	8	154,727	10	6	304,366	14	11	26,460	14	8	119,170	15	13	7,463
11	15	13	4,986	15	13	5,562	15	13	7,715	14	8	204,976	15	13	5,305	15	13	6,428	16	13	10,829
12	16	13	7,234	16	13	8,071	16	13	11,196	15	13	10,221	16	13	7,698	16	13	9,327	17	25	14
13	17	25	9	17	25	10	17	25	14	16	13	14,831	17	25	10	17	25	12	18	11	58,862
14	18	11	38,961	18	11	43,605	18	11	60,488	17	25	19	18	11	41,841	18	11	50,698	19	11	53,726
15	19	11	44,599	19	11	59,571	19	11	82,634	18	11	80,131	19	11	38,190	19	11	46,274	19	25	183,911
16	19	25	112,695	19	25	116,473	19	25	161,566	19	11	109,470	19	25	130,730	19	25	158,402	20	25	68,044
17	20	25	45,039	20	25	50,408	20	25	69,923	19	25	214,036	20	25	48,368	20	25	58,606	21	25	108,623
18	21	25	71,899	21	25	80,469	21	25	111,623	20	25	92,632	21	25	77,213	21	25	93,557	22	23	19,552
19	22	23	12,942	22	23	14,484	22	23	20,092	21	25	147,873	22	23	13,898	22	23	16,840	24	25	61,524
20	24	25	37,603	24	25	48,137	24	25	66,773	22	23	26,617	24	25	43,733	24	25	52,990	26	23	4,868
21	26	23	2,975	26	23	3,809	26	23	5,283	24	25	88,458	26	23	3,460	26	23	4,193	27	23	741
22	27	23	453	27	23	580	27	23	804	26	23	6,999	27	23	527	27	23	638	28	30	4,200
23	28	30	2,831	28	30	3,133	28	30	4,346	27	23	1,065	28	30	2,986	28	30	3,618	29	23	3,442
24	29	23	2,320	29	23	2,568	29	23	3,562	28	30	5,758	29	23	2,447	29	23	2,965	31	30	815
25	31	30	557	31	30	608	31	30	844	29	23	4,719	31	30	579	31	30	702	2	39	73,102
26	2	39	44,269	2	39	56,940	2	39	78,985	31	30	1,118	2	39	51,963	2	39	62,963	2	44	1,319,588
27	2	44	948,891	2	44	1,197,037	2	44	1,660,477	2	39	104,636	2	44	1,117,628	2	44	1,296,407	6	45	650,000
28	6	45	150,000	6	45	250,000	6	45	400,000	2	44	1,895,364	6	45	250,000	6	45	400,000	8	45	436,984
29	8	45	125,000	8	45	200,000	8	45	350,000	6	45	650,000	8	45	200,000	8	45	350,000	11	45	1,419,162
30	11	45	1,108,058	11	45	1,347,678	11	45	1,743,660	8	45	500,000	11	45	1,151,845	11	45	1,248,700	12	45	306,044
31	12	45	186,285	12	45	246,726	12	45	342,248	11	45	2,457,861	12	45	217,548	12	45	263,596	13	41	1,404,094
32	13	41	855,737	13	41	1,130,836	13	41	1,568,646	12	45	453,396	13	41	998,082	13	41	1,209,347	23	41	67,055
33	23	41	42,192	23	41	51,525	23	41	71,474	13	41	2,078,076	23	41	47,665	23	41	57,755	25	41	479,601
34	25	41	302,380	25	41	340,473	25	41	472,290	23	41	94,686	25	41	340,918	25	41	413,081	30	41	113,966
35	30	41	77,866	30	41	85,097	30	41	118,043	25	41	625,670	30	41	81,012	30	41	98,159	41	36	46,575
36	41	36	28,177	41	36	35,991	41	36	49,926	30	41	156,378	41	36	33,107	41	36	40,115	44	38	229,887
37	44	37	112,096	44	37	130,816	44	37	181,462	41	36	66,139	44	37	144,963	44	37	117,857	44	40	266,430
38	44	38	140,014	44	38	181,986	44	38	252,442	44	38	334,425	44	38	163,413	44	38	198,002	45	32	17,567
39	44	40	191,429	44	40	247,851	44	40	343,808	44	40	391,489	44	40	224,041	44	40	271,464	45	33	9,212
40	45	32	10,656	45	32	13,773	45	32	19,106	45	32	25,311	45	32	12,487	45	32	15,131	45	34	26,358
41	45	33	5,600	45	33	7,306	45	33	10,135	45	33	13,427	45	33	6,548	45	33	7,934	45	35	68,305
42	45	34	16,293	45	34	20,831	45	34	28,896	45	34	38,280	45	34	18,736	45	34	22,702	45	37	447,091
43	45	35	41,477	45	35	54,125	45	35	75,080	45	35	99,463	45	35	48,554	45	35	58,831	45	40	48,750
44	45	37	159,415	45	37	218,518	45	37	303,119	45	37	641,952	45	37	172,845	45	37	267,222	45	42	245,339
45	45	42	149,163	45	42	195,445	45	42	271,113	45	40	63,972	45	42	174,396	45	42	211,311	45	43	60,463
46	45	43	36,741	45	43	47,664	45	43	66,117	45	42	359,159	45	43	42,979	45	43	52,077	45	46	42,974
47	45	46	26,051	45	46	33,679	45	46	46,718	45	43	87,589	45	46	30,548	45	46	37,014	45	47	88,224
48	45	47	53,599	45	47	70,125	45	47	97,274	45	46	61,890	45	47	62,713	45	47	75,987			
49										45	47	128,865									
50																					

H. Transcript of codes Minimum Cost-Flow (MCF) problem

Run in OPL language of the IBM ILOG CPLEX Studio 128 – adapted from one of sources in IBM Library

```
//
-----------------------------------------------------------------------
------
Minimum Cost Flow Model - Indonesian Export Trade
Adaptive Policy Decision Pathways for Shipping Network Planning in
Indonesia

Graduation MSc Thesis
Ingrid Rosalyn Indriana (4747704)
//
-----------------------------------------------------------------------
------

int NumNodes = ...;    // Number of nodes
range Nodes = 1..NumNodes;
{int} Gateway = {2,6,8,11,12,13,23,25,30};
{int} Hub = {39,41,44,45};


// Get the supply (positive) and demand (negative) at each node
float SupDem[Nodes] = ...;

// Create a record to hold information about each arc
tuple arc {
   key int fromnode;
   key int tonode;
   float distance;
   float portrelated;
   float contrelated;
}

// Get the set of arcs
{arc} Arcs = ...;

//Maximum capacity of port to handle containers in TEUs
int MaxCap[Gateway] = ...;
int MaxCap1[Hub] = ...;

// The network flow model has decision variables indexed on the
arcs.
dvar float+ Flow[a in Arcs];

//Objective
dexpr float TotalCost = sum (a in Arcs) a.distance * a.portrelated *
Flow[a] + sum (a in Arcs) a.contrelated * Flow[a];

minimize TotalCost;
```

```
//Constraint
subject to {
   // Preserve flows at each node.  Note the use of slicing
   forall (i in Nodes)
     ctNodeFlow:
      sum (<i,j,d,p,c> in Arcs) Flow[<i,j,d,p,c>]
    - sum (<j,i,d,p,c> in Arcs) Flow[<j,i,d,p,c>] == SupDem[i];
   // Gateway capacity constraint
    forall (i in Gateway) sum (a in Arcs: a.tonode==i) Flow[a] +
SupDem[i] <= MaxCap[i];
    forall (j in Hub) sum (a in Arcs: a.tonode==j) Flow[a] +
-1*SupDem[j] <= MaxCap1[j];
}


execute DISPLAY {
   writeln("\n<from node,to node,Flow[a]>\n");
   for(var a in Arcs)
      if(Flow[a] > 0)
         writeln(a.fromnode,",",a.tonode,",",Flow[a]);
}
```

I. OD matrix of distance – domestic arc, transshipment arc, and international arc

Domestic arc	Belawan	Palembang	Panjang	Tanjung Priok	Tanjung Emas	Tanjung Perak	Bitung	Makassar	Sorong
Lhokseumawe	311	933	1127	1263	1470	1687	2544	1907	2973
Belawan	0	734	1137	1064	1271	1130	2347	1708	2687
Teluk Bayur	903	824	507	674	884	932	2144	1433	2729
Dumai	291	459	732	689	862	951	1690	1299	2069
Jambi	608	126	529	456	664	762	1739	1100	2324
Palembang	734	0	404	330	506	635	1660	1015	2245
Bengkulu	1092	623	306	473	683	911	1943	1232	2527
Panjang	1137	404	0	214	337	495	1723	1012	2308
Tanjung Pandan	921	234	422	216	401	604	1463	824	2048
Batu Ampar	483	261	665	591	799	761	1874	1235	2327
Tanjung Priok	1064	330	214	0	234	384	1517	806	2102
Tanjung Emas	1271	538	424	210	0	194	1382	671	1967
Tanjung Perak	1488	761	652	438	194	0	1231	520	1815
Banten	1177	444	74	254	286	444	1763	1052	2348
Benoa	1795	1061	704	782	431	294	1608	1588	1679
Benete	1901	1168	811	597	1098	267	1513	1695	1585
Tenau	2398	1664	1307	1082	1595	752	1005	635	1076
Pontianak	874	393	682	420	461	546	1512	873	2077
Sampit	1301	615	733	527	392	360	1110	471	1695
Banjarmasin	1430	744	820	614	479	328	992	353	1577
Samarinda	1730	1044	1107	819	637	535	616	331	1201
Tarakan	1661	1306	1217	1109	932	821	458	556	925
Bitung	2347	1660	1723	1279	1382	991	0	724	585
Pantoloan	1854	1167	1230	1024	889	737	503	287	1087
Makassar	1708	1015	1012	762	593	437	790	0	1375
Kendari	2805	2118	2076	1975	1840	1689	458	1248	806
Gorontalo	2201	1514	1578	1371	1236	1085	153	644	738
Ambon	2879	2211	2039	1314	1933	980	551	587	494
Ternate	2540	1872	1935	1729	1594	1442	212	1002	482
Sorong	2807	2245	2308	2102	1967	1815	585	1375	0
Jayapura	3442	2880	2944	2737	2602	2451	1220	2010	718

Transshipment arc	Port Said	Shanghai	Colombo	Singapore
Belawan	5075	3171	1324	483
Palembang	5696	2812	1945	261
Panjang	5599	3101	1961	665
Tanjung Priok	5766	2909	2129	591
Tanjung Emas	5975	2902	2338	799
Tanjung Perak	6204	2976	2567	1016
Bitung	7235	2004	3557	1874
Makassar	6524	2540	2887	1235
Sorong	7736	2319	3986	2327

International arc	Caucedo	Pointe Noire	Panama Canal	Mombasa	Vladivostok	Rotterdam	Dubai	Port Said	Los Angeles	Shanghai	Melbourne	Santos	Colombo	Singapore	Cape Town	Tin Can Island
Port Said	0	0	0	3222	0	0	3132	0	0	8101	0	0	0	5445	0	0
Shanghai	14694	11099	15827	6981	1118	11999	6627	8101	19270	0	5844	13281	4350	2692	9327	12168
Colombo	0	7214	0	2742	0	7673	2276	3775	14943	4350	0	0	0	1695	5356	8270
Singapore	12038	8757	13171	4325	0	9343	3971	5445	16614	2691	4356	10904	1695	0	6899	9813

J. OD matrix of container-related cost – domestic arc, transshipment arc, and international arc

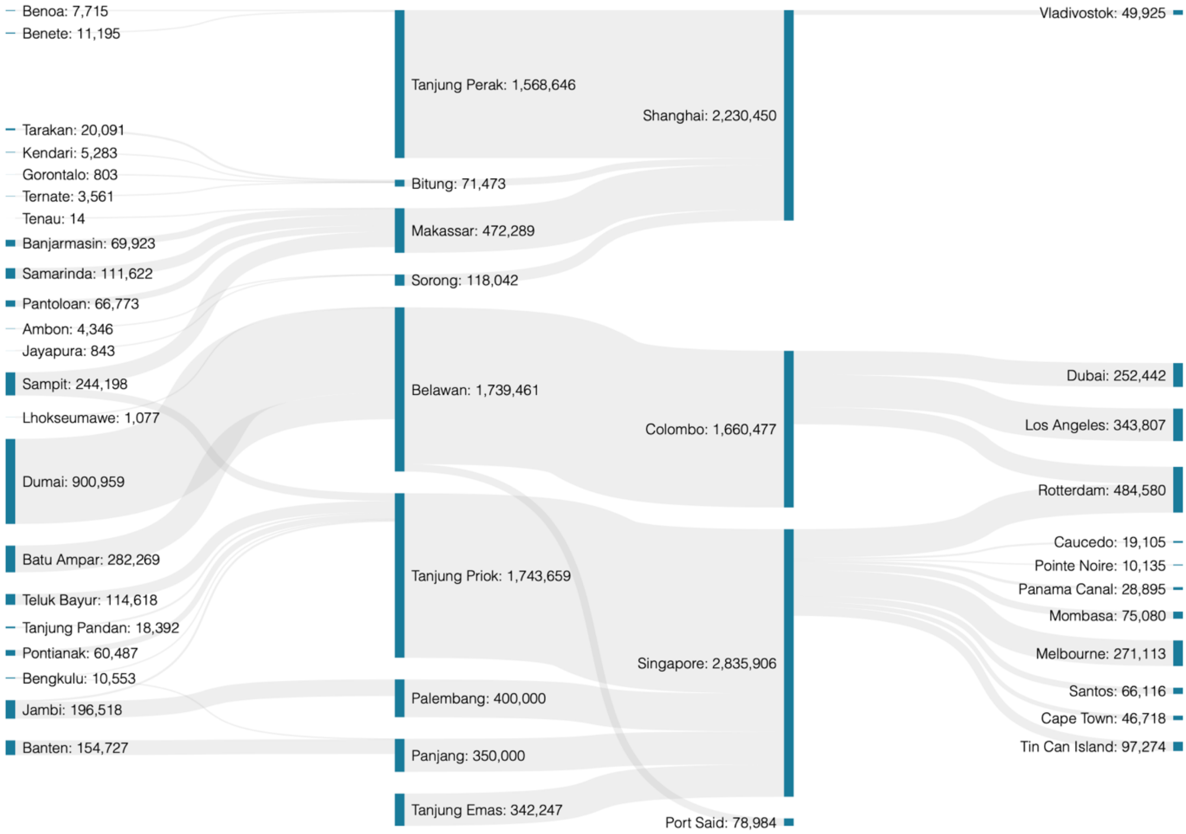
Domestic arc	2	6	8	11	12	13	23	25	30
1	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
2	$ -	$ 70.00	$ 70.00	$ 68.00	$ 73.00	$ 68.00	$ 79.00	$ 72.00	$ 73.00
3	$ 114.00	$ 115.00	$ 115.00	$ 114.00	$ 119.00	$ 114.00	$ 124.00	$ 118.00	$ 119.00
4	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
5	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
6	$ 70.00	$ -	$ 71.00	$ 69.00	$ 75.00	$ 69.00	$ 80.00	$ 73.00	$ 75.00
7	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
8	$ 70.00	$ 71.00	$ -	$ 69.00	$ 75.00	$ 69.00	$ 80.00	$ 73.00	$ 75.00
9	$ 114.00	$ 115.00	$ 115.00	$ 114.00	$ 119.00	$ 114.00	$ 124.00	$ 118.00	$ 119.00
10	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
11	$ 68.00	$ 69.00	$ 69.00	$ -	$ 73.00	$ 68.00	$ 78.00	$ 72.00	$ 73.00
12	$ 74.00	$ 75.00	$ 75.00	$ 74.00	$ -	$ 74.00	$ 84.00	$ 78.00	$ 79.00
13	$ 68.00	$ 69.00	$ 69.00	$ 68.00	$ 73.00	$ -	$ 78.00	$ 72.00	$ 73.00
14	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
15	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
16	$ 114.00	$ 115.00	$ 115.00	$ 114.00	$ 119.00	$ 114.00	$ 124.00	$ 118.00	$ 119.00
17	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
18	$ 83.00	$ 84.00	$ 84.00	$ 83.00	$ 88.00	$ 83.00	$ 93.00	$ 87.00	$ 88.00
19	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
20	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
21	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
22	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
23	$ 79.00	$ 81.00	$ 81.00	$ 79.00	$ 84.00	$ 79.00	$ -	$ 83.00	$ 84.00
24	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
25	$ 72.00	$ 73.00	$ 73.00	$ 72.00	$ 77.00	$ 72.00	$ 82.00	$ -	$ 77.00
26	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
27	$ 86.00	$ 87.00	$ 87.00	$ 85.00	$ 91.00	$ 85.00	$ 96.00	$ 89.00	$ 90.00
28	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
29	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00
30	$ 73.00	$ 75.00	$ 75.00	$ 73.00	$ 78.00	$ 73.00	$ 83.00	$ 77.00	$ -
31	$ 77.00	$ 78.00	$ 78.00	$ 76.00	$ 82.00	$ 76.00	$ 87.00	$ 80.00	$ 81.00

Transshipment arc	39	41	44	45
2	$ 206.29	$ 192.88	$ 196.29	$ 190.10
6	$ 207.79	$ 194.38	$ 197.79	$ 191.60
8	$ 207.79	$ 194.38	$ 197.79	$ 191.60
11	$ 205.95	$ 192.54	$ 195.95	$ 189.76
12	$ 219.49	$ 206.08	$ 209.49	$ 203.30
13	$ 205.95	$ 192.54	$ 195.95	$ 189.76
23	$ 224.65	$ 211.24	$ 214.65	$ 208.46
25	$ 209.99	$ 196.58	$ 199.99	$ 193.80
30	$ 211.10	$ 197.69	$ 201.10	$ 194.91

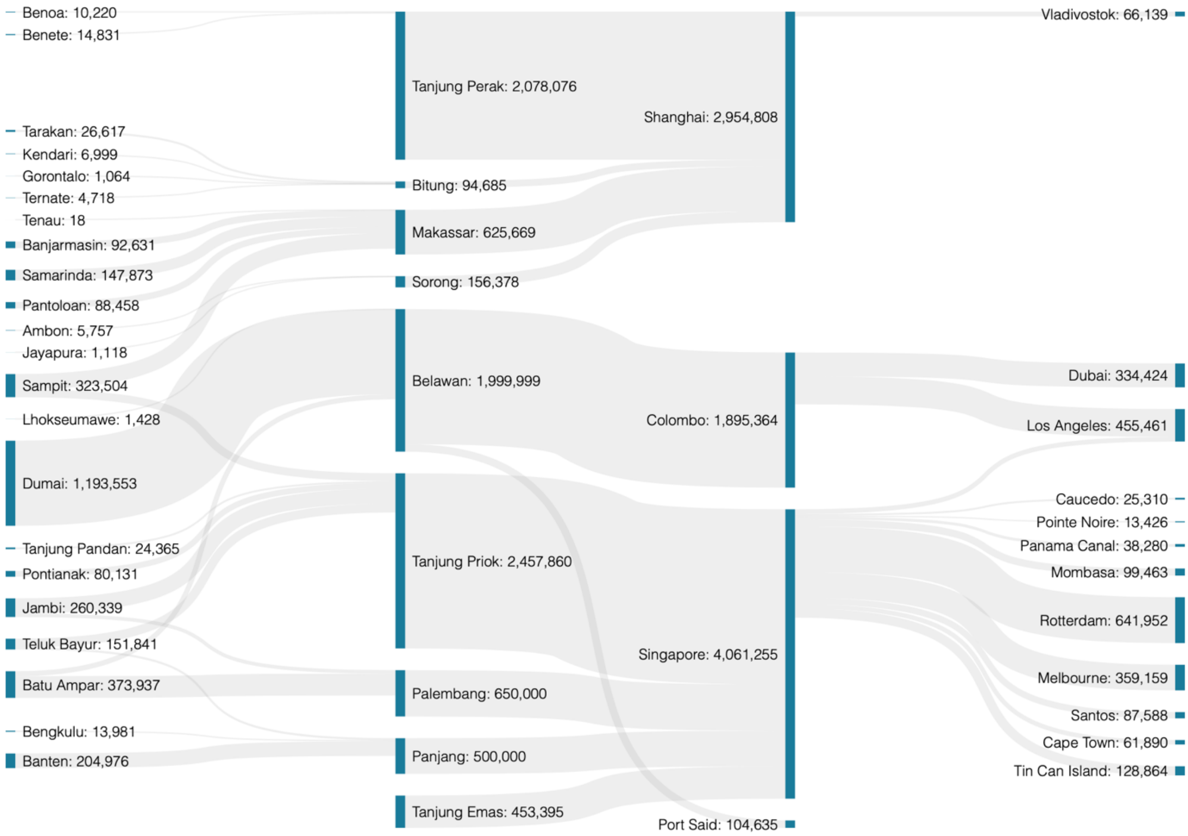
International arc	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
39	$ 351.56	$ 326.56	$ 386.56	$ 275.56	$ 326.56	$ 327.43	$ 316.23	$ -	$ 326.56	$ 308.86	$ 324.84	$ 287.93	$ 312.27	$ 306.08	$ 305.81	$ 276.68
41	$ 338.15	$ 313.15	$ 373.15	$ 262.15	$ 313.15	$ 314.02	$ 302.82	$ 308.86	$ 313.15	$ -	$ 311.43	$ 274.52	$ 298.86	$ 292.67	$ 292.40	$ 263.27
44	$ 341.56	$ 316.56	$ 376.56	$ 265.56	$ 316.56	$ 317.43	$ 306.23	$ 312.27	$ 316.56	$ 298.86	$ 314.84	$ 277.93	$ -	$ 296.08	$ 295.81	$ 266.68
45	$ 335.37	$ 310.37	$ 370.37	$ 259.37	$ 310.37	$ 311.24	$ 300.04	$ 306.08	$ 310.37	$ 292.67	$ 308.65	$ 271.74	$ 296.08	$ -	$ 289.62	$ 260.49

K. Sankey Diagrams of flow pattern

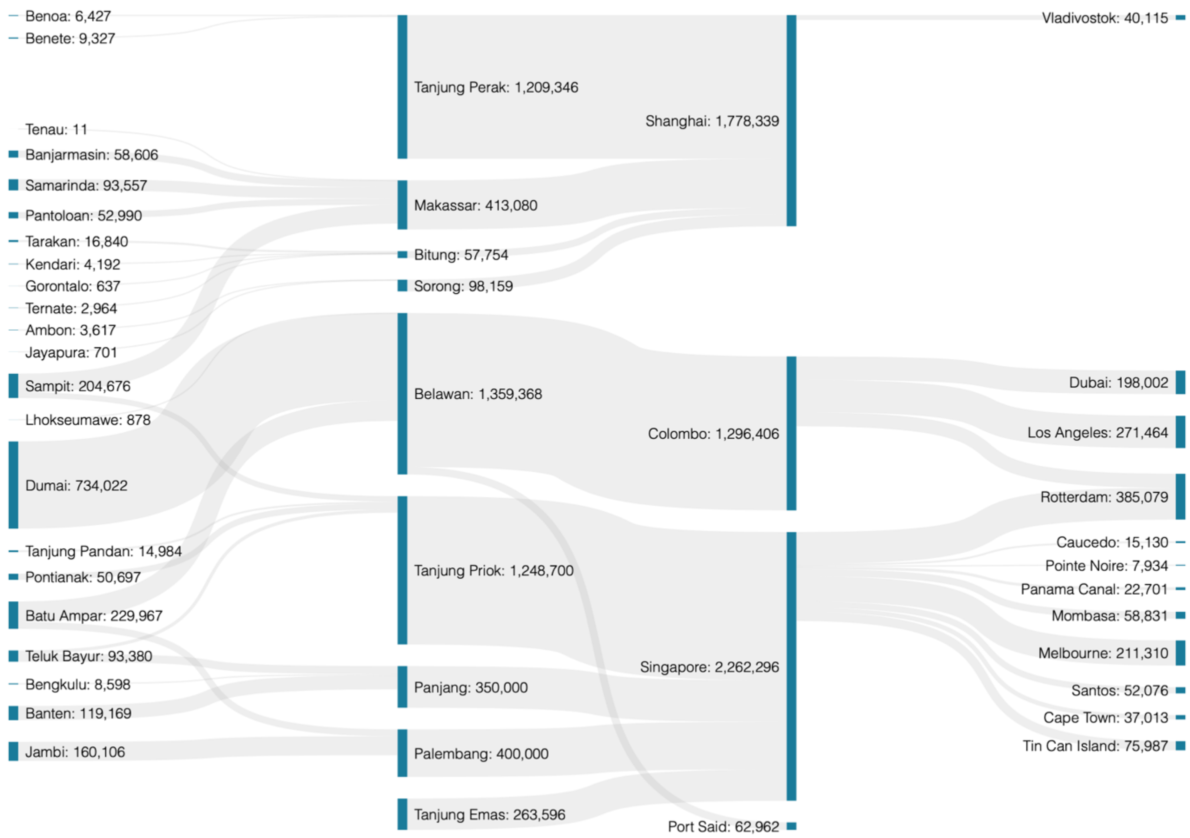
a. Period 2 – Optimistic scenario



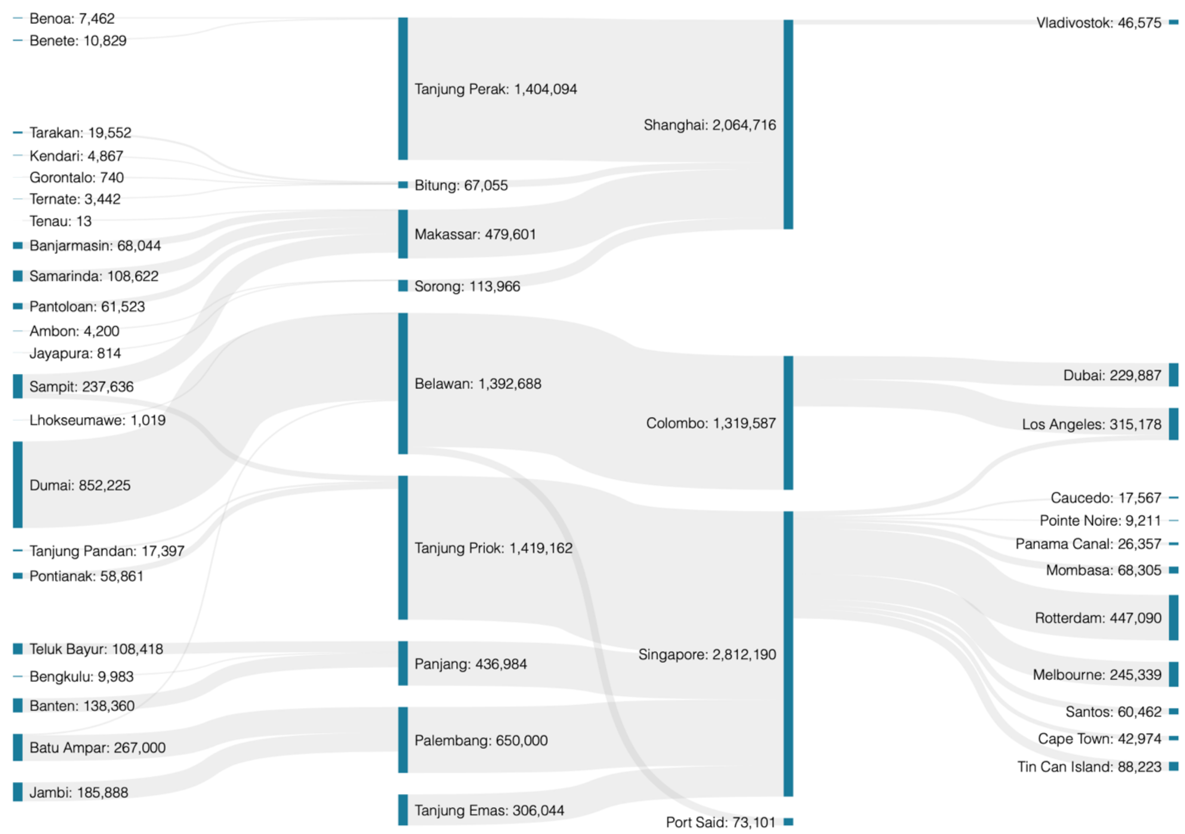
b. Period 3 – Optimistic scenario



c.   Period 2 – Pessimistic scenario



d.   Period 3 – Pessimistic scenario



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Adaptive policy decision pathways for robust shipping network investment planning in Indonesia

A model application to Indonesian export trade

Indriana, I.

Abstract

Due to its archipelagic nature, Indonesia enforces to make substantial investments in its maritime sector, especially port infrastructure, in order to promote trade, economic growth, and ease disparity among Indonesia's island regions. The challenge, of course, is that Indonesia has many ports to invest in and a limited budget; it must prioritize among various port development projects. The government therefore needs to choose wisely in order to avoid wasting money by constructing shipping network plans. To improve the current state of policy decision-making for the Indonesian shipping network, we hereby develop adaptive policy decision pathways focused on Indonesian containerized exports. The objective of this study is to build adaptive policy decision pathways that can cope with dynamic future uncertainties and results to help the government develop robust network investment plan that helps the Indonesian government achieve its objective of improving connectivity and value-added exports through lower logistics costs. The main general finding is that flow pattern is very sensitive to demand volumes. Moreover, Minimum Cost-Flow (MCF) model used in this study is able to identify the flow pattern so that is very useful to analyze the potential of gateways.

Keywords: *Adaptive policy decision pathways; shipping network planning; Minimum Cost-Flow problem; Indonesian export trade; Indonesia*

I. INTRODUCTION

Indonesia is an archipelagic country with approximately 17,000 islands grouped into 7 big island regions. The country relies heavily on the sea transport; thus, Indonesia needs to make substantial investments in its maritime sector, especially port infrastructure, in order to promote trade, economic growth, and ease disparity among Indonesia's island regions. The challenge, of course, is that Indonesia has many ports to invest in and a limited budget; it must prioritize among various port development projects. The government therefore needs to choose wisely in order to avoid wasting money by constructing shipping network plans. A shipping network plan should take future demand projections into consideration. This would normally imply developing at least two long-term scenarios for a specific year in the future and projecting cargo volumes for each. Even this, however, may not be sufficiently robust due to the fact that there are plausible uncertainties that might happen in between the year the plan is developed and the forecasted year which are difficult to capture in a single year in the future.

One of the most important aspects in shipping network planning in Indonesia is designating which ports are to become international container gateways as these ports will play an important role in connecting Indonesia with foreign markets and therefore have a strong impact on its economy. According to the data from the Seabury Ocean Trade database, international containerized trade flows account for half of the value of Indonesia's total exports, 67% of the value of Indonesia's imports, and half of the value of Indonesia's total international trade. Containers can therefore significantly impact Indonesia's trade balance. Generally, export and import are two aspects those are regularly evaluated as economic indicators of a country. Specifically, export is very important and has been one of the pivotal development agenda points in Indonesian economic development due to the wave of globalization since the 1980s that implies rapid growth of global trade (Presidential Decree No 26/2012, 2012).

To improve the current state of policy decision-making for the Indonesian shipping network, we hereby develop adaptive policy decision pathways focused on Indonesian containerized exports using both historical data and containerized export projections. The objective of this study is to build adaptive policy decision pathways that can cope with dynamic future uncertainties and results to help the government develop robust network investment plan that helps the Indonesian government achieve its objective of improving connectivity and value-added exports through lower logistics costs. The question is therefore "*How to build adaptive policy decision pathways for shipping network planning in Indonesia that supports robust investment decisions under future uncertainties?"*

The result of this study will contribute to fill the research gaps of how to develop adaptive policy-making for robust investment network plan taking into account export trade of Indonesia. The policy should consider the periodic implementation of optimal shipping network plan in dealing with the future plausible uncertainties. This model improves on previous studies by satisfying the following criteria: (1) addressing uncertainties in a deeper approach by generating ensembles of scenarios; (2) building adaptive policy-making framework which deals with shipping network plan problem in Indonesia; (3) identifying the performance of the implemented network plan. Beyond that, this research will be useful for the government in building a master plan for shipping network in the country, especially in making decisions of international container gateways development.

This paper is structured as follow. Chapter 2 provides a summary of the literature review of adaptive planning approaches and incorporates shipping network planning into one of the approaches, then identifies the scientific gap. Chapter 3 explains the methodology used in this research. In Chapter 4, the current, past and future situation of Indonesia are elaborated as the starting stage of the methodology in this research. Chapter 5 provides data analysis of container export trade in Indonesia including the results of the demand forecast model. In Chapter 6, the model is applied for all scenarios and periods. Chapter 7 performs model validation and identifies sensitivity analysis results. Finally, Chapter 8 provides the conclusion and further recommendations.

II. LITERATURE REVIEW

The concept of adaptive policy planning emerged as one of the solutions to anticipate future uncertainties and challenges in supporting many policy domains including decisions in shipping network planning. Generally, there are three paradigms in adaptive policy planning/policy-making process that is considering future uncertainties. (van der Pas, Walker, Marchau, van Wee, & Kwakkel, 2013) distinguished based on literature three basic paradigms that policy-makers apply when dealing with future uncertainties. The paradigm used in this approach is the third one, the so-called 'Dynamic Adaptive Policymaking', which aims to build policies that change over time just because the future cannot be predicted. The decisions made in the beginning of the process could be different from what will be made somewhere in the future under specific conditions of uncertainty.

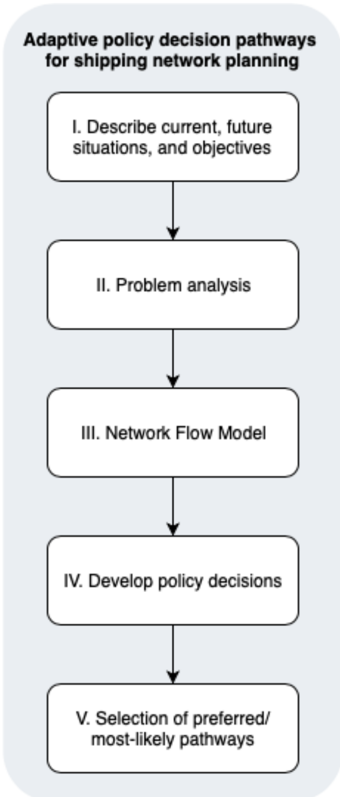

Figure II 1
Stepwise of approach

A concept of adaptive policy planning that is widely discussed in the existing academic literature is developed based on the presence of uncertainties combined with the needs of robust quality in policy decisions. A variety of techniques and tools, such as strategic planning, scenarios, adaptive policy pathways, sensitivity analysis, , investment decision-making process, adaptive policy-making ("APM"), complex adaptive systems, assumption-based planning ("ABP"), and individual port adaptive planning have been put forward in the port and shipping literature (Frankel, 1989), (Faisal, 2015), (Lagoudis, JR, & Salminen, 2014), (Yeo, NG, Lee, & Yang, 2014), (Tu, Adiputranto, Fu, & Li, 2018)

(Haasnoot, Kwakkel, Walker, & Maat, 2013) and (Taneja, Walker, Ligteringen, Van Schuylenburg, & Van Der Plas, 2010).

The approach used in this research is adaptive policy decision pathways to be applied in shipping network planning. The characteristics of that approach are identified from several aspects such as focus of the approach, planning process, and types of actions that can be taken. The focus of this approach is to explore actions for achieving objectives over time by including dynamic interaction between the network infrastructure and market. The dynamic interaction comes from the difference future scenarios represented by different demand values over specified periods of time.

In the planning process, a short stepwise consisted of 5 steps for designing adaptive pathways is taken. This stepwise is considered as the core of methodology of this research. The steps involved are: (1) describe current, future situations and objectives; (2) problem analysis; (3) network flow model; (4) develop policy decisions; (5) selection of preferred policy decision pathways (Figure II 1). Figure below shows an example of an Adaptation Pathways map that is applied for shipping network planning problem which illustrates the periods, ranges of demand, and transfer points represent conditions under which a decision (in this example is flow pattern) no longer meets the desirable objectives. (Haasnoot, Kwakkel, Walker, & Maat, 2013) make an interesting analogy towards this Adaptation Pathways map as 'different ways leading to Rome' just like maps of public transport routes that consists of several options to go to Rome. Therefore, this policy pathways map is used to determine the options of pathways in making policy decisions.

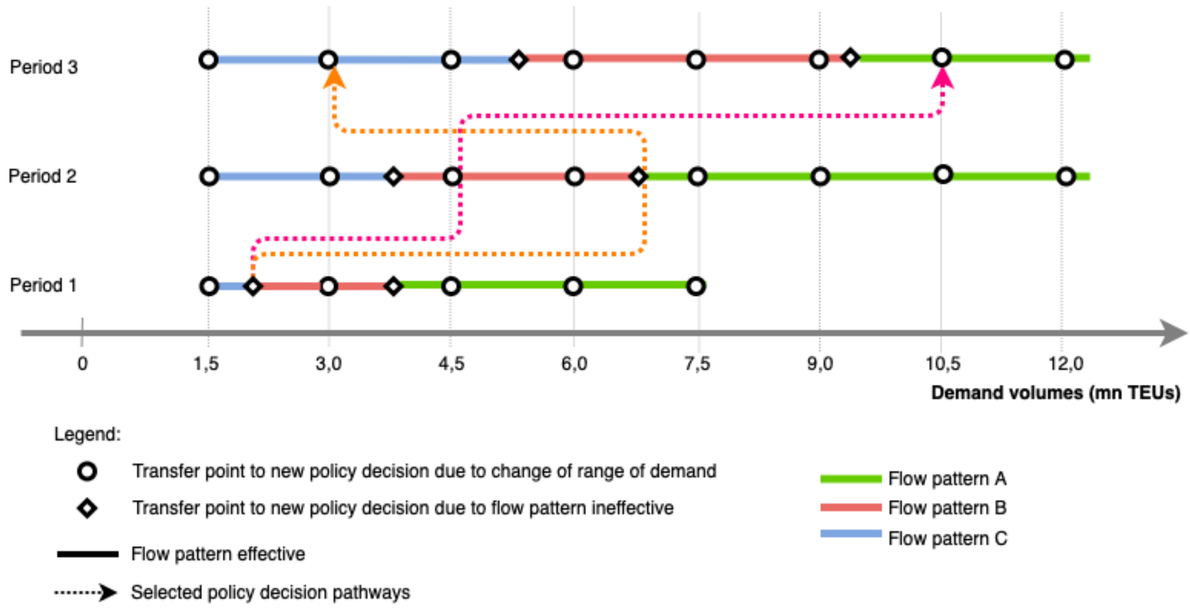

Figure II 2 Example of Adaptation Pathways Map
Adapted from: (Haasnoot, Kwakkel, Walker, & Maat, 2013)

Furthermore, previous research provided broad studies regarding shipping network design and optimization. Model-based design and computational techniques were performed to find the optimal network for certain problem (Faisal, 2015), (Tu, Adiputranto, Fu, & Li, 2018) and (Halim R., 2017). Research in network design done for Indonesia mostly studied how to design a network given future scenarios considering trends and developments that influence the network itself. A study carried out by (Faisal, 2015) clearly developed three different scenarios that capture the possibilities of different outcomes of an OD matrix due to the existence of trends and developments. The projected scenarios are set for a single year only that is 2030. Moreover, that study focused only on domestic (intra-Indonesian) trade. Another study by (Tu, Adiputranto, Fu, & Li, 2018) comes up with the results for hub selection over three different periods based on the objective minimizing total cost. Although the OD matrix used in that study is the total of both international and domestic flows, the origins and destinations are all ports in Indonesia.

The literature review therefore suggests that there is still no study which performs research focused on shipping networks that takes dynamic decisions over time and links it to adaptive policy decision pathways. Specifically, for the approach adaptive policy decision pathways, the focus of previous studies is more on environmental issues, water management, and global climate change. This implies that to date, there is no research available for the application of adaptive policy decision pathways on shipping network planning, whereas the decisions underlying the shipping network planning are very important decisions for the policy-makers to come up with optimal policy recommendations. Another aspect which makes this study unique is that it focuses on exports as a way to help identify which ports should become international gateways. Generally, previous studies were not focusing on exports, which typically are important for governments however has not been necessary imported in academic literature. Many governments have the ambition to promote value added exports and these are usually shipped in containers. Container exports could therefore be used in helping to designate international gateways. To summarize, the scientific gap is that no study was found addressing the following aspects: (1) application of adaptive policy decision pathways for shipping network planning; (2) assessing dynamic robustness of the policy over time; and (3) taking export trade that the origins are Indonesian ports and the destinations are worldwide ports.

III. METHODOLOGY

Before going into details of model application, the following figure is a model flowchart shows the detailed model formulation.

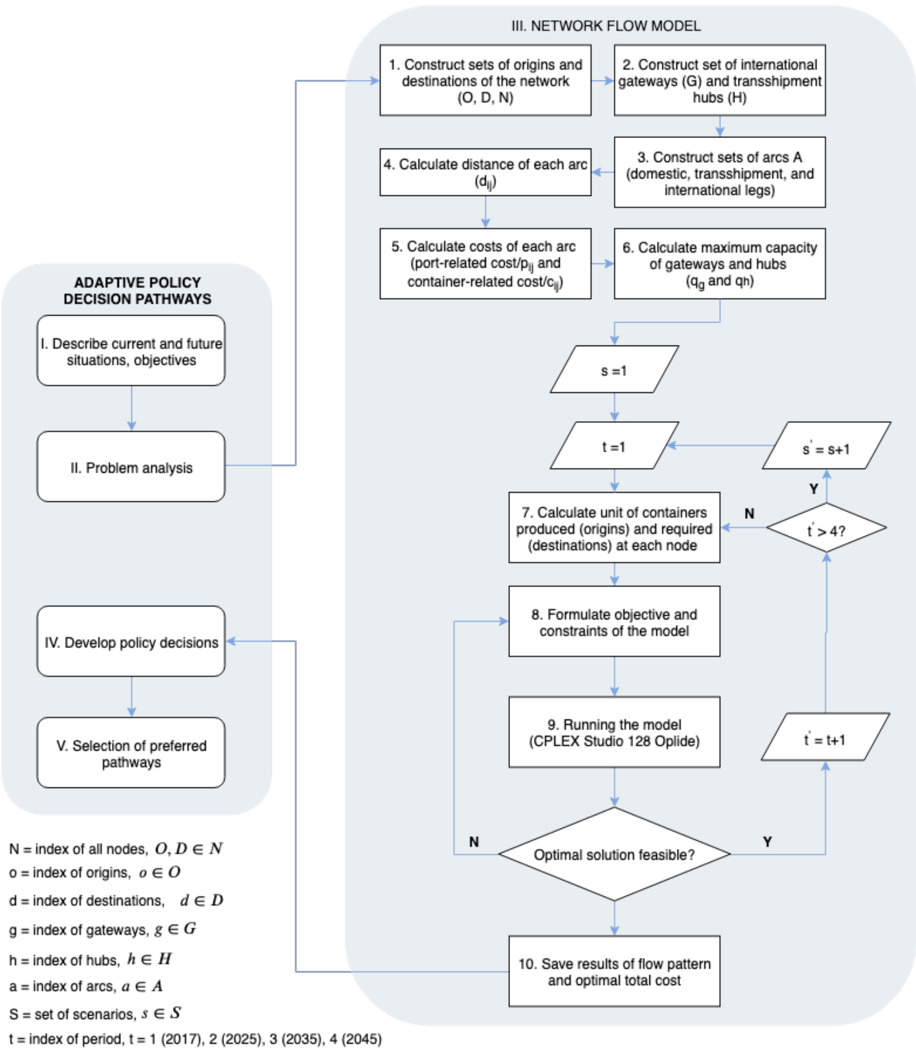

Figure III 3 Model flowchart of adaptive policy decision pathways for shipping network planning

a. Step I and II: Describe current and future situation, objectives and problem analysis

The proposed approach is started with examining current and future situation as well as objective of the policy planning. This step involves studying the current condition of Indonesia and challenges the country currently facing, the historical information about network plans built in the past, future projection represented by constructed scenarios. The proposed approach is started with examining current and future situation as well as objective of the policy planning. This step involves studying the current condition of Indonesia and challenges the country currently facing, the historical information about network plans built in the past, future projection represented by constructed scenarios. From this examination, definition of success and the objectives of the policy-makers are identified. The objectives of public policy are determined in this step as well. There are two key objectives of policy planning in regard to shipping network planning, those are (i) to reduce transportation costs which involves reducing economic disparity within Indonesia and (ii) to promote value added exports in terms of containerized cargo.

Based on analysis of trends and developments, the future projection is performed by developing the plausible scenarios for the purpose of applying demand forecast model. The forecast model is based on a regression-based gravity method which is a commonly used quantitative analysis method in economic forecasting. The regression analysis involves analyzing the impact of variables on bilateral trade flows. In this forecast model we use the multiple formats, and so the equation for multiple linear regression. Multiple linear regression has the additional condition that the independent x variables should have none or minimal collinearity. This means that the independent x variables used in the model should ideally not be correlated to each other. For example, if GDP and population are both used in a model, but GDP growth is driven by population growth then only one of the two independent variables should be used.

For this model, we forecast the demand with constructed parent scenarios namely optimistic (the upper bound) and pessimistic (the lower bound). Note that the research for this forecast model was done jointly with an expert from Port of Rotterdam Authority. The forecast model is done also for the internal objective of the company. Having the two parent scenarios, we can capture more uncertainties by generating random values based on forecasted demand in each scenario and results in numbers of cases, then are called as branch scenarios. This random number generation results in 13 scenarios, which originally come from 100 cases randomly generated, those are categorized as branch scenarios.

b. Step III: Network flow model

The model involved in building adaptive policy for shipping network planning is Minimum Cost-Flow (MCF) problem. The objective of MCF is to minimize the shipping network cost to meet export demand. Here, costs are defined as generalized cost that is calculated by considering two types of costs: shipping-related costs and container-related costs. Shipping-related costs are the costs that depend on the location of the ports as it is calculated with the distance and depend on the vessel size thus it is calculated with container volumes (in TEUs) as well. Meanwhile, container-related costs are the costs that depend on the number of TEUs being handled as it is calculated with the container volumes.

The mathematical formulation explained here is partly adjusted from the original MCF problem in order to be aligned with the problem in this research, that is adaptive policy decision pathways for shipping network problem.

Table 1 Set, parameters, and decision variables of MCF-transshipment problem

Sets	
A	Set of arcs
N	Set of all nodes
O	Set of origin nodes [O= 1,2,3…, m]
D	Set of destination nodes [D= m+1, m+2…, n]

G	Set of transshipment nodes that also origin nodes = gateways [$G \subseteq O$]
H	Set of transshipment nodes that also destination nodes = hubs [$H \subseteq D$]
S	Set of transient scenarios/cases [S = 1,2,3…, r]
T	Set of periods [T= 2017, 2025, 2035, 2045]
Parameters	
D_{ij}	Distance between i to j [nm], $i,j \in A$
P_{ij}	Shipping-related cost between i to j [USD/nm], $i,j \in A$
C_{ij}	Container-related cost between i to j [USD/TEU], $i,j \in A$
q_i	Maximum capacity of port (= gateways or hubs) [TEU]
Z_i^{st}	Amount of flow originated from origin i [TEU] in scenario/case s and period t
Y_j^{st}	Amount of flow destined to destination j [TEU] in scenario/case s and period t
Decision variable	
X_{ij}^{st}	Flows between i to j [TEU] in scenario/case s and period t, $i,j \in A$

Mathematical model

$$Minimize \sum_{i=1}^{m} \sum_{j=m+1}^{n} D_{ij} P_{ij} X_{ij}^{st} + \sum_{i=1}^{m} \sum_{j=m+1}^{n} C_{ij} X_{ij}^{st} \quad (1)$$

Subject to,

$$\sum_{j \in N} X_{ij}^{st} - \sum_{j \in N} X_{ji}^{st} = Z_i^{st} \qquad for\ i \in O, s \in S, t \in T \quad (2)$$

$$\sum_{i \in N} X_{ji}^{st} - \sum_{i \in N} X_{ij}^{st} = Y_j^{st} \qquad for\ j \in D, s \in S, t \in T \quad (3)$$

$$\sum_{j \in V \setminus \{i\}} X_{ij}^{st} + Z_i^{st} \leq q_i \qquad for\ \forall\ i \in G, s \in S, t \in T \quad (4)$$

$$\sum_{i \in V \setminus \{j\}} X_{ij}^{st} + Y_j^{st} \leq q_j \qquad for\ \forall\ j \in H, s \in S, t \in T \quad (5)$$

$$X_{ij}^{st} \geq 0 \qquad for\ \forall\ i \in O, j \in D, s \in S, t \in T \quad (6)$$

Equation (1) is the objective function which to minimize total costs consisting of shipping-related cost depending on distance of arc as well as on flow variable and container-related cost which is depending on flow variable. The total cost is calculated for each scenario and each time period. Equation (2) and (3) is the so-called flow conservation constraint which ensures that all flows go out of a node reduced by flows go into a node equals net amount of flow originated or destined at a node. Both equation (4) and (5) are the maximum capacity constraints for gateways and ports. The last constraint defines the domain of variables. The MCF model then is being applied for each scenario resulting from Step I as well as for each time period determined in this research.

The model is written and run in the OPL language of the IBM ILOG CPLEX Studio 128. For each cycle (meaning that for each scenario and period), the average time needed to have the running finished is about 2 minutes. In regard to branch scenarios, however, running the MCF model for all 100 cases each period will take much time and turns out become inefficient process. Therefore, all 100 cases per period are grouped into frequency tables and results in 13 ranges of interval. Demand value that is taken into account as the input for the MCF model is the mid-range of each interval.

c. Step IV and V: Develop policy decisions and selection of pathways

The output of previous step are flow patterns that have optimal total shipping network cost for each scenario and each period, and the amount of flow per arc. These outputs become the input for step IV and later step V. Flow pattern is determined based on number of provincial ports that tranship containers to international gateways, throughput volumes and throughput growth. Therefore, each flow pattern captures which gateways are promising as the more a gateway receives bigger flows from provincial ports, the more promising it becomes.

The focus on step IV is to map the flow pattern based on certain demand and period. The same demand range can yield to different patterns. The same period can also have different optimal flow patterns depend on the demand that should be handled. Therefore, applying the network model to varied demand volume ranges from parent and branch scenarios may lead to different flow patterns.

The flow patterns can be translated into policy decisions consist of recommendations of which ports should be developed as international gateways and what function the port should be developed into. To establish policy decision pathways map, we can group all demand values from all periods and scenarios into several ranges, as well as their optimal flow pattern. Afterwards, we determine the optimal pathway that consists of several flow patterns. The selected pathway is then considered as policy decision for particular condition of future demand values over periods. Definition of pathways in this research is the direction the government/policy-maker take in deciding policy through several periods within plausible distinct volumes of demand. Finally, this map guides policy-makers to make decision of shipping network planning under future uncertainties in terms of demand volumes.

IV. DATA ANALYSIS

The export flows data are collected and formed into an Origin-Destination ("OD") matrix of 31 main ports in Indonesia and major 16 regional ports in the world (see Table 2). This set of export data not only represents the flows between ports in Indonesia, but also the direction the flows take between Indonesian ports and ports in the world. Moreover, from the methodological point of view, export data can help the model to capture the importance of a port to take a role as international container gateway, which is the key decision of shipping network planning in Indonesia.

Table 2 List of provincial ports, international gateway hubs, transshipment hubs and regional ports

Provincial ports		Int. gateway hubs		Transshipment hubs		Regional ports	
1	Lhokseumawe	2	Belawan	39	Port Said	32	Caucedo
3	Teluk Bayur	6	Palembang	41	Shanghai	33	Pointe Noire
4	Dumai	8	Panjang	44	Colombo	34	Panama Canal
5	Jambi	11	Tanjung Priok	45	Singapore	35	Mombasa
7	Bengkulu	12	Tanjung Emas			36	Vladivostok
9	Tanjung Pandan	13	Tanjung Perak			37	Rotterdam
10	Batu Ampar	23	Bitung			38	Dubai
14	Banten	25	Makassar			40	Los Angeles
15	Benoa	30	Sorong			42	Melbourne
16	Benete					43	Santos
17	Tenau					46	Cape Town
18	Pontianak					47	Tin Can Island
19	Sampit						
20	Banjarmasin						
21	Samarinda						
22	Tarakan						
24	Pantoloan						
26	Kendari						
27	Gorontalo						
28	Ambon						
29	Ternate						
31	Jayapura						

a. Shipping cost analysis

After having the OD container demand and distance matrix, another data needed is cost.

i. Shipping-related cost

Shipping-related costs consist of two types of costs namely vessel chartering costs and fuel consumption cost. To calculate the unit cost for shipping-related cost which should be in USD/TEU.nm, the following equations are used.

$$F_{C,ij} = Fuel\ consumption \times Fuel\ Price \qquad \forall i \in O, j \in D \qquad (7)$$

$$P_{ij} = \frac{\frac{V_{C,ij}}{S_S \times 24} + \frac{F_{C,ij}}{S_S \times 24}}{\gamma_S} \qquad \forall i \in O, j \in D \qquad (8)$$

$$C_{P,ij} = P_{ij} \times D_{ij} \times X_{ij} \qquad \forall i \in O, j \in D \qquad (9)$$

Where P_{ij} is the unit cost for shipping-related cost (USD/TEU.nm) $C_{P,ij}$ is the shipping-related cost (USD) from node i to node j, S_s is the vessel speed (knot), γ_S is vessel size (TEUs), D_{ij} is the distance between node i and node j (nm), and X_{ij} is container flows on arc (TEUs). Index i and j here are representing two ports between each arc. The vessel chartering cost $V_{C,ij}$ for each arc is fixed, and fuel cost $F_{C,ij}$ is calculated by Equation 10. Dividing D_{ij} with S_s results in shipping time in hours, therefore, to calculate in daily basis, we divide shipping time with 24 to get shipping time in days. O and D denote origins and destinations where the vessel starts and ends the trip respectively.

ii. Container-related cost

Container related costs consist of two types of handling costs those are container handling charges and container handling time cost. Handling cost is the stevedoring costs which is paid for container handling activities at ports. For container handling, ports do two types of activity be it loading, unloading or both. In this network configuration with directed graph, we can determine which port does loading, unloading, or both activities. This implies that when the container is at gateway or hub, the container is being unloaded and loaded, otherwise when the container is at origin or destination nodes. To calculate the unit cost for container-related cost which should be in USD/TEU, the following equations are used.

$$T_{H,ij} = \frac{1}{R_{L,i} \times Cr_i \times 24} + \frac{1}{R_{U,j} \times Cr_j \times 24} \qquad \forall i \in O, j \in D \qquad (10)$$

$$C_{ij} = E_{ij} + (T_{H,ij} \times V_{C,ij}) \qquad \forall i \in O, j \in D \qquad (11)$$

$$C_{C,ij} = C_{ij} \times X_{ij} \qquad \forall i \in O, j \in D \qquad (12)$$

Equation 10 is used to calculate handling time ($T_{H,ij}$) for each arc based on loading rate of ($R_{L,i}$) and unloading rate ($R_{U,j}$) in a particular arc, and number of cranes for certain port, Cr_i and Cr_j. To have the handling time in days, we need to divide with 24. This handling time is then multiplied by vessel chartering cost ($V_{C,ij}$). Equation 11 is used to find the unit cost, C_{ij}, in USD/TEU of container-related costs which is the sum of two types of costs: container handling charges E_{ij} and container handling time cost. Finally, to find the container-related costs, we need to multiply the unit cost with the number of TEUs handled in each arc (X_{ij}). O denotes origins where the inflows being loaded, while D denotes destinations where the outflows being unloaded. After having all the inputs required to calculate the total cost of the shipping network, we identify the total cost by the following equation:

$$TC = \sum_{i \in O} \sum_{j \in D} C_{P,ij} + \sum_{i \in O} \sum_{j \in D} C_{C,ij} \qquad (13)$$

Where the total shipping network cost TC (USD) is the sum of total shipping-related cost and total container-related cost of all arcs used in the network.

b. Port capacity

Given that two of the constraints in the network flow model, which are Equation 4 and 5, we need to estimate the port capacity. Table 3 below shows both the gateway capacity for base year the estimation of future capacity of gateways. Note that port capacity here implies total capacity for all types of container flows i.e. domestic, import, and export flow.

Table 3 Gateways capacity for base year and future periods

Port ID	Port names	Location	Island Region	Capacity (TEUs)			
				Base year	2024	2034	2045
2	Belawan	Belawan, Sumatera Utara	Sumatra	1,100,000	1,500,000	2,000,000	2,000,000
6	Palembang	Palembang, South Sumatra	Sumatra	150,000	250,000	400,000	650,000
8	Panjang	Panjang, Lampung	Sumatra	125,000	200,000	350,000	500,000
11	Tg. Priok	Jakarta, DKI Jakarta	Java	7,100,000	8,600,000	15,500,000	22,500,000
12	Tg. Emas	Semarang, Jawa Tengah	Java	700,000	700,000	700,000	1,000,000
13	Tg. Perak	Suarabaya, Jawa Timur	Java	3,700,000	3,700,000	5,000,000	5,000,000
23	Bitung	Bitung, Sulawesi Utara	Sulawesi	500,000	900,000	1,200,000	1,500,000
25	Makassar	Makassar, Sulawesi Selatan	Sulawesi	800,000	1,800,000	3,000,000	3,000,000
30	Sorong	Sorong, Papua Barat	Papua	95,000	500,000	1,500,000	1,500,000

c. Developed scenarios

i. Parent scenarios

Based on the trends and developments, we can build assumptions on represented variables and develop scenarios for the forecast model which is explained in this sub chapter. The scenarios developed herein are based on high-level analysis as the aim of the scenario analysis is not to predict the future, rather to identify the differences in future evolutions under assumed conditions. These scenarios are based on variable assumptions for long-term planning which are split into three periods: 2017-2024, 2025-2034, 2035-2045. The splitting into three periods allows assigning various growth rates and updating changes to the model at different periods according to the changes in economic growth and other trends and developments. The container export projection of Indonesia up to 2045 from the forecast model built in this research is shown in Figure 1. The green line showing the optimistic scenario and the grey line is the pessimistic scenario. This result is used as one of the elements in developing policy decisions as well as when applying network flow model.

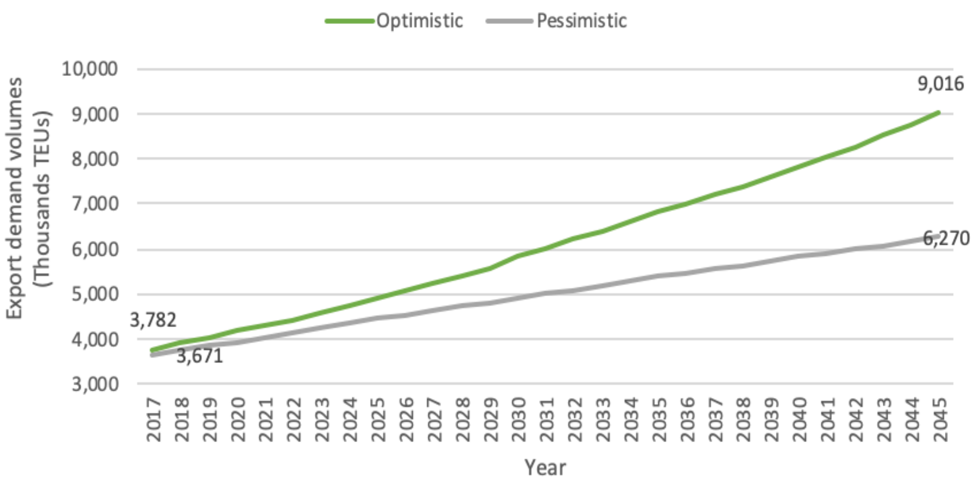

Figure 1 Graph of container export volume projection for Indonesia – parent scenarios (Source: Author's calculation)

ii. Branch scenarios

The branch scenarios are randomly developed based on the forecasted demand in two previous parent scenarios: optimistic and pessimistic. To generate random numbers those are normally distributed we need two inputs namely mean and standard deviation. As the model will be applied in three different periods, random values are generated for a particular period. After some iterations, the most optimal CV is 30% as lower number provides less uncertain values amongst 100 cases and higher number provides less likely values as it gives negative numbers which are not likely for future demand volumes. Furthermore, normality tests are performed for datasets of each period using Shapiro-Wilk theorem and done in SPSS Statistics software.

Since there are 100 demand values for each period, it is more efficient to binning the numbers into several intervals then used in the network flow model. Visual binning resulted from SPSS Statistics software gives 15 intervals for period 1, 13 intervals for period 2, and 15 intervals for period 3. Thus, we take only 13 intervals to generate 13 cases of demand values that each consists of three different periods. Furthermore, the midpoint for each interval is then considered as the demand value for certain case in a particular period. shows the random number generation results for 13 scenarios/cases for all periods that represents total export demand values in each period. In the table, we can see that each period is represented by the last year of every period, that is 2024 for Period 1, 2034 for Period 2 and 2045 for Period 3. From Figure 2 we can see that from generating random numbers and take them as branch scenarios, we capture different growth of demand throughout periods which are different with the ones in parent scenarios. In parent scenarios, the demand is always increasing from period to period though in pessimistic the demand is smaller than optimistic; thus, the flow pattern will remain similar. Meanwhile, in branch scenarios, we can analyze network flow patterns when the network dealing with demand uncertainties from period to period. Bear in mind that total export demand values per each period here are *yearly* values.

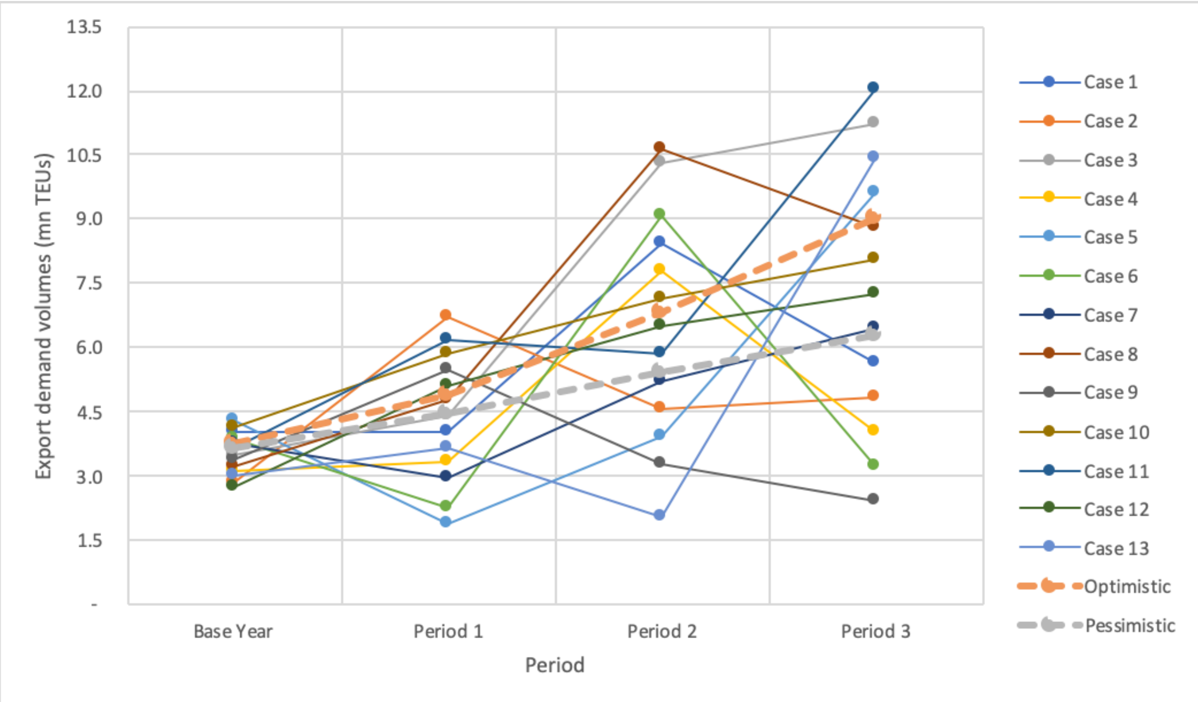

Figure 2 Projected demand of optimistic, pessimistic, and branch scenarios

V. MODEL APPLICATION AND RESULTS

The model is applied to each scenario in each period. Therefore, each scenario in each period has its own optimal solution of flow pattern from the model. Assessing flow pattern is done based on number of provincial ports that transshipped their containers to particular gateway, throughput volume and throughput growth per gateway. Since each iteration from network flow model generates flow decision variables as well, therefore flow pattern assessment is done for each scenario and each period. Flow pattern indicates how promising a port is. For example, the more a gateway received flows from provincial port, the more important it is to the Indonesian export trade, and thus the more promising. For this analysis, we only look at the flow variables of gateways as our focus in this research is on international gateways development. Moreover, it is possible that different scenarios or different period has similar flow pattern. On the other hand, for some scenarios in different period but within same range of demand, the flow pattern can be different. Table 4 shows number of provincial ports that transshipped their containers to gateway of all scenarios.

Table 4 Number of provincial ports that transshipped their containers to gateway – all scenarios

Gateway	Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045
Belawan	3	3	2	3	3	2	3	2	2	3	3	2	2	3	2
Palembang	1	1	4	1	2	5	1	1	1	2	2	5	5	2	1
Panjang	1	1	3	1	3	3	1	1	1	3	1	3	3	3	3
Tanjung Priok	7	8	2	8	3	0	7	9	9	4	7	0	0	3	7
Tanjung Emas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bitung	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Makassar	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sorong	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Gateway	Scenario 6			Scenario 7			Scenario 8			Scenario 9			Scenario 10		
	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045
Belawan	2	3	2	3	3	3	3	2	3	3	2	2	3	3	3
Palembang	3	1	5	2	2	2	1	1	2	1	5	5	2	1	2
Panjang	3	1	3	3	3	3	1	1	3	1	3	3	1	1	3
Tanjung Priok	3	8	0	4	4	3	7	9	5	7	1	0	7	7	4
Tanjung Emas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bitung	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Makassar	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sorong	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Gateway	Scenario 11			Scenario 12			Scenario 13			Optimistic			Pessimistic		
	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045	2024	2034	2045
Belawan	3	3	2	3	3	3	3	2	2	3	3	3	3	3	3
Palembang	1	2	1	1	1	2	2	5	1	1	1	2	1	2	2
Panjang	1	3	1	1	3	3	3	3	1	1	2	3	1	3	3
Tanjung Priok	8	4	9	7	5	3	4	0	9	7	6	5	7	4	3
Tanjung Emas	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tanjung Perak	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Bitung	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Makassar	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Sorong	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2

Moreover, Figure 3 to Figure 10 below are the graphs showing throughput TEU for each gateway in different scenarios. We present them starts from parent scenarios (optimistic and pessimistic) and branch scenarios (Scenario 1 to 13). From these figures, we notice that the gateway throughput between period is changing following the fact that yearly total demand for that specific period does also change. Thus, the growth of throughput per gateway is identified.

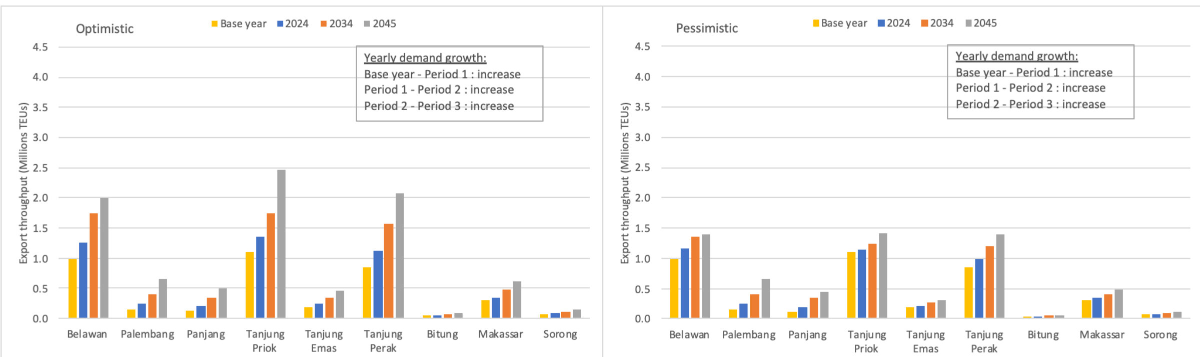

Figure 3 Throughput per gateway over periods – Parent scenarios

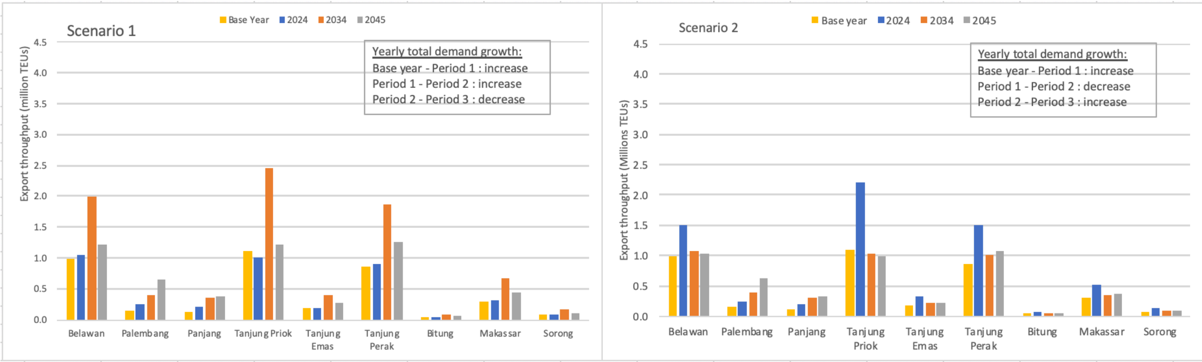

Figure 4 Throughput per gateway over periods – Scenario 1 and Scenario 2

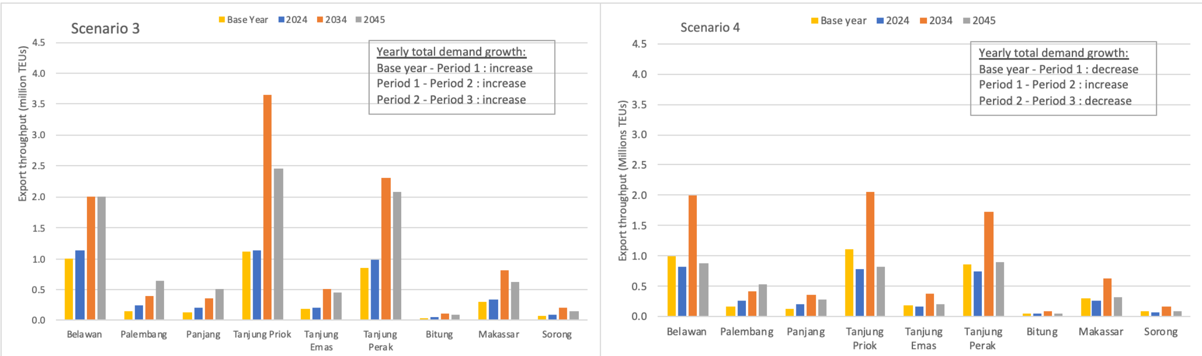

Figure 5 Throughput per gateway over periods – Scenario 3 and Scenario 4

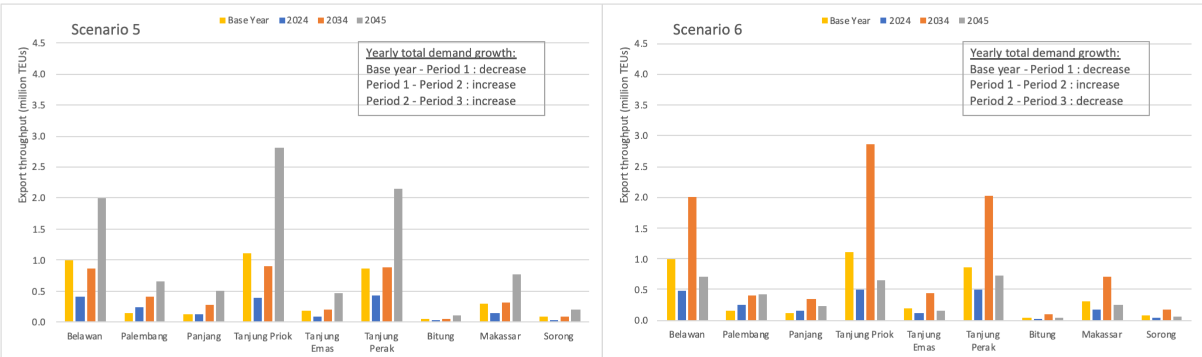

Figure 6 Throughput per gateway over periods – Scenario 5 and Scenario 6

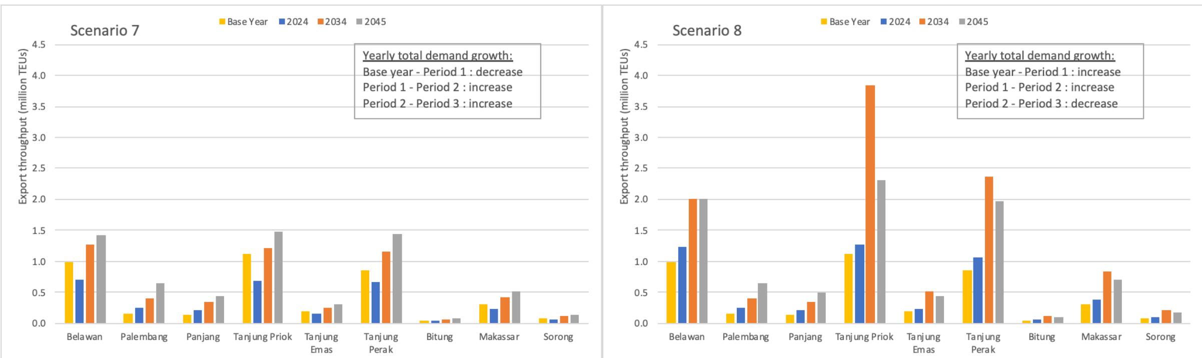

Figure 7 Throughput per gateway over periods – Scenario 7 and Scenario 8

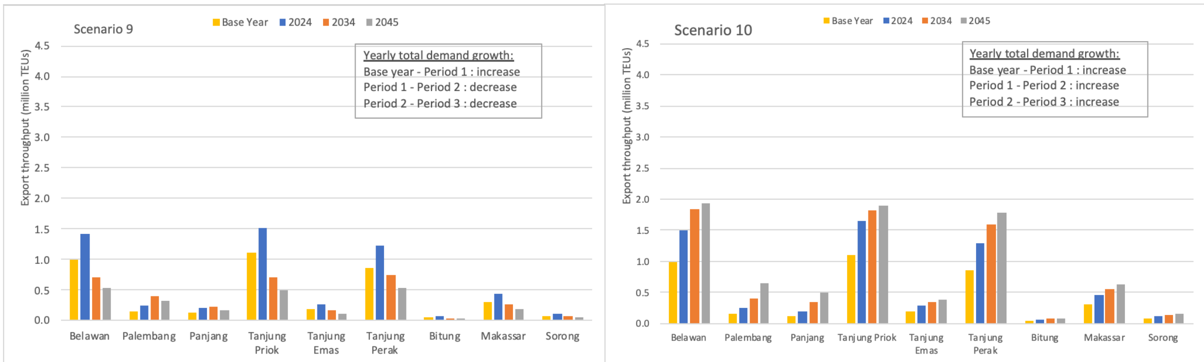

Figure 8 Throughput per gateway over periods – Scenario 9 and Scenario 10

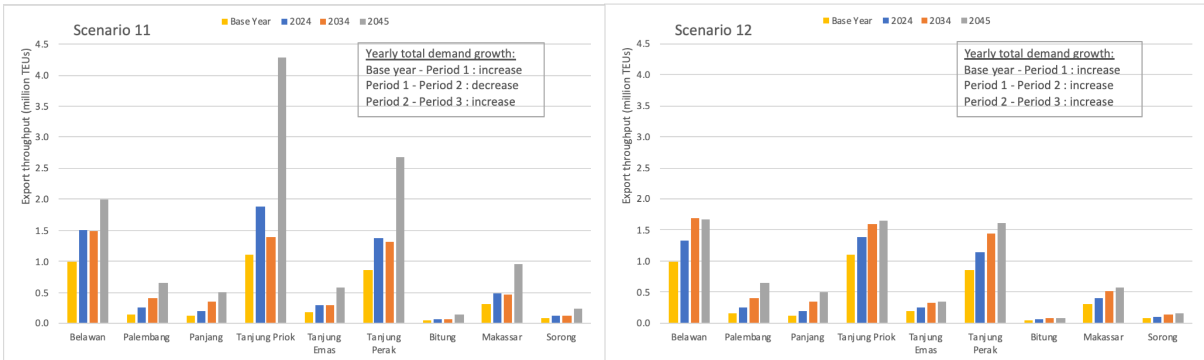

Figure 9 Throughput per gateway over periods – Scenario 11 and Scenario 12

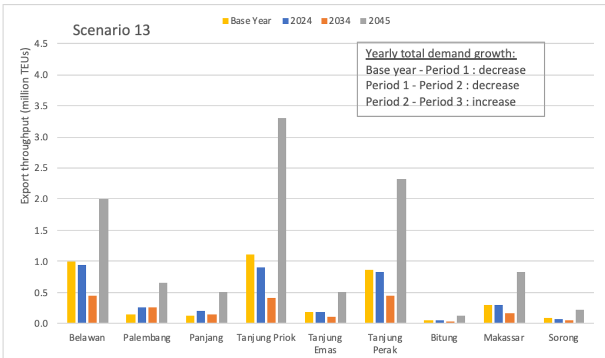

Figure 10 Throughput per gateway over periods – Scenario 13

From throughput per gateway and numbers of provincial ports that transshipped containers to particular gateway, we identify that there are some scenarios that have identical flow pattern, and some are significantly distinct with each other. In each flow pattern, there may be gateways that either have high number of throughputs in TEUs but fluctuate over periods or increasing throughput growth though the yearly total demand values drops at the same time.

These flow pattern analyses lead us to several findings. Firstly, Tanjung Priok, Tanjung Perak, and Belawan are the top three gateways that have higher throughput in TEUs throughout different scenarios. Secondly, compare to Bitung and Sorong, which gateways are located in eastern part of Indonesia, export throughput of Makassar remains higher. Moreover, in most of scenarios, throughput growth of Palembang steadily growing with amount of TEUs that is comparable with Makassar, even though the yearly total demand tends to fluctuate from year to year. In regard to flow pattern, though some yearly total demands are in the same range, and in the same period, the flow pattern possibly result differently. There are several scenarios that have identical flow pattern in particular period. We classify that and come up with three different flow patterns, as follow:

1. **Flow pattern A**: in average 30% of exports are handled by Tanjung Priok, while Belawan and Tanjung Perak are followed in second and third highest percentage of handling exports.
2. **Flow pattern B**: Tanjung Priok, Belawan and Tanjung Perak having similar average percentage in handling exports, yet Belawan has the highest percentage. Smaller number of provincial ports come to Tanjung Priok.
3. **Flow pattern C**: No provincial ports come to Tanjung Priok, though it still handles export flows originated from its pair-province (Jakarta and West Java). Palembang shows more significant average percentage of handling exports and provincial ports that are used to transship via Tanjung Priok, shift to Palembang.

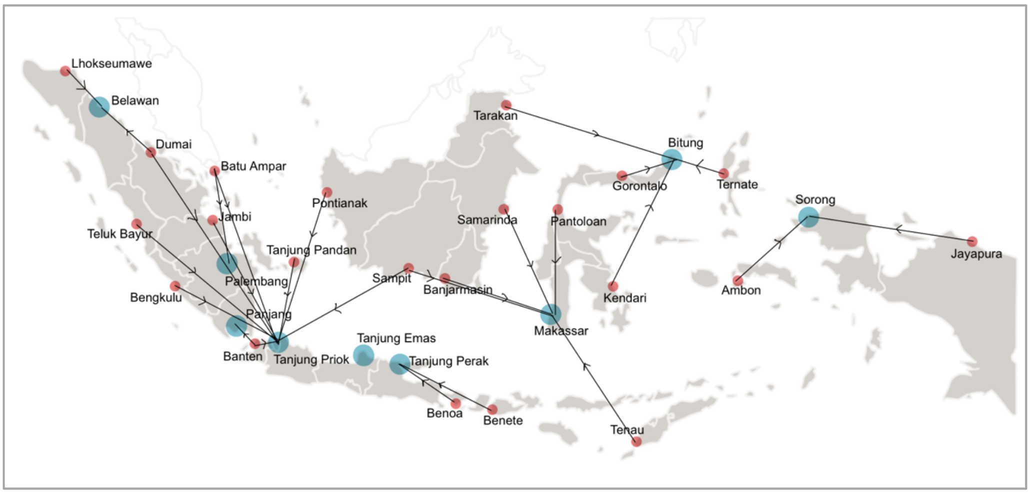

Figure 11 Network with Flow Pattern A – (only domestic arcs considered)

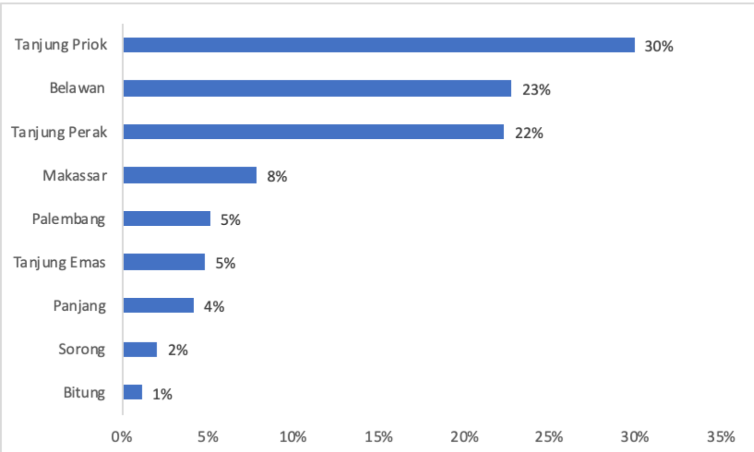

Figure 12 Average percentage of export being handled per gateway – Flow pattern A

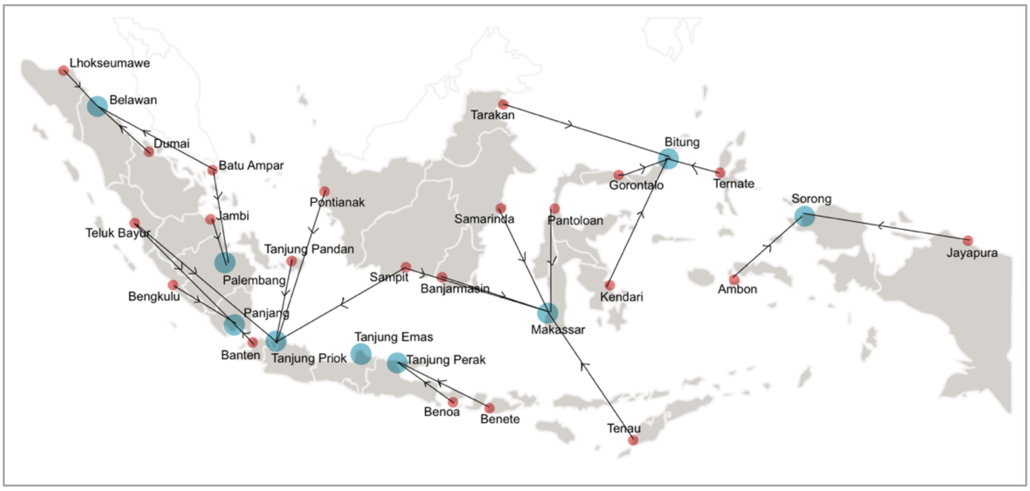

Figure 13 Network with Flow Pattern B – (only domestic arcs considered)

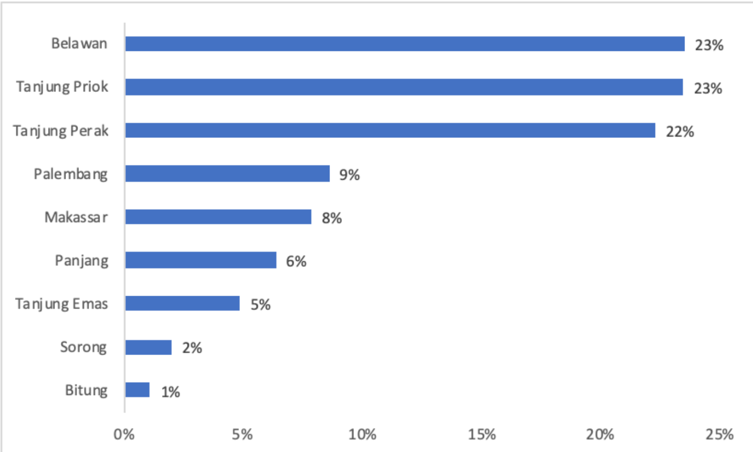

Figure 14 Average percentage of export being handled per gateway – Flow pattern B

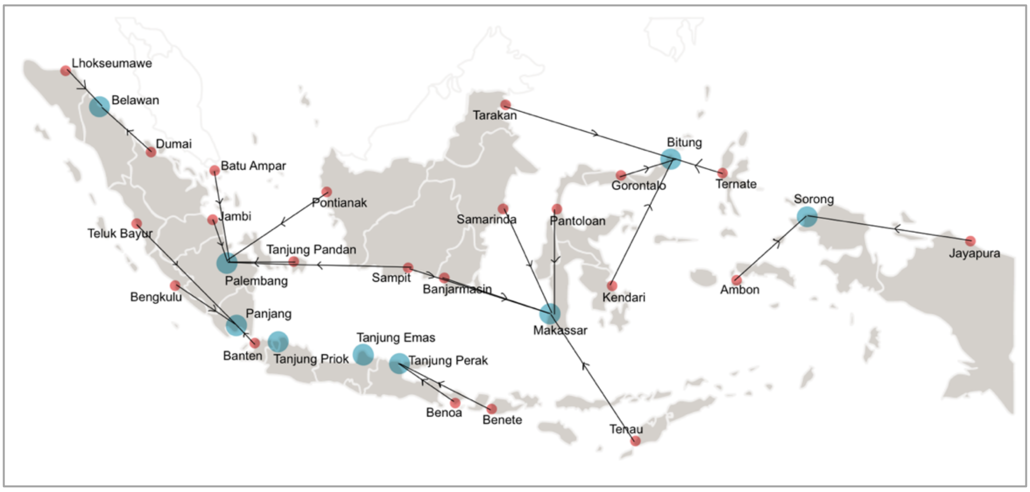

Figure 15 Network with Flow Pattern C – (only domestic arcs considered)

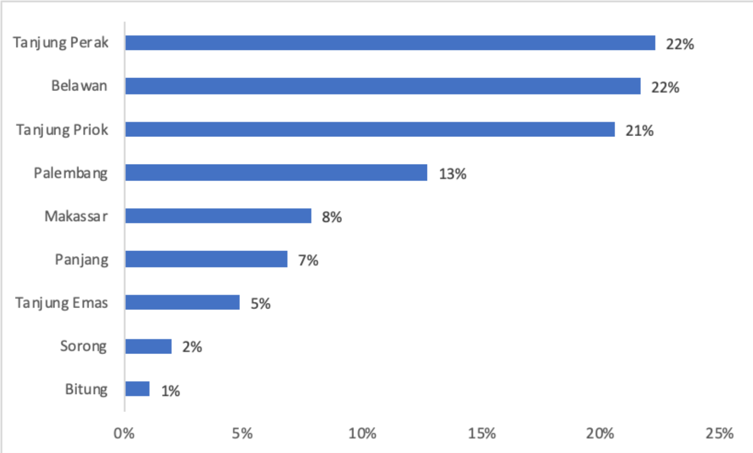

Figure 16 Average percentage of export being handled per gateway – Flow pattern C

Based in these flow patterns, we analyze how each of them being effective in certain period and range of demand. For example, in optimistic scenario period 1 and to, flow pattern A remains effective to be implemented as the model gives results that flow pattern A is the optimal solution under that particular condition. Then, we can build policy pathways map with x-axis represents demand volumes and mapping the flow pattern for each period (Figure 17). Linked to each flow pattern is a policy decision. Policy decisions are the recommendations for policymakers in regard to international container gateways development (see yellow-highlighted box)

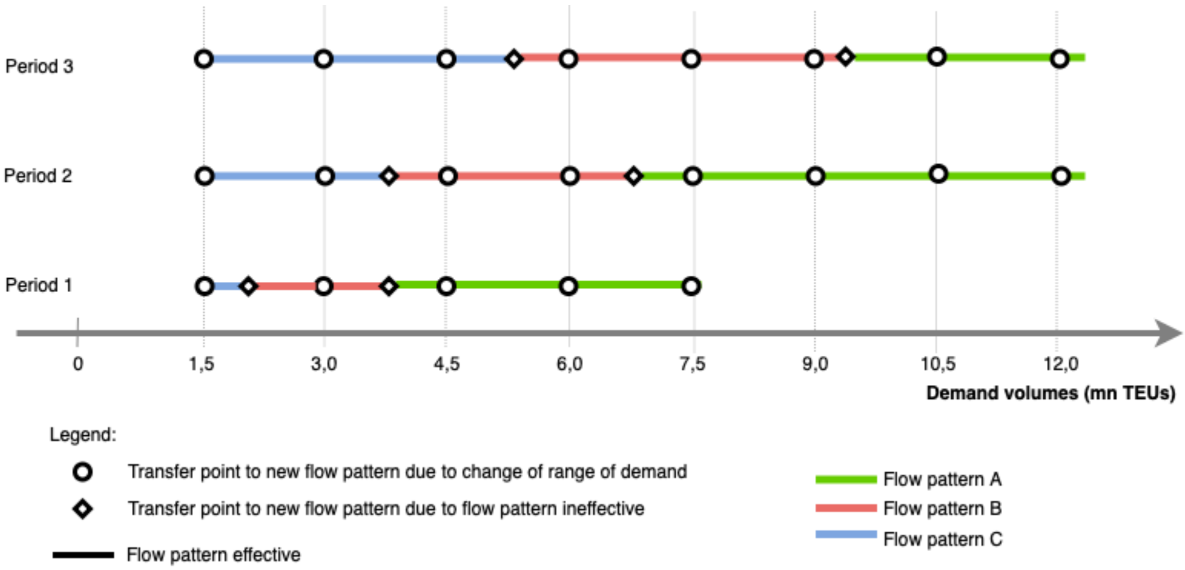

Figure 17 Policy pathways map based on flow pattern assessment of all scenarios

Policy Decision A

The focus in this policy is the development of Tanjung Priok. Tanjung Priok is developed to cope with big yearly demand volume in the future. In other words, it is developed to be the main international container gateway in the country. Belawan and Tanjung Perak become other main gateways with smaller scale than Tanjung Priok. Moreover, Makassar become feeder gateway. The most optimal condition to implement this policy decision is when the flow pattern A is effective.

Policy Decision B

The focus in this policy is the development of Belawan, Tanjung Priok, and Tanjung Perak as main gateways with relatively same scale in handling the exports. They are developed with similar scale to cope with a mid-range of yearly demand volumes. Moreover, Palembang and Makassar become feeder gateways. The most optimal condition to implement this policy decision is when the flow pattern B is effective.

Policy Decision C

The highlight in this policy is the development of Palembang to function as feeder gateway. Palembang is developed to deal with small yearly demand volume in the future that results in more optimal shipping network cost for that range of demand. Tanjung Perak, Belawan, and Tanjung Priok still become the main gateway. The most optimal condition to implement this policy decision is when the flow pattern C is effective.

Based on these policy decisions we can conclude that there are **3 main gateways** remain important for the export trade in Indonesia: ***Belawan, Tanjung Priok, and Tanjung Perak***. Moreover, there are 2 gateways those are likely to become **feeder gateways: *Palembang and Makassar***.

In shipping network planning and policy decision-making, policy-makers need to have reliable predictive pathways to cope with future uncertainties. Thus, the last step in the adaptive policy decision pathways for shipping network planning is the selection of pathways that guide policymaker to make decision over periods under certain conditions. To assume the conditions, What-If Analysis approach is used. The condition is based on yearly total demand growth between periods. The growth is whether increase, decrease, or stable.

Here, we presume three different conditions: (1) yearly demand from period 1 to period 3 remains increasing; (2) yearly demand from period 1 to period 2 increases, but then decreases from period 2 to period 3; (3) yearly demand from period 1 to period 2 is stable, but then increases from period 2 to period 3. The result of policy decision map with selected adaptive pathways for those three different conditions is in Figure 18 below.

By applying this approach, we can analyze how the flow pattern changes from period to another period and therefore may lead to different policy decisions. Having this approach in shipping network planning will help policymaker to have several predictive pathways and thus can support policy decision-making. As what the model results, the flow pattern is very sensitive to demand volumes that it tends to change given the demand value and capacity of a port in a particular period.

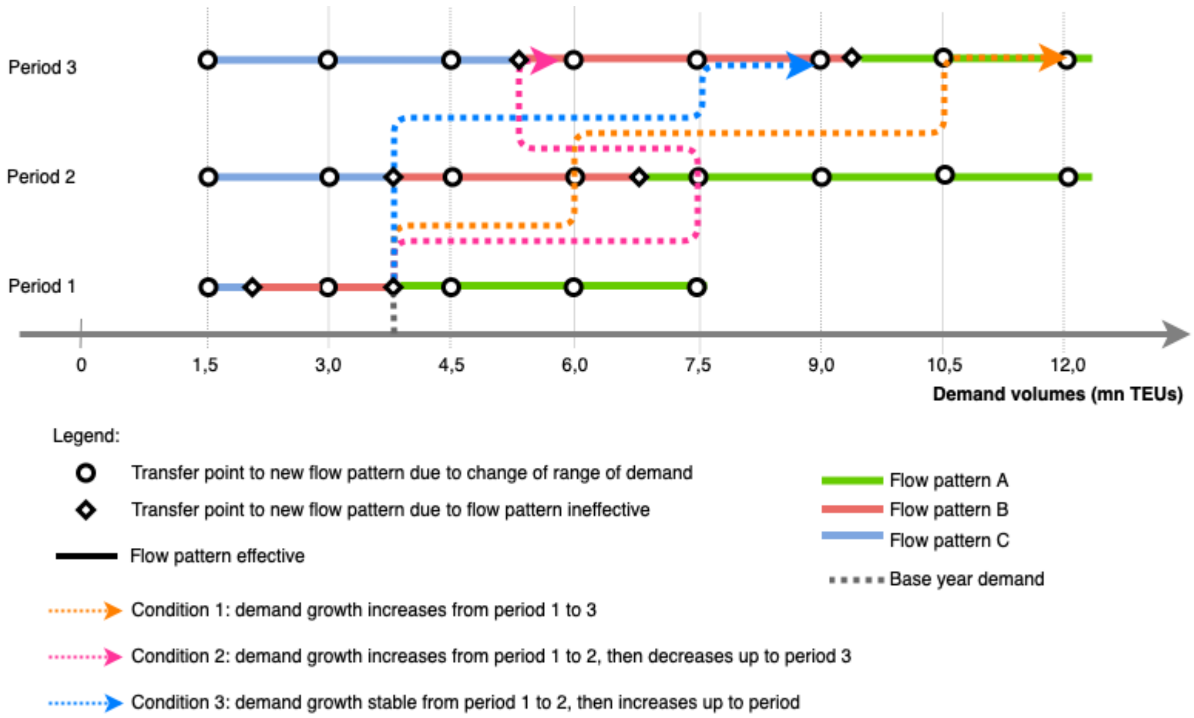

Figure 18 Preferred adaptive policy decision pathways for three different conditions

VI. VALIDATION AND SENSITIVITY ANALYSIS

Furthermore, we do validation and sensitivity analysis for the model used in this research. The validation is done in two cases. This validation is related to an additional gateway candidate namely Kuala Tanjung, which is currently still a greenfield port project in Indonesia. The two cases are: (1) 50:50 case, with demand estimation: Kuala Tanjung takes 50% of total demand volumes of Belawan and (2) extreme case, which only Kuala Tanjung and Bitung developed as international container gateways.

The first case leads to conclusion that Kuala Tanjung is more optimal to be developed as international container gateways compare to Belawan. Having Kuala Tanjung in the network also makes the shipping network cost lower than if the network does not have Kuala Tanjung. Moreover, the second case leads to conclusion that it is not efficient to invest only on Kuala Tanjung and Bitung as gateways since the shipping cost per TEU for the resulted flow pattern is 22% higher compare to the initial flow pattern under the same scenario. On the other hand, considering this extreme plan might be potential to significantly promote eastern part of Indonesia. Since the flow pattern shows that Kuala Tanjung be the dedicated gateway for western part and so is Bitung for eastern part of Indonesia. By focusing only on two international container gateways may lead to efficient and effective spending of investment and thus the quality of both gateways become stronger and significantly improved.

Moreover, we perform sensitivity analysis with respect to changes in number and type of cranes. A study done previously on two big ports in Indonesia Tanjung Priok and Tanjung Perak, there are two types of crane (re: crane) currently used in both ports, namely single-lift crane and twin-lift crane. Besides varying the type of crane, we also set variation of number of cranes which is set from 0 (initial number of cranes), +1, +2, and +3. The first finding of this sensitivity analysis is that as the number of cranes increased, the cost gets lower. Moreover, change all cranes into twin-lift type makes the cost per TEU the lowest no matter how many additional cranes is. See Figure 21. This will lead to different flow pattern once the improvement of cranes applies differently for some ports/gateways.

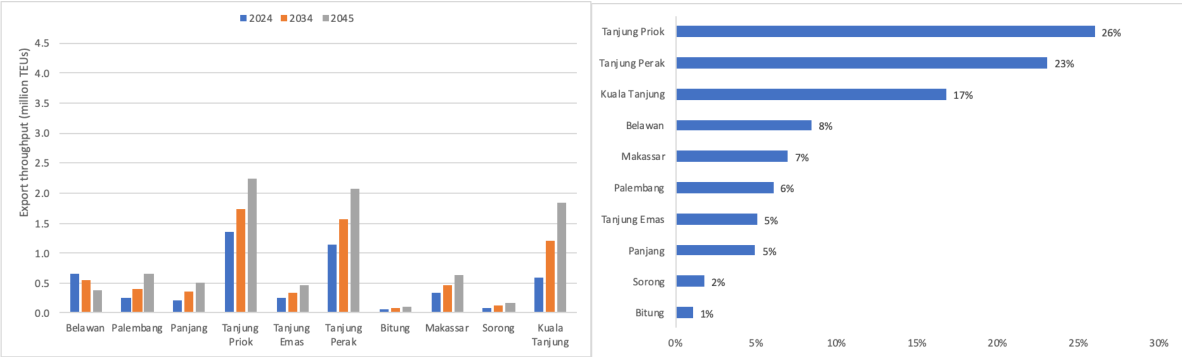

Figure 19 Throughput and average percentage of export being handled – 50:50 case

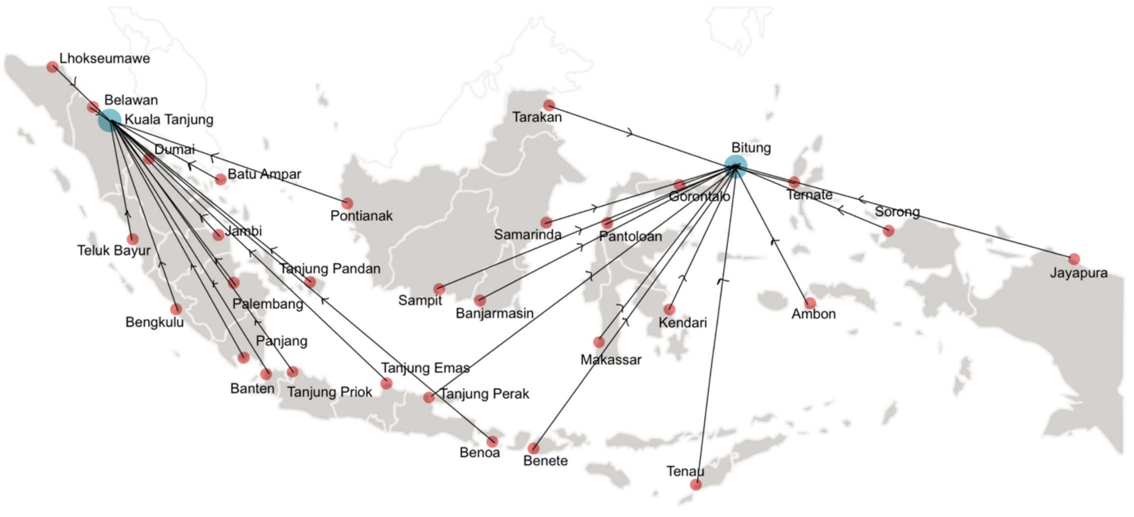

Figure 20 Network with Flow Pattern Extreme Case – (only domestic arcs considered)

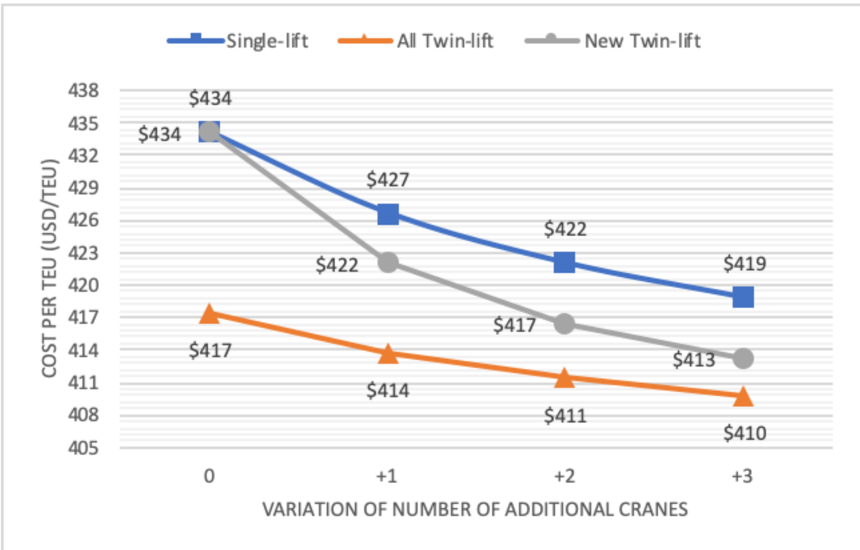

Figure 21 Effects of variation of number of cranes on cost per TEU

VII. CONCLUSION

As the conclusion, the main finding from the model is that flow pattern is very sensitive to demand volumes. That is why there are some scenarios even in the same range of demand but not exactly have the same demand values, may lead to different flow pattern. Second general finding is that MCF model is able to identify the flow pattern so that is very useful to come up with the first finding. In regard to this, during policy decision-making process it is therefore very important to deal with future uncertainties which considering variation of demand volumes. By applying adaptive policy decisions for shipping network planning, the results show that there could be more than one plausible policy decision for a single period. Given that shipping network planning is future long-term plan with full of uncertainties, using the approach of adaptive policy decision pathways with integration of network flow model is one of the solutions. The key factor in this model is thus demand volumes which results in flow variables for each of ports. Then, these flow variables create a pattern which we can further analyse to identify under which condition the flow is being effective. Since each of flow pattern gives the information about flows in each port and how ports connect to each other, we can determine the promising ports within each flow pattern. Based on this, policy decision pathways are able to be built, thus supports more robust investment planning for ports development in Indonesia under future uncertainties.

The recommendations are divided into several perspectives. In terms of model improvement, it is recommended to take the model to the higher level of operational research and computational model. Since the model is used the very classic one, nodes and arcs are predetermined. Therefore, the model used in this research is not yet designing a network. Moreover, the recommendation for further research is to consider different types of commodities as one additional variable in the shipping network problem, which may result in more detailed policy recommendations. This is due to the fact that export trade in Indonesia also includes other types of commodities.

As insights for policymaker, the approach used in this research is done in strategic level. Therefore, further analysis once the results want to be applied in tactical and operational level are required. Lastly, the recommendation from the perspective of data collection is by expanding the system to intermodal transport to capture the accessibility and connectivity amongst ports and their hinterland through other modes such as road transport. Therefore, if more detailed data collected, especially in related to hinterland connection, the analysis will be more reliable, and the policy decisions will touch cross-sector recommendations.

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