Multimodal Freight Transport Network Design and Optimization Using Bilevel Optimization Model

Case Study: Indonesia

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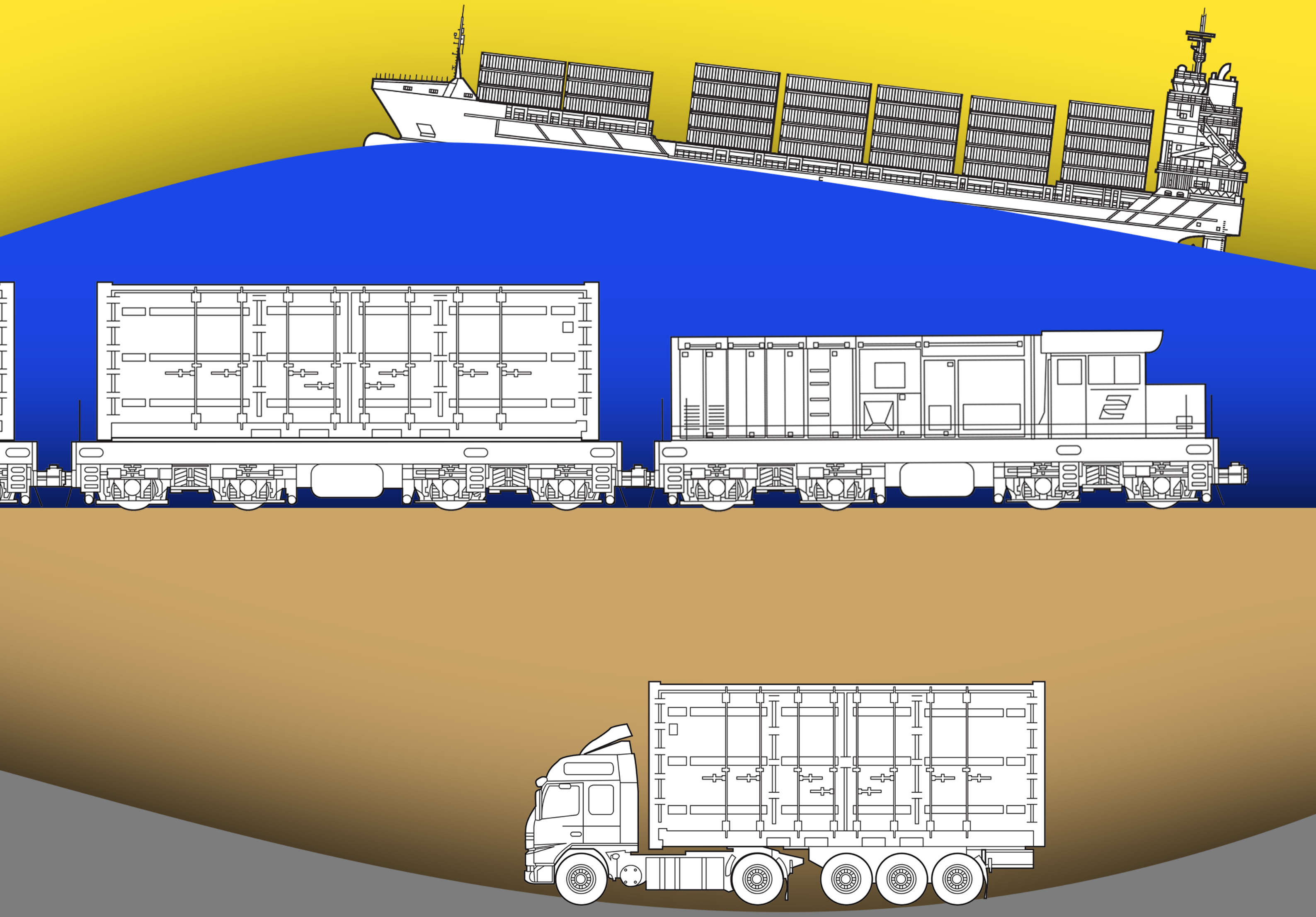

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by

Evan Clearesta

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Preface

I witnessed the conditions in Indonesia as a developing country. I witnessed the disparity of the life quality between the Western and Eastern part of Indonesia. The price for basic goods are much higher in the East and the access to those places are much more expensive. Through discussions and conversations with my colleagues I grew a fond interest in transportation and logistics. One key aspects in economic growth of a country. I realized how important it is for an archipelagic country to develop an efficient transport system. Then I decided to choose transportation and logistics as my specialization.

I firstly came to Professor Lori asking for a topic that I found in the graduation portal, solely aiming for a topic in which I could learn further about the sector of transport and logistics. But I got what I asked for. I am really thankful when he offered me a bunch of possible researches that I can do for Indonesia. I was like a kid excited to enter his first class at school wanted to do them all. At the same time I was thinking I could do all of them and astonished by how could he trust me with all of them. For me, it was a challenge, a trust and a path to go further.

The process was not a smooth one. I went through a lot of stressful time. Sometimes I do not think that I can make it all. But I kept trying and got there slowly. No word can tell how rending it is when I finally made it. When Ron and Bert said that I did a good work. When Ron said my work would be useful for the further research and when Bert sent me an email before the green light said that I would absolutely get a green light from his side seeing my work. It feels like magic.

On my green light meeting, Professor Lori asked me if I can improve my work by adding other calculation which is part of my colleague's thesis, another investment evaluation and a more advanced calculation method, I felt challenged and also trusted. I strive to do all of them. And I did.

This work is a result of a man that learned from scratch with almost zero knowledge on the field, that went through hard times on the process with a lot of support from his teachers, family and friends.

To all of the efforts that I did. I would like to give my sincerest and heartfelt gratitude to Professor Lori Tavasszy who believed and trusted me with the challenges, to Ron van Duin with his supports and feedbacks, to Bert van Enserink with his knowledges during my 2 years study period and to Ni Luh who made this research possible in her research. I would also never make this without the warmest support from my father and mother that were always there when I need the most, on my hardest time. To my friends and the people that once stepped in my life that supported me mentally with the laughters, talks and presences. And the last but not least to the Indonesian government who gave me the financial support for my study through the scholarship.

I would not make it this far without the help and support of all the people around me. I present this result for all the help, all the support, for the advancement of science, and for a better life of the people in Indonesia. I will never stop learning. This phase taught me to overcome my limit, to break the impossible, to give back what I had took.

Evan Clearesta
February 2017

Executive Summary

Introduction

As one of the main focus within the National Masterplan on the Acceleration of National Development, Indonesia now turns their infrastructure development focus and concept towards the multimodal transportation. As a result, the Ministry of National Development Planning in 2015 planned develop road, railway and maritime transportation for both passenger and freight transportation. Within the freight transportation scope, they aim to reduce the disparity between the Western and Eastern part of Indonesia, as well as reducing the general logistics costs. Several policies have been developed. On maritime transportation, the central government planned the development of 24 main ports and the national maritime highway concept. Concerning road transportation, road maintenance and new highway route construction have been planned. As for railway transportation, construction of new railway connections in all the big islands in Indonesia will be performed.

Based on the past research by the Ministry of Transportation, the modal share in Indonesia is mostly dominated by road transport using trucks. For an archipelagic nation that mostly surrounded by water and with islands that have long spanning distance, this is a proof that the transportation in Indonesia still can be optimized. Trucks are not the most efficient means of freight transportation as it can only carry limited amount of goods and is slower compared to the other modes. By creating policies to boost the usage of the other modes, the logistics costs in Indonesia can be reduced and the network can be optimized.

Another issue faced by Indonesia is the domination of unimodal transportation systems. Even though most of the shipments are long-haul shipments, trucks are still mainly used. Hence, the economies of scale are not be achieved. By introducing a multimodal transportation system, the freight transportation in Indonesia can be optimized further and made more efficient. Multimodal transportation could be the solution to solve the high logistics cost faced by the country. It has been set as an achievement target by the central government within the National Master Plan on Acceleration of National Development to solve the logistics costs issue and trade imbalance issue.

This research focused on the multimodal transportation network design and optimization in Indonesia along with the analysis on the government's policies on freight transportation. Beside the integration of the freight modes, the government also planned to cut the fuel subsidy that accounts to a big portion of the national spending. Therefore, the main focus of this research is to develop a multimodal network along with several policy recommendations to support the Indonesian government to optimize the network. Hence, in order to operationalize the objective of this research, the following research question was formulated.

"What are the recommendations of optimized multimodal transport network design in Indonesia by considering the future infrastructure developments"

The scope of this research itself will focus on freight transportation between provinces in Indonesia. The freight transport modes are limited to the main modes used, which are trucks, railway and maritime transportation. In order to analyze the effect of the policies, this research performed several scenario analysis for the year 2030. The year was decided based on the target of the National Master Plan. The results then were compared to the present condition.

Multimodal Freight Transport Network Design and Optimization

In order to design the multimodal freight transport network in Indonesia, the unimodal transport network in Indonesia was first build. The unimodal network was integrated into a multimodal network by adding transshipment links between the modal specific links.

The data for the network parameters was gathered from different resources. The network parameters consist of vehicle data (i.e. speed and operational cost), node set, link set, link distance, transshipment time and transshipment cost was listed and added to the model. The data was then added to the program. The AIMMS program was used to build the model. For the network flow between provinces, the latest available data is the origin-destination (OD) freight flow matrix in 2011. The future OD flow data was predicted using the growth factor method. The growth factor data used by Faisal (2015) was used in this research.

The optimization problem was modeled as a bi-level optimization problem. The lower level problem is the network optimization problem. The objective of the network optimization problem is minimizing the logistics cost. Four-step modeling approach was used on this level. Firstly, the k-shortest route method was used to find a set of routes with different criteria such as least distance, least free-running time, least cost, and least-transshipment. Secondly, the route-choice probability was calculated using path-size logit model that takes into account the path overlap within a route. Thirdly, the freight was assigned to the network based the route-choice probability. From these steps, the total cost of the network, the modal share and the link flow data were obtained.

The upper level problem covers the investment optimization problem. The objective on this level is to maximize the benefit to cost ratio (BCR) of the given set of possible improvement actions. The upper level problem was solved with simulated annealing method with tabu constraints. Simulated annealing is one of local search heuristic method that was inspired by the physical process of a heated solid that is cooled down. The lower the temperature gets, the lower the chance that bad solution will be accepted. In every iteration, the benefit to cost ratio (BCR) of the combinations were calculated through the lower level optimization. The network improvement combination was added to the existing network and optimized on the lower level. The benefit was defined as the difference between the logistics cost on the improved network and the existing network. Finally, the BCR was calculated by dividing the benefit with the total investment cost to improve the network.

After the model has been verified and validated, several scenarios were tested and analyzed. Five scenarios were defined based on the current policy plan by the Indonesian government. The first scenario is the status quo scenario, where no improvement will be performed on the network. In this scenario, the effect of the freight flow growth on the existing network is assessed. The second scenario explores the effect of the fuel subsidy reform policy by the central government. The third scenario explores the possibilities of relocating the subsidy to other modes. The fourth scenario analyzes the effect of network improvement plan on constructing all the new railway connections in all the big islands in Indonesia. The last scenario analyzes the alternative to implement a prioritization on the network improvement actions in order to avoid the significant change on the network by performing all actions at once.

The first scenario shows that if no improvement is added to the network, there will be no significant change within the network, the flow concentration will still be the same, as well as the modal share. The second scenario shows that by removing the subsidy from trucks will reduce the trucks‘ modal share by 3.6% to 80% and increase the railways‘ modal share to 6%. In terms of expenditures, the central government could also save as much as 119.4M€. The third scenario shows that maritime transportation are not sensitive to fuel subsidy as maritime transport costs are mostly affected by the transshipment cost. On the other hand, the railways' modal share is more sensitive to the fuel price change. By giving 40% subsidy on its fuel, the railways‘ freight flow increased by 176%, thus increasing the railways‘ modal share to 7%. The implementation of all network improvements scenario found that the change in the network would also change the modal share significantly. With the BCR of 1.21, compared to the calculation of every action‘s BCR if they are to be implemented individually, this BCR is relatively small. Beside the BCR calculation, network accessibility measurement and net present value (NPV) analysis was also performed. With the actions implemented, the overall accessibility of the network would improve, especially the accessibility level in the Eastern part of Indonesia. The highest increase would be in Papua, with 22.9% increase in its accessibility level. On the financial side, the NPV analysis showed that the project would have positive NPV within 19 years after the investment has been made. To explore the possibility to ease the significant modal share change, the fifth scenario was analyzed. In the fifth scenario, prioritization was added to the improvement plan. The prioritization sort the improvement action combinations based on their BCR value relative to the current network or the previous improvement. Using this alternative, the modal share will change gradually.

Policy Recommendations

Based on the result of the scenario analysis on the central government's future plan, two policy recommendations were proposed. The first recommendation to the central government is to perform the fuel subsidy reform on trucks. The fuel subsidy reform would give benefit to the central government by saving the subsidy expenses. Hence, the financial allocation could be moved to other important sectors. The second recommendation is to implement the improvement actions with the prioritization. Not only does this alternative allow for incremental change, it would also provide the decision maker valuable time to react to hurdles during the process. Performing the improvement actions also found to be beneficial to the whole country by increasing the overall accessibility level of all the provinces in Indonesia. Beside the positive benefit to cost ratio given by the all actions, financially, the project would have positive net present value within 19 years after the investment was made for the scenario that the improvement actions are to be implemented all at once and 15 years in the case that the improvement actions are to be implemented based on their priority rank.

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Chapter 1

Introduction

This chapter discussed the background of this research. Starting with explaining the current practical problem in Indonesia and scientific problem on freight transportation, this chapter specified the research plan in order to solve part of the problems. Given the problem, firstly the objective was defined. Secondly the research questions were formulated along with the approaches that will be taken to answer them. Lastly, the planned outcome, the data gathering plan and the research structure were listed.

1.1 Research Problem

Globally, freight transportation plays an important role in shaping the global economy. Freight transportation makes economic activities and transactions feasible, connecting actors within supply chain networks that are geographically dispersed. By connecting the supply-based regions and the demand-based regions, freight transportation has received a big attention in the global supply chain.

The world trade has grown significantly in the last few decades from about 4 trillion USD in 1990 to about 24 trillion USD in 2014 (UNCTAD, 2015). The increase in the world trade leads to higher demand in more reliable and cheaper freight transportation. In order to cope with the increasing freight transport demand, most actors aim to achieve high performance levels both in terms of economic efficiency (i.e. maximum profits, minimum costs) and service quality (i.e. total delivery time, service reliability) (T. Crainic & Laporte, 1997). Many research in freight transportation domain in strategic, tactical and also operational level have been conducted. Within the strategic planning scope, multimodal transportation is seen as a way to reduce the cost and increase the transport network efficiency. T. G. Crainic and Kim (2007) define multimodal transportation as the transportation of a person or a load from its origin to its destination by a sequence of at least two transportation modes, the transfer of one mode to the next being performed at an multimodal terminal (p. 467).

Several research have analyzed multimodal transportation network design and its optimization with different objectives (i.e. minimum cost, distance, time, investment). The chapter of T. G. Crainic and Kim (2007), the review papers of Christiansen, Fagerholt, Nygreen, and Ronen (2007), T. G. Crainic and Bektas

(2007), and (Steadieseifi, Dellaert, Nuijten, Woensel, & Raoufi, 2014) are the most recent review papers on multimodal transportation planning problems. Overall, multimodal transportation has more benefit in terms of cost efficiency (Janic, 2007) and emission level (Liao, Tseng, & Lu, 2009) compared to unimodal transportation. Multimodal transport system is also useful in expanding the freight transport system in developing countries, where road transportation still has much more share compared to the other transport modes. Using the combination of multiple transport modes, the cost of medium and long-haul transport can be significantly reduced compared to the use of a single transport mode (Banomyong & Beresford, 2001). Therefore, for medium and large developing countries, it would be beneficial to implement multimodal transport system for medium and long-haul freight transport.

Indonesia is the largest archipelagic country in the world with more than 17,000 islands and surrounded by water (i.e. ocean, sea, straits and rivers) in 80% of its total area. Indonesia is still highly dependent on road mode freight transportation, especially trucks. And the logistics costs for transporting goods in Indonesia are really high. In order to reduce the costs, the Indonesian government has issued maritime highway policy to reduce the maritime logistics costs and to increase the maritime transport efficiency. However, there is still room for improving the freight transport system in Indonesia by integrating the different modes of transport that are available. Thus, creating a more efficient system with lower logistics costs.

1.1.1 Practical Problem

With the characteristic of an archipelago nation, Indonesia has some serious challenges on freight transportation domain. Both inter-islands and intra-island transportation are required to ensure the connectivity of the separated areas. The need of inter-islands connectivity makes maritime transportation important to connect the islands. However, based on global competitiveness index 2015-2016, Indonesia‘s maritime transport infrastructure is ranked 82 among the 144 other countries (World Economic Forum, 2015). This means that the maritime transportation in Indonesia is still far from efficient. For intra-island connectivity in Indonesia, road transport using trucks is mainly used. Hence, within an intra-island transportation, unimodal transport system is mainly employed.

The inefficiencies in Indonesia‘s inter-island supply chains have caused several problems. These inefficiencies adversely affect the Indonesian economy in three ways: different regional economic growth rates; disparities in prices of commodities in different locations; declining competitiveness of domestic products in export and local markets (Bahagia et al., 2013). The inefficiencies also led to high domestic logistics costs in both Indonesia‘s sea and inland freight costs. One of the reasons that causes the high logistics cost are the differences in trade volumes between the origins and destinations. The utilization of trucks as the main transport mode also contributes to the high total logistics cost in Indonesia.

Currently, the maritime transportation in Indonesia has lower modal share compared to land transportation. The maritime transportation share is only 7.9%, while the hinterland transportation share that is dominated by the use of trucks is 91% (Indonesian Ministry of National Development Planning, 2013). The significant use of land transport has generated several problems such as increased congestion, increased energy consumption and negative environmental impacts.

Acknowledging the need for a better maritime transport infrastructure as an alternative, as well as to support the land transport and to reduce the logistics costs, the Indonesian government introduced the maritime highway policy in 2014 and planned several new land infrastructure constructions. The maritime highway policy aims to develop strategic ports in Indonesia to form a backbone of national maritime transportation network (Ministry of National Development Planning, 2014). Development of other supporting ports and ship procurement also take part in this policy, along with the main maritime routes for freight transportation.

From the research, the maritime highway network could increase the efficiency as well as reducing the cost by 44.5% (Bahagia et al., 2013). In the maritime highway network, the network is switched from a single port call to hub-and-spoke network where multi-port calls (MPC) are operationalized, and therefore increasing economics of scale. 24 main ports are developed as the hub ports and the smaller ports become the feeder to the hubs. The network is illustrated in Figure 1.1 below.

Figure 1.1: The maritime highway corridors in Indonesia (Indonesia Port Corporation II, 2012)

Indonesia has also been focusing in infrastructure planning and development in land transportation especially in new rail and road infrastructure on every islands. The development aims to increase the transport efficiency in Indonesia. Even so, the transport system in Indonesia can be improved further by introducing multimodal transportation system. Currently, the development of each transport mode infrastructure are not yet integrated with other modes. The need for an multimodal transport system has been discussed by the Indonesian government as stated in the Sislognas, Sistranas and the Masterplan for Acceleration and Expansion of Indonesia‘s Economy (MP3EI). Therefore, by introducing multimodal transport system, the transport network in Indonesia can be optimized even further, thus reducing the total logistics costs and increasing the network efficiency.

1.1.2 Scientific Problem

Network design is one of the most difficult and challenging problem in the transport and logistics research (Yang & Bell, 1998). It can be modeled as a discrete or continuous model. The discrete model of the network design problem is a NP-complete problem, which means it is unlikely to solve the problem within polynomial computation time (Johnson, Lenstra, & Kan, 1978).

Several researches in various articles and books presented the methods in solving the network design problem, such as Magnanti and Wong (1984), Yang and Bell (1998), Steenbrink (1974). These researches showed that there are many ways in solving the network design problem. Even though the methods are different, they also have certain similarities. One of the way to formulate most network design problem is by formulating it as a bi-level problem. A bi-level problem consist of upper and lower level problem, in which both levels has its own objective function. The upper level usually consists of the problem whether new links or connections should be added to the model or not. Network improvements such as capacity expansion of the links or nodes can also be part of the upper level problem. The lower level problem is the freight assignment problem, where the flow is assigned to the network.

The bilevel problem can be solved in different ways. The existing approaches in the literatures can be categorized into three groups (i.e. discrete and exact approach, discrete and heuristic approach, and continuous and heuristic approach). The first group, a branch and bound algorithm (Leblanc, 1975) and a branch and backtrack algorithm (Poorzahedy & Turnquist, 1982) was used. In the second group, a cumulative genetic algorithm (Xiong & Schneider, 1992) is used. The third group methods are used most frequently. Some methods are; simple approximation method (Pearman, 1979), decomposition method (Steenbrink, 1974), and simulated annealing (Friesz, Cho, Mehta, Tobin, & Anandalingam, 1992).

The lower level problem can be solved by using different traffic assignment methods. The traffic assignment method should be chosen between static or dynamic assignment, between deterministic or stochastic assignments, and between single or multi-user assignment. The different assignment methods are discussed extensively in Ortuuzar and Willumsen (2011).

Previously, not many research have been performed on freight network design problem in Indonesia. Russ et al. (2005) conducted a research on bilevel optimization of Indonesia‘s transport network but only limited in several parts of the country. In their research, the model is aimed to deliver network improvement recommendations. However, the research does not extensively explore the other possible policy recommendation for the national transport network. Faisal (2015) performed a network optimization in Indonesia but only limited to the maritime network for the maritime highway policy with several scenarios. (de Baat et al., 2015) analyzed the multimodal transportation for different commodities in Java. Therefore, in the previous researches, there is no complete model of Indonesia‘s transport network where the different transport modalities have been built.

Reflecting on the limitation of the previous research, this research aims to build a national multimodal transport network in Indonesia along with the possible network improvements. Besides optimizing the network, this research also explored the other policy alternatives within the scenarios to tackle the freight transport problem in Indonesia.

1.2 Research Objectives and Research Questions

Based on the aforementioned research problems, the main objective of the research, therefore is to provide an optimized multimodal transport network design recommendation for Indonesia. The model should incorporate the future infrastructure planning with the current logistics infrastructure in Indonesia in order to analyze the future alternatives and scenarios. In the end, an integrated maritime and land transport network for multimodal transport system can be achieved and investment recommendations (i.e. freight terminal locations and new links) could be proposed. The challenge would be in integrating both maritime and land transport networks into the model and to cope with the limited access to information and data in order to build the model. The research also has other objectives to achieve the main objective, which are:

1. To build the unimodal network schematizations of Indonesia transport networks.
2. To design the multimodal transport network for Indonesia.
3. To perform optimization on the multimodal transport network with the objective to minimize the total transportation cost and to maximize the benefit to cost ratio (BCR).
4. To perform scenario analysis on the model.
5. To give policy recommendations based on the result of the scenario analysis.

In order to operationalize the research objectives, the following research question was formulated: ***What are the recommendations for multimodal transport network design and optimization in Indonesia by considering the future infrastructure developments?***. To answer the main research question, the following sub-questions (SQs) are formulated.

SQ 1. Which factors should be incorporated into the model?

There are specific criteria of what factors should be incorporated to the model. In order to specify the factors, the current condition in Indonesia‘s transport network should be analyzed. The factors listed will be analyzed to define the objective, the constraints, scope, limitation assumptions, data inputs and further incorporated to the optimization model.

SQ 2. How can an optimization model be made to optimize the multimodal transport network in Indonesia by taking into account the aforementioned factors?

After the important factors have been listed, the optimization model will be formulated. The next step is to design the multimodal transport network in Indonesia. The initial multimodal transport network will be build and schematized using AIMMS software. Then, the optimization method will be chosen based on literature studies and the optimization model will be made in order to optimize the new multimodal transport network. Several mathematical formulations of the listed factors will be integrated into the optimization model.

SQ 3. What is a good design of multimodal transportation in Indonesia?

The network optimization is a combinatorial optimization problem, which means there is no one best solution to the problem, but a set of solutions to the problem. The data and all the input variable will be entered to the optimization model and the model will be executed with all the constraints and input in order to achieve the objectives. The model will give a set of solutions to the problem, which will be analyzed further

SQ 4. How should the policies be implemented based on the model?

Using the model, the policies and plans by the main decision maker regarding Indonesia‘s freight transportation will be analyzed. Several scenarios will be developed based on the government‘s plans. The result of the scenario analysis will be analyzed and policy recommendations based on the result will be given.

1.3 Research Scope

A model is a simplified representation of reality. It is called a simplified representation because not all details are added to the model. Several details are omitted, thus the simplification is achieved. Real life condition contains many variables that sometimes it is not clear whether certain relations or entities are optional or important within the system. Hence, the model designer must define an own interpretation based on the model purpose. Therefore, the model should have certain scope in order to give the model certain boundary based on the model purpose. The scope of the research is formulated based on Sun, Lang, and Wang (2015) the optimization model formulation characteristics as listed below

1. **Scale**. The research focuses on designing a multimodal freight transport network on the national scale of Indonesia. The scope of the supply chain network will be the chain from the manufacturer until the destination warehouse.

2. **Objective**. The objectives of the model itself are to minimize the total logistics costs and to maximize the benefit to cost ratio (BCR) for the infrastructure investments. The problem was modeled as a bilevel optimization problem.

3. **Modes**. The model would includes all the possible freight transport modes that are available in Indonesia, which are road, rail, and maritime mode.

4. **Commodity and Commodity integrity**. The model will analyze the supply chain network of single and unsplittable commodity. The commodity will be measured in twenty feet equivalent unit (TEU).

5. **Network Resources**. The network is assumed to be an uncapacitated network where the inventory capacity is not included in the constraints. Therefore the links and the nodes are assumed to have unlimited capacity. This limitation is due to data unavailability of the nodes and links capacity.

6. **Data Assumption**. The model will be assumed as a deterministic model with fixed value of certain data (i.e. distance, demand, cost).

7. **Perspective**. The perspective of Indonesian government as policy maker will be used. Specifically, the central decision maker is the Indonesian Ministry of National Development Planning.

1.4 Research Approaches

The following research methods will be performed to answer the research questions.

Table 1.1: Research Methods for answering research questions

Sub-question	Research Method	Description
1	Literature Review	Literature review will be used to find the factors related to the current situation in Indonesia and also to find the important factors that should be included into the model from other scientific research.
2	Literature Review	Literature review will be performed to compare optimization problems in network design problems. Based on the literature review the suitable optimization model will be chosen and adjusted to the research problems and objectives.
3	Network Schematization	The transport network of different transport modes in Indonesia will be schematized using AIMMS software.
	Mathematical Modeling of Optimization Model	Mathematical modeling will be used to formulate the decision variables, objective and constraints of the optimization model
	Programming and Simulation	The model will be run using AIMMS in order to achieve the objective of the optimization model

Table 1.1: Research Methods for answering research questions

Sub-question	Research Method	Description
4	Scenario Analysis	The model will be used to test several future scenarios. Further, the results of the scenario analysis will be used as the basis on giving the policy recommendations

The following Figure 1.2 illustrated the approach for the research project. Firstly, the theory related and the current situation in Indonesia will be studied. Secondly, several models will be formulated. The multimodal transport network will be modeled as the lower level problem, then the list of future infrastructure developments will be added to the upper level problem and the solution technique model for the bilevel optimization problem. Thirdly, the integrated multimodal transport supernetwork of Indonesia will be optimized with the optimization model with the objective of minimizing the logistics costs and maximizing the benefit and cost ratio. Fourth, the scenario analysis will be performed to the optimized network in order to test the network robustness for certain future scenarios. After the network design satisfies the requirements, the result will be analyzed, recommendation will be delivered and the research will be concluded.

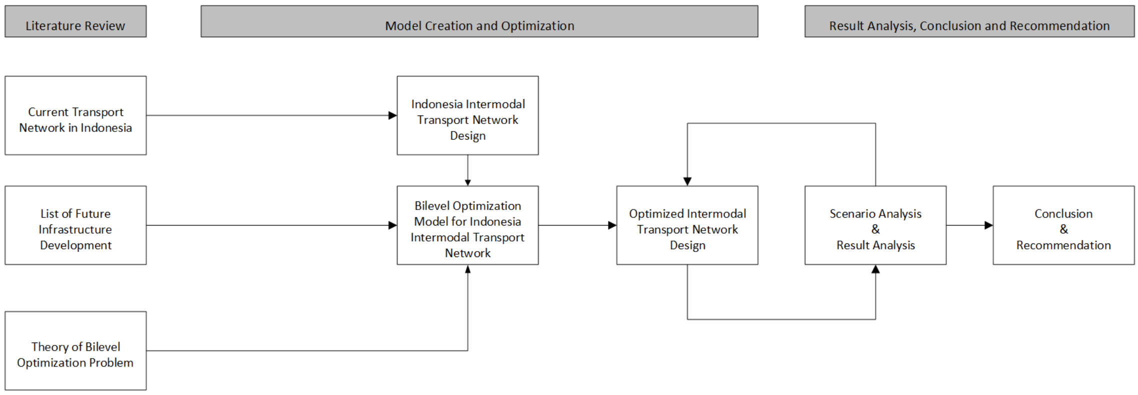

Figure 1.2: Research Framework

1.5 Research Outcomes

There are three expected outcomes from this research. Firstly, an optimized multimodal transport network design for Indonesia. The multimodal transport network will be schematized using AIMMS. In the future, this network schematization can be used for other policy research and analysis in Indonesia. Secondly, the research will give policy recommendations on the central government‘s plan concerning Indonesia‘s transport and logistics systems. The policy recommendations will be given based on the result of the scenario analysis performed.

1.6 Data Gathering and Information Sources

Data and information needed in this study are mainly used as inputs for the model. Table 1.2 below lists the data that would be needed in order to perform the research along with the source that will be used to procure them. Mostly, the data are not widely available or easily accessed on the web. Therefore, in order to obtain all the data, several communications were made with some colleagues.

Table 1.2: Data list and sources

Data Needed	Information Source
Origin-destination demand data between provinces in Indonesia	Ministry of Transportation (2014).
List and information of Ports in Indonesia	Directorate General of Sea Transportation in the Transportation Ministry of Indonesia.
Transport cost function (transport cost, handling cost, transshipment cost)	Bahagia et al. (2013)
Indonesian GDRP data per province	Indonesian Central Statistics Bureau (2016b)
Time and Distance between origin and destinations by mode	Open Government Indonesia (n.d.)

1.7 Report Structure

This thesis report comprises of eight chapters. The chapters are as follows.

The First Chapter is the introduction part of the research. This chapter explains the general overview of the practical and scientific problems, the research objectives, research questions, and the scope of this study.

The Second Chapter elaborated the problems that are intended to be solved in this research. This chapter also introduces the general condition of Indonesia, which is the country used as the case study. Further, it covers the explanation of the current conditions of Indonesian freight transport facilities and infrastructures. Several policies regarding the freight transportation by the central government of Indonesia are elaborated as well.

The Third Chapter elaborated further the policies related to freight transportation in Indonesia. These policies need to be incorporated into the future scenario to see how they would perform. Actor analysis was also performed in this chapter to understand the policy making environment in Indonesia.

The Fourth Chapter breaks down the aspects required to be considered for the model building process in order to answer the research questions and also the data that will be used in the model. In this chapter, the model resolutions, the key performance indicators and the scenarios are elaborated. Then, based on these requirements, the specifications of the model are determined. The data used for the model along with the source and the data processing are also elaborated in this chapter.

The Fifth Chapter discusses model framework along with the knowledge backgrounds required for the model in more depth. Literature studies were performed and used in order to build the model framework. Further, based on the model requirement, the model specifications were defined and the components were explained.

The Sixth Chapter explained the implementation of the model framework on the program. Firstly, the codes programmed within the model that are created based on the theories are presented and explained. Then, in order to ensure the model works as expected, the validation process is performed and analyzed in this chapter.

The Seventh Chapter shows the application of the model on the case study. The scenarios defined in the third chapter are added in the model and then the result of the program execution are analyzed further. The model verification was also performed in this chapter using the base case scenario. In the end, policy recommendations are given based on the scenario analysis.

The Eighth Chapter lists and explains the conclusion of this research along with several recommendations for future improvements.

Chapter 2

Present Freight Transport Condition in Indonesia

In this chapter, the current situation of Indonesia‘s transport system is described and analyzed including the geographical characteristics, socio-economic characteristics, and the development in the transport and logistic sector in Indonesia. The problems of the high logistics costs and the lack of an integrated transport system are also elaborated in this chapter.

2.1 General Overview of Indonesia‘s Geography and Socio-Economy

Indonesia is a vast archipelago country with more than 17,000 islands. Indonesia has an area of about 5.1 Million km^2, with 75% are the sea area, making Indonesia the world‘s 15th largest country in terms of land area. It is located between Indian Ocean and Pacific Ocean and between the Asian continent and Australian continent.

Figure 2.1: Map of Indonesia

Indonesia has 33 provinces, as listed in Table 2.1 below, with Jakarta as the capital city of the country. These 33 provinces along with the capital will be incorporated into the model. The set of provinces will be the zones with the capital city as its centroid.

Table 2.1: Provinces in Indonesia and the capital cities

No	Province	Capital City	No	Province	Capital City
1	Nangroe Aceh Darussalam	Banda Aceh	18	West Kalimantan	Pontianak
2	North Sumatera	Medan	19	East Kalimantan	Samarinda
3	Riau	Pekanbaru	20	South Kalimantan	Banjarmasin
4	West Sumatera	Padang	21	Central Kalimantan	Palangkaraya
5	Jambi	Jambi	22	North Kalimantan	Tanjung Selor
6	South Sumatera	Palembang	23	South Sulawesi	Makassar
7	Bengkulu	Bengkulu	24	North Sulawesi	Manado
8	Lampung	Bandar Lampung	25	Central Sulawesi	Palu
9	Riau Islands	Tanjung Pinang	26	South East Sulawesi	Kendari
10	Bangka Belitung	Pangkal Pinang	27	Gorontalo	Gorontalo
11	**DKI Jakarta**	**Jakarta**	28	West Sulawesi	Mamuju
12	West Java	Bandung	29	West Nusa Tenggara	Mataram
13	Central Java	Semarang	30	East Nusa Tenggara	Kupang
14	East Java	Surabaya	31	Maluku	Ambon
15	Special Region of Yogyakarta	Yogyakarta	32	North Maluku	Ternate
16	Banten	Tangerang	33	Papua	Jayapura
17	Bali	Denpasar	34	West Papua	Sorong

The characteristics of an archipelago country, makes planning in transportation system more complex. Compared to European countries which are interconnected with land connection or inland waterway connection, the transportation system in Indonesia is more challenging. Not all places are connected, some locations have very limited accessibility. Unlike the intra-island transportation that usually uses trucks or trains, the inter-islands transportation requires one or more change of transport modes. With the associated cost of changing transport mode (i.e. transshipment cost and waiting time), inter-islands transportation becomes relatively more expensive compared to intra-island transportation.

Indonesia can be categorized as one of the countries in the world that has the fastest acceleration of economic growth. Figure 2.2 below showed the GDP growth rate of Indonesia from 2006. Over the period, Indonesia's GDP growth was always positive

Figure 2.2: Indonesia GDP Annual Growth Rate (Trading Economics, n.d.)

Within the mid term development planning or RPJMN, Indonesia is also targeting further growth in its GDP. Indonesia‘s GDP is projected to increase by 7% in average for the period 2015-2019 that is also supported by industrial growth by 7.4% in the same period. These number are obtained based on the assumption that the government‘s plan in all sectors achieved their target by the end of the period. The GDP growth projection is showed in Table 2.2 below.

Table 2.2: Projection of Indonesias National GDP and Industry sector Growth for the period 2015-2019 [%] (Indonesian Ministry of National Development Planning, 2014)

Growth [%]	2015	2016	2017	2018	2019	Average
National GDP	5.8	6.6	7.1	7.5	8.0	7.0
Industrial Sector (non oil & gas)	6.1	6.9	7.4	8.1	8.6	7.4

2.2 Freight Transportation in Indonesia

Infrastructure plays an important role within freight transportation. A good infrastructure would ensure a more effective and efficient transportation system in a country. Indonesia‘s logistic infrastructure is generally lags behind compared to its neighboring countries (i.e. Malaysia, Singapore and Thailand). This issue is caused by the small investment made in the transport system and the related infrastructures following the 1997 Asian financial crisis where Indonesia got a big impact from the crisis. Until 2004, the transport and logistic sector was the target of the budget cut during the period of economic recovery after the crisis.

2.2.1 Transport Network Infrastructure in Indonesia

The main transport network infrastructure in Indonesia is comprised of three big networks: road networks, railway networks and maritime networks.

Road Network

Road mode is the most dominant mode with the highest modal share in Indonesia. Based on the Origin-Destination (OD) demand survey in 2011, road mode has 91.25% share of the total modal share in Indonesia. With trucks as the most commonly used vehicle in road mode, roadways networks are really important to support the freight activities, along with other supporting infrastructure such as road terminals. Indonesia has 330,495 km of roadways, of which 26,866 km is national road that is built and maintained by the central government. It serves 9 million passenger cars, 2.3 million buses, 4.7 million trucks, and 61 million motorcycles in 2010. Of the whole road networks, 209,000 kms were unpaved. The general condition of Indonesia‘s road infrastructure in 2002 is illustrated in Table 2.3 below.

Table 2.3: General Condition of Road Infrastructure in Indonesia in 2002

Road Status	Length [km]	Road Condition [%]			
		Good	Average	Lightly Damaged	Heavily Damaged
National Road	26,866	64.30	34.00	6.90	4.80
Provincial Road	37,164	34.10	32.10	16.90	16.90
Regional Road	240,946	19.00	34.00	28.50	18.50
City Road	25,518	9.00	87.00	4.00	0.00
Total	330,495	23.60	37.10	23.60	15.80

The damages in the roadways have been causing massive congestions in many road networks. It limits the speed of the vehicles, thus causing longer transportation time and leads to higher fuel consumption. In the end, the low network efficiency causes high transportation cost. In 2001, the total road user cost reached Rp 1,55 trillion per day (Direktorat Jenderal Perhubungan Darat, 2005).

For freight transport, the national road is mostly used as it has the capacity to support the heavy trucks and connects big cities in Indonesia. The road network in Indonesia is illustrated in Figure 2.5 below, comprising 330,495km of road networks.

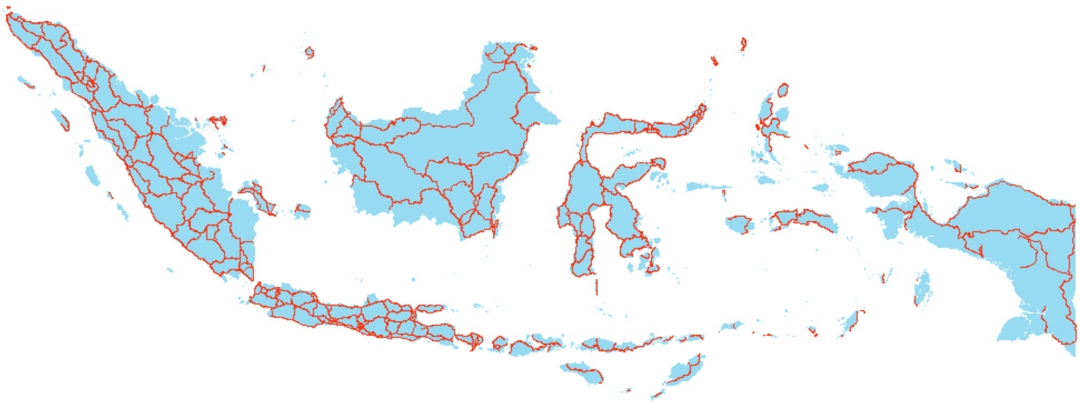

Figure 2.3: Indonesian National Road Network

Rail Network

The railway network in Indonesia was built during the Dutch colonial period around one hundred and fifty years ago. The railway development was aimed to optimize freight transportation of products from mining and farming activities, especially in Sumatra and Java. Until 1939, the railway network was expanding with 6,800 km total coverage, however, it has been declining for more than a decade (Kawaguchi, Wachi, & Yagi, 2010).The decline is caused by several factors, such as the Asian monetary crisis in 1997, the more dominant and faster development on passenger service, aging rolling stocks, and the strong competition from the road transportation.

The modal share of rail transport in Indonesia only accounts for 7% for passenger and 0.6% for freight, while road transport (i.e. truck) accounts for 84% for passenger and 91% for freight transport (Mutohar, Tomonori, & Sutomo, 2010). The impact of the competition between rail and road led to the closure of several railway lines (i.e. Java, South Sumatra, North Sumatra, and West Sumatra) with the total of 2,000 km.

Indonesia has 6,797 km of railway tracks, but only 3,327 km is integrated as a network and are all located on the Java island (Dikun, 2010). The railways are divided into two unconnected networks. Three networks are in Java and one network is in Sumatra. The railway network carried 203 million passengers in 2010, of which 98% is in Java. The annual freight traffic volume is approximately 19 million of tons, which consists of crude palm oil, cements, coal, steel, agricultural products, and consumer goods. The freight activity is concentrated in Sumatra. In terms of axle load, the Indonesian railway network remains of a low standard with only 9–18 tonnes, with relatively low size and a rail weight between 33 kg/m (R33) to 54 kg/m (R54). The rail strength and the carrying capacity constraints limit the capability of Indonesia's railway network.

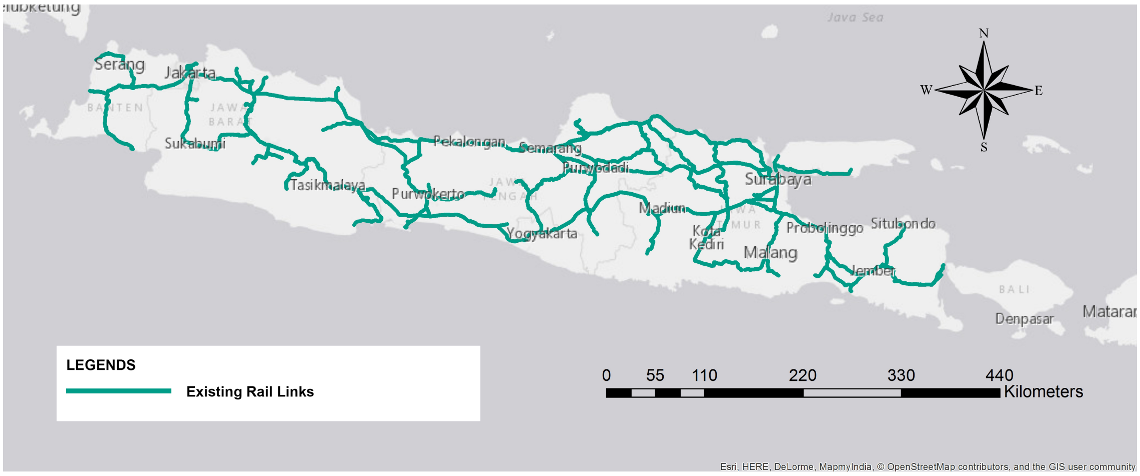

Figure 2.4: Existing Rail in Java

The current rail freight market in Indonesia is relatively small. Firstly, it is because the network is not fully interconnected, except on Java island. In Sumatra, the distances from extraction points to the storage points that are approximately 250–300 km means that the mode is mainly used for point to point transport. Secondly, the total freight load is limited by low axle load capacity. In 2008, the total goods transported in both Java and Sumatra are 19 billion tonnes, with the total trips of approximately 5,500 billion tonnes-km (Dikun, 2010). 80% of the transported goods are on Sumatra railway network, with over 15 billion tonnes of goods. The significant number in Sumatra is because the railway in Sumatra is mainly used to transport coal, fertilizers, palm oil, cement and container traffic. In Java, the rail freight activity is relatively low due to the dominance of passenger transport activity with 95% of the national level in Java.

Maritime Network

As an archipelago country, Indonesia is surrounded with a large body of water. This characteristic is both a challenge and an advantage for Indonesia to utilize maritime transportation. In order to balance the economic development, the government has to make sure that all the islands are well connected with the transportation infrastructure, which makes the maritime transport became an important aspect in the economy. One of the policy in maritime transport is the maritime highway policy.

The main program of the maritime highway policy is to develop a hub and spoke network, with several strategic ports as the main hub in maritime transport that will be the backbone of the network (Indonesian Ministry of National Development Planning, 2014). The main objective of this policy is to increase the national connectivity covering all regions in Indonesia from the Eastern part to the Western part of the country and to reduce the total logistic costs in Indonesia. The network of the maritime highway policy is illustrated in Figure 2.5 below. The red line is the main route that connects the 5 strategic ports as the hubs, while the yellow dots represent the supporting ports as the spokes.

Indonesia has 25 international ports out of 111 commercial ports across the country. Four major ports act as strategic national hubs, which are Tanjung Priok (Jakarta), Tanjung Perak (Surabaya), Belawan (Medan), and Makasar (South Sulawesi).

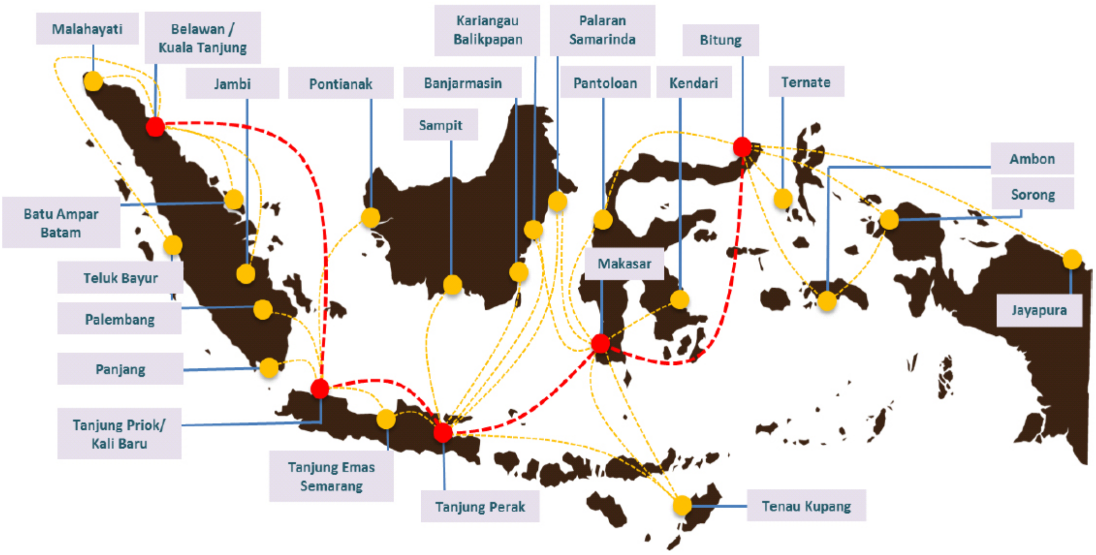

Figure 2.5: Map of Indonesia's 24 main ports (BAPPENAS, 2015)

Multimodality in Indonesia

Freight transport that utilizes several modes is therefore indispensable to ensure the connectivity of all the islands. However, very low attention was given to the utilization of multimodal transport system in Indonesia especially on the national level. Freight transport in Indonesia is highly dependent on road modes. This is caused by the dominance of intra-island freight transport, especially within Java, Sumatra and between both islands (Lubis et al., 2005).

The transportation modal share in Indonesia for passenger and freight transport is showed in table 2.4 below. There is a clearly significant difference in the modal share, especially the roads mode with 84.13% modal share for passenger transport and 90.34% modal share for freight transport. Comparing to the other transport modes, it is clear that road mode is dominating the transport modal share in Indonesia.

Even though Indonesia is an archipelagic country, the goods distributions characteristic that are mostly intra-island transport, has led to the dominance of the road transport mode. There are also railways and river networks. However, these modes are not very well developed. Sumatra, Java and Borneo holds a huge potential for river transport. Even so, the choice is not really popular and mostly it is only used for barge transport by several coal mining industries.

Railways has the second biggest modal share in passenger transport but has a really low modal share for freight transport. This is due to the dominance of passenger transport in railway services. The railway connectivity in Indonesia is very low. The networks only exist in Java and Sumatra, where in Sumatra the

Table 2.4: Indonesia National Transportation Market Estimation (Lubis et al., 2005)

Mode	Passengers		Goods	
	Millions/year	%	1,000 tons/year	%
Roads	2,021.08	84.13	2,514.51	90.34
Railroads	175.90	7.32	17.25	0.62
Rivers	10.31	0.43	28.00	1.01
Straits	116.03	4.83	27.40	0.98
Sea	42.34	1.76	194.81	7.00
Air	36.54	1.52	1.37	0.05

railways are used for mining transportation and in Java, the railway service is used for both passenger and freight transportation. Sea transport comes second with 7% modal share for freight transports. That is a relatively low share for a nation which 60% of its total area is covered with water body. Based on these facts, it can be seen that Indonesia has not utilized the railways and maritime transportation to its fullest especially for long distance shipments.

2.2.2 Unbalanced Economic Development in Indonesia

Even though Indonesia has positive GDP growth in long period, the economic development in Indonesia mostly is focused on the Java island. This centralized development is illustrated in Figure 2.6 below that shows the gross domestic regional product (GDRP) of the provinces in Indonesia. Mostly the green area i.e. the provinces with high economic growth are located in Java, some are in Sumatra and one in Kalimantan. The economic growth in Java is due to concentrated industrial clusters, while the other area outside Java have good economic growth mainly because they are rich on natural resources such as oil, gas, and palm; or because of tourism. It is distinguishable that the economic growth in the Eastern part of Indoesia is really low.

The high economic growth in Java island has led to urbanization which is a population shift from rural to urban area. Many people from other islands moved to Java. The Figure 2.7 below showed the population concentration in every province in Indonesia. The figure clearly shows that the population is highly concentrated in Java island. Most areas in the Eastern part of Indonesia have a population density of less than 50 people per km^2. Other indicator to analyze the imbalance in economic development is the regional poverty level, showed in Figure 2.8. The low GDRP is a sign of high poverty in the respective province. This has become a big issue regarding economic development. The poverty level in the Eastern region is significantly higher than the level in the Western region.

In line with the research objectives, the facts about Indonesia‘s socio-economic condition should be considered into the transportation model. The aim of the improvement of the transport network should be not only limited to decreasing the total logistic costs, but also to balance the economic development and accessibility of more remote locations within the network. Therefore, a more balanced demand and supply in the future as the result of a better transport network can be considered

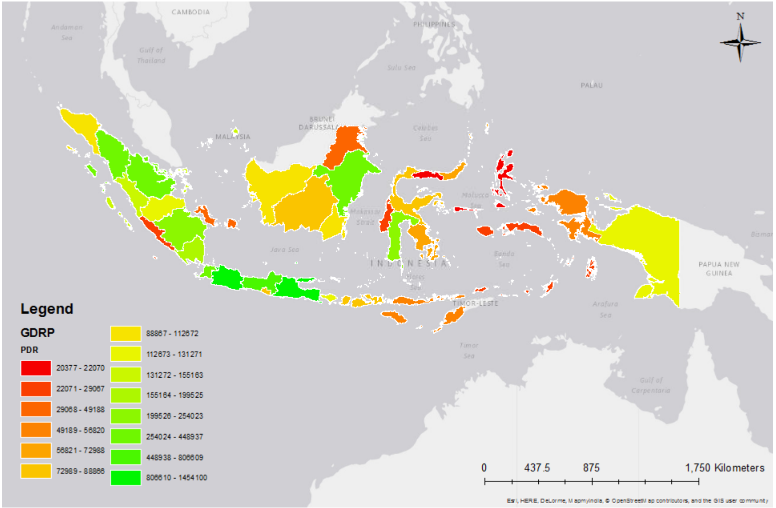

Figure 2.6: GDRP per province in Indonesia (Self illustration from Indonesian Central Statistics Bureau (2016b))

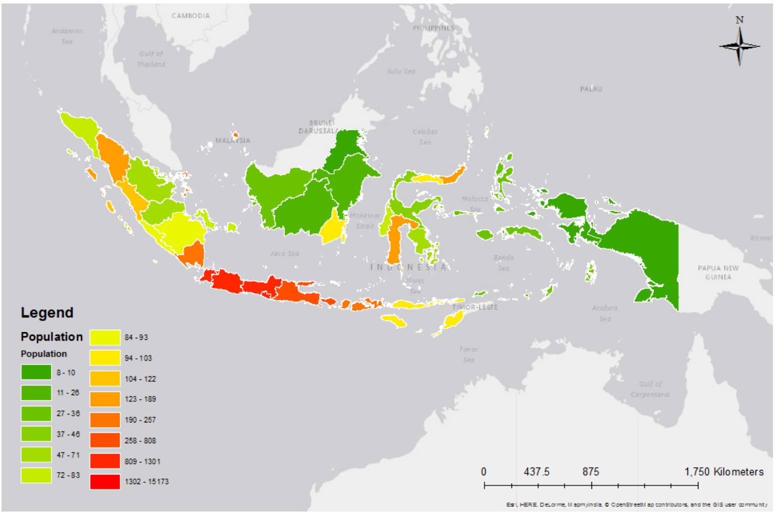

Figure 2.7: Population of every province in Indonesia (Self illustration from Indonesian Central Statistics Bureau (2015))

as one of the important factors.

2.2.3 High Logistic Costs

A good transport system leads to low logistic costs, which would increase the ability of a country to compete with other countries in terms of economic development. However, in Indonesia, the logistics costs are relatively high compared to the other countries as shown in Table 2.5 below.

The high logistic costs in Indonesia is illustrated by Figure 2.9 below. The chart showed that the shipping cost to places within Indonesia is higher compared to overseas shipping, even though the distance differences are really significant.

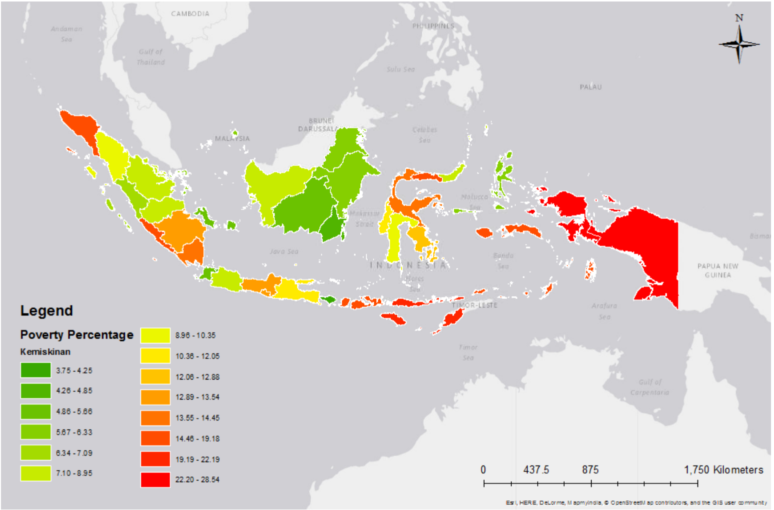

Figure 2.8: Poverty level of every province in Indonesia (Self illustration from Indonesian Central Statistics Bureau (2016a))

Table 2.5: Logistic cost in several countries (World Bank, 2013)

Country	Logistic Cost [% of GDP]
United States of America	9.9
Japan	10.6
South Korea	16.3
Singapore	8.0
Malaysia	13.0
Thailand	20.0
Vietnam	25.0
Indonesia	27.0

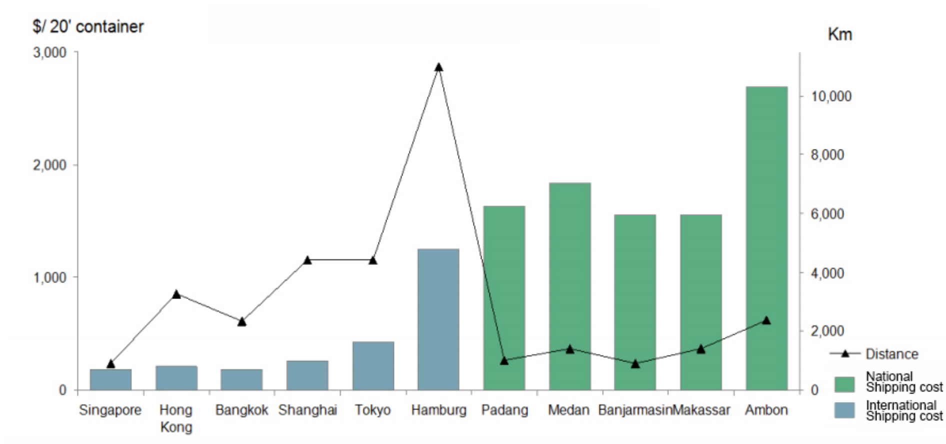

Figure 2.9: Comparison of container shipping cost from Jakarta to national and international destination (Lino, 2013)

The logistic costs in Indonesia is even higher compared to its neighbors in South

East Asia. There are several causes of the high logistics cost in Indonesia, namely, the high trucking cost; the low infrastructure quality and performance; and the trade imbalance between the Western part of Indonesia and the Eastern Part of Indonesia, especially Papua. The low transport infrastructure performance and also the lack of both main infrastructures in Indonesia are reflected by its rank in the Global Competitiveness Index. Based on the Global Competitiveness Report by the World Economic Forum (2015), Indonesia‘s Global Competitiveness Index is in the 81st position of a total of 140 countries. This position is far below the neighboring countries such as Singapore, Malaysia, Thailand, Vietnam and Philipine. Indonesia still ranks far below Malaysia and still lower than Thailand as well. Moreover, Indonesia‘s rank is worse than the previous year, in which Indonesia is in 72nd position.

Table 2.6: Transport Infrastructure Rank among 5 ASEAN big countries (World Economic Forum, 2015)

	2014-2015					2015-2016				
	Indonesia	Malaysia	Thailand	Vietnam	Philipines	Indonesia	Malaysia	Thailand	Vietnam	Philipines
Overall Infrastructure	72	20	76	112	95	81	16	71	99	106
Road	72	19	50	104	87	80	15	51	93	97
Maritime	77	19	54	88	101	82	16	52	76	103
Air	64	19	37	87	108	66	21	38	75	98
Rail	41	12	74	52	80	43	13	78	48	84

Another cause of the high logistic cost as mentioned before, is the trade imbalance between the Eastern and Western part of Indonesia. Figure 2.10 shows the freight production and attraction in every province in Indonesia. The visualization is made based on Indonesian OD Matrix data in 2011. The figure shows that most freight activities are concentrated in Java and Sumatra. The activity level is much lower in the eastern part especially Papua. This leads to low economies of scale. The low demand and supply from the eastern part leads to fewer trip frequency to the East. Most of the time there are also problems of empty containers because the supply and demand imbalance. That is also the reason why international shipments cost much less compared to national shipping cost.

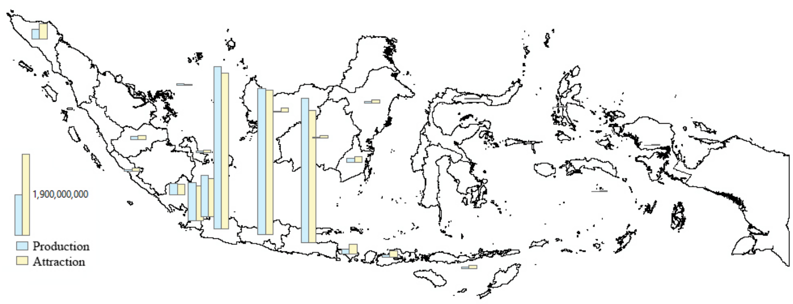

Figure 2.10: Freight Production and Attraction in Indonesia (Self illustration from (Ministry of Transportation, 2014)

High trucking cost is another major cause of the high total logistic costs in Indonesia. One of the main factors is the congestion on the route, either from the warehouse/factory to the seaport, or the other way around. The average trucking costs in Surabaya are IDR1,900,000 with the average distance of 68km which is almost half of the total costs spent from the warehouse to the port, before being loaded to the vessel. Meanwhile, in Makassar, the trucking costs amount to almost reach three quarter of the total cost spent from warehouse before being loaded to the vessel. The highest trucking cost are from Jakarta to Sorong. In Sorong the local government regulation prevents a container truck to go outside the port. Thus, multiple truck trips from port to consumers are required. While in Jakarta, the worsening traffic congestion from the industrial area in East Jakarta to the port of Tanjung Priok is the main cause. The high logistic cost components in Indonesia is illustrated in Figure 2.11 below.

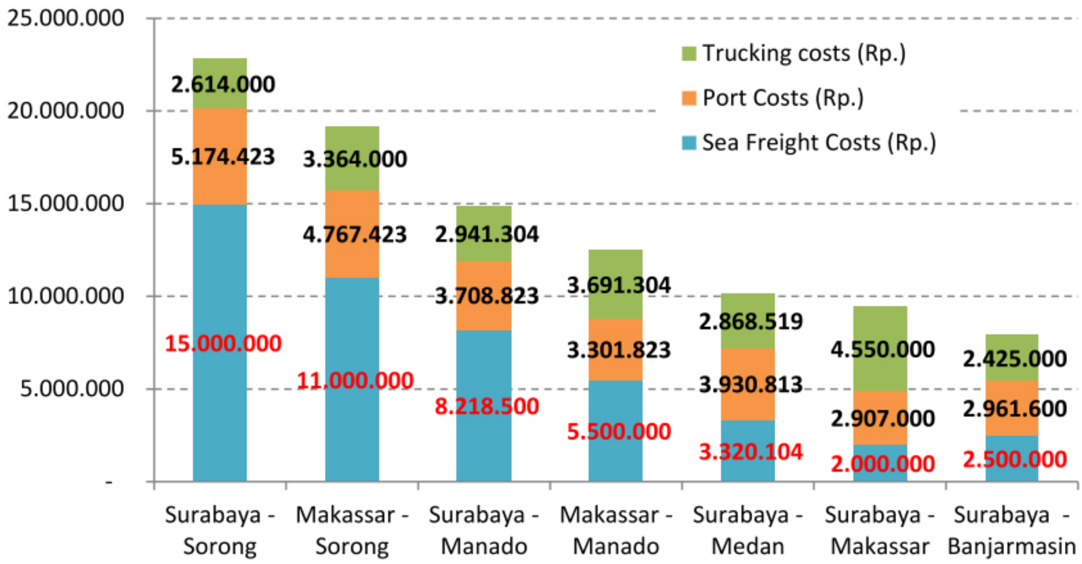

Figure 2.11: Overall Transportation Cost for 20 TEU Container (Bahagia et al., 2013)

2.3 Summary of Freight Transportation Condition in Indonesia

In this chapter, the current condition of freight transportation in Indonesia are explained. Understanding the current situation is important before building the model. By understanding the problem, the modeler could understand what are the scope, the boundaries, and the objective of the model.

In general, the main problems in Indonesia's freight transportation are the low usage of multimodal transport, unbalanced economies and the high logistics costs. The freight transportation in Indonesia still mostly adopt the unimodal transportation system, especially in the intra-island transportation. For the inter-islands connection, mostly ferries were used to transport the trucks. For an archipelagic nation, a multimodal system could increase the efficiency in the transportation system, especially on the long distance shipments. The central government of Indonesia has planned the modal integration to achieve multimodality in Indonesia. Therefore, based on this problem, it is important to build a multimodal network model for Indonesia.

Beside the freight transportation condition, the unbalanced economic growth is another issue faced by Indonesia. This problem has a causal relation with the transport system condition. There is imbalance in the supply and demand between the Western and Eastern part of the country. The centralized development has also caused the economic growth in Java to be bigger compared to other part of the country, especially for the Eastern region.

The imbalance in freight demand and supply caused high logistics cost on shipment to the Eastern part of Indonesia, because most of the time the ship returned with empty containers. Therefore, they could not achieve the economies of scale. Hence, the logistics cost to send goods to the Eastern parts of Indonesia became really high thus causing higher goods price in those areas.

Chapter 3

Actor Analysis and Current Freight Transport Policies

This chapter analyze the problems in Indonesia further through actor analysis and studying the current policies in freight transportation. Within the actor analysis, the multi-actor environment of the problem were explored. And through the analysis of the current policies, the targets and the objectives set by the decision maker were studied to be incorporated into the model.

3.1 Actor Analysis

The freight transportation improvement issue is a big national issue in Indonesia. As an archipelagic nation, the transportation in Indonesia is really complex, requiring involvement of many actors within each transport modalities. Those big and important actors come from both public and private sectors.

As multiple actors are involved in creating a multimodal transport policy in Indonesia and the implementation of such policy has an impact on these stakeholder, where some actors might be in favor and other against it. Knowing these actors' attitudes and stances are pivotal to successful implementation of the policies. Without an actor analysis, one alternative might be found unsuitable due to opposition by certain actors that are not in favor in the future. By performing the actor analysis, the possible reactions by each actors regarding the alternatives can be analyzed and future opposition could be prevented. Therefore, an actor analysis will be performed according to the methodology presented by Hermans and Thissen (2009).

In an actor analysis, firstly the actors will be identified and listed. Secondly, a formal diagram will be used to map the relations between actors. Thirdly, each actor will be analyzed in terms of the actors' interests, goals and resources. Lastly, the actors will be ordered based on its power level, interest level and attitude towards the issue.

Later on in this research, the analysis of actors' position towards the policy implementation were analyzed further. Some actors that are not in favor of certain policies might build a policy barrier through certain means in order to prevent the negative effect of the policy towards them. Therefore, it is important to analyze the actors' barriers and exploring the possible alternatives to prevent or to solve the actor's issue towards the policy.

3.1.1 Overview of Actors Involved

To identify the list of actors that are involved in this issue and to reduce the chance of skipping any engaged actors, the Mitroff identification approach was used as a starting point (Hermans & Thissen, 2009). Afterwards, a short description of each actor is given.

The following actors were identified by means of the Mitroff identification approach.

1. The imperative approach: identifying actors that have a stake in the existing problem or will be affected by the solutions proposed or enacted.
   (a) Indonesian Railway Company (PT KAI) (Indoneia Infrastructure Initiatives, 2010)
   (b) Indonesia Ship Operator (PT PELNI) (Indonesian Ministry of National Development Planning, 2014)
   (c) Truck operator (Bahagia et al., 2013)
   (d) Indonesia Port Corporation (IPC) (Indonesia Investment Coordinating Board, 2015)
2. The positional approach: identifying actors based on their formal positions in legislative associations that can initiate, adjust, and implement policies, regulations and processes. For the case at hand and through this approach the following actors are identified based on the Indonesia development Masterplan (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011) :
   (a) Ministry of Transportation
   (b) Ministry of Public Works
   (c) Ministry of Economy
   (d) Ministry of Finance
   (e) Ministry of State Owned Enterprise
   (f) Ministry of National Development Planning
3. The opinion leadership approach: Identifying actors that play a role in affecting the opinion of other actors. By using this approach, the following actors were recognized:
   (a) Indonesia Infrastructure Initiative (Indii) - Australian Aid
4. The demographic approach: identifying actors that are affected differently by the problem and its potential solutions because of the difference in age, gender, residence, level of education, occupation etc. By using this approach, the following actors were recognized:

(a) Local truck drivers

(b) Local governments

It is important to note that at this stage of the actor analysis the following actors were identified; however, in such an iterative process of problem construction and solution advising, new actors may come into the picture.

While defining the boundaries of the network of actors involved, the following were taken into consideration:

1. The level at which the problem prevails was studied against the actor‘s involvements, interests, and power exertion

2. The pool of actors was chosen in a manner to encompass the various interests, preferences and dilemmas relevant to the problem

Consequently, two techniques were used to further structure the list of actors. The first technique is grouping the actors based on their roles and positions such as: The Indonesian Government, Local Governments and Nongovernmental organizations. The second technique is classifying the actors based on their interests in the problem such as: Stimulating multimodal transportation and protecting road transportation. The list can be seen in Table 3.1 below.

Table 3.1: Actor roles and interests (Modified from Enserink et al. (2010))

Actors‘ Role in Governance	**Actors‘ Issues of Interest**
Central Government	National Transportation System Development
Ministry of National Development Planning*	**Ministry of National Development Planning***
Ministry of Transportation	Ministry of Transportation
Ministry of Public Works	Coordinating Ministry of Economic Affairs
Coordinating Ministry of Economic Affairs	Ministry of State Owned Enterprises
Ministry of Finance	Ministry of Public Works
Ministry of State Owned Enterprises	National Economy
State Owned Enterprises	Coordinating Ministry of Economic Affairs
Indonesian Railway Company (PT KAI)	Ministry of State Owned Enterprises
Indonesian Ship Operator (PT PELNI)	Company Profitabiity
Indonesian Port Corporation (IPC)	Indonesian Railway Company (PT KAI)
Non-Governmental Actors	Indonesian Ship Operator (PT PELNI)
Truck Operators	Indonesian Port Corporation (IPC)
Local Truck Drivers	Truck Operators
	Local Truck Drivers

*Main Actor

3.1.2 Actor Description

The following sections will provide a short description of the actors involved.

Ministry of Transportation. The Ministry of Transportation is one of the ministries of the Indonesian government and is responsible for the governance and regulation of transport in Indonesia. (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)

Ministry of Public Works. Ministry of Public Works is one of the ministries of the Indonesian government and is responsible for providing infrastructures such as roads and bridges, dams, irrigations, waterways, water supply, public buildings, and other public infrastructures to serve the economic activities in Indonesia. (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)

Ministry of Economic Affairs. Ministry of Economic Affairs is one of the ministries of the Indonesian government and is responsible for planning and policy co-ordination, as well as synchronization of policies in the fields of economics. (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)

Ministry of Finance. Ministry of Finance is one of the ministries of the Indonesian government and is responsible for managing finance and state assets. It covers the policy making in several sectors such as fiscal, economy, politics, social and cultural, and institutional sector in Indonesia. (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)

Ministry of State Owned Enterprise. Ministry of State Owned Enterprise is one of the ministries of the Indonesian government and is responsible for coordinating the function of state owned enterprises (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011). Within the scope of the freight transportation in Indonesia, the involved state owned enterprises are the Indonesia Railway Company (PT KAI), the Indonesia Ship Operator (PT PELNI), and the Indonesia Port Corporation (IPC).

Ministry of National Development Planning (BAPPENAS). Ministry of National Development Planning (BAPPENAS) is one of the ministries of the Indonesian government and is responsible for formulating national development planning and budgeting (annual, five-years, and long term) (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011). BAPPENAS has also a responsibility to coordinate international development (bilateral, unilateral and multilateral) cooperation.

Indonesia Railway Company (PT KAI). Indonesia Railway Company (PT KAI) is a state owned enterprise that is responsible for governance, regulation, maintenance and operation of railways in Indonesia. PT KAI is the major operator of railways in Indonesia for both freight and passenger transportation (of Connectiviy, 2010) .

Indonesia Ship Operator (PT PELNI). Indonesia Ship Operator (PT PELNI) is a state owned enterprise that is responsible for providing sea mass transportation that covered passenger and goodies transport amongst the island in Indonesia (of Connectiviy, 2010).

Indonesia Port Corporation (IPC). Indonesia Port Corporation (IPC) is a state owned enterprise that is responsible for the governance, regulation, maintenance and operation of ports and harbors in Indonesia. IPC has four company numbers based on its coverage (i.e. IPC I, IPC II, IPC III, IPC IV). IPC I is responsible for the ports in Aceh, North Sumatra, Riau, and Riau islands. IPC II is responsible for the ports in West Sumatra, Jambi, South Sumatra, Bengkulu, Lampung, Bangka Belitung, Banten, Jakarta, and West Kalimantan. IPC III is responsible for the ports in Central Java, East Java, Bali Nusa Tenggara, South Kalimantan and Central Kalimantan. And the rest are under the responsibility of IPC IV.

Indonesia Infrastructure Initiative (IndII). Indonesia Infrastructure Initiative (IndII) is an Australian Government-supported initiative (Indoneia Infrastructure Inititatives, 2010). The main program of Indii is to promote economic growth in Indonesia by working with the Government of Indonesia to enhance infrastructure policy, planning, delivery and investment. IndII focuses primarily on water and sanitation issues and on transport (with particular attention to roads and urban mobility), as well as a number of cross-sectoral policy issues.

Truck Drivers. As the one with the highest modal share compared to railways and maritime, truck drivers would feel the impact of the multimodal policies since the policies might lower their modal share (Bahagia et al., 2013). The high number of the group that is spread all over the country give them a bargaining power over the policy.

Local Governments. The local government has the authority to issue policies at regional level. The freight transport development covers the transport infrastructures that span along many regions. Therefore, the role of the local governments is important for the success of the projects, especially in socializing the projects to the residents along the project areas.

3.1.3 Formal Relations

In order to understand the actors and the environment they interact within, one must understand what formal and informal relationships these actors have within the system. In general the actor‘s behavior is depicted by its position and relationship with its fellow actors. Within the formal relationship, legislation and hierarchical relation play the most important role. They describe the expected functions of the actors within the problem system and the boundaries of the action that can be taken. The formal (informal) relationship chart can be found in Figure 3.1 below.

From the formal relations diagram it becomes apparent that the regulations and policies established by the central government of Indonesia influence the different transport modalities through the respective transport mode‘s operator. The freight transportations in Indonesia are mostly operated by the national enterprises (PT PELNI, PT KAI, IPC), unless for the trucks, which shares are held by private owners and operators. The national enterprises are regulated by the Ministry of State Owned Enterprises. While the truck operators are regulated and coordinated under the Ministry of Transportation.

In order to apply the multimodal policies, all the ministries are coordinating with each other. The final development plans are issued by the Ministry of National Development Planning in the term of Middle Term National Development Plan and Long Term National Development Plan.

Based on the formal relations diagram, the central government of Indonesia has huge influence over the policies. They can issue the policy without taking into consideration the demands from the lower parties. However, this might result in an opposition especially by the truck operators which are independent from the governmental bodies. The opposition by the truck operators could be an issue when the central government wants to apply the multimodal transportation policy as they are the major transport mode used in Indonesia. Therefore, the truck operators could have huge blocking power against the policy if the policy is not in their favor. This becomes a challenge for the central government when taking into account the demand from the truck operators within the policy making process. Best policies are made when stakeholders can find themselves presented in the policies as this prevents barriers on the policy implementations.

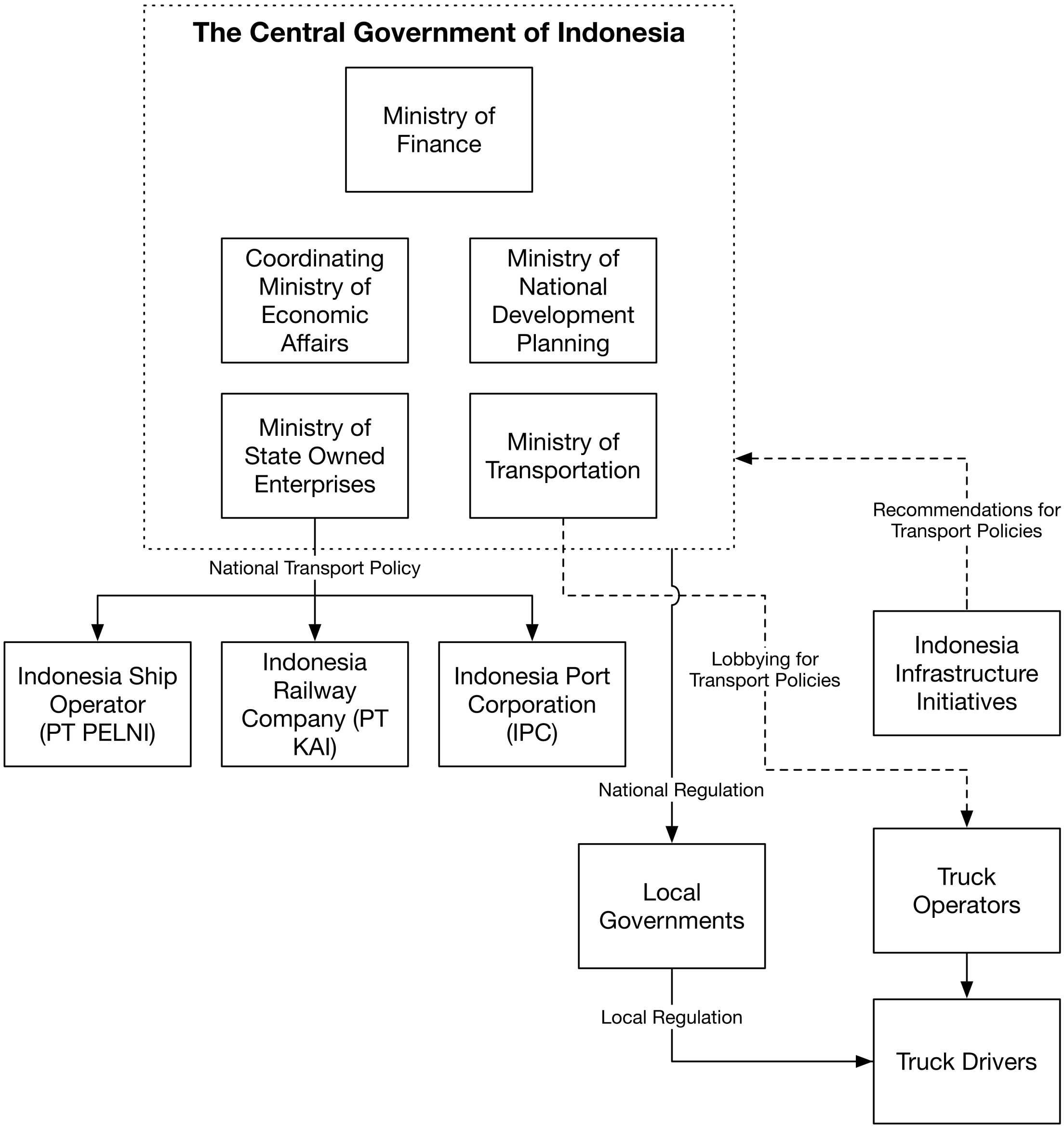

Figure 3.1: Formal relations diagram

3.1.4 Problem Formulation of the Actors

To understand how a problem can be solved, it is essential to know how the actors that are concerned with this problem, think about the problem. In complex multi actor systems, actors mostly have different desires and objectives, this is what makes the problem complex. To understand the position of the actors concerning the problem, a problem formulation can be made for each actor. The problem formulation provides insight in the desired situation and what prevents the actors from reaching that desired situation. The problem formulation for the actors involved in this stakeholder analysis can be found in Table 3.2.

Table 3.2: Overview of actors problem formulations

Actors	**Interest**	**Existing situation**	**Causes**	**Possible Solution**
Ministry of Transportation (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)	Improving Indonesia‘s transportation System	Semi-optimal transportation within Indonesia	Unimodal Transportation System	Optimizing the network design and introducing multimodal transportation system
	Increasing the connectivities and accessibilities of all cities			
Ministry of Public Works (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)	Maintaining and Improving Indonesian Road	Congestions on road network and low vehicle speed.	Bad road quality in some areas, high vehicle to road capacity ratio	Road reparation and widening, building new roads, balancing transportation modal share.

Table 3.2 Continued: Overview of actors problem formulations

Actors	Interest	Existing situation	Causes	Possible Solution
Coordinating Ministry of Economic Affairs (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)	Increasing Indonesia‘s economic growth rate Solving Indonesia‘s economic growth imbalance	Imbalance in economic growth between the Western part and Eastern part of Indonesia	High demand but low supply from Eastern part of Indonesia	
Ministry of Finance (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)	Improving investment climate in Indonesia	High Investment required for infrastructure construction	There are many new infrastructure construction by 2030 as stated in RPJMN	Setting priorities based on the projects' Benefit to cost ratio

Table 3.2 Continued: Overview of actors problem formulations

Actors	Interest	Existing situation	Causes	Possible Solution
Ministry of National Development Planning (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011)	Planning Indonesia‘s medium and long term plans	Imbalance in economic growth between the Western part and Eastern part of Indonesia	High demand but low supply from Eastern part of Indonesia	Prioritizing development of economic zones in Eastern part of Indonesia
Local Government	Increasing local economic growth	Price Disparities, economic growth imbalance compared to provinces in Java island	High logistics costs from Java island	Optimizing the network design to lower the logistics costs
Indonesian Railway Company (PT KAI) (of Connectiviy, 2010)	Providing railway transporatation throughout Indonesia	Low rail connectivity, Low railway modal share.	Railway infrastructures only exist in Java and small part of Sumatra	Modal integration using multimodal transport system, building long distances rail network in other islands
Indonesian Ship Operator (PT PELNI) (of Connectiviy, 2010)	Providing maritime transportation throughout Indonesia	Suffer from loss due to low freight shipment using maritime service	Trade flow imbalance between the western and eastern part of Indonesia	Operating and optimizing the maritime highway system
Indonesia Port Corporation (IPC) (of Connectiviy, 2010)	Providing port infrastructures and services throughout Indonesia	Costly transshipment process	Differences in port handling facilities and infrastructures and local regulations	Improving port infrastructure, generalizing the policy on every ports

Table 3.2 Continued: Overview of actors problem formulations

Actors	Interest	Existing situation	Causes	Possible Solution
Truck Operator Association (Bahagia et al., 2013)	Representing the voice of the truck owners to the government	High cost for inter island shipment	High transshipment cost and long waiting time at ports	Subsidy on transshipment costs

3.1.5 Interdependencies

In multi actor systems, the significance of actors behavior mostly depend on the resources, power and influence of actors. In this way, some of the actors can be defined as critical if they have power to influence other actors and take a particular stand regarding the problem or even block the solution.

In terms of the power, the central governments or the ministries have the biggest power as they are able to issue the policy on the national level. As the main policy maker, the Ministry of National Development Planning is supportive towards the multimodal transport network policy in Indonesia. The other ministries are coordinating with the Ministry of National Development Planning to arrange the components of the policy based on their respective responsibilities. Based on the RPJMN, the Indonesian government would make use of their resources in order to ensure the success of the multimodal transportation policy. The success of the multimodal transport policy will make the transport system in Indonesia more effective and efficient, hence it could be a key for Indonesian companies to compete on the international level. However, before a policy is implemented, the policy issued by the Indonesian government should have the agreement from the impacted actors.

IPC, PT PELNI, PT KAI which are state owned enterprises have a high interest and power within the network and fully support the multimodal transport policies. The policies could increase their modal share, thus making them more profitable. PT Pelni faces the inefficiency and loss due to the current transportation system which they have to cover the cost resulted from the trade imbalances. PT KAI could build new railway networks in all the big islands in Indonesia which could increase their profit and also the modal share of railways. As the port operator, IPC is also in favor with the multimodal transport policy as the policy would improve the infrastructure in Indonesian ports, thus making them more efficient.

Multimodal transport could increase speed, reliability and efficiency. The multimodal transport policy could also be considered to be a motivation to push for further innovation on road transport, however, the market share of road transport is already big in Indonesia and the implementation of multimodal transport could reduce the market share because it would stimulate the other modes of transport. This would be the threat for the truck operators in Indonesia, which leads to their diffused position within the network.

3.1.6 Power and Interdependencies of Actors

The next step is the identification of the power and interests of the stakeholders. This is done by mapping the stakeholders on three characteristics or dimensions. The characteristics that are described considering stakeholders are (Murray-Webster & Simon, 2006):

1. Actors power or ability to influence the system. This may be their potential to influence derived from their positional or resource power in the system, or may be their actual influence derived from their credibility as a leader or expert.

2. Actors interest or involvement in the project or program as measured by the extent to which they will be active or passive.

3. Their attitude to the project or program as measured by the extent to which they will support, oppose or diffused (can either support or block, depending the impact of the project)

The power-interest matrix below will map the actors within the network based on their power, interest and attitude towards the multimodal network policy.

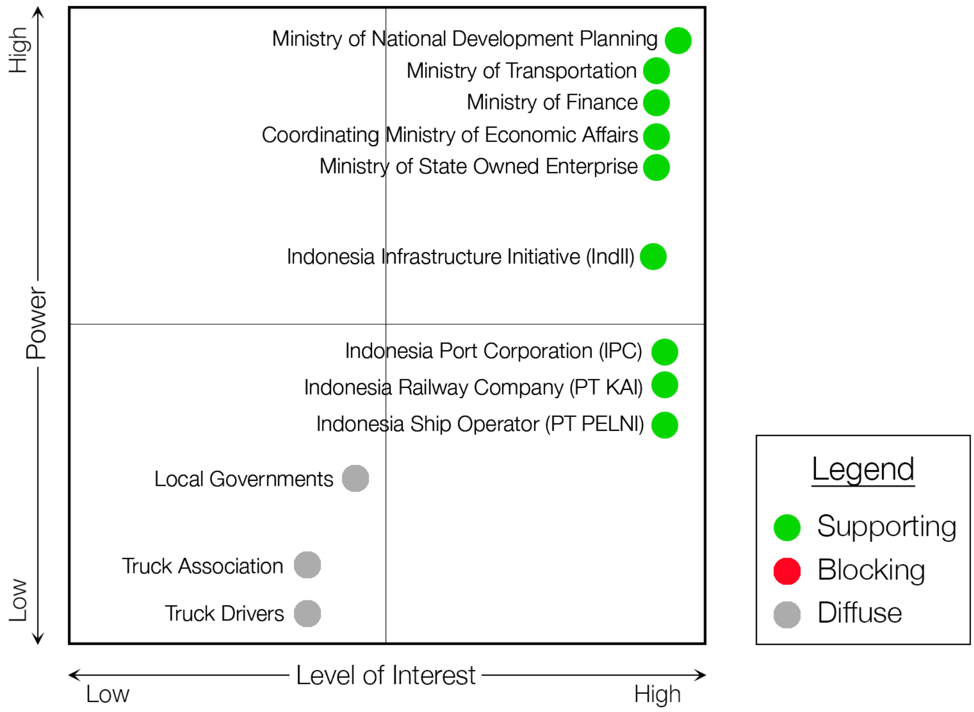

Figure 3.2: Power-Interest Matrix of the Actors

Based on the power-interest matrix showed in Figure 2, there is no actors that oppose the multimodal transport policy. However, there are certain actors that have diffused attitude towards the multimodal transport policy. They can support the policy if the policy has favorable benefits for the effort they do but they can also oppose the policy if the risks are high.

3.2 Freight and Logistics Development Plans

The Indonesian government has developed several policies in order to increase the efficiency of Indonesian transportation network. There are three main policy for transportation network and transportation infrastructure development. Those policies are *Master Plan Percepatan Pembangunan dan Ekonomi Indonesia* (MP3EI) or The master plan to accelerate the development and the economy of Indonesia and*Rencana Pembangunan Jangka Menengah* (RPJMN) or Tactical development planning.

MP3EI is Indonesia's development plan covering several aspects, such as social, cultural and economy. It is a long term development plan from 2005 - 2025. MP3EI is intended to accelerate and foster economic development across the nation through six economic development corridors. The main strategies of MP3EI are: (1) Economic corridor development, (2) Strengthening the national connectivity and (3) strengthening human resource capability and science-technology. Through MP3EI, the Indonesian government has invested 250 billion USD for infrastructure development which includes 2 seaport projects, 4 railway projects, 10 road and bridge projects and 2 energy projects (Ministry of Economic Affair, 2011).

Along with MP3EI, RPJMN defined development plan on many aspects and also includes the national freight and logistics system. The RPJMN is updated every 5 years. It is a more detailed planning based on the strategic plan defined by MP3EI. One of the target within MP3EI and RPJMN is to boost multimodal transportation in Indonesia. In the transportation and logistics sector, the development plans include the maritime highway policy, development of Indonesian ports and dry ports, building new dry ports, building new railway network in all the main islands, existing road revitalization and new road construction.

3.2.1 Rail Network Construction

From 2011–2015, the government aims to improve the role of trains to handle long distance cargo transport on Java and Sumatra. Following the improvement, from 2016–2020, the government has planned to develop trans-Java and trans-Sumatra railway to connect production centers and transport nodes. The new network is expected to start operating between 2021–2025 and will become the alternative to road freight (Bahagia et al., 2013).

The rail network construction is one of the biggest plan that would require huge investments. The government is planning to build rail network that connects all Indonesia's special economic zone. In Sumatra, the rail network will connect Aceh, Medan, Pekanbaru, Padang, Jambi, Palembang and Lampung which have the total length of 2,168 km and would cost IDR65 trillion. In Java, the existing single track network will be upgraded to double track network which would double the rail capacity. The total length is 441 km.

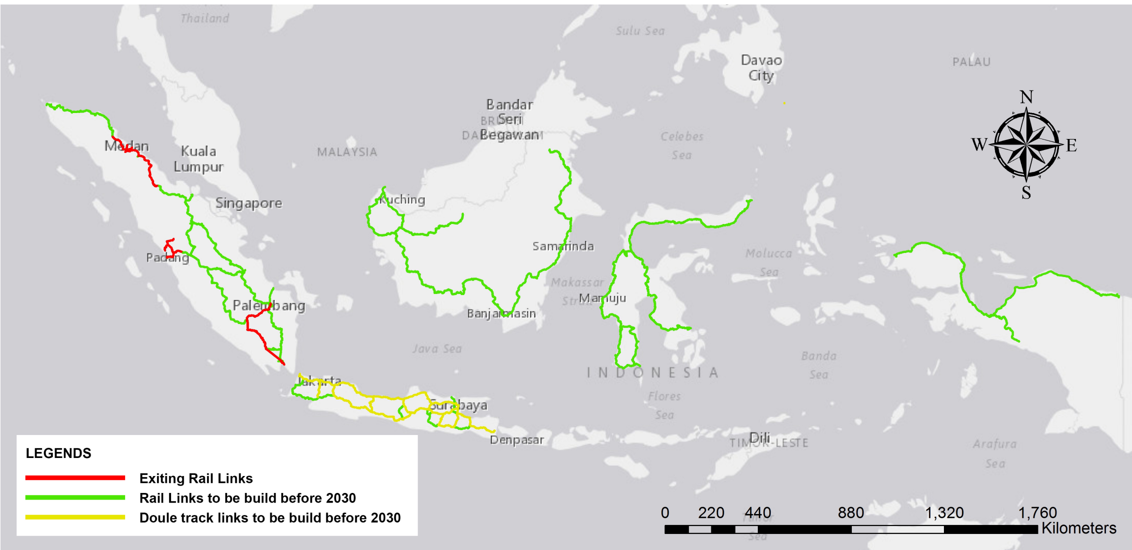

Figure 3.3: Existing and planned rail network in Indonesia (Ministry of Transportation and Infrastructure and Australian Aid, 2014)

3.2.2 Maritime Highway Policy

The objective of maritime highway policy is to operate a maritime network that continuously connect the eastern and western part of Indonesia. The maritime highway policy operates hub and spoke network design. Therefore, for this policy, the government has chosen 5 main ports as main or hub ports and 19 other ports as feeder ports.

Several aspects are taken into account in selecting the 24 ports within the maritime highway policy. They are chosen based on the respective port location, the port‘s facilities and infrastructure, the port‘s capacity, the port‘s accessibility and the port‘s throughput. The hub ports are the ports with higher throughput, capacity and accessibility compared to the feeder ports. These hub ports also have better existing facilities and infrastructure, which means, fewer improvement would be required when assigning them as the hub ports.

Main consideration in selecting the above 24 ports are the strategic location of the ports; existing facilities and infrastructures; existing capacity and throughput of the ports; and service coverage of the ports (access from other regions to the ports). Ports in strategic location and wide coverage areas certainly become priority and potentially to be hub ports in the network. These ports usually have higher capacity and throughput such as Tanjung Priok, Belawan, Tanjung Perak, and Makassar. In addition, existing facilities and infrastructures availability are also considered to minimize development budget. Ports with better existing facilities and infrastructures will be more prioritized to be chosen as strategic ports in maritime highway policy (Indonesian Ministry of National Development Planning, 2014).

Table 3.3: Identification of 24 strategic ports in maritime highway policy (Indonesian Ministry of National Development Planning, 2014)

Ports	**City**	**Provinces**	**Role**
Malahayati	Banda Aceh	Nanggroe Aceh Daroessalam	Feeder
Belawan	Medan	North Sumatera	Hub
Kuala Tanjung	Kuala Tanjung	North Sumatera	Hub (International)
Teluk bayur	Padang	West Sumatera	Feeder
Batu Ampar	Batam	Riau Islands	Feeder
Jambi	Jambi	Jambi	Feeder
Palembang	Palembang	South Sumatera	Feeder
Panjang	Bandar Lampung	Lampung	Feeder
Tanjung priok	Jakarta	DKI Jakarta	Hub
Tanjung emas	Semarang	Central Java	Feeder
Tanjung perak	Surabaya	East Java	Hub
Pontianak	Pontianak	West Kalimantan	Feeder
Sampit	Palangkaraya	Central Kalimantan	Feeder
Kariangau	Balikpapan	East Kalimantan	Feeder
Palaran	Samarinda	East Kalimantan	Feeder
Tenau kupang	Kupang	East Nusa Tenggara	Feeder
Makassar	Makassar	South Sulawesi	Hub
Pantoloan	Palu	Central Sulawesi	Feeder
Bitung	Manado	North Sulawesi	Hub (International)
Kendari	Kendari	South East Sulawesi	Feeder
Ambon	Ambon	Maluku	Feeder
Ternate	Ternate	North Maluku	Feeder
Sorong	Sorong	West Papua	Hub/Feeder
Jayapura	Jayapura	Papua	Feeder

The policy covers maritime connectivity for both people and freight transportation. In relation with freight maritime network design, Ministry of Development Planning has also broken down the above definition into five main elements of maritime highway policy:

1. Reliable Ports. Maritime highway policy will focus on development of strategic ports to form a backbone of freight maritime network that can serve all

region in Indonesia from west to east. Every port in the network must be reliable in its services and performances. Some important issues to be considered in reliable ports development based on the policy are sufficient ports capacity and productivity; effectiveness activities documentation; data and information system; water entrance (for inland transport, piping, etc.); internal infrastructure such as dock size, water depth, electricity, etc.; and strong supporting institutions (ports operator, local government, etc.).

2. Sufficient load from west to east and vice versa. Loaded and unloaded freight volume have to be sufficient to make certain routes become feasible. Otherwise, regulation and subsidy from the government can also be applied but only for short term. In the long term, through optimum maritime network and effective infrastructure development and regulation to minimize cost, the transportation cost will be feasible for all routes that serves all regions in Indonesia from west to east.

3. Effectiveness of supporting inland transportation. Inland transportation for access to ports is very important such as road, railway and piping line. The development of inland transportation is certainly required to be taken part on ports infrastructure development planning on the policy.

4. Routine and scheduled freight shipping. At present, routine and scheduled freight shipping is difficult to be applied in Indonesian ports especially in small ports with lack of supporting infrastructure. On the other hand, big ports usually face unexpected problems such as high dwelling time, long queue and traffic jam inside the ports area that have already discussed in previous part. All of these problem must be solved and freight shipping in every port must have routine schedules. Sufficient load and sustainable maritime network with reliable ports are required to maintain the routine schedules of freight shipping.

5. Sufficient Number Shipping industry. The number and capacity of shipping industry have to fulfill increasing demand due to development of strategic ports on maritime highway policy. With the policy, maritime transportation is expected to become cheaper and reliable so the share of freight shipment through maritime transportation modes will be better than the current situation, so the higher number and capacity of shipping companies are required.

3.2.3 Road Network Improvement

Within the RPJMN, the Indonesian government also plans to build new toll road connections in several islands in Indonesia (i.e. Sumatra, Java, Sulawesi). These toll roads are intended to increase the road capacity and the connectivity between the cities within the route (Ministry of National Development Planning, 2015).

Table 3.4 below shows the list of new toll roads construction plan in Indonesia. However, based on the list, the toll roads covers mostly intercity connection within a province. Therefore, the toll network is not within the scope of the model.

Table 3.4: Toll Roads Development Plans in Indonesia (Ministry of National Development Planning, 2015)

Island	Route	Length [km]	Investment Cost [$\times 10^6$ IDR]
Sumatra	Medan - Tebing Tinggi	61.8	6718
	Medan - Binjai	15.8	2411
	Pekanbaru - Dumai	135	18321
	Palembang - Indralaya	22	2469
	Kayuagung - Betung	111.65	13708
	Bakauheni - Terbanggi Besar	150	18422
Java	Serpong - Balaraja	30	6928
	Pasirkoja - Soreang	10.57	2482
	Cileunyi - Dawuan	58.5	11328
	Pandaan - Malang	37.62	3262
Sulawesi	Manado - Bitung	39	2531

3.3 Fuel Subsidy Cut

One of the thing that caused the road mode more attractive for shipper is that the diesel fuel is subsidized by the government. Ships and trucks use the same type of fuel. However, only road transport receives fuel subsidy that make the fuel cheaper compared to maritime transports.

As long as the subsidy exist, trucks would be more favorable compared to the other modes because it is a cheaper option, even though it is less reliable and less efficient compared to the other modes. In Indonesia, subsidy reduction have been discussed for the last few years. However, the subsidy reduction was only applied on gasoline which mostly used by passenger cars.

Beside the impact on the freight transport modal share, the fuel subsidy also influenced the national spending. Every year, the Indonesian government have to allocate for the fuel subsidy (Nugroho, 2009). Within the National Spending Funds Allocation Plan, subsidy is defined as a payment by the national government to PERTAMINA (the national distributor company for oil and gas) in the case that their profit is smaller compared to the cost of fuel distribution (Kamar Dagang Indonesia, 2013). The amount of expenditure accounted to the fuel subsidy in Indonesia is significantly bigger compared to expenditure on education and health sector as illustrated in Figure 3.4 below. By cutting the fuel subsidy, the national government could save on the funds and allocate the funds to the other critical sectors.

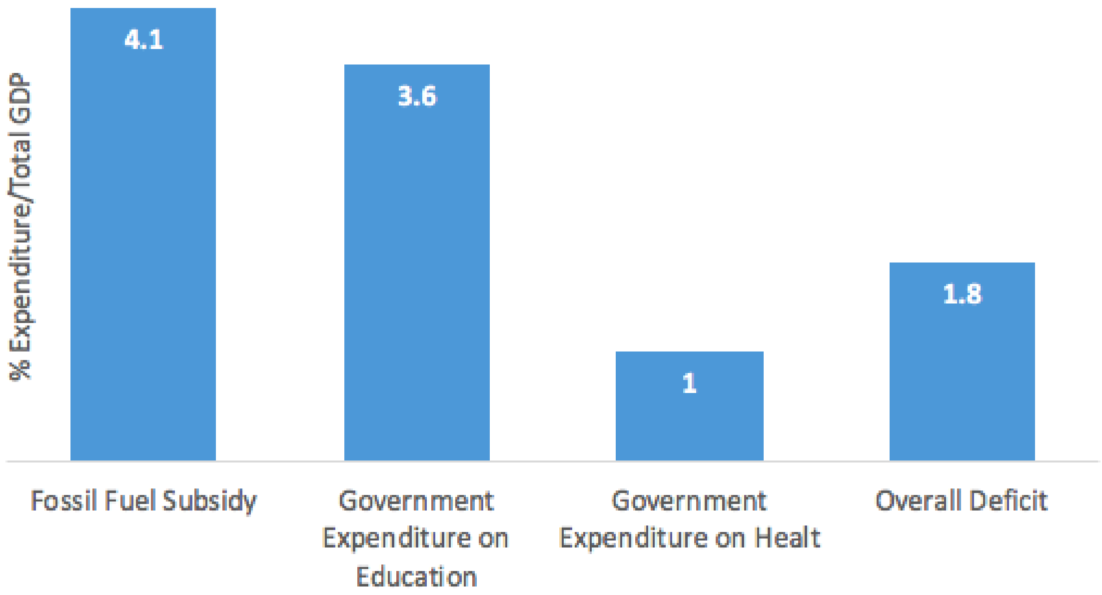

Figure 3.4: Fossil Fuel Subsidies Compared to Other Expenditures (Asian Development Bank, 2015)

The fuel subsidy is the difference between the reference oil price and the retail fuel price without tax. The reference oil price for Indonesia is calculated based on the sum of Mid Oil Platt's Singapore (MOPS) and the distribution cost. MOPS is the price on the stock sale and purchase transactions on the Singapore oil. This definition is illustrated in Figure 3.5 below.

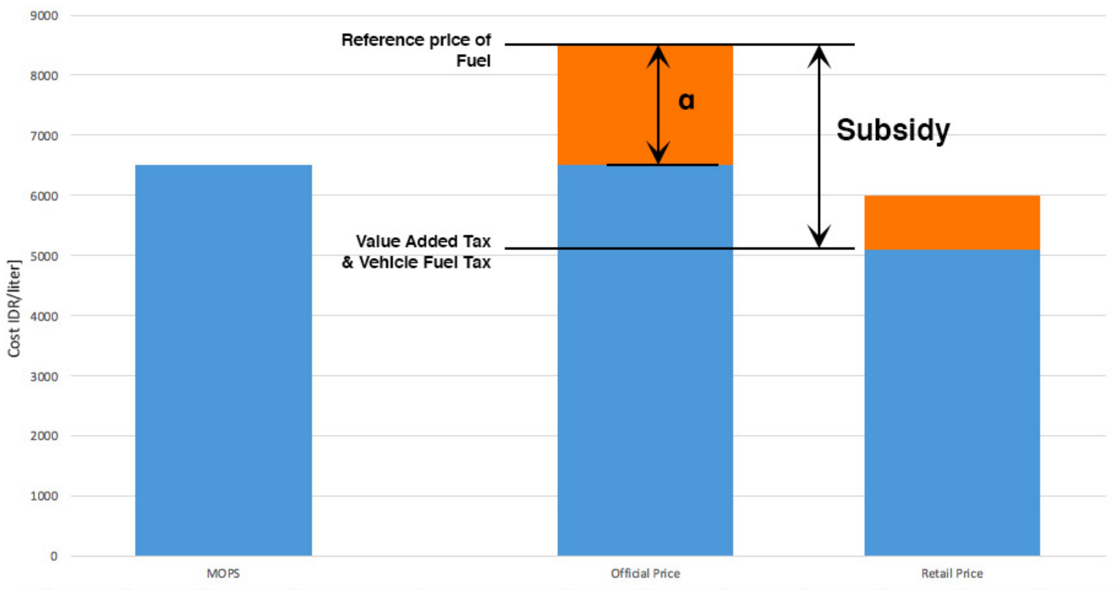

Figure 3.5: Fuel Subsidy in Indonesia (Askolani, 2010)

The government gives subsidy up to 40% of the fuel price. However, this subsidy only applicable mostly on road transportation of both freight and passenger transport.

High subsidy by the government has made the fuel price in Indonesia much cheaper compared to the reference fuel price especially in South East Asia. The Figure 3.6 below shows how the fuel price in Indonesia is relatively cheaper compared to the neighboring countries due to the subsidy from the government.

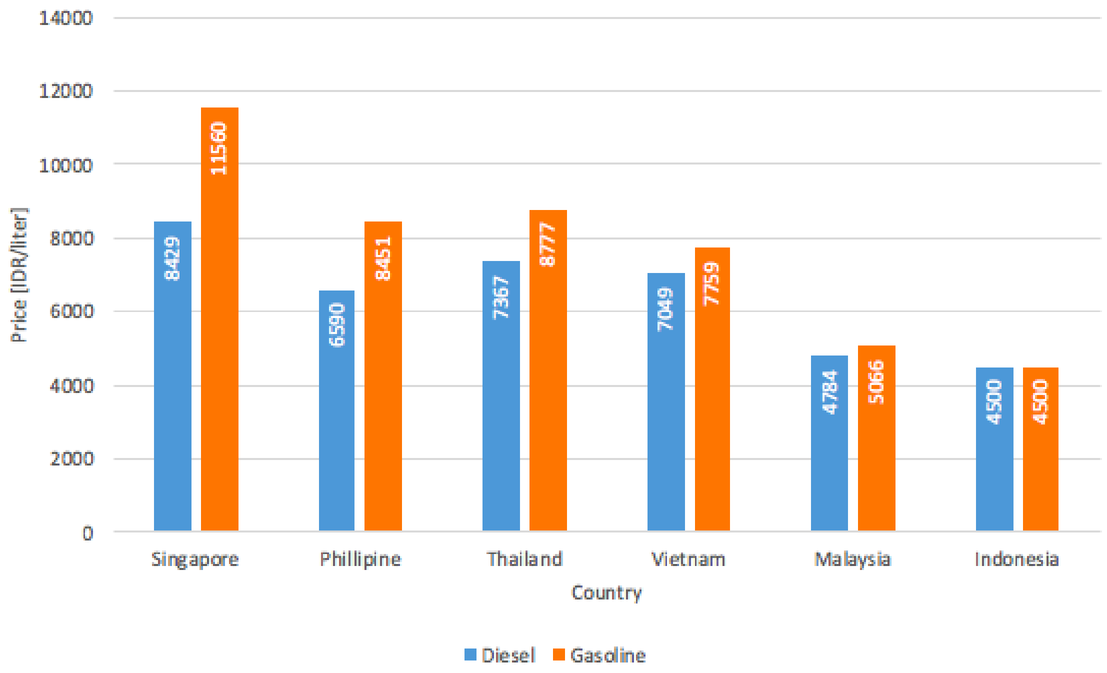

Figure 3.6: Fuel Prices in Different Neighboring Countries (Askolani, 2010)

The government has planned to totally cut the fuel subsidy through the fuel subsidy reform. With fuel subsidy reform, final energy consumption is projected to decline by over 10% in 2030 (Asian Development Bank, 2015). The combined effect of a decline in energy consumption and fuel switching is estimated to reduce CO2 emissions by over 9% relative to the status quo condition in 2030. Beside the positive effect on the national economy, the fuel subsidy reform would also give an impact on freight transportation.

By reforming the fuel subsidy policy, the most impacted actor within the freight transportation would be the shippers and the truck operators. The truck operators might face a higher operational cost due to the increase of the fuel price. Thus, leading to higher transportation cost for the shippers. However, this effects would push the truck operators to refine their business model and would make them try to innovate in order to be able to compete with the other modes given the higher operational cost. Therefore, the service quality and the efficiency of the mode would be increased in the long run.

3.4 Future Scenario on Policies Implementation

The policies discussed earlier in this chapter are the central government‘s plan on improving the freight transportation system in Indonesia. The policies will be implemented in the future on the network. Therefore, it is interesting to analyze the future effect of the policies on the freight transportation system in Indonesia.

Within the model, the future effect of the policies can be calculated by adding several new parameters. For the fuel subsidy reform, the model will add the subsidy rate on every mode and add the calculation of each modal‘s operational cost given the subsidy rate. The general equation of the modal operational cost with the subsidy rate will be as follows.

$$\rho^m = \rho^{m*}(1 - \omega S^m) \tag{3.1}$$

ρ^m = Subsidized operational Cost of mode m j
ρ^{m*}= Operational Cost of mode m without subsidy
ω^m = Percentage of fuel cost of mode m
S^m = Subsidy rate for mode m

The percentage of the fuel cost ω is the constant that represents to how much the fuel cost accounts to the total operational cost of a mode. The variable subsidy rate S will be modified in the scenario‘s program.

3.5 Summary

This chapter discussed the actor analysis and the policies in Indonesia that are related to its freight transportation system. The actor analysis was performed in order to understand the policy making Indonesia. Based on the actor analysis, the Ministry of National Development Planning is the main actor in this issue. The Ministry of National Development Planning work together with the other ministries on defining the strategic and tactical planning on Indonesia‘s freight transportation and other important sectors. Therefore, as the issuers of the policy, the position of the Ministry of National Development Planning is crucial in this issue.

Together with the other ministries, the central government has defined several policies in freight transportation. Within the *Strategic and Tactical National Planning* (RPJMN), the central government has planned to improve the existing transportation network especially for the freight transportation. The central government planned to build new road connections, highways, maritime transportation facilities, and rail network. However, within the model, only the rail network improvement will be added to the future scenario. The reason is because most of the other improvement plans (i.e. road construction, port construction) are at the regional level, while the model will be build on provincial level.

Another highlighted policy in Indonesia is the fuel subsidy reform. The central government planned to totally cut the fuel subsidy that was given to road transportation, which in the freight transportation, it is given to trucks. The fuel subsidy spending from the central government accounts to 4.1% of the total national expenditure. It is even bigger compared to the fundings allocated to health and education. In order to see the effect of these policies in the future, they are added as scenarios in the model.

Chapter 4

Model Specification

This chapter explained the foundations of the model building process. Firstly, the requirements were stated, then the model specifications were defined based on the requirements. Further on, this chapter explained the model parameters and the data that are used to build the model.

4.1 Model Requirements

Before specifying how the problem should be modeled, it is important to firstly define the model requirements. A model consists of several elements. The elements that should be defined are the objective(s), the key performance indicator (KPI), the model resolution, the data, and the scenarios.

Firstly, It has an objective, which is the main purpose of each model. The objective could be maximizing or minimizing certain variable or if there are several variables, a combination of the maximizing and minimizing objective could be combined depending on the problem. Secondly, one or more key performance indicators (KPIs) should be defined to measure the quality of the model results. Thirdly, the model resolution such as the spatial and temporal resolution must be defined to give boundary to the model. By defining the boundaries, the model will performs within the problem scopes. Fourthly, the list of available data should be made in order to make sure that all the parameters can be used in the model. Last but not least, the scenarios should be defined. Defining the scenario is important to understand which parameters should be modified depending on the scenarios.

4.2 Model Specification

4.2.1 Model Objective

The model objectives refers to the basic purpose that the model serves. Based on the research objectives, the following purposes of the model is intended to be used for freight flow modeling and a quantitative tool for decision making support.

Within a transport model, freight flow modeling is a key component to the model. Through freight flow modeling, one can analyze how the flow is distributed within the transport network and find where the bottleneck lies. Furthermore, it is one indicator that determine how a scenario or policy would affect the network. Therefore, it helps in decision making process as a quantitative analysis tool.

4.2.2 Key Performance Indicators

In order to meet the goal of the research, specific outcomes of the model are needed. Therefore, the following Key Performance Indicators (KPIs) are defined. With these KPIs, insights about the current situations can be obtained and can be used to compare the obtained result of the research from different scenarios to the current situation.

Modal Split[**%**] The modal split indicates the modal share of a transport mode in the freight transportation. The modal share of a mode is obtained by calculating the amount of goods transported using the mode to the combined amount of goods transported using all the available modes. This KPI can be used to indicate the shift of freight transport modality in different scearios.

Generalized transport costs per mode[**IDR**] This KPI indicates the total transport cost required when transporting certain amount of goods between two zones. The generalized transport costs is the sum of link cost, the transport mode cost, travel time cost and handling cost.

4.2.3 Model Resolution

In order to make a transport model, the units of the model, the modalities, the spatial resolution, and the temporal resolution need to be specified.

Units of the Model

Based on the model requirement, a static model can be operated given the function as a supportive quantitative tool for decision making support. The freight data over a year based on origin-destination (OD) matrix will be modeled. The freight is expressed in the unit of tonnages. The monetary values are converted to euro for the purpose of simplification. For other parameters, metric measurement units are used (i.e. km for distance and hour for time).

Modalities

Several means of transportation exist in Indonesia, i.e. Road mode, rail mode and sea mode. These three transport modes will be included in the multimodal transport network model. The study by Lubis et al. (2005) showed that in 2005, the modal split for freight transportation in Indonesia is estimated as follows:

- Road Transport = 90.35%
- Rail Transport = 0.6%
- Sea Transport = 9.0%

- Other = 0.05%

As the other means of transport (i.e. Inland waterway and air transport) have really low percentage in the freight transport modal share, therefore, they are neglected in the this study. Thus, only road, rail and sea modes are taken into account and incorporated into the model.

In the model building process, the aforementioned modal share data is used as a parameter to validate the model. This is because there is no data available on the modal share at the provincial level and the national modal share data is not applicable to all regions in Indonesia. Some area are only accessible through road network, while some should be reached with sea transport.

Temporal Resolution

This model will be used as an insight to support decision making process for strategic transportation problem. Therefore, it is important to define certain important points in time based on the problem or the scenario to be analyzed.

Beside network design optimization, the model is also intended to be used for investment planning on transport network development. Therefore, the model should be able to analyze the network for long term changes. Dynamic model would give insight in the effects of changes in production and attraction level on the freight flows. However, a relatively large amount of data would be required for such model. As the aims of the model is to find the suitable combination of transport network infrastructure development given the freight flow in a certain point of time, a static model would be sufficient.

The timeframe of the model follows the data availability, especially the origin and destination (OD) freight flow data. The latest OD data that is available is the 2011 OD data. Therefore, the base year analysis will use the data in 2011. For the future scenarios, the national growth rate data was used to calculate the predicted future OD data.

Spatial Resolution

The spatial resolution refers to the model aggregation regarding the spatial data available (i.e. household level, city level, provincial level, national level, and international level). The temporal resolution refers to the specification of the time periods. The availability of the data will determine the aggregation or dis-aggregation of the model.

In order to model the freight flows in Indonesia, the country should be divided at least to the provincial level. Therefore, the provinces will be the zones in the network. The links that connect the zones should also be specified. And within a zone, a point should be specified as the 'gravity point', to be used as the origin and destination node.

Indonesia is divided into four level of administrative borders, which are provinces, cities or districts, sub-districts, and villages. More data is available on the first administrative level, the province level. In order to obtain higher accuracy of the model, due to the data availability and to build an aggregated model of Indonesia, the model covers the freight flows between the provinces in Indonesia. The province acts as a zone, with the capital city as the centroid. Therefore, the network consists of 33 zones. Each port and rail terminal that are used for transshipment activities or as a multimodal hub, have a separate centroid as an origin and destination for intra-islands and inter-islands trade.

The network of the model is divided into three network layers, namely road, rail and maritime network. The layers connect all seaports, dry ports, terminals and centroids in the network. For model aggregation reason, the road links are limited to national roads and toll roads. This assumption is also based on the fact that trucks are directed on the national roads and toll roads to minimize the congestion inside the cities. The loading and unloading activities in a terminal are integrated to the links that connect the ports or the terminal to the respective origin or destination centroid.

4.2.4 Data Collection

The data collection process was done by the means of desk research and correspondences with other researchers and employees in the related companies. The following table summarize the list of data needed and the sources of the data.

Table 4.1: Data list and sources

Data	Source
Coordinates	Open Government Indonesia (n.d.)
Port list	Indonesian Ministry of National Development Planning (2014)
Trucking cost	The Asia Foundation (2008)
Truck speed	The Asia Foundation (2008)
Rail cost	Wijaya et al. (2014)
Rail speed	Wijaya et al. (2014)
Maritime cost	de Baat et al. (2015)
Vessel speed	Yamada (2013)
Transshipment Cost	(Bahagia et al., 2013)
Transshipment time	de Baat et al. (2015)
Road Distances	Open Government Indonesia (n.d.)
Rail Distances	Open Government Indonesia (n.d.)
Maritime Distances	Open Government Indonesia (n.d.)
OD Matrix	Ministry of Transportation (2014)

The coordinates data are retrieved from Indonesia GIS data from the Ministry of National Development Planning. The GIS data contains the position of every province's capital city which acts as a node within the model. The GIS also contains the infrastructure data such as port location, road network along with the road length data. The RPJMN listed the list of ports in Indonesia that will be focused on for the maritime highway policy. The ports mentioned on the list are integrated to the model.

The transport mode data are collected from different researches and documents.

The truck cost and speed are processed from the research article by The Asia Foundation (2008). The article presented the research on trucking cost in several locations in Indonesia. The rail cost and speed are obtained from the research by Wijaya et al. (2014) that performed a research on railway cost structure in West Sumatra. The maritime costs used in the research by de Baat et al. (2015) that presented the multimodal transportation system optimization in Java island. The transshipment costs are compiled from the IPC data on different port's transshipment costs.

4.2.5 Scenarios

The model should be robust to support decision making process in which future scenarios will be applied to the model. Therefore, several scenarios were defined to be analyzed. To develop scenarios for the freight transport model, the degrees of freedom should be based on the expected growth or changes of the Indonesian future. Within MP3EI, the Indonesian government planned to increase the national connectivity by 2025. (Coordinating Ministry for Economic Affairs and Ministry of National Development Planning, 2011). In order to increase the national connectivity, MP3EI made these following plans on transportation:

1. Optimizing the current transport and logistics network
2. Improving multimodal connectivity
3. Improving the existing network facilities and infrastructures
4. Building new infrastructures on road, rail and shipping network.

The plans based on the MP3EI therefore will be used as the base for the scenario development. Aligning with the plans mentioned, the following scenarios are developed.

1. Base case scenario optimization. Within MP3EI, the first target is to optimize the current transportation network in Indonesia. Improving multimodality and reducing the total transport cost is also part of the network optimization objective. Therefore, in the first scenario, the current freight transport network will be optimized. The multimodal network will be built and the design year OD data will be used for the optimization of the existing network.
2. Cutting diesel subsidy. As mentioned in previous chapter, fuel subsidy on trucks is the reason why trucks are more favorable even though it is less efficient and less reliable compared to maritime transport. Using the scenario of cutting the fuel subsidy from road transportations, the effect of the flow, the cost and the modal share within the network will be analyzed.
3. Finding optimum subsidy level. The third scenario is to find a balance in subsidy in all the transport modes. By giving subsidy to all the transport modes and adjusting the total subsidy to optimize the modal share, the network efficiency could be increased. This option could reduce the total logistics cost for the shippers and lower operational cost for the modal operators. However, it might increase the spending of the government on the fuel subsidy.

4. Future transport network infrastructure development. The Indonesian government has planned several infrastructure construction such as new railway network construction in Sumatra, Java, Kalimantan, Sulawesi, and Papua. Within this scenario, the investment plan regarding the new facility construction will be analyzed in terms of the benefit and cost ratio. Therefore, the result would be a policy recommendation regarding the plan and the effects on the network.

5. Future improvement prioritizing based on BCR. Instead of performing all of the improvement all at once, the government could prioritize the improvement actions based on the benefit to cost ratio of certain set of improvement actions. The result of this scenario will be compared with the result of the fourth scenario. In the end, policy recommendation will be explored based on the comparison of the two scenarios.

4.3 Network Data

The network data is required in order to build the network visualization. The network consists of the physical network of maritime and inland transportation services. The network was build using province node with the capital city as the centroids, port nodes and rail terminal nodes. Links are created to connect the nodes based on the real physical network.

4.3.1 Zone and Centroid Data

Based on the spatial resolution of the model, the zones are defined from the provincial data. Therefore a province is a zone with supply and demand information based on the OD matrix. The centroid of the zone is the capital city of the respective province. The complete list is shown in Table 2.1. The location of each centroid is added based on the respective centroid‘s coordinate. The coordinates are extracted from GIS data of Indonesia‘s ports. Figure 4.1 below illustrated the location of every centroid nodes based on their coordinates.

Figure 4.1: Zones and centroid nodes (Self Illustration from Open Government Indonesia (n.d.))

4.3.2 Road Network

The road network data is obtained from the national road network GIS data of Indonesia. Within the model, the aggregated version of the road network was made. The aggregated network is illustrated in Figure 4.2 below.

Figure 4.2: National Road Network (Self Illustration from Open Government Indonesia (n.d.))

4.3.3 Maritime Ports and Network

The maritime ports incorporated into the model are based on the ports associated with the Indonesian maritime highway policy in the RPJMN. There are 6 main or hub ports and 26 feeder ports as illustrated in table 4.2 below.

Table 4.2: Hub and feeder ports in Indonesia (Indonesian Ministry of National Development Planning, 2014)

Hub Ports	**Hub Ports Coverage Regions**	**Affiliated Feeder Ports (Spokes)**	**Feeder Ports Coverage Area**
Belawan/ Kuala Tanjung	North Sumatera	Malahayati	Nanggroe Aceh Darussalam (NAD) Province
		Batu Ampar	Riau Islands, Bangka-Belitung, Riau
		Jambi	Jambi
		Teluk Bayur	West Sumatera, north part of Bengkulu
Tanjung Priok	West part of Java Islands (DKI Jakarta, Banten, and West Java)	Palembang	South Sumatera and south part of Bengkulu
		Panjang	Lampung
		Tanjung Emas	Central Java
		Pontianak	West Kalimantan
Tanjung Perak	East Java, Bali, and West Nusa Tenggara	Tanjung Emas	Central Java
		Sampit	Central Kalimantan
		Banjarmasin	South Kalimantan
		Palaran	Part of East Kalimantan (Samarinda)
		Kariangau	Part of East Kalimantan (Balikpapan)
		Tenau Kupang	East Nusa Tenggara
Makassar	South Sulawesi	Pantoloan	Central Sulawesi, West Sulawesi
		Kendari	South East Sulawesi
		Palaran	Part of East Kalimantan (Samarinda)
		Kariangau	Part of East Kalimantan (Balikpapan)
		Tenau Kupang	East Nusa Tenggara
Bitung	North Sulawesi, Gorontal	Ternate	North Maluku
		Ambon	Maluku
		Sorong	West Papua
		Jayapura	Papua
Sorong	Papua	Ternate	North Maluku
		Ambon	Maluku
		Jayapura	Papua

The hub ports are connected by the main route of maritime highway network that connects the regions in Indonesian from West to East as illustrated in Figure 1.1 . The distance between ports in Indonesia are obtained from nautical distance calculator database, ports.com. The matrix shown by Table 4.3 below shows the distance between the hub ports in Indonesia.

Table 4.3: Distance matrix of main ports in Indonesia [km]

	Belawan	Tj. Priok	Tj. Perak	Makassar	Bitung
Belawan	-	1535	2046	2662	3502
Tj. Priok	1535	-	713	1452	2543
Tj. Perak	2046	713	-	827	1946
Makassar	2662	1452	827	-	1284
Bitung	3502	2543	1946	1284	-

Then, the distance data between the main ports and their feeder ports are gathered and combined into one maritime distance matrix. The maritime network model is illustrated in Figure 4.3 below.

Figure 4.3: Indonesia Maritime Network (Self Illustration from Open Government Indonesia (n.d.))

4.3.4 Rail Terminal and Network

The intercity rail network in Indonesia only exist in Java island. Within the model, the main rail freight route is added to the network model. Most rail connections, connect the capital cities, while some provinces have rail access to the maritime port as well. Figure 4.4 below illustrated the rail network connections in Java island. And the following Table 4.4 listed the rail terminal names and the respective terminal type.

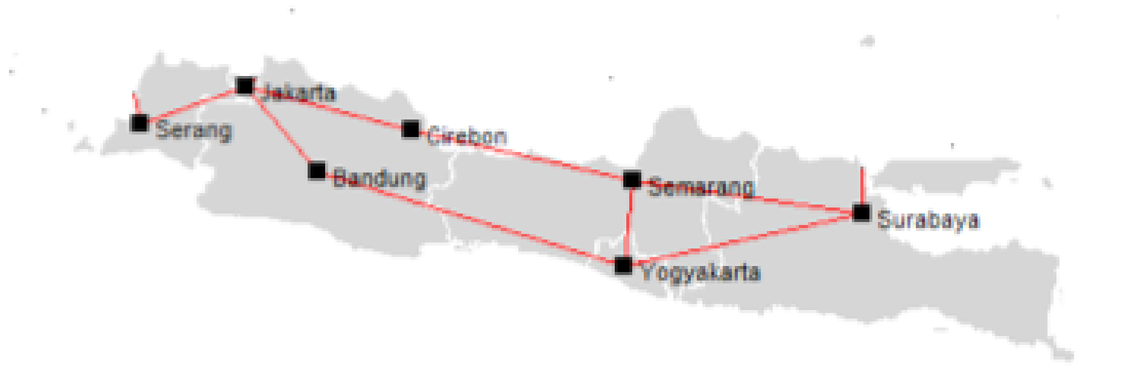

Figure 4.4: Java rail network (Self Illustration from Open Government Indonesia (n.d.))

Table 4.4: Rail terminals in Indonesia (PT Kereta Api Indonesia, 2016)

Province	Rail Terminal Name	Type
Banten	Merak	Port Rail Terminal
	Serang	Intercity Terminal
DKI Jakarta	Jakarta Gudang	Port Rail Terminal
	Jakartakota	Intercity Terminal
West Java	Gedebage	Intercity Rail Terminal
Central Java	Semarang Tawang	Intercity Rail Terminal
Yogyakarta	Lempuyangan	Intercity Rail Terminal
East Java	Pasar Turi	Intercity Rail Terminal
	Kalimas	Port Rail Terminal

4.3.5 Supernetwork

In 3 previous sections, the uni-modal transport network of road, rail and maritime network have been modeled. In order to model the transport supernetwork, all 3 uni-modal networks are combined by adding transshipment links. The resulting network is shown by Figure 4.5 below.

Figure 4.5: Integrated transportation network in Indonesia

The three unimodal network of trucks, maritime and railways are integrated into one multimodal transport network within the supernetwork. The different modalities are connected using transshipment links that contains the transshipment cost and time data. Therefore, the extra cost and time are only applied if the shipper choses to use the transshipment link to change the transport mode.

4.4 Network Parameters

4.4.1 Operational Costs

The operational cost is the distance cost of the available transport modes. The operational cost for all the 3 modes are listed in Table 4.5 below.

Table 4.5: Mode Operational Cost [€/km]

Truck	Rail	Sea Shipping
0.32	0.27	0.3

The trucking cost is based on the research by The Asia Foundation (2008) that analyzed the trucking cost in several routes in Indonesia. Based on the research, the average operational cost of truck in 9 routes is 0.32 €/km/ton. The research by The Asia Foundation (2008) also found that fuel contributes to the total trucking cost by 39%.

The maritime operational cost is obtained from the inter-island logistics performance research by Ministry of Trade (2014). The maritime operational cost in Indonesia varies in every routes. However, there are only route data from port of Makassar and port of Tanjung Perak available. Thus, the average maritime operational cost is used for the whole network. Therefore, the average of 0.3 €/km/ton is obtained

The rail operational cost is obtained from the research of railway cost component by Wijaya et al. (2014). The research broke down the cost component of freight transportation using railway mode in West Sumatra. Based on the research calculation, the freight transporting cost using railway in West Sumatra is 0.27 €/km/ton. Since, there is no data found on the railway cost in Java, the value is assumed the same in other rail network.

4.4.2 Value of Time

The value of time is the cost for the time spent on the network. In this research, the freight is treated as a multi commodity freight. Based on the research by de Baat et al. (2015), there are different value of time for different freight categories. This research treated the commodity as a single multi commodity freight. Therefore, the average of the commodity value of time of all the commodity groups is used.

Table 4.6: Value of time of different commodities (de Baat et al., 2015)

NSTR 1-digit	Commodity	VoT [€/hr/TEU]
0	Agricultural products and live animals	0.23
1	Foodstuff and fodder	0.21
2	Solid mineral fuels	0.04
3	Crude oil	0.03
4	Ores and metal waste	0.2
5	Metal products	0.42
6	Crude and manufactured building materials	0.09
7	Fertilizers	0.14
8	Chemicals	0.2
9	Machinery, transport equipment, manufactured articles and miscelllaneous articles	0.49
Average		0.205

4.4.3 Mode Speed

The mode speed is derived from the average speed of the mode on the whole network. The average vehicle speed data used in the research by Russ et al. (2005) was used. For the truck, the average speed is set to 60 km/h, 26 km/h for maritime network and 65 km/h for rail network.

Table 4.7: Mode Speed (Russ et al., 2005)

Speed per Mode (km/h)		
Truck	Rail	Sea Shipping
60	65	26

4.4.4 Terminal Handling Cost and Time

The terminal handling time represents the total time spent for the transshipment processes (i.e. roll on, roll off, queueing). Not much data are available in Indonesia regarding the transshipment time. The dwell time at Gedebage rail terminal is 1 day (Ferdian, 2005). And the only port dwell time known is the dwell time in Tanjung Priok, which is 4.8 days (Bahagia et al., 2013). For the reason of simplicity, the dwell time data in Gedebage will be used for the transshipment time between rail and road mode. While, the transshipment time from both rail and road network to the maritime network will use the Tanjung Priok‘s data. Table 4.8 below summarize the transshipment time between the available modes.

Table 4.8: Transshipment time between modes (de Baat et al., 2015)

From mode	To Mode	Time (days)
Road	Rail	1
Road	Maritime	4.8
Rail	Road	1
Rail	Maritime	1
Maritime	Road	4.8
Maritime	Rail	1

4.4.5 Origin Destination Matrix

The input data for the model on freight flows were obtained from the OD Matrix data by Coordinating Ministry for Economic Affairs and Ministry of National Development Planning (2011) . The OD matrix is the aggregated flow between each origin to the destination. The data does not specify the specific flow of different goods or the flow using different means of transportation mode between the origin and the destination.

4.4.6 Growth Factor Method for Future OD Data Calculation

The calculation of the OD matrix for the design year was done using the ’growth rate’ calculation. The following equation is used for the design year OD Matrix calculation (Ortuuzar & Willumsen, 2011).

$$T_{ij} = \tau_{ij} \cdot t_{ij} \tag{4.1}$$

where T_{ij} is the flow from i to j on the design year, τ_{ij} is the growth factor and t_{ij} is the freight flow at the base year.

For the calculation of the growth factor, the available real growth factor data from 2013-2015 was used. While for the year 2016-2019,the target growth factor that is stated in RPJMN is used. And for the years ahead after 2019, it is assumed that the government would at least try to maintain the growth rate from 2019. For 2016, a complete official GDRP growth data is not yet available. Therefore, the projected growth based on the target in RPJMN is used.

After all the growth factor of every provinces have been listed, then the growth factor in 2030 will be calculated as the sum-product from year 2012-2030. The growth factor of a region determines the change (either increasing or decreasing) in its supply. Therefore, the growth factor of North Sumatra for instance, will affect the number of freight flows from North Sumatra.

Table 4.9: Initial OD matrix sample for Sumut, Jabar, and Sulsel Province in year 2011 (Ministry of Transportation, 2014)

	Destination		
Origin	Sumut	Jabar	Sulsel
Sumut	291,943,329	74,086,960	7,832,272
Jabar	73,210,120	1,961,544,047	17,907,477
Sulsel	4,365,642	6,002,047	156,634,718

Table 4.10: Growth factor calculation for period 2012-2030 (Faisal, 2015)

Year	GDRP Growth (1+Growth)		
	Sumut	Jabar	Sulsel
2012	1.062	1.063	1.084
2013	1.06	1.061	1.076
2014	1.061	1.058	1.075
2015	1.061	1.055	1.074
2016	1.067	1.066	1.074
2017	1.072	1.071	1.083
2018	1.076	1.078	1.091
2019	1.081	1.077	1.091
2020	1.081	1.077	1.091
2021	1.081	1.077	1.091
2022	1.081	1.077	1.091
2023	1.081	1.077	1.091
2024	1.081	1.077	1.091
2025	1.081	1.077	1.091
2026	1.081	1.077	1.091
2027	1.081	1.077	1.091
2028	1.081	1.077	1.091
2029	1.081	1.077	1.091
2030	1.081	1.077	1.091
Total Growth Factor 2030	3.971	3.77	4.863

Table 4.11: Estimation of OD matrix sample for Sumut, Jabar, and Sulsel Province in year 2030

	Destination		
Origin	North Sumatera	West Java	South Sulawesi
North Sumatera	1,159,306,959	294,199,319	31,101,953
West Java	276,002,153	7,395,021,057	67,511,189
South Sulawesi	21,230,116	29,187,953	761,714,635

4.5 Future Development Data

For the future scenario, as stated within the RPJMN, the Indonesian government plans to improve the freight transport network infrastructures and connectivity in Indonesia. Several improvement plans were made for the infrastructure of each transport mode (i.e. rail, truck and maritime). The most significant improvements are for the rail mode.

The Indonesian government plans to build new railway networks in all the big islands in Indonesia, which are in Sumatra, Kalimantan, Sulawesi and Papua, where railway network was not exist, unless in Sumatra, where some areas have small railway networks for earth resources.

Within this research, only the railway network improvement will be taken into account. This is because the capacity constraints is not taken into account do to the data availability regarding the capacity constraints of each mode. The road and maritime networks are mostly focused on the improvement of the existing infrastructures, which means, increasing the capacity of the respective links.

The new railway links to be built are listed in Table 7.11 below along with the links' respective length and investment costs.

Table 4.12: New Railway Network in Indonesia‘s Islands (Ministry of Transportation and Infrastructure and Australian Aid, 2014)

Island	Origin	Destination	Length [km]	Investment Cost [$\times 10^{12}$ IDR]
Sumatra	Aceh	Medan	577	14.50
	Medan	Dumai	527	7.53
	Dumai	Pekanbaru	152	4.56
	Pekanbaru	Padang	374	11.23
	Padang	Jambi	518	15.56
	Jambi	Palembang	260	7.81
	Palembang	Lampung	386	11.59
	Padang	Palembang	1175	35.29
	Pekanbaru	Jambi	465	13.99
Kalimantan	Pontianak	Palangkaraya	984	29.55
	Palangkaraya	Banjarmasin	260	4.14
	Banjarmasin	Samarinda	500	15.27

Table 4.12: New Railway Network in Indonesia‘s Islands (Ministry of Transportation and Infrastructure and Australian Aid, 2014)

Island	Origin	Destination	Length [km]	Investment Cost [$\times 10^{12}$ IDR]
Sulawesi	Bitung	Manado	48	1.44
	Manado	Gorontalo	427	12.82
	Gorontalo	Palu	583	17.51
	Palu	Mamuju	395	11.86
	Mamuju	Makassar	350	10.51
Papua	Sorong	Manokwari	382	11.47
	Manokwari	Jayapura	1230	36.94

The railway network constructions mentioned in Table 7.11 above will be integrated in the upper level problem within the bilevel optimization problem. The bilevel optimization program will find the good combination of the improvements in order to maximize the benefit to cost ratio.

4.6 Summary of Model Requirement and Specification

This chapter has elaborated the model specification. The specifications that were defined are, the model objectives, scope, data, the model resolutions, and the scenarios that will be performed on the model. The problem has two main objectives. Hence, it was modeled as a bi-level optimization problem. In the lower level problem, the objective is to minimize the generalized logistics cost of the network. On the upper level, the objective is to integrate the improvement plan by the central government and maximizing the total benefit to the investment cost ratio.

This chapter also presented the model illustration on Indonesia‘s unimodal network for each mode (i.e. trucks, railway, and maritime). The network representations are the aggregated version of the real network. For road network, only national roads was added to the model. For maritime network, the network based on the maritime highway plan was used. While for the railway network, the data from the Indonesian Railway Company (PT KAI) was used. Further, the parameters that were used in the network were presented in this chapter. Lastly, the network improvement plans data were discussed and presented.

Chapter 5

Model Framework

After the model specifications and parameters were explained in the previous chapter, this chapter focuses on the model building. The model framework along with its building blocks were explained in this chapter. The components of the framework were build based on literature studies on freight transportation modeling methods.

5.1 Network Representation

The basis of a transportation network model is the graph model (Cascetta, 2001). The graph consists of a set of nodes, N and a set of links that connect the nodes, L. Thus, the graph G can be represented as $G(N, L)$.

The nodes corresponds to a point with certain position within the network where a particular event happens. Important nodes in the transportation networks are called centroid nodes, which represent the beginning or the end of individual trips. As mentioned in the previous chapter, the centroid nodes within the models are the capital province of each provinces in Indonesia.

The nodes are connected with each other by links. The links have a direction which indicate the starting node and the end node of a link. A link can be represented by a single index (i.e. l), that represents its position in the list of the link set or by the pair of node indices (i, j) that it connects. Another way is representing the links using a so-called node-link incidence matrix indicating with zero-one variables whether a particular link directly connects to a particular node. The later is used in the model. Links contain several network attributes such as distances [km], link cost [EUR/km], transshipment cost [EUR/ton], transshipment time [hour] and freight flow on the respective link [ton].

Between an origin and the destination, there might exist one link or more that connect the origin and destination point. The collection of these links are called *path*, k. These paths are sequences of phases allowing travel from a given origin to a given destination and therefore represent possible trips. Each path is associated with one and only one OD pair. While there might exist more than one paths that connect one origin and destination(OD) pair. Similar to the definition of path, a route is a collection of links and nodes between an OD pair. In this research both term are used as a synonym.

5.2 Multimodal Transport Super Network

Transport supernetwork model is a transport network model that allows simultaneous choice of transport modes and route, including transshipment points (Sheffi, 1984). It combines several uni-modal networks into a single integrated multi-modal network. The different modes are connected through the transshipment links that represent the possibilities of modal change. The transport supernetwork model combines the problems of multimodal transport network into single user equilibrium model. Within model, virtual (dummy) links are added to represent several choice dimensions such as the transshipment links. These transshipment links contain the informations regarding the costs and times required for the transshipment between different modalities. The integrated supernetwork is illustrated in Figure 5.1 below.

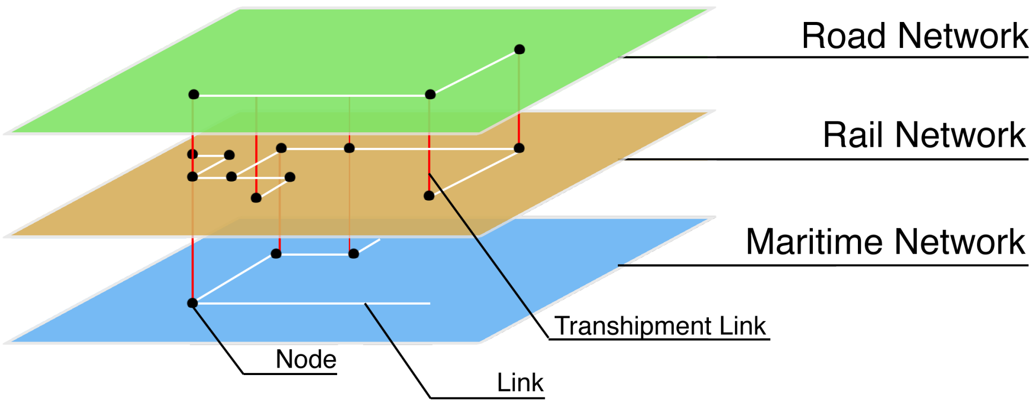

Figure 5.1: Integrated supernetwork illustration

Compared to an uni-modal transport network, the following process should be followed for a supernetwork traffic assignment.

1. the supernetwork building process,
2. the choice set generation,
3. the route choice modeling,
4. the traffic assignment

The transport supernetwork building process consist of addition of transfer links between modes at certain multimodal terminals. Therefore, the transfer links unite several uni-modal networks into one multimodal network. Such supernetwork has an interesting property which, the mode choice is now part of the route choice model. Therefore, in a transport supernetwork, the multi dimensional travel choice situation faced by traveler is transformed into a one dimensional choice situation of alternative routes within the network.

The terminals play important role for the freight movements. L. A. Tavasszy (1996) proposed a simple transhipment link with fixed values of cost and delay time, while Gulat, Florian, and Crainic (1990) used a more specific representation of transfer link that creates more links in the multimodal terminal. Southworth and Peterson (2000) created a more detailed representation of multimodal terminal by separating transshipment link into terminal access link and transfer link inside the terminal. However, the application is mainly intended for database and routing purposes only. The transshipment link within the integrated supernetwork is illustrated below.

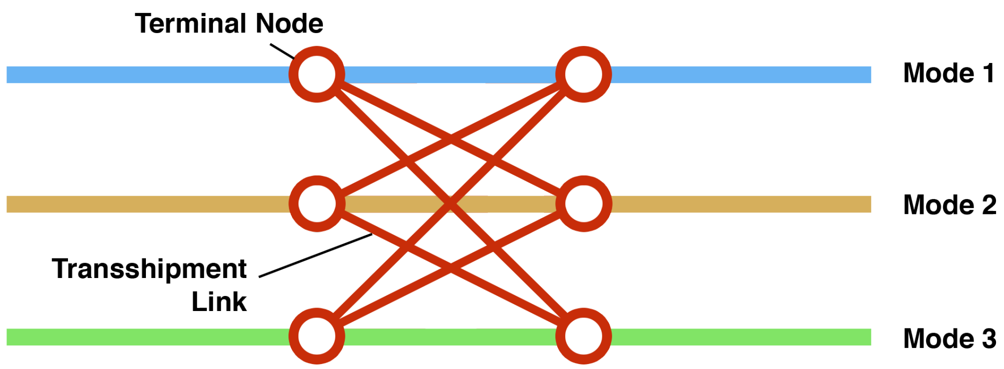

Figure 5.2: Transshipment Links Representation (adapted from L. Tavasszy et al. (2011))

At the terminal, it is possible to change from one mode to the other through the transshipment link. By using the transshipment links, the transshipment time is added to the total travel time and the transshipment cost is also added to the total logistics costs.

5.3 Framework

The figure 5.3 in the following page shows the framework used in the model. A bilevel optimization approach is used in the model. Firstly, using the OD trade flow data along with the additional data on the different modalities are added to the generated integrated multimodal network. Secondly, the lower level optimization is performed by executing a route choice set generation to generate several alternative least cost route based on different route choice behavior. The choice behavior added to the model are least distance route choice and least cost route choice. Thirdly, the route choice probability is calculated using path size logit model and lastly, the freight assignment and modal split calculation are performed. The results (Freight flow data and total transport cost) of the lower level problem are used in the upper level problem to calculate the cost difference and later for the BCR calculation.

The upper level problem used the improvement action list data. The data are defined based on the central government‘s network improvement plans. The action combination are defined later in the model. There are three combinations used, which are; implementing all action, calculation of each improvement's BCR by only adding one improvement action; and finding a good improvement combination and priority using random search method. After defining the improvement action combination, the chosen combination are added to the transport network. Lower level optimization of the improved network is performed taking into account the link addition. Afterwards, the cost difference is calculated and finally the BCR value is obtained.

The result of the model execution were analyzed further. The analysis performed are the KPIs analysis and recommendation analysis for the network design. In the scenario analysis, this model framework is used as the base framework. Several modification will be added based on the scenario analysis requirements.

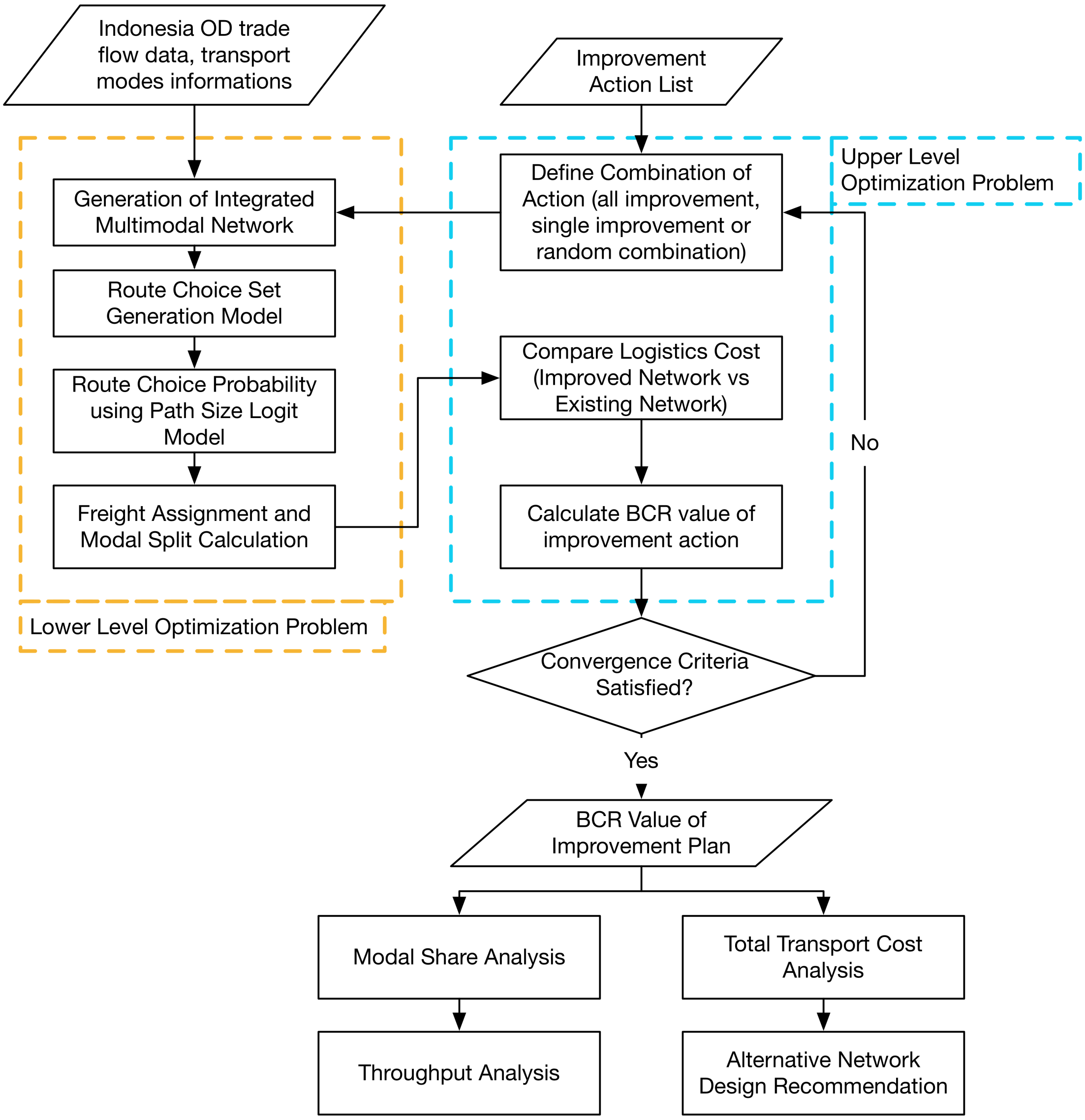

Figure 5.3: General framework of the model

5.4 Generalized Cost

The cost from node i to node j using mode m is expressed as a generalized cost composed of a fare component and a time cost component. The fare cost component consists of distance cost (fuel consumption) and transshipment cost. While the time cost component is the product of the total time on links and the transshipment waiting time. The generalized cost formula is shown in equation 5.1 below, adapted from (Russ et al., 2005) .

$$C_{ij}^{m} = d_{ij}^{m}\rho^{m} + C_{ij} + \alpha_{g}^{m}\left(\frac{d_{ij}^{m}}{s^{m}} + Q_{ij}^{m}\right) \tag{5.1}$$

C_{ij}^{m} = General cost from i to j using mode m [Euro/tonnages]
d_{ij}^{m} = distance from i to j using mode m [km]
ρ^{m} = operational cost of mode m per km [Euro/(km·Tonnage)]
C_{ij} = Transshipment cost from i to j [Euro/tonnage]
α_{g}^{m} = Value of time [Euro/hr]
s^{m} = average speed of mode m from i to j [km/h]
Q_{ij}^{m} = The transshipment time from i to j using mode m [h]

The only variable that dependent on the freight volume is the transshipment cost. The generalized cost is modeled as a deterministic function because there is limited data to make the stochastic model.

5.5 Freight Flow Modeling

In order to model the freight flow in the network, four step modeling approach was used. The four step modeling provides a mechanism to estimate direct demand functions together with link performance function (Mcnally, 2007). With the availability of the OD Matrix data, the modeling was started from the trip distribution phase. Then, the flow in the network is calculated using all or nothing (AON) assignment and considering the Wardrop‘s equilibrium.

5.5.1 Trip Distribution

Trip distribution represents the the number of trips that occur between each origin zone and each destination zone. The calculation of the OD matrix for the base year and the design year are using the Growth Factor method (Ortuuzar & Willumsen, 2011). This method is chosen because there is only the OD matrix data for 2011 available. Therefore, the OD matrix for 2016 and for the future scenario should be constructed. The growth factor data is compiled from the Gross Domestic Regional Product (GDRP) data by Indonesian Central Statistics Bureau and from the Ministry of Development Planning. It consists of the real GDRP growth value for year 2012-2013 and government projection for the growth target for 2015-2019. The years following 2019 uses the same growth rate as the growth rate in 2019 as projected in RPJMN.

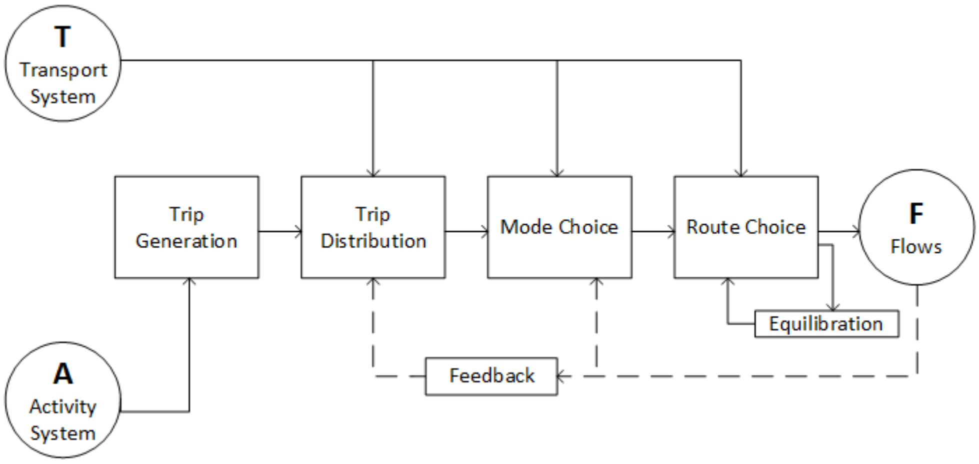

Figure 5.4: Four Step Modeling (Mcnally, 2007)

With the availability of only the GDRP data, this makes the use of singly constrained growth factor methods in order to calculate the design year OD matrix feasible. In this case, the GDRP and the projected growth is an origin-based growth factor (τ_i) that can be applied to the corresponding rows in the trip matrix (Ortuuzar & Willumsen, 2011). This can be written as:

$$T_{ij} = \tau_i \cdot t_{ij} \text{ for origin-specific factors} \tag{5.2}$$

$$T_{ij} = \tau_j \cdot t_{ij} \text{ for destination-specific factors} \tag{5.3}$$

T_{ij} = Design year OD Matrix flow from origin i to destination j
$\tau_{i,j}$ = Origin(i) and destination(j) growth factor
$t_i j$ = Base year OD Matrix flow from origin i to destination j

5.5.2 Route Choice Model

"All-or-nothing"(AON) assignment is the simplest route choice and assignment method (Ortuuzar & Willumsen, 2011). This method do not include congestion effects. It is also assumed that all transport actors aims to minimize their own cost, thus they select the minimum route between the origin and the destination. Therefore, all users consider the same attributes for route choice, thus every route has same weight.

The mathematical formulation below is used for the AON assignment. The objective is to select the combination of paths that leads to the least cost route from origin o to destination d.

$$\min \sum_{ijm} C_{ij}^m y_{ij}^m \tag{5.4}$$

$$\sum_j y_{ji} - \sum_j y_{ij} = \begin{cases} -1 & \text{if } i = orig \\ 0 & \text{if } i \in I \\ 1 & \text{if } i = dest \end{cases} \tag{5.5}$$

$$y_{ij} = \{0, 1\} \tag{5.6}$$

The result of the AON mathematical program is a combination of path from origin o to destination d. However, there are two limits of AON algorithm. AON assignment assumed that there is no capacity constraint on the candidate route and it does not take into account the route choice heterogeneity of the users (Zhang, Wiegmans, & Tavasszy, 2013).

In order to cope with the algorithm‘s limitation, two approaches are taken. Firstly, to introduce the capacity constraint, deterministic user equilibrium algorithm was employed. Secondly, to take into account the route choice heterogeneity, the set of route choice is generated. The alternative routes is the k-shortest path of the network (Yen, 1971). Therefore, this model adopts the route based approach on flow assignment. Both approaches are elaborated further in the following subsections.

5.5.3 Choice Set Generation and Choice Function

The route choice set are generated using shortest path algorithm for every origin and destination combination. In order to introduce route choice to the model, another route alternative is defined using k-shortest path (Yen, 1971).The k-shortest path uses AON as initial shortest routes. Then it removes one link in every iterations and find the k-shortest path.

The AON will define the initial shortest path without flow on it. Then after the flow is assigned, the flow will be updated through iteration until it reaches convergence and resulted with the optimum shortest path given the flow on the network

The route choice is modeled using Logit model (Ortuuzar & Willumsen, 2011) as follows.

$$P_r = \frac{\exp(-\lambda C_r)}{\sum_{r \in R} \exp(-\lambda C_r)} \tag{5.7}$$

P_r = Choice probability of route r
C_r = Total cost of route r [€/Tonnage]
λ = Parameter to be calibrated

However, the logit model does not take into account the path overlap between the alternative routes. An overlapping path would be a bottleneck on the route, therefore, it should be taken into account while choosing the best route. In order to cope with the overlapping path, a path size (PS) logit model is employed. The model used is as follows (Ben-Akiva & Bierlaire, 1999).

$$P_r = \frac{\exp(-\lambda C_r - \ln S_r)}{\sum_{r \in R} \exp(-\lambda C_r - \ln S_r)} \tag{5.8}$$

The degree of path overlap, S_r is defined as

$$S_r = \sum_{a \in \Gamma_r} \left(\frac{z_a}{z_r} \right) \frac{1}{N_a} \tag{5.9}$$

S_r = Degree of path overlap r
Γ_r = set of links in route r
z_a = length of the overlapping link a [km]
z_r = length of route r [km]
N_a = the number of times link a is found in the other route

PS Logit adds correction term to the utility of the alternative routes. A route with no overlapping links does not need correction, thus has a size of one. The size of partially overlapping links is weighted based on the respective link‘s contribution or its length compared to the whole route length.

5.6 Bilevel Optimization Problem

5.6.1 Lower Level Problem

The lower level problem is the network optimization problem. For the bilevel optimization problem, a link improvement variable which is the result of the upper level problem solution is added into the generalized cost function. The generalized cost function then becomes a function of network improvement.

$$C_{ij}^{m*} = d_{ij}^{m*} \rho^m + C_{ij} + \alpha_g^m \left(\frac{d_{ij}^{m*}}{s^m} + Q_{ij}^m \right) \tag{5.10}$$

C_{ij}^{m*} = General cost from i to j using mode m with the improved network [Euro/tonnages]
d_{ij}^{m*} = distance from i to j using mode m with the new links added [km]
ρ^m = operational cost of mode m per km [Euro/(km*Tonnage)]
C_{ij} = Transshipment cost from i to j [Euro/tonnage]
α_g^m = Value of time [Euro/hr]
s^m = average speed of mode m from i to j [km/h]
Q_{ij}^m = The transshipment time from i to j using mode m [h]

Within the cost function, it can be distinguished that there is d_{ij}^{m*}. It is the distance data, where the new link distances are added to the distance data. Therefore, using this new dataset, the optimization model will take into account the new links within the network when finding the least cost routes.

Solution Technique

The lower level program is solved using the mathematical program to find the route set. Then, using the path size logit, the route choice probability is calculated and then the route cost are calculated by multiplying the freight cost with the route probability and the total freight between the origin and destination. The approach illustrated in figure 5.5 below shows the steps for the freight assignment at the lower level problem.

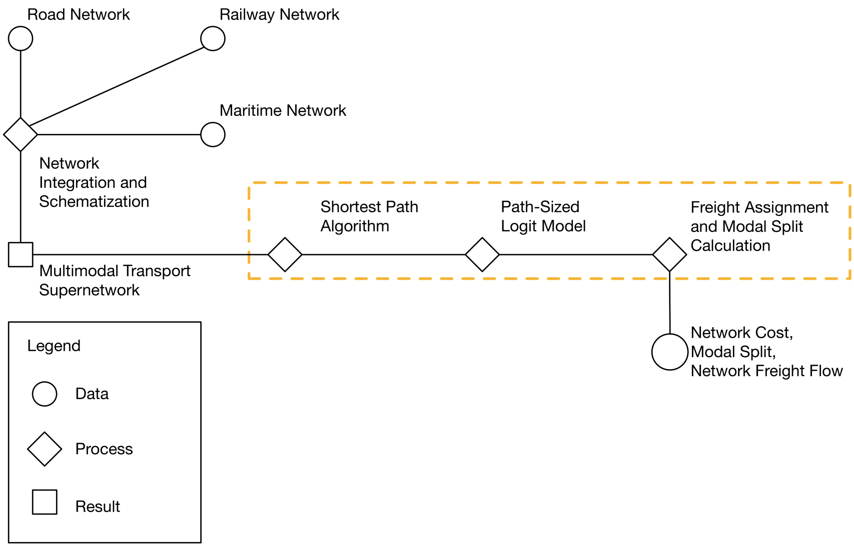

Figure 5.5: Lower Level Modeling Aproach

5.6.2 Upper Level Problem

The upper level of the model is to solve the investment planning problem. This investment planning can be considered as a combinatorial optimization problem. The objective is to determine the best combination of infrastructure development and improvement to improve the existing transport network.

For the upper level problem, three subset is added to the set of links, $L = L_1 \cup L_2 \cup L_3$. L_1 can be defined as the set of existing links that will not be modified, L_2 as the set of existing links with possible actions to be implemented, and L_3 as the updated version of subset L_2 or the links that will be improved.

A set of possible combinations of action Y that is associated with L_3 is then defined. And action implementation variable y_a with binary value of 1 if the action related to link l on the set of L_2 or L_3 is implemented. The BCR calculation formula by Russ et al. (2005) was adopted in this research and showed below.

$$\max_{y \in Y} z(y) = \frac{G_o - \sum_{m \in M} \left(\sum_{a \in A_1} C_a^m(x_a^m) x_a^m + \sum_{a \in A_2} C_a^m(x_a^m, y_a) x_a^m \right)}{\sum_{a \in A_2} b_a y_a} \tag{5.11}$$

$z(y)$ = Benefit to cost ratio

G_o = initial transport cost without improvement [€/tonnages]
A_1 = set of links without improvement
A_2 = set of improved links
C_a^m = Transport cost on link a using mode m [€/tonnages]
x_a^m = flows on link a by mode m [tonnages]
y_a = action implementation indicator
b_a = investment cost on link improvement if implemented [€]

Solution Technique: Simulated Annealing with Tabu Search Constraint

In order to solve the upper level problem, a local search heuristic method called simulated annealing (SA) was used. Simulated annealing method was inspired by physical process in solids when they are heated and cooled in a heat bath Metropolis, Rosenbluth, Rosenbluth, Teller, and Teller (1953). In an annealing process, the heated solid will have high entropy and by the time the temperature cools down, the entropy will get lower and more stable.

Simulated annealing works like a standard local search heuristics, but sometimes it accepts worse solution (Kirkpatrick, Gelatt, & Vecchi, 1983). Within simulated annealing, if a neighboring solution is better than the current solution, it will be accepted. On the other hand, if the neighbor solution is worse than the current solution, the solution could be accepted with certain probability based on Boltzman distribution (Kirkpatrick et al., 1983). The probability is calculated through the equation 5.12 below.

$$P = e^{\frac{\Delta E}{T}} > r \tag{5.12}$$

$$\Delta E = E_{new} - E_{old} \tag{5.13}$$

$$P \begin{cases} \geq 1 & \text{accept} \\ > r & \text{accept} \\ < r & \text{reject} \end{cases} \tag{5.14}$$

P = Probability the new solution will be accepted
ΔE = Energy Difference [kJ]
T = Current Temperature [°C]
r = random number between 0 and 1
E_{new} = Energy from new temperature [kJ]
E_{old} = Energy from previous temperature [kJ]

The lower the temperature gets, the less likely the worse solution to be accepted. Therefore, when the temperature gets low, the calculation moves toward the convergence. In every iteration, the temperature drops with the function stated in equation 5.15 below. The cooling rate determines how fast the temperature drops.

Usually, the cooling rate is set between 0.8 to 0.99. In this research, every time the temperature drop, one iteration is performed.

$$T_{new} = \alpha T_{prev} \tag{5.15}$$

T_{new} = New temperature [°C]
T_{prev} = Previous temperature [°C]
α = Cooling rate

Additionally, to increase the efficiency of the program, the tabu search constraint was added to the simulated annealing program. Tabu search is another type of local search heuristics. Tabu search is a local search method that has short term memory to escape local minima and to avoid cycles (Glover & Laguna, 1997). Cycle means using the solution that has been tested in the previous calculation. Within tabu search, there is a parameter that is called "Tabu list". The tabu list contains the set of solutions that have been evaluated in the previous iterations. Using the tabu list, the program can be prevented from going back to the used moves. In the program, the tabu list is updated after each iteration.

To perform the simulated annealing, the following steps were taken.

1. Initialize initial temperature, final temperature and initial random upper level solution. In this research, the initial temperature was set to 1000 $°C$ and cooled until 0.01 $°C$ with the cooling rate of 0.95/iteration.
2. Perform lower level optimization with the initial upper level solution and calculate the BCR value.
3. Generate a random neighboring solution. In this research, 2-opt method was used to change two values of the initial solution to obtain the neighboring solution.
4. Calculate the BCR value, given the neighbor solution on the upper level.
5. Compare the BCR value between the two solutions. If the neighbor solution has higher BCR value, move to it. Otherwise, calculate the acceptance probability of the neighboring solution.
6. Repeat step 3-5 until the target temperature is achieved.

5.7 Multimodal Freight Accessibility Measurement

Accessibility is a significant factor in transportation planning on expressing the mobility of passenger, freight or information (Rodrigue, Comtois, & Slack, 2006). The higher one country‘s transportation system efficiency, the higher the accessibility level of many locations in the country. This applies vice versa. Burns (1979) emphasized accessibility as the freedom of individual to decide whether to participate or not in different activities.

In order to measure the accessibility level, the potential accessibility measures or the gravity-based measures concept is used to describe the accessibility to opportunities. This measure is used in the form of market potential in location analysis (Geurs & Eck, 2001). For the accessibility measure in a multimodal transportation system, Lim and Thill (2008) developed the accessibility measures for intermodal freight accessibility using the potential accessibility measures. The potential accessibility measurement takes into account the accessibility of a zone as a sum of the generalized logistics costs between the origin and the destination point. The zones are weighted in terms of the zones‘ opportunities. The weights W_j are considered the agglomeration effects on the zone j, while the impedance function $f(c_{ij})$ takes into account the assumption that the attraction of a destination zone decreases with distances, travel time, or costs. The basic potential accessibility measurement equation used is as follow.

$$A_i = \sum_j W_j f(c_{ij}) \tag{5.16}$$

A_i = measure of accessibility at location i
W_j= weight representing the opportunities at potential location j
$f(c_{ij})$ = the impedance function
c_{ij} = the generalized logistics costs from i to j [€]

The weight W_j is calculated by considering two type of opportunities of the location, which are the economic opportunities of location j (W_{jE}) and the logistics opportunities of location j (W_{jL}). Hence, the weight W_j is the sum of the two opportunities as stated in equation 5.17 below.

$$W_j = W_{jE} + W_{jL} \tag{5.17}$$

W_j = weight representing the opportunities at potential location j
W_{jE} = the measure of economic activities/ opportunities in location j
W_{jL} = the measure of logistics activities/ opportunities in location j

The economic opportunities of location j (W_{jE}) is measured using equation 5.18 below. The equation takes into account the zones‘ consumption expenditure on manufactured goods, the employment in different industrial sectors and the purchases of the industries from other manufacturing industries.

$$W_{jE} = X_j + \sum_k \frac{E_{jk}}{\sum_i E_{ik}} Y_k \tag{5.18}$$

W_{jE} = the measure of economic activities/ opportunities in location j
X_j = the personal consumption expenditure on manufactured goods in j
E_{jk} = the number of employees in industrial sector k in j
Y_k = purchases of industry k from manufacturing industry

While the logistics opportunities of location j (W_{jL}) is as follows.

$$W_{jL} = \sum_l \frac{E_{jl}}{\sum_i E_{il}} Y_l \tag{5.19}$$

W_{jL} = the measure of logistics activities/opportunities in j
E_{jl} = the number of employees in industrial sector l in j
Y_l = the purchases of industry l from logistics industry

The impedance function represents the disincentive to travel as the logistics costs increase. In this study, the exponential function is used. The exponential function was formulated as follows based on Ortuuzar and Willumsen (2011).

$$f(c_{ij}) = exp(-\beta c_{ij}) \tag{5.20}$$

$f(c_{ij})$ = the measure of logistics activities/opportunities in j
β = parameter indicating the sensitivity to travel cost
c_{ij} = the generalized cost between i and j [€]

The value of β is crucial for the model. The generalized costs will have no effect on the function if the β is 0. And the bigger the β value, the more sensitive the function to the generalized costs. In this research, the value of β used in the research by Martalia (2016) is adopted.

5.8 Net Present Value (NPV)

Several methods exist to conduct an investment evaluation, such as payback period, internal rate of return (IRR), net present value (NPV), and profitability index (PI) (Ross, Westerfield, & Jaffe, 2005). Payback period method calculates the time required until the break even point of the project finance is achieved. The period is calculated by simply adding up future cash flow without discounting the value. Therefore, this method is not robust for financial evaluation. Overcoming the limitation, the NPV method takes into account the discount rate into the calculation. In addition, payback period evaluation also ignores cash flows beyond the cut off point, which might lead to misinterpretations. Some projects might be profitable when viewed as a long-term investment. IRR is closely related to NPV. The IRR on an investment is the required return, that results in zero NPV when its used as the discount rate. could be associated with the Expected Return from the project. If the result of IRR is more than the Expected Return, then an investment is acceptable. It should be rejected if the value is less than Expected Rate of Return.

In this research, the NPV method will be used as an additional evaluation for the investment plans. Net Present Value (NPV) analysis is used to measure whether a project would be beneficial to the project owner by calculating the cash flows of the project, taking into account the discount rate that occurs every year. The value of money in the future will be less that its value today. The future value of the present money is quantified using the equation 5.21 below.

$$PV = \frac{FV}{(1+r)^t} \tag{5.21}$$

PV = Present value of money [€]
FV = Future value of money [€]
r = the discount rate [%]
t = the number of years

In NPV analysis, the decision whether the project is acceptable or not is based on the final NPV value. If the NPV is bigger or equal to 0, then the project is acceptable. On the other hand, if the NPV is less than 0, then the project is not beneficial for the project owners.

5.9 Conclusion

This chapter discussed the model frameworks that will be used as a basis to build the model. The methodologies and the methods were elaborated. The methods are explained based on the literature reviews. The model framework cover the steps taken for the model to work. Firstly, the data discussed from the previous chapter were added to the model. Secondly, for the lower level optimization problem, the k-shortest path algorithm was employed to find the k number of optimum (least cost, least distance, shortest time, shortest free running time) routes between each origin and destination in the OD data. Thirdly, using the path size algorithm, the probability of the network user on choosing each route was calculated for then the freight flow was assigned based on the route choice probability. Lastly, this chapter explained the benefit to cost ratio calculation which is the objective variable of the upper level problem. The upper level optimization problem then will be solved using the random search method that generates random combination of the decision variable until the best solution was found.

Chapter 6

Model Building, Verification and Validation

This chapter proceeded the modeling process after the model structures were defined in the previous chapter. The model components are integrated into a working model with several codes that translate the model framework into several programs. After the programs were made, the model was first verified and validated in order to ensure that it works properly and gives the right result.

6.1 AIMMS Model

AIMMS is a mathematical modeling tool with its own language. It is a mathematical modeling tool with full graphic user interface for advanced mathematical modeling. AIMMS includes many different solvers for linear, mixed-integer and non-linear programming such as baron, cplex, canopt, gurobi, knitro, path, snopt and xa (Bisschop & Roelofs, 2006).

The sets, parameters and variables used in the main model are as follows.

Indices

n	index of nodes
o	index of origin nodes
d	index of destination nodes
i	index of start point within shortest path
j	index of end point within shortest path
m	index of modes

Parameters

ρ^m	operational cost per km for mode m [IDR/km]
VoT^m	value of time for mode m [IDR/h]
v^m	velocity of mode m [km/h]
d_{ij}^m	distance between origin i to destination j using mode m [km]
T_{ij}^m	flow between origin i to destination j using mode m [ton]
G_n^t	Growth Rate of node n in year t [ton]
BCR	flow between origin i to destination j using mode m [ton]

Variables

C_{ij}^m Transport cost between origin i to destination j using mode m [IDR]
y_{ij}^m binary variable if link from i to j is within the shortest route
z_{ij}^m binary variable if new link from i to j is added to the network

6.2 Program Codes

After declaring the sets, parameters, variables and mathematical programs in AIMMS, then a program should be made in order to run the execution of the model. Within the model, three programs exists.

6.2.1 Path Finding Model

The following code is used for the path finding model.

```
for (o,d) in ODMatrix(o,d) do
origin       := o;
destination    := d;

Solve PathFindingModel;

Route(o,d,i,j)   := ArcSelected(i,j);
RouteCost(o,d)   := TotalCost;
endfor
```

The first line defines all of the origin-destination (OD) pair that should be included in the program. The program will find the least cost route between each OD pair. The *PathFindingModel* contains the mathematical equation for the path finding algorithm.

The equation in the software is modeled based on equation 5.4. By solving the mathematical equation, two results are obtained. Firstly, the variables $ArcSelected(i,j)$ which is a matrix that contains the selected path between the OD pair that gives the least cost route. Secondly, the *totalcost* variable returns the final objective value. The variable $Route(o,d,i,j)$ stores the least cost path for every OD pair and the variable $RouteCost(o,d)$ stores the route cost for every OD pair.

6.2.2 BCR Calculation

The BCR calculation program is used for scenario analysis, specifically in the fourth scenario of performing all the improvement actions. The BCR calculation is based on Equation 5.11.

```
AllDistances(m,i,j) := Initial_Distances(m,i,j) +
  NewLink_Distance(m,i,j);
  for (o,d)in ODMatrix(o,d) do
  origin      := o;
  destination := d;

  Solve PathFindingModel;
```

```
  Solve New_PathFindingModel;
  Route(o,d,m,i,j)    := ArcSelected(m,i,j);
  RouteCost(o,d)      := TotalCost;
  Route2(o,d,m,i,j)   := New_ArcSelected(m,i,j);
  RouteCost2(o,d)     := New_TotalCost;
  CostDifference(o,d) := TotalCost(o,d) -
    New_TotalCost(o,d);
  BCR    := sum((o,d),CostDifference(o,d)) /
    sum((m,i,j)|Imp_ArcSelected(m,i,j),
    ImprovementCost(m,i,j));
  endfor
```

6.2.3 Upper Level Solution Technique

The upper level random search program is derived based on the solution technique described in subsection 5.6.2. The program created a random combination of improvement actions added the chosen new links to the network and recalculates the lower level optimization problem. In the end, the BCR value of the combination is obtained. The program code is as follows.

```
Solve PathFindingModel;
!Initiate temperature and iteration count
iteration                  := 1;
Temp                       := 10000;


Distances((m,i,j)|ImprovementList(m,i,j))    := 1000000000000;

!Initaite first solution
InitialSolution((m,i,j)|ImprovementList(m,i,j))    := binomial(0.5,1);
CombinationMemory(it,m,i,j)                 := InitialSolution(m,i,j);

!Calculate BCR
Distances((m,i,j)|InitialSolution(m,i,j))    := AllDistance(m,i,j);

solve LowerLevelProblem;

BCR := [sum((o,d,x,m,i,j),FlowLink(o,d,m,i,j)*RouteSetCost(o,d,m,i,j))
    - sum((o,d,m,i,j),New_FlowLink(o,d,m,i,j)*New_RouteSetCost(o,d,m,i
    ,j))]/sum((m,i,j)|InitialSolution(m,i,j),ImprovementCost(m,i,j));

BCR_memory(it)                  := BCR;
Temperature_memory(it)               := Temp;

Temp *= 0.95;
LAA    += 1;

while Temp > 0.1 DO
Distances((m,i,j)|ImprovementList(m,i,j))        := 1000000000000;

repeat
  Neighbor((m,i,j)|ImprovementList(m,i,j))            := binomial(0.5,1);
```

```
   Sumneigbor                  := sum((m,i,j),Neigbor(m,i,j));
32   Sumprevious                 := sum((m,i,j),Copy_Combinationbaru(m,i,j));
   break when Abs(sumneigbor-sumprevious) = 2;
34 endrepeat;

36 if sumneigbor = 0 then
repeat
38   Neighbor((m,i,j)|ImprovementList(m,i,j))          := binomial(0.5,1);
   Sumneigbor                  := sum((m,i,j),Neigbor(m,i,j));
40   Sumprevious                 := sum((m,i,j),Copy_Combinationbaru(m,i,j));
   break when sumneigbor>0;
42 endrepeat;
endif;
44
Distances((m,i,j)|Neighbor(m,i,j))      := AllDistance(m,i,j);
46
solve LowerLevelProblem;
48
BCR := [sum((o,d,x,m,i,j),FlowLink(o,d,m,i,j)*RouteSetCost(o,d,m,i,j))
    - sum((o,d,m,i,j),New_FlowLink(o,d,m,i,j)*New_RouteSetCost(o,d,m,i
    ,j))]/sum((m,i,j)|InitialSolution(m,i,j),ImprovementCost(m,i,j));
50
if BCR > Solusi_BCR(LAA-1) then
52 BCR_memory(it)              := BCR;
Tempt_memory(it)             := Temp;
54 CombinationMemory(it,m,i,j)     := Neighbor(m,i,j);

56 elseif BCR < Solusi_BCR(LAA-1) then
IF exp((BCR-SOlusi_BCR(LAA-1))/Temp) > uniform(0,1) THEN
58 BCR_memory(it)              := BCR;
Temp_memory(it)              := Temp;
60 CombinationMemory(it,m,i,j)     := Neighbor(m,i,j);
else
62 BCR_memory(it)            := BCR_memory(it-1);
Temp_memory(it)           := Temp;
64 CombinationMemory(it,m,i,j) := CombinationMemory(it-1,m,i,j);
endif;
66 endif;

68 it += 1;
Temp *= 0.95;
70 endwhile;
```

The simulated annealing program starts by solving the lower level problem (line 1) with the existing network design in order to obtain the initial cost data. Then, it generates the initial solution and evaluate the solution by performing the BCR calculation. Then, the program generates the random neighboring solution by changing 2 values of the initial solution (line 37-44).

In this program, the variable $ProgramDistance(m,i,j)$ is used as the distance variable for the mathematical equation. This variable is the sum of the initial network distance data and the improvement link distance data. Line 8 is used to set the link penalty on the link distance in the improvement list. The variable

$InitialSolution(m, i, j)$ generate a random combination of the improvement actions. The combination of improvement actions of every iterations are stored within the variable $CombinationMemory(it, m, i, j)$. Using this variable, the user could check which combination of actions that gives the highest BCR value. After the combination of actions are selected, then the distance of the chosen links are returned to the real value by the code in line 15.

Having all the parameters ready, then the lower level calculation is performed again in line 16 This code recalculates the least cost path for every OD pair. Therefore, the new network cost is obtained and the cost difference between the initial network and the network with improvements and the BCR is calculated in line 24. It divides the cost difference with the total improvement cost of the new links that are chosen in that one single iteration. Then, the process are repeated again until the stopping criteria is satisfied. Line 52-67 are the probability calculation if the new solution is worse than the previous solution.

After the program has been executed, the highest BCR value is selected from the variable $BCR_memory(it)$. Using max function the BCR value is obtained, and using ArgMax function, the iteration number can be identified. By knowing the iteration number, the combination of action can be identified from the variable $IterationCombination(it, m, i, j)$.

6.3 Model Verification Using Test Network

In order to ensure that the model works as how it should be, the model should be verified first. To verify the model, the model is used to solve optimization problem using simple test networks. The model result will be compared with manual calculation.

The verification process consists of three part. Firstly, the test network is generated. Three test networks with different complexity were made for the validation process. Secondly, the lower level optimization problem which is shortest path finding model is validated by finding the shortest path between two points within the test network. Thirdly, the bilevel optimization model is verified. Some possible improvement actions are added to each network. The model will calculate if the improvement(s), or which improvement(s) give the highest benefit to cost ratio.

6.3.1 Test Network Generation

Three test networks were made. The three networks are (1) a square network (4 nodes and 4 links), (2) a hexagonal network (6 nodes, 6 links), and (3) two hexagonal network (12 nodes, 13 link) with maritime connection between the two networks. The networks structure along with the distance data are illustrated in Figure 6.1 below.

These network will be used further to validate both the lower level optimization and the bilevel optimization. The straight lines indicate the existing links and the dashed lines indicate the links that could be added as improvement to the network.

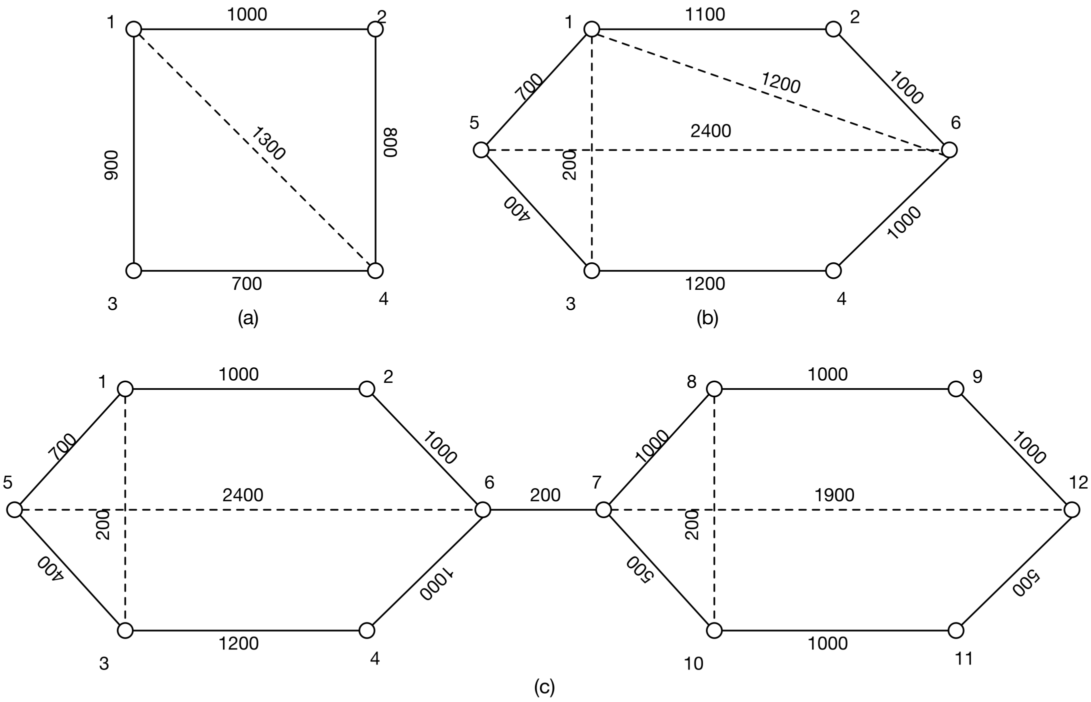

Figure 6.1: Test Network Illustration. (a) Square Network, (b) Hexagonal Network, and (c) Two Hexagonal Network

6.3.2 Initial Lower Level Problem Optimization

The lower level problem consists of shortest or least cost path finding problem. For all network, a shipment of 200 TEU is assigned. For the first network, the trip starts in node 1 and ended in node 4. For the second network; from node 5 to node 6. And lastly, for the third network; from node 5 to node 12.

Only one mode is available within this network. The related parameters such as the vehicle speed and the value of time, are based on the real data. For trucks, the velocity is 60 km/h and the value of time is 0.2 €/hr/TEU. Manual calculation was done on paper and then compared with the computational result in the following Table 6.1.

Table 6.1: Comparison of lower level optimization using manual calculation and AIMMS program

Network	Manual Calculation			AIMMS Model Calculation		
	Path	Dist [km]	Cost [€]	Path	Dist[km]	Cost [€]
1	1-3-4	1600	405.3	1-3-4	2500	405.3
2	5-3-4-6	2600	658.67	5-3-4-6	2000	658.67
3	5-3-4-6-7-10-11-12	4800	1216	5-3-4-6-7-10-11-12	4800	1216

The result shows that for the lower level optimization, the AIMMS program that is showed in subsection 6.2.1 gives the same result as the manual calculation. Therefore, it can be concluded that the code works as how it should be.

6.3.3 Bilevel Optimization

For the bilevel optimization model validation, improvement plans were added to the test network. The improvement plan is indicated by the dashed line in Figure 6.1. The benefit and cost ratio (BCR) will be calculated for each improvement and also the possible combinations of several improvements. Table 6.2, 6.3, and 6.4 below shows the comparison of BCR calculation by manual calculation and by AIMMS model.

Based on the table, the calculation of upper level optimization using the upper level solution techniques gives the result as the manual calculation. Therefore, the upper level program works as how it should be.

6.3.4 Model Verification Conclusion

Both the lower level and the upper level program has been tested by comparing the program result with manual calculation. Three test network with different network size was created in order to be used for the model verification process. Using the program that is written as the code presented in subchapter 6.2.1, 6.2.2, and 6.2.3.

The program result represented in subchapter 6.3.2 and 6.3.3 showed that the program works as how it expected to be. Therefore, based on the result, it can be concluded that the program can be used further for the real network optimization problem. The following chapter presents the result of the real network optimization in different scenarios using the programs.

Table 6.2: Bilevel Optimization of Test Network 1

Improvement	Manual Calculation					AIMMS Model Calculation				
	Path	Distance [km]	New Cost [x100€]	Action Cost [x100€]	BCR	Path	Distance [km]	New Cost [x100€]	Action Cost [x100€]	BCR
1	1-4	1300	394.3	100	0.91	1-4	1300	394.3	100	0.91

Table 6.3: Bilevel Optimization of Test Network 2

Improvement	Manual Calculation					AIMMS Model Calculation				
	Path	Distance [km]	New Cost [x100€]	Action Cost [x100€]	BCR	Path	Distance [km]	New Cost [x100€]	Action Cost [x100€]	BCR
1	5-3-4-6	2500	758.3	15.38	1.97	5-3-4-6	2500	758.3	15.38	1.97
2	5-6	2600	788.6	184.6	0	5-6	2600	788.6	184.6	0
3	5-1-6	1900	576.3	92.3	2.3	5-1-6	1900	576.3	92.3	2.3
1,2	5-6	2600	788.67	200	0	5-6	2600	788.67	200	0
1,3	5-3-1-6	1800	546	107.69	2.2	5-3-1-6	1800	546	107.69	2.2
2,3	5-1-6	1900	576.3	276.92	0.76	5-1-6	1900	576.3	276.92	0.76
1,2,3	5-3-1-6	1800	546	292.3	0.83	5-3-1-6	1800	546	292.3	0.83

Table 6.4: Bilevel Optimization of Test Network 3

Improvement	Manual Calculation					AIMMS Model Calculation				
	Path	Distance [km]	New Cost [x100€]	Action Cost [x100€]	BCR	Path	Distance [km]	New Cost [x100€]	Action Cost [x100€]	BCR
1	5-3-4-6-7-10-11-12	4800	1456	15.4	0	5-3-4-6-7-10-11-12	4800	1456	15.4	0
2	5-6-7-10-11-12	4600	1395.3	184.6	0.33	5-6-7-10-11-12	4600	1395.3	184.6	0.33
3	5-6-7-10-11-12	4800	1456	15.4	0	5-6-7-10-11-12	4800	1456	15.4	0
4	5-3-4-6-7-12	4700	1425.67	146.15	0.21	5-3-4-6-7-12	4700	1425.67	146.15	0.21
1,2	5-6-7-10-11-12	4600	1395.3	200	0.3	5-6-7-10-11-12	4600	1395.3	200	0.3
1,3	5-3-4-6-7-10-11-12	4800	1456	30.77	0	5-3-4-6-7-10-11-12	4800	1456	30.77	0
1,4	5-3-4-6-7-12	4700	1452.67	161.54	0.19	5-3-4-6-7-12	4700	1452.67	161.54	0.19
2,3	5-6-7-10-11-12	4600	1395.3	200	0.3	5-6-7-10-11-12	4600	1395.3	200	0.3
2,4	5-6-7-12	4500	1365	330.76	0.275	5-6-7-12	4500	1365	330.76	0.275
3,4	5-3-4-6-7-12	4700	1425.67	161.54	0.19	5-3-4-6-7-12	4700	1425.67	161.54	0.19
1,2,3	5-6-7-10-11-12	4600	1395.3	215.38	0.28	5-6-7-10-11-12	4600	1395.3	215.38	0.28
1,2,4	5-6-7-12	4500	1365	346.15	0.26	5-6-7-12	4500	1365	346.15	0.26
1,3,4	5-3-4-6-7-12	4700	1425.67	176.92	0.17	5-3-4-6-7-12	4700	1425.67	176.92	0.17
2,3,4	5-6-7-12	4500	1365	346.15	0.26	5-6-7-12	4500	1365	346.15	0.26
1,2,3,4	5-6-7-12	4500	1365	361.53	0.25	5-6-7-12	4500	1365	361.53	0.25

6.4 Model Validation

In order to validate the model, the OD Matrix in 2011 is used and the result will be compared with the real data based on the KPIs. However, only the modal share data in 2011 is available to be compared. Therefore, the modal share calculated by the optimization program will be compared with the real modal share data of Indonesia. As stated before in table 2.4, the modal share in Indonesia for truck is 90.3%, 0.62% for railways, and 7% for maritime transportation.

The model was executed using the initial data with the given modal costs, time value, transshipment cost, transshipment time, and the existing network. The initial result of the lower level optimization is illustrated in figure 6.3 below. The result gives the modal split of every modalities. The modal share of trucks/ rail/maritime based on the base year model in percent is 83.6/2/14.2. The optimization of the current network design, yields to the following freight flow within the network.

Figure 6.2: Route Choice from Aceh to Manokwari

The model generated 3 different routes between each origin and destination pair. The freight flow result of the whole network is showed in figure below.

Figure 6.3: Network Freight Flow

The difference is mainly due to the aggregation of the road networks. Whereas in the real network, there are more alternative and choices for the truck mode to choose the route. Within the model, only the national roads are included. This aggregation leads to deviation between the model and the real world. Therefore, these deviation should be considered when understanding the result of the model. The deviation is showed in table 6.5 below.

Table 6.5: Modal share deviation of model result compared to real data

	Road	Maritime	Rail
Real data [%]	90.3	0.62	7
Model Result [%]	83.6	2	14.2
Deviation [%]	-7	223	103

6.5 Chapter Summary

This chapter has discussed the modeling in AIMMS. The main program codes for the lower and upper level optimization problem were presented. Before using the programs to perform the scenario analysis, the model should first tested in order to make sure that it works as how it should be and represents the real world condition. Therefore, model verification and validation were performed.

In order to verify the model, three test network were generated. These test networks were be added to the model and the optimization programs were executed for these networks. The model verification was done by comparing the model calculation and manual calculation on paper. In the end, it was found that the results given by the model and the results obtained through manual calculation are the same. Therefore, it was concluded that the model works as how it should be. Hence, it was verified.

To validate the model, the integrated freight network of Indonesia that was modeled earlier was used. The network parameter was added, and the OD data on 2011 was used. The result of the model was be compared with the real data from the government in order to check if the model would give the same result with the real data. However, the real data is limited. The only data that could be compared is the modal share data on 2011. Therefore, the modal share data was used as a comparison. The model result shows that the optimize network has a modal share of trucks/rail/maritime of 83.6/2/14.2 all in percent. It is slightly different compared to the real data where the modal share of trucks/rail/maritime are 90.3/0.62/7 in percent. However, this difference might be caused by the aggregation of the network in the model, especially on the road network. Not all road networks covered by the model. Therefore, when using the model and understanding the model result, the deviation in the calculation as stated in table 6.5 should be considered.

Chapter 7

Scenario Analysis and Policy Recommendation

In this chapter, the model that has been validated and verified is used to analyze different scenarios. The model parameters were modified based on the scenario that will be analyzed. Later on, based on the findings of the scenario analysis, several policy recommendations were given to support the decision making process of the Indonesian government.

7.1 Scenario Analysis

The Indonesian government has planned several policies for Indonesia's freight transportation. In order to analyze how the policies would affect the transportation system, the policies were turned into several scenarios. Through the scenario analysis, the prediction of how the policies will affect the system in the future could be obtained based on the model result.

The first scenario is the base case scenario where the future OD data was optimized with existing network. The second scenario is implementation of fuel subsidy reform policy, where the fuel subsidy for trucks are cut. The third scenario is giving subsidy all modes to balance the modal share. The fourth scenario is adding new links to the network. And the last scenario is finding good prioritization for the improvement actions.

7.1.1 Scenario 1: Base Case Scenario

The base case scenario is the network design optimization of the existing network. Thus, no network modification or improved are added to the network. The future OD data of 2030 is used in order to see how the transport network would perform in the future if the network is in status quo.

This scenario similar to the scenario used for the model validation. Only that in the model validation, the OD data in 2011 was used to compare the model result with the existing data on modal share. Therefore, the result of the model validation was used as a comparison with the result of the base case scenario analysis using the defined KPIs.

In order to obtain the future OD data in 2030, the growth factor method was used. The growth factor data used is based on the Indonesia's future growth rate calculation by (Faisal, 2015) that can be seen in Appendix A. Performing the future OD calculation with the growth rate data, the 2030 OD data in Appendix C was obtained.

Within the base case scenario, the network is optimized by firstly finding the optimum route between each origin and destination within the OD data. Then, using the path-logit, the freight was assigned. The optimization result of the base case scenario yields the freight flow in the network as illustrated in Figure 7.1 and the modal split stated in Table 7.1 below.

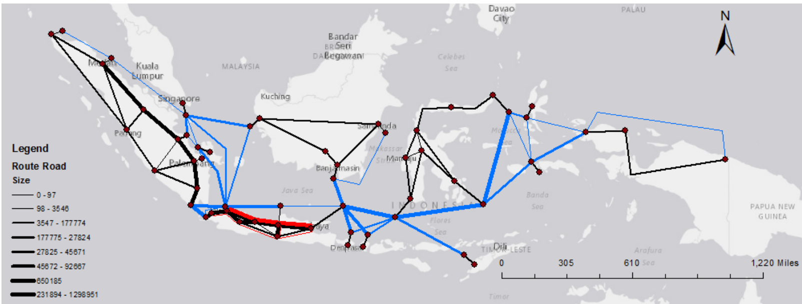

Figure 7.1: Base Case Freight Flow in 2030

Table 7.1: Base Case Scenario Modal Split [%]

Truck	Railway	Maritime
83.6	2	14.2

The total generalized logistics cost of this scenario is 2.54*10^9€. The railway freight traffic is in the route between Jakarta and Surabaya, with 0.5% of the total freight flow. For the maritime transportation, the link with the most flow is between Lampung and Banten , with 0.9% of the total flow. While, in the road transport, the freight flow is mostly concentrated between Semarang and Surabaya, with 2% of the total flow. For the railway freights, the flow concentration between Jakarta and Surabaya is mainly because that is the only route that covers a relatively long distance shipment. The other routes in Java are not that long that the economies of scale are not achieved. Therefore, the transshipment cost are relatively big for the given distances.

Compared with the flow in 2011, the changes are not significant. This is due to the fact that the demand is exogenous in this model. With the growth factor method, the increase in the OD demand is linear depending on each region's growth rate. Therefore, since there is no improvement or new links added to the network and shortest path algorithm was used for the route set generation, the concentration of the freight flow is similar. These reasons are also applied to the modal share. Which is the reason why the modal share in 2030 is the same compared to the modal share in 2011.

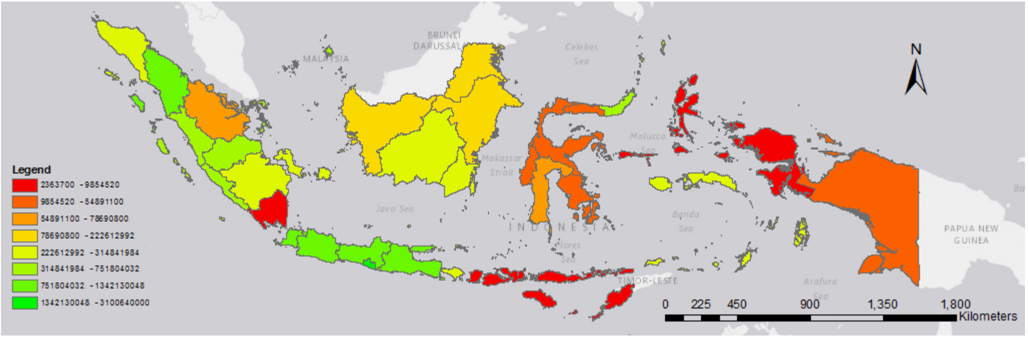

Figure 7.2: Network accessibility in base case scenario

Performing the accessibility measurement on the base case scenario, the calculation result was illustrated in Figure 7.2 above. The network accessibility illustration in Indonesia in the base case scenario proved the imbalance between the Western and Eastern part of Indonesia. Java has the highest overall accessibility level. North Sumatera and North Sulawesi also have relatively high accessibility level since both provinces are international hub.

Based on this result, with no change in the current network, the freight flow, the modal share and the generalized transport cost of the network does not change significantly. Therefore, in order to improve the network in terms of the generalized logistics cost, the modal share and the freight flow, other scenarios should be explored.

7.1.2 Scenario 2: Cutting Truck Fuel Subsidy

This scenario explores and analyzes the possible effect of the government‘s plan on fuel subsidy reform that was discussed in section 3.3. The fuel subsidy for trucks has been the reason why road transport is cheap in Indonesia. Making the the competition between the transport become low, hence slowing down innovation in the sector.

Based on The Asia Foundation (2008), the fuel accounts to 39% of the total operational cost for trucks. The cost component of truck‘s operational cost is listed in table 7.2 below. By cutting the fuel subsidy, the trucking cost would increase, thus the other modalities could be cheaper alternatives on freight transportation. Beside increasing the modal share of other modes, this policy might also benefit the central government by cutting their spending on fuel subsidy. Therefore, the cost difference could be saved.

Currently, the operational cost for trucks is 0.3 €/km/TEU, in which the fuel cost is 0.12€/km. Therefore, by cutting the subsidy, which is 40% of the fuel cost would increase the operational cost to 0.5€/km/TEU. This scenario analysis was executed with the model by changing the operational cost parameter for trucks.

By cutting the subsidy, the central government could decrease the national spending for up to 119 M€. Yearly, the Indonesian government spent 2,768M€on fuel subsidy expenditure. Therefore, this saving would reduce the spending by 2%. Beside the saving, the model result also showed that there is a small shift in the modal share from trucks to train due to the policy. Based on Table 7.3, the signifi-

Table 7.2: Truck Transport Cost Component in Indonesia (The Asia Foundation, 2008)

Cost Component	Cost [IDR]	Cost Percentage [% Cost/Total Cost]
Fuel Cost	1,370	39
Lubricant Cost	457	13
Tire Cost	457	13
Maintenance Cost	141	4
Mechanic Cost	105	3
Driver Cost	387	11
Depreciation Cost	176	5
Interest	351	10
Total	3,514	100

Table 7.3: Modal Share with and without Subsidy on Truck Fuel

	With Subsidy	Without Subsidy
Truck	83.6	80
Train	2	6
Ship	14.2	14

cant changes in modal share happened to trucks and trains. The increase in truck‘s operational costs leads to the decrease in the mode‘s modal share by 3.6%. The freight flows that was from trucks are shifted towards railways. This is shown by the increase by 4% in railways' modal share. Maritime‘s modal share is slightly decreased by 0.2%. The decrease happens because maritime transports are dependent on the truck shipments from the hinterlands. Since most railway stations are located in the city, the shipment from the hinterland to the stations that are closer to the hinterland in some locations caused the shift from maritime transports to railway transports. Even though, the change in the modal share is relatively small, the 4% increase in railway‘s modal share means 173.3% gain in the railway‘s fright flow. Moreover, this policy is also really good for shifting the modal share from trucks, which would lead to better efficiency, economies of scale, and lower carbon emission.

7.1.3 Scenario 3: Finding Balanced Subsidy for All Modes

Cutting the fuel subsidy for trucks might also yields to higher total logistics cost in the network. It might also leads to opposition by the truck associations that might lose their modal share. Therefore, instead of cutting the whole subsidy, distributing the subsidy across all the modalities might be an alternative to the problem.

Maritime Transportation Cost Component

Based on the research by Muslihati (2012) on the cost component for liner shipping in Indonesia, the fuel cost account to 41.43% of the total operational cost of a ship.

Table 7.4: Maritime Transport Cost Component in Indonesia (Muslihati, 2012)

Cost Component	Cost [IDR]	Cost Percentage [% Cost/Total Cost]
Depreciation Cost	34,180,375	1.68
Interest Cost	51,450,459	2.53
Insurance Cost	10,793,803	0.53
Sailor Cost	442,938,527	21.80
Fuel Cost	841,883,798	41.43
Lubricant Cost	79,590,915	3.92
Grease Cost	6,000,000	0.30
Fresh water Cost	27,912,180	1.37
Port Cost	49,160,411	2.42
Sailing Cost	7,889,444	0.39
Maintenance Cost	480,329,862	23.64
Total	2,032,129,774	100.00

Rail Transport Cost Component

The research by Wijaya et al. (2014) analyzed the cost component on railways in West Sumatra. Based on the research, the fuel accounts to 48.37% of the total operational cost for railway transports. The cost components are listed in table 7.5 below.

Table 7.5: Railway Transport Cost Component in Indonesia (Wijaya et al., 2014)

Cost Component	Cost [IDR]	Cost Percentage [% Cost/Total Cost]
Fuel Cost	1,673,438	48.37
Lubricant Cost	318,750	9.21
Locomotive Maintenance	318,750	9.21
Wagon Maintenance	395,117	11.42
Depreciation Cost	318,750	9.21
Crew Cost	375,000	10.84
Station Cost	60,000	1.73
Total	3,459,805	100

Solution Technique

In order to find the best subsidy rate on each modality, an optimum level of subsidy should be found. Therefore, another variable of subsidy level is added to the upper level problem for this scenario. The subsidy level variable has a value between 0%to 40%. The program shall performed the optimization with all possible combination of subsidy level on the three modalities. An increment of 5% is used. Therefore, there are 9^3(729) possible combination of the subsidy level. For this scenario, the following program is used.

```

solve lowerlevelproblem;

Subsidy('truck')   := 0;
Subsidy('maritime') := 0;
Subsidy('rail')    := 0;

iteration := 1;

while subsidy('truck')  < 0.41 do
  while subsidy('maritime') < 0.41 do
    while subsidy('rail') < 0.41 do
    subsidyIteration(iteration,'truck') := subsidy('truck');
    subsidyIteration(iteration,'maritime')  := subsidy('maritime');
    subsidyIteration(iteration,'rail')  := subsidy('rail');

    SubCost('truck')  := (BasicCost('truck') * (1 - 0.4 * Subsidy('truck'));
    SubCost('maritime') := (BasicCost('maritime') * (1 - 0.41 * Subsidy('maritime'));
    SubCost('rail'  ) := (BasicCost('rail') * (1 - 0.48 * Subsidy('rail'));

    SubCostiter(iteration,m)  :=  SubCost(m);

    solve lowerlevelwithsubsidy;

    TotalPerMode(m) := sum((i,j),Copy_PathFlow(m,i,j));
    TotalMode    := sum(m,Copy_TotalPerMode(m));
    ModalSplit(m) := Copy_TotalPerMode(m)/Copy_TotalMode;

    Moldatsplititeration(iteration,m) := ModalSplit(m);

    CostDifferece := [sum((o,d,x,m,i,j),FlowLink(o,d,x,m,i,j)*RouteSetCost(o,d,x,m,i,j)) - sum((o,d,x,m,i,j),Copy_FlowLink(o,d,x,m,i,j)*Copy_RouteSetCost(o,d,x,m,i,j))]/1000;
    CostDiffIteration(iteration)  := CostDifference;

    ModeUsage(iteration,m)  :=  sum((o,d,x,i,j),Copy_FlowLink(o,d,x,m,i,j));

    iteration += 1;
    subsidy('rail') += 0.05;
    endwhile;
```

```
    Subsidy('rail')   := 0;
    subsidy('maritime') += 0.05;
    iteration += 1;
    endwhile;;

subsidy('truck') += 0.05;
Subsidy('maritime') := 0;
iteration += 1;
endwhile;
```

Program Result

The program result of the modal share, new generalized logistics cost, modal flow is listed in Appendix D. Based on the program result, several characteristic of the transportation in Indonesia based on its fuel price can be deducted. Firstly, the scenario analysis found that the maritime transportation is not sensitive to the change on its operational cost. The maritime transport‘s modal share only change slightly and stays around 14% even though the subsidy on fuel was added. This happens mainly because within maritime transportation, the transshipment costs have bigger influence in the total generalized cost of maritime shipment. Therefore, giving subsidy on its fuel is not a robust solution on introducing higher modal share on maritime transportation. Instead, in the future, the reduction in transshipment cost with several means such as increasing the port efficiency and reducing the dwelling time at port could be explored to reduce the total logistics cost when using maritime transportation.

Secondly, on the contrary, railway transportation and road transportation using trucks are more sensitive to the changes in their operational cost. Introducing the fuel subsidy to both modes affect their modal share to certain extent. Several interesting findings in the model result are as follows.

1. By keeping the subsidy for trucks and giving 40% fuel subsidy on railway transport‘s fuel cost yields to a 2% increase in railway transport‘s modal share from 2% to 4%. This scenario would also increase the freight flow using railway networks by 176%. However this option would not be a robust alternative as the government would need to increase their spending on fuel subsidy. However, this alternative would be contrary to the fuel subsidy reform policy since this would increase the fuel subsidy expenditure. This alternative would require 24M€for the railway fuel subsidy.

2. By removing fuel subsidy from road transport and giving 40% subsidy on railway transport, the modal share for railway will increase by 5%. The modal share of trucks/maritime/rail become 79%/14.2%/7%. This result shows that the change in the operational cost in the case the road transport price increase and price decrease in railway transport, the freight flows are absorbed by the railways. This scenario yields to an increase by 210% in railway freight flow, 0.03% decrease in maritime freight flow, and 5.8% decrease in road freight flow. This is the scenario that benefit railway transport the most. In terms of

the saving, the government would need to allocate 48M€to railway's subsidy. Therefore, taking into account the saving from removing the truck's subsidy, the central government would still save 70M€.

3. By giving 40% subsidy for railways, 20% for maritime, and 20% for trucks, the flow decrease on maritime transportation is minimized to zero and the flow decrease in road transportation is reduced to 4.3%. Yielding a modal share of truck/maritime/railways of 80%/14.2%/6.2%. However, the model result shows that this alternative would lead to higher expenditure on the fuel subsidy.

Based on the program result, by cutting the fuel subsidy from road transportations to other modes, the central government would still gain benefits from the savings. The main reason of this argument is that the amount of money given to the road transportations are relatively big because the amount of the fuel consumed by road transportations. Meanwhile, the low usage of fuel in railway transportations requires a relatively smaller spending on the fuel subsidy compared to road transportation. Therefore, even though the central government is to give 40% fuel subsidy on railway transportation, there would still be savings from cutting the fuel subsidy from road transportation.

7.1.4 Scenario 4: Implementing All Network Improvement Actions

As mentioned in subchapter 3.2, the Indonesian central government plans to perform several improvement actions on the existing network. One of the significant improvement is the railway network expansion with the total of addition 17 new railway connections. The central government intends to build new railway networks in all of the big islands in Indonesia (i.e. Sumatra, Kalimantan, Sulawesi, Papua).

This scenario assumes that all of the railway network development will be implemented. Therefore, all of the railway network improvement are added into the network model as new links. The BCR of this scenario will be analyzed along with the other KPIs. In order to calculate the BCR, the new network was built by adding all the new links into the existing network. Further, the optimization will be performed to the new model and then compared with the existing network.

The flowchart illustrated in Figure 7.3 below was used on the model to calculate the BCR of this scenario. The lower level problem consist of the freight assignment of the network with no improvement. On the upper level, the chosen improvement actions, which are all actions in this scenario, was added to the network and the freight assignment was performed. Then, the difference between both optimized network was calculated. Given the difference of the generalized logistics cost, the BCR is then calculated.

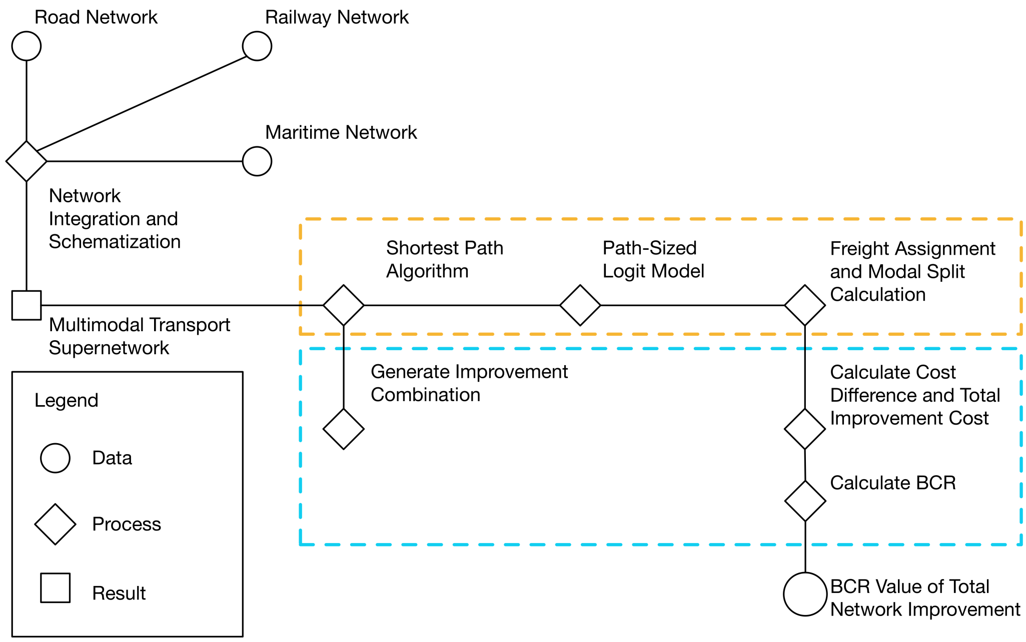

Figure 7.3: Flowchart for BCR Calculation of All Improvement

BCR Calculation

Adding the new connections to the network, the model showed that there are changes in the transport modal share and the total logistics costs. The modal share of the improved network is showed in Table 7.6 below.

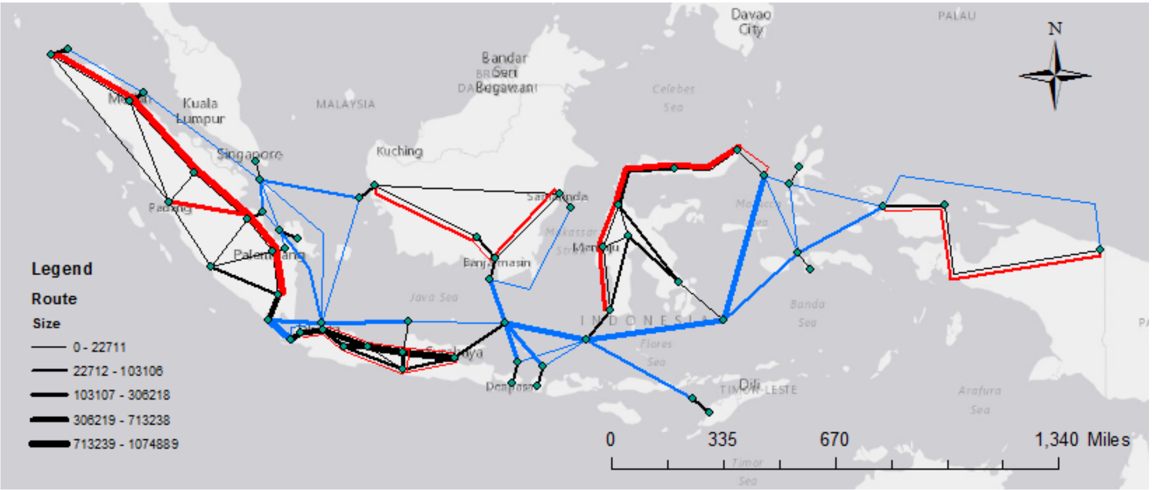

Figure 7.4: Freight Flow on the Improved Network

Table 7.6 shows that there are significant changes in the modal share between the existing and the improved network. The modal share of trucks significantly decreased by 19.6%, followed by significant increase of railways' modal share by 20%. Maritime transport's modal share also decreased slightly by 1.2%. Based on Figure 7.4, the freight flow in Sumatra and Sulawesi are concentrated on the railway

Table 7.6: Modal Share of Existing and Improved Network

	Existing Network	Improved Network
Truck	83.6	64
Train	2	22
Ship	14.2	13

transportation. Compared to Java, the rail tracks in Sumatra and Sulawesi are much longer. Therefore, long distance shipment using railways in those two islands would have bigger economies of scale effects. The significant change might draw certain opposition especially from the actors that are related to road transportation. Therefore, implementing all improvement at once might not be a good policy for all the actors.

By performing all the improvement actions, the BCR obtained is 1.21. It is a relatively low BCR. In order to understand the improvement actions effect on the total BCR, the BCR value of each improvement in the case they are implemented individually were calculated. The Table 7.7 below shows the BCR value of every improvement action in the case that they are implemented individually.

BCR Calculation on Individual Action Implementation

The flowchart illustrated in Figure 7.5 below was used on the model to calculate the BCR of each improvement action. Compared to the previous scenario that added the whole improvement actions, the flowchart was modified. One improvement action was added in each iteration from the improvement actions set. The added improvement action then excluded from the set on the next iteration. In the end, the list of BCR if only one new link is added to the link was obtained.

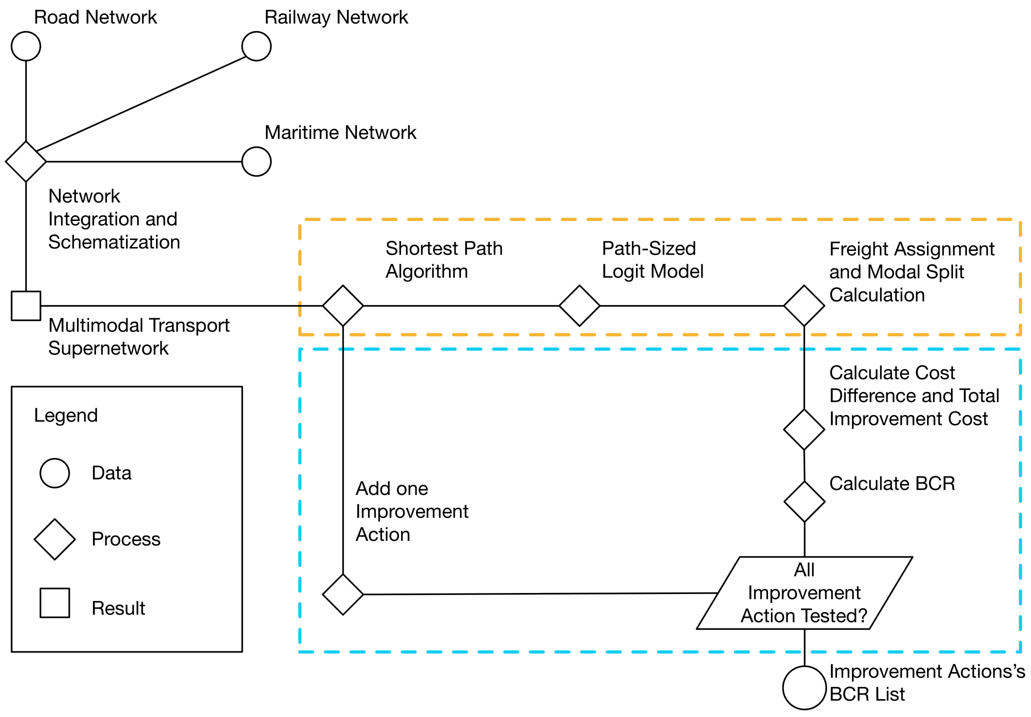

Figure 7.5: Flowchart for BCR Calculation of Single Improvement

Table 7.7: BCR of each action in case it is individually implemented.

No	Origin	Destination	Investment Cost [$\times 10^{12}$ IDR]	BCR
1	Aceh	Medan	14.5	1.99
2	Pekanbaru	Medan	12.06	2.38
3	Padang	Pekanbaru	11.23	2.57
4	Jambi	Pekanbaru	13.99	2.06
5	Jambi	Padang	15.56	1.85
6	Jambi	Palembang	7.81	3.69
7	Lampung	Palembang	11.59	2.49
8	Palangkaraya	Pontianak	29.55	0.98
9	Banjarmasin	Pakangkaraya	4.14	6.96
10	Samarinda	Banjarmasin	15.27	1.89
11	Manado	Bitung	1.44	20.01
12	Manado	Gorontalo	12.82	2.25
13	Palu	Gorontalo	17.51	1.65
14	Mamuju	Palu	11.86	2.43
15	Makassar	Mamuju	10.51	2.74
16	Sorong	Manokwari	11.47	2.51
17	Jayapura	Manokwari	36.94	0.78

The computational result shows a range of different BCR values from 0.78 to 20.01. The Figure 7.6 below shows the relation between the total investment cost on the improvement action and the BCR value of each action. Based on the figure 7.6, and reflecting to the BCR formulation in equation 5.11, there is an inverse relation between the BCR value and the total investment cost. The bigger the investment cost, the smaller the BCR value tends to be. On the other hand, the smaller the investment cost, the higher the BCR tends to be. The significant value between the highest and the lowest BCR value can be explained with the difference between the two improvement actions' investment cost. The new railway link form Manado to Bitung only require 1.44 Trillion IDR investment, while the railway link from Jayapura to Manokwari requires 36.94 Trillion IDR. Therefore, based on the single improvement calculation, it would be better to perform the improvement based on the total investment cost, starting from the improvement actions that require the least cost.

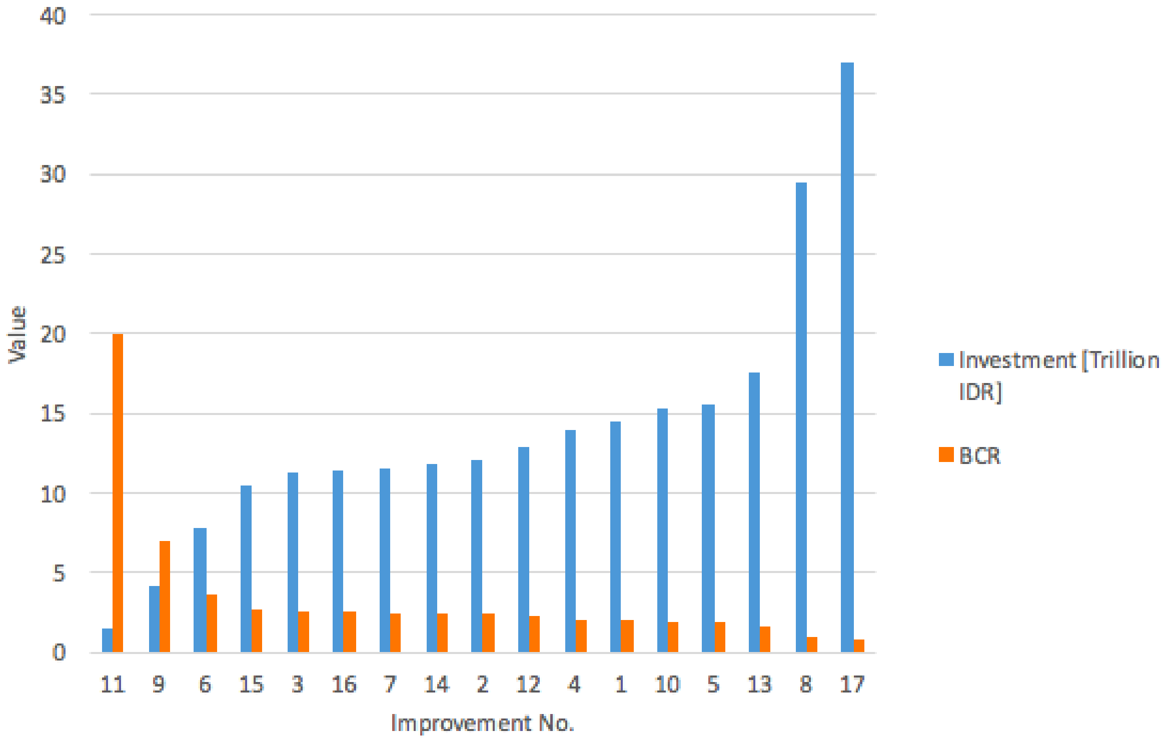

Figure 7.6: BCR and Investment Cost Relation

Performing all of the improvement action at once gives a positive BCR value of 1.21. However, reflecting to the BCR value of the one action at a time strategy, there are improvement actions with very high BCR value and there are improvement action with relatively small BCR value. The action with small BCR value reduces the combined BCR value because they require more investments. Therefore, even though it also gives high benefit, the high investment costs made the cost difference between the existing and the improved network become insignificant.

Network Accessibility Measurement after Improvement

In order to check the benefit of the improvement plan, the accessibility measurement was performed on the new network. The economic data on 2030 was calculated using the growth factor method and the transport cost between the zones after the new links have been added were used. In terms of the change in the network accessibility, this scenario proved to increase the accessibility of all the places in Indonesia. As illustrated in Figure 7.7 below, the most significant increase can be seen in the Eastern part of Indonesia. The highest increase is in the Papua province with 22.9% increase in its accessibility.

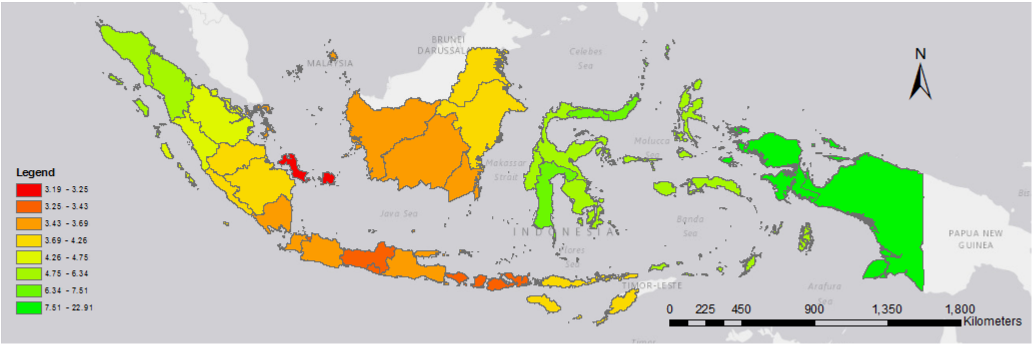

Figure 7.7: Accessibility increase after network improvement

Based on the network accessibility calculation, the improvement actions found to have positive effect on the overall network accessibility. The construction of new rail networks in the Eastern part of Indonesia also could decrease the economic growth gap between the East and the West. Therefore, based on this measurement, the plan to build new rail networks could partly solve the economic growth imbalance in Indonesia.

NPV Analysis

Additionally, to ensure the investment plan is financially beneficial for the central government, an NPV analysis was performed. In the NPV analysis, several assumptions were made.

1. It is assumed that the project will be going on for 10 years from 2020 and the investment will be made on 2020.

2. The latest net revenue of PT KAI in 2015 was 2,700,000 million IDR (PT Kereta Api Indonesia, 2016). In the calculation, it was assumed that the revenue on 2020 will stay the same. Even though in reality, the revenue might increase, the calculation used this value to give pessimistic calculation on the NPV analysis. Therefore, if the NPV is positive, in practice the payback period could even be earlier that the calculation.

3. The income from the railway network in the other islands after the constructions have been completed, will be calculated using the ratio of the rail freight flow on the respective island to Java island. The ratio is then multiplied with the net revenue made by the railways in Java. Based on the model calculation, the rail flow in every islands are listed in table 7.8 below.

Table 7.8: Rail freight flow ratio compared to Java

	Java	Sumatera	Kalimantan	Sulawesi	Papua
Freight flow ratio	1	4.98	0.28	1.1	0.03
Net Revenue [$\times 10^{12}$ IDR]	2.7	13.45	0.76	2.97	0.08

4. Based on the annual report by PT KAI, every year, there is an increase in the net revenue made by the company. Therefore, beside the discount rate applied to the cash flow every year, a revenue growth factor was also added to the calculation. The revenue from 2011 - 2015 were stated in Table 7.14 below. For the calculation, the average of the revenue growth, which is 23% was used for the future revenue calculation.

Table 7.9: Operational revenue of PT KAI

	Year				
	2011	2012	2013	2014	2015
Revenue [$\times 10^{9}$ IDR]	6094	6966	8600	10478	13938
Increase [%]		14	23	22	33

5. The discount rate of 5% was used. This number was obtained from Indonesia‘s interest rate forecast on 2020 by Trading Economics (n.d.)

Using the aforementioned assumptions, the NPV calculation was performed and showed in Table 7.10 below.

Table 7.10: NPV calculation on rail investment

Period	Year	Cash Out [$\times 10^{12}$ IDR]	Cash In [$\times 10^{12}$ IDR]	Total Income [$\times 10^{12}$ IDR]	PV [$\times 10^{12}$IDR]
1	2020	238.25	0.00		0
2	2021	0	0.00	0.00	-238.25
3	2022	0	0.00	0.00	-238.25
4	2023	0	0.00	0.00	-238.25
5	2024	0	0.00	0.00	-238.25
6	2025	0	0.00	0.00	-238.25
7	2026	0	0.00	0.00	-238.25
8	2027	0	0.00	0.00	-238.25
9	2028	0	0.00	0.00	-238.25
10	2029	0	0.00	0.00	-238.25
11	2030	0	10.59	10.59	-227.66
12	2031	0	15.26	25.85	-212.40
13	2032	0	17.88	43.73	-194.52

Table 7.10 **Continued:** NPV calculation on rail investment

Period	Year	Cash Out [$\times10^{12}$ IDR]	Cash In [$\times10^{12}$ IDR]	Total Income [$\times10^{12}$ IDR]	PV [$\times10^{12}$IDR]
14	2033	0	20.94	64.67	-173.58
15	2034	0	24.53	89.21	-149.04
16	2035	0	28.74	117.94	-120.31
17	2036	0	33.66	151.61	-86.64
18	2037	0	39.44	191.04	-47.21
19	2038	0	46.20	237.24	-1.01
20	2039	0	54.12	291.35	53.10

The NPV calculation shows that the project will have positive NPV after 19 years since the investment was made, or 9 years after the construction projects have been completed. Given the fact that in the assumptions, the average revenue growth was used and the revenue on 2020 was assumed to be the same as 2015, the project could turn to have higher NPV and even have faster payback period in the real practice,.

Based on the accessibility measurement and NPV analysis of the improvement plan, the actions would benefit both the user and the decision maker as the investor. Firstly, the accessibility measurement showed that the network improvement would increase the accessibility of the Eastern part of Indonesia. Hence, it might decrease the economic growth imbalance. Secondly, the NPV analysis showed a positive NPV. Based on the positive NPV, this project would be financially beneficial to the investors.

However, reflecting on the significant change in the modal share and in order to find the good combination of improvement actions, another scenario analysis using the fifth scenario was performed. In the following scenario analysis, the good combination of improvement actions are searched through using heuristic approach.

7.1.5 Scenario 5: Adding Improvement Actions Based on the BCR

In this scenario, instead of implementing all improvement all at once, priorities are given to the combination of improvements that yields high BCR value. Therefore, based on the result of this scenario, policy advices can be given to the central government as the main decision maker on the improvement priorities.

The simulated annealing with tabu search constraint in subsection 6.2.3 is used for this scenario. The combinations of improvements are chosen randomly. The starting temperature of the simulated annealing was set to 1000 $^{\circ}C$ with the cooling rate of 0.95/iteration. Each time the program is executed, one priority was found. The chosen actions are then excluded form the possible improvement action set on the next execution. The first priority from the first execution result is shown in table 7.11 below and figure 7.8 shows the iterations in the program execution.

Table 7.11: Chosen Improvement

Island	Route		Length [km]	Investment Cost [×10^12 IDR]
Sumatera	Medan	Pekanbaru	679	12.09
	Pekanbaru	Jambi	465	13.99
	Padang	Jambi	518	15.56
	Jambi	Pelambang	260	7.81
Kalimantan	Palangkaraya	Banjarmasin	260	4.14
Sulawesi	Bitung	Manado	48	1.44

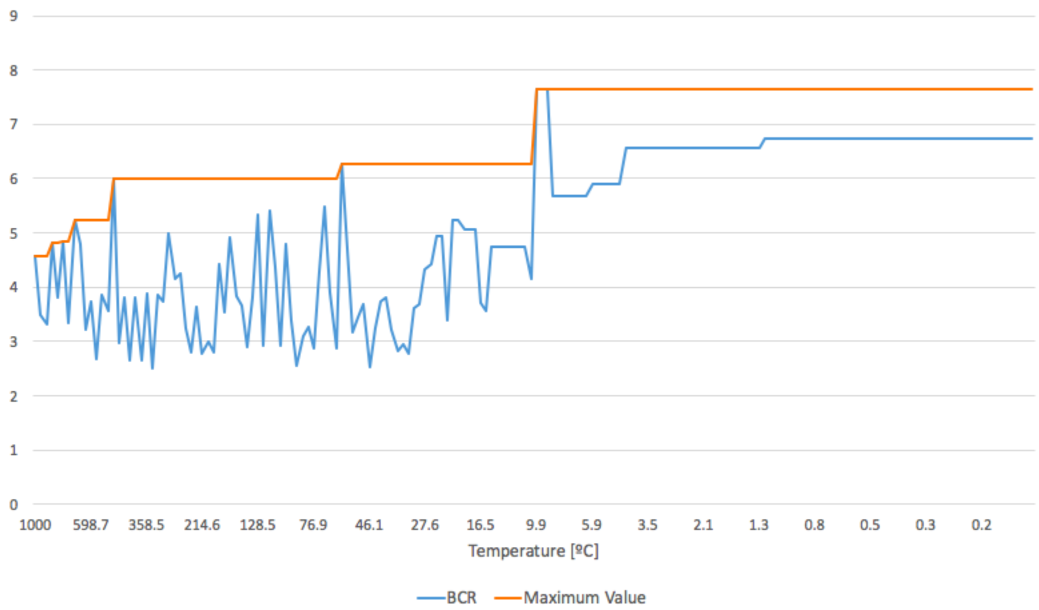

Figure 7.8: Upper Level Iteration Process

As shown by figure 7.8, at the beginning of the simulated annealing program, as the temperature is still high, the program still accept the worse solutions. However, as the temperature decrease, the result goes into a convergence. Further, these improvements from the first execution were added to the existing network as the first improvement priority. Then, the program was executed again until all the improvements are added to the network. The following Table 7.12 below shows the improvement priority based on the model iterations result.

Contrasting to the choice of implementing all the improvement actions all at once, by prioritizing the actions, the change in the modal share can be controlled in an incremental manner. The result in Table 7.12 shows that in the implementation of the first priority, the modal share for railways is 4% and dramatically increase to 22.9% after the last improvement action is performed.

The model search the actions based on the BCR of the combination in every iteration. Therefore, every level of priority will give positive BCR when added to the network. The BCR values do not have a linear pattern in the model result. This is because the calculation of the BCR is relative to the previous action(s) chosen.

Table 7.12: Improvement Action Priority Based on Model Iterations

Priority	Route		BCR	Modal Split			Cost Difference [IDR]
				Rail	Maritime	Maritime	
1	Medan Pekanbaru Padang Jambi Palangkaraya Bitung	Pekanbaru Jambi Jambi Pelambang Banjarmasin Manado	7.65	0.163	0.133	0.704	301,027,944,000
2	Palembang Palu Mamuju	Lampung Mamuju Makassar	15.4	0.214	0.128	0.658	374,736,620,500
3	Padang Sorong	Pekanbaru Manokwari	23.2	0.217	0.128	0.656	376,947,241,300
4	Aceh Samarinda Manado Gorontalo	Medan Banjarmasin Gorontalo Palu	10.41	0.247	0.127	0.625	447,120,886,400
5	Pontianak Manokwari	Palangkaraya Jayarpura	9.7	0.252	0.126	0.622	460,973,887,700

For instance, the addition of link from Pekanbaru to Padang in the second priority yields a BCR value of 25.6. It is relative to the cost difference between the network with the link between Pekanbaru and Padang added and the network with the links in priority 1.

This result could be used by the decision maker to help the implementation process. Firstly, the decision maker could adjust the priority based on the progress of the current development. For example, if in the process, there is certain event such as fuel subsidy reform that would affect the network, by performing the priority calculation again, the priority list could be adjusted to adapt with the changes. Secondly, the incremental approach of this scenario would let the decision maker to cope with the disturbances in every phase of the network improvement before proceeding with the next priority. Shall there be some disturbances such as opposition after the first phase (implementation of priority 1), the decision maker could try to solve the problem and perform an evaluation for the future implementations. By choosing the incremental approach, the decision maker could also adjust the network to adapt with the changes given the new links. This would also give benefit to other actors such as shippers or third party logistics actors to adjust their shipment route based on the new links.

NPV Analysis for Prioritization Approach

To ensure the prioritization approach would also be financially beneficial to the decision maker, another NPV calculation and analysis should be performed. The NPV analysis used the same assumption as the NPV analysis in section 7.1.4. Additional assumptions were added in this NPV analysis. They are as follows.

1. The first priority will start in 2020

2. The following priorities will be started two years after the previous one.
3. Each priority project will be completed within 5 years. In the fourth scenario, if the government managed to finish all the constructions within 10 years, it means roughly, the construction speed would be 841.8 km/year given the total new links length is 8418 km. The assumption of 5 years was taken by considering that the project might be delayed.

The table 7.13 below shows the change in the rail flow ratio between the islands in Indonesia and Java island. Same with the first NPV analysis, the net revenue in the islands other than Java will be the product of the net revenue by PT KAI in Java and the rail flow ratio.

Table 7.13: Rail flow ratio in Indonesia in each project phase

Priority	Year	Java	Sumatera	Kalimantan	Sulawesi	Papua
1	2020	1	3.16	0.1		
2	2022	1	4.52	0.1	0.455	
3	2024	1	4.63	0.1	0.455	
4	2026	1	4.98	0.14	1.1	
5	2028	1	4.98	0.28	1.1	0.03

As mentioned before, the net revenue of PT KAI in Java is 2.7×10^{12} and every year, the net revenue increase by an average of 23%. Therefore, by applying the revenue growth and multiplying the net revenue with the freight flow ratio, the net revenue that will be obtained by PT KAI after each priority action is shown in table 7.14 below.

Table 7.14: Net Revenue of PT KAI in every islands [$\times 10^{12}$ IDR]

Priority	Year	Java	Sumatra	Kalimantan	Sulawesi	Papua
1	2020	2.70	8.53	0.27		
2	2022	4.08	18.46	0.41	1.86	
3	2024	6.18	28.61	0.62	2.81	
4	2026	9.35	46.56	1.31	10.28	
5	2028	14.15	70.44	3.96	15.56	0.42

Further, the NPV calculation was performed. The result of the NPV calculation is shown by table 7.15 below. The cash out is the total investment cost of each priority. Discount rate of 5% was used in this calculation baed on the interest rate forecast by Trading Economics (n.d.).

Table 7.15: NPV calculation on rail investment with prioritization

Period	Year	Cash Out [$\times 10^{12}$ IDR]	Cash In [$\times 10^{12}$ IDR]	Total Income [$\times 10^{12}$ IDR]	PV [$\times 10^{12}$ IDR]	Description

Continued: NPV calculation on rail investment with prioritization

Period	Year	Cash Out [$\times10^{12}$ IDR]	Cash In [$\times10^{12}$ IDR]	Total Income [$\times10^{12}$ IDR]	PV [$\times10^{12}$IDR]	Description
1	2020	55.03				Start Priority 1
2	2021				-55.03	
3	2022	33.96			-88.99	Start Priority 2
4	2023				-88.99	
5	2024	22.7			-111.69	Start Priority 3
6	2025		6.90	6.90	-104.79	Priority 1 Completed
7	2026	60.1	8.08	14.98	-156.81	Start Priority 4
8	2027		14.73	29.71	-142.08	Priority 2 Completed
9	2028	66.49	17.26	46.97	-191.31	Start Priority 5
10	2029		20.66	67.62	-170.66	Priority 3 Completed
11	2030		24.20	91.82	-146.46	
12	2031		34.00	125.82	-112.46	Priority 4 Completed
13	2032		23.29	149.11	-89.17	
14	2033		47.93	197.04	-41.24	Priority 5 Completed
15	2034		56.15	253.19	14.91	

The NPV calculation performed on the fifth scenario shows positive value after 15 years. Compared to the fourth scenario, the payback period is 5 years faster. Based on this NPV calculation, this approach would be more beneficial for the central government. The only drawback is that they might not be able to finish the whole new link constructions before 2030.

Comparing the priority approach with the choice to perform all improvement actions at once, the priority approach is more robust to changes in the process. This method could also give the decision maker a room to evaluate the process and tackle the problems faced during the process and use it as a reflection for the next phases. The incremental changes is another benefit of this method. In the implementation of all actions at once, the change, especially in the modal share is really significant. The significant change could turn to be an opposition by the impacted actors such as the truck operators and the shippers. In terms of financial aspect, the prioritization approach would also have positive NPV and would give faster payback period to the investors.

7.2 Policy Recommendation and Policy Barriers Analysis

Based on the scenario analysis, three policy recommendations can be given to the central government of Indonesia, especially to the Ministry of National Development Planning as the main decision maker. The first policy recommendation is to perform the fuel subsidy reform policy and introducing subsidy to railway transportation. And the second policy is to perform the improvement action based with priorities based on the benefit to cost ratio of the actions.

In this section, the aforementioned policy recommendations were elaborated further and the possible barriers that might appear from certain actors are elaborated and discussed.

7.2.1 Fuel Subsidy Reform

Based on the scenario analysis, the fuel subsidy reform would benefit the central government by cutting the fuel subsidy spending that accounts to 4.1% of Indonesia's total spending (Asian Development Bank, 2015). Firstly, by implementing the fuel subsidy reform, the central government will be able to relocate the spending to another vital sectors of the nation or to the infrastructure development.

Secondly, by cutting the fuel subsidy, the modal share of trucks would be reduced and shifted to railways. Shifting the freight to railways would also reduce the total carbon emission as railway transportation emit lower emission compared to trucks. By using railways, the total logistics cost would also be reduced especially in long distance shipment. This is reasonable because railways could carry more freights compared to trucks, leading to higher economies of scale. Even further, by adding additional subsidy to the railway transportation, the modal share for railways could be increased even more to 7%.

Thirdly, this alternative would be a way to introduce competition in freight transportation sector. The decrease in truck's modal share that is followed by the increase in railway's modal share that absorbed the freight flows from trucks would trigger the truck operators to bring innovation. In order to compensate the policy impact, they would have to increase the efficiency of the mode. Therefore, this policy might give a benefit to the whole transportation network's efficiency.

However, there would be several barriers on the policy implementation. Firstly, there might be opposition especially from shippers and truck operators. For many years, the truck operators and the shippers have enjoyed the relatively cheaper cost of using trucks for freight transportation. The increase in the operational cost due to increasing fuel cost might force the shipper to find a new alternative for a cheap shipment and the truck operators to win their market share again. These impacts that they might suffer could be a cause for them to oppose this alternative.

Secondly, the railway capacities might not be able to fulfill the whole shipment. The railway networks have limitation in terms of the number of available locomotives for freight transportation, the wagon capacities and the journey frequency. Further analysis on the railway capacity should be performed. Otherwise, this policy would not be robust in the future and instead, would lead to a higher logistics cost in the country.

Thirdly, this alternative would be most beneficial in the area with railway connections. However, not all areas are connected with other modes than trucks in Indonesia. The low accessibilities of many areas are the reason that the road transportation have the highest modal share in the country. Therefore, the implementation might cause higher goods prices in certain areas due to higher transport cost.

These policy barriers could be tackled in several ways. The change in the modal share is not significant but the effect might be felt by the actors at the lower level such as the truck operators and the drivers. Operating with subsidy for a long time, the innovation in transportation in Indonesia especially in road modes is relatively slow. Therefore, in order to increase the efficiency of the network, the central government should be able to help the transportation sectors with researches for innovations and implementing them to the network.

Step by step improvement should also encouraged. Firstly, the network should be adapting to the fuel subsidy reform policy. The freight transport network would need time to adjust the shift in the freight flow and the change in the generalized logistics costs. Oppositions from the actors should be discussed and handled. Then, by increasing the capacity of railway networks and building the new networks, the central government could begin to shift the flow to railway transportation that is more efficient in terms of the speed, capacity and the emission. Therefore, the following policy recommendation should also be encouraged.

7.2.2 Performing Improvement Action Based on Priority List

The analysis performed on scenario 4 which is implementing all the improvement actions at once gives a significant change in the freight network. It would increase the overall accessibility of the network and would give positive net present value for the investors. In terms of the transport modal share, the modal share of trucks fell by almost 20%, the flow shifted mostly to railway transportation. This is a relatively drastic change in the modal share.

On the other hand, the result from the fifth scenario analysis shows that by implementing prioritization on the improvement actions, results in a more gradual change in the freight flow. The modal share also gradually shifted from trucks to railways. In the fifth scenario, the actions' priority are defined based on the actions' or the combinations' BCR value relative to the previous improvement. In this policy, an incremental approach was taken.

By adopting the incremental approach on the infrastructure development, firstly, the government would have more time to response shall there are some obstacles on the process. The obstacles would not affect the whole construction of the new links because the constructions are not started at the same time. Therefore, the central government would have the time to avoid the problem from happening again for the construction of the next priorities.

This alternative would also gives some room for evaluation from the ongoing or the past projects of the network improvement. By performing evaluation on the plans, the future projects could be executed more efficiently. The incremental characteristic of this policy also gives flexibility on the decision. The priority can be adjusted in the process. For instance, if there are some unforeseen changes on the network, the changes could be added to the model, therefore, the priority list will be updated, ensuring the highest BCR possible is obtained. This benefit would favor the Ministry of Transportation because it would prepare them for a better preparation on every islands since the new railway system in the different islands would require new planning. Through evaluation on the development of the previous priority, the Ministry of Transportation could evaluate the issues that existed and adjust the planning.

The barriers for this alternative would be the longer process time for the whole plan completion. Compared to the implementation of all improvement actions at once, this approach would require longer time. This might pose an issue for the government itself. For the Ministry of Investment, the longer duration might lead to higher project cost and to be flexible to the change on the priorities means extra cost on the delay and change o planning. Therefore, a good planning and further cost and benefit analysis would be required in order to ensure that this planning is robust for the government.

7.3 Summary of Scenario Analysis and Policy Recommendations

After the model has been verified and validated, the scenario analysis using the model was performed. Five scenarios were tested using the model. The first scenario is the base case scenario, in which there is no change nor improvement on the network. The future OD data on 2030 that was calculated using the growth factor method was used in the model to analyze the freight flow, the logistics cost and the modal share in the future if there is no improvement on the network. The result showed that in the base case scenario, there was no change in the flow concentration nor in the modal share. This is because the only change is in the OD data. Therefore, given the same network configuration, the route choice on this scenario was the same as the model with the 2011 OD data in the model validation section.

In the second and third scenario, the fuel subsidy reform policy was explored. Firstly in the second scenario, the future effect by removing the fuel subsidy from trucks was tested. It was found that this action would let the central government to save approximately 62.5M€on the transportation sector. Further in the third scenario, the possibilities to give subsidy to the other modes were explored. It was found that the maritime transportation‘s modal share is not really sensitive to the change in the fuel price. On the other hand, by giving subsidy to railways transportation, the modal share of railways could increase up to 7%.

In the fourth and fifth scenario, the central government‘s plan to construct new railway links on the network was tested. It was found that by performing all improvement actions, the benefit to cost ratio (BCR) was 1.21. This action will also affect the modal share significantly. By building new railway connections in all the islands in Indonesia, the railway‘s share would increase from 2% to 22%, absorbing the freight flow from trucks. Hence, the trucks' modal share reduced from 83.6% to 64%. This option would give a significant impact on the network. However, it might rose some oppositions especially from truck operators and shippers that use trucks. Thus, the fifth scenario was explored, where instead of performing all actions at once, prioritization was used. The priority list listed the combination of improvement actions based on their BCR relative to the previous improvement. With this alternative, the network would have some period to adjust and the flexibility when the project is facing certain obstacles. From the financial point of view, both scenarios appear to have positive NPV. However, comparing the NPV calculation, the fifth scenario has faster payback period compared to the fourth scenario, with 5 years difference.

Based on the result of the scenario analysis that was performed, two policy recommendations were presented. Firstly, this research would recommend the central government to perform the fuel subsidy reform. The removal of truck‘s fuel subsidy would let the government to cut their spending and relocate the funds to other important sectors. It was found that the impact of this policy is relatively small. It will only reduce the modal share of trucks slightly.

Secondly, this research encourages the use of prioritization on the network improvement actions. Compared to the construction of all links at once, the option to build new links based on their priority level would give incremental effect on the network especially on the modal share. This option would also give the central government a room to adjust the project based on the obstacles that might appear on the process.

Chapter 8

Conclusions, Reflections and Recommendations

This chapter concludes the study performed in this report. The first section provides answers on the research questions posted at the start of the report. The second section shows the recommendation for further study related with multimodal transportation in Indonesia. The third section reflects the difficulties faced and what improvement that should be done by author.

8.1 Conclusions

The research question as defined in the Chapter 1 is: *What are the recommendations of optimized multimodal transport network design in Indonesia by considering the future infrastructure developments?*. To answer the main research question, the four sub-research questions were answered first in this research. Below the answers for the sub-research questions are stated.

1. *Which factors should be incorporated into the model?* From the findings on chapter 2, 3, and 4 the factors that need to be incorporated into the model were analyzed. Firstly, chapter 2 discussed the problems in freight transportation in Indonesia. The problems are the high logistics cost and the imbalance between the Western and the Eastern part of Indonesia. Based on these problems, the objectives of the model were defined. Then, in chapter 3, the future plans of the Indonesian central government were elaborated. These policies and plans were added to the model as the future scenarios, which are the future network improvement and the fuel subsidy reform. Chapter 4 studied further the model specification on the technical perspective. The network parameters, variables, and the required data were discussed.

2. *How can an optimization model be implemented to design multimodal transport network in Indonesia with taking into account the aforementioned factors?* Based on the discussion on chapter 4, the model requirements and specifications were defined. The model framework defined how the model should work. Based on the model framework, firstly, the data and the model parameters should be prepared. Then, after the parameters and the data were added

to the model, the lower level optimization was performed. The lower level optimization consists of route-set generation using k-shortest path with different objectives, route-choice modeling using path-size logit algorithm, and the freight assignment. Then, the upper level optimization using local search heuristics found the global optimum of the improvement actions that yields the highest BCR.

3. *What is the good design of multimodal transportation in Indonesia?* The scenario analysis analyzed the possible scenario in the future on Indonesia‘s freight transport network. Based on the scenario analysis, it was found that a status-quo option would lead to no change in the network. On the second scenario, it was found that by removing the fuel subsidy through the fuel subsidy reform the government could save on the transport expenditure that accounts to 4.1% of the national GDP. Scenario 4 founds that by constructing new railway connections in all the islands would lead to a better freight transport network with the benefit to cost ratio of 1.21. Even better, the scenario 5 which analyzed the improvement prioritization presented a priority list that yields better result on the network improvement BCR. The implementation of the improvement plans was also found to be able to increase the overall transport network accessibility in Indonesia, especially in the Eastern part of Indonesia.

4. *How the policies should be performed based on the model result?* Based on the result of the scenario analysis, two policy recommendations were given. The first one is to implement the fuel subsidy reform. By performing the fuel subsidy reform on trucks in the freight transportation system, the government could save up to 119M€. On the modal share aspect, the policy would only reduce the modal share of trucks slightly by 3.6%. The freight flow shifted mostly to railway transportations, increasing the railway modal share to 6%. The second policy is to build new railway links in all the islands with a prioritization based on the actions' BCR on the network. Performing all the actions at once would significantly change the modal share of trucks/railway/maritime from 83.6%/2%/14.2% to 64%/22%/13%. By using prioritization, the change could be done incrementally. This would avoid oppositions by the impacted actors such as the truck operators and shippers. By adopting this approach, the government would also have the flexibility to adapt with the uncertainties and other obstacles in the process and adjust the planning based on the situations. The NPV analysis shows that both the choice to implement all of the improvement actions at once and by prioritization would give positive NPV. However, the prioritization approach would have faster payback period by 5 years compared to the all at once approach. Even so, the whole project will require 3 more years if the prioritization approach was taken.

Based on the answers for the sub-research question, the main research questions can be answered. This research would recommend the decision maker, which in this issue is the Ministry of National Development Planning to implement the fuel subsidy reform to reduce the usage of trucks in freight transportation and to allocate the funds to other important matters within the scope of the national planning. By increasing the railway usage in the network, a higher economies of scale and lower emission could be achieved. This could also trigger the truck operators to innovate to make their business more efficient with the increasing operational cost. Adding the new railway connections on the network would also increase the share of railways in Indonesia.

8.2 Recommendations

Due to limitation of time in this research, not all of the contents related to logistics hub can be captured. On the other way around, in order to successfully developing the multimodal transportation network in Indonesia, attention needs to be paid to several details, for which further studies may be needed.

Network capacity data. This research does not incorporate network capacity data into the model. The reason is due to the data limitation issue and the time scope. The unconstrained network capacity might lead to overestimating the capacity of certain links and nodes. For instance, the railway network might be unable to satisfy the whole freight flow as showed in the model, which leads to higher modal share in the result.

Stochasticity. Deterministic model was used in this research. In the deterministic model, all of the parameters are assumed to be known and the output of the model is highly determined by the model parameters. Therefore, the dynamic in the real world can't be captured by the model. Within the stochastic model, randomness could be integrated in the model. For instance, in the deterministic model, the delay due to congestions could not be added to the model. By using the stochastic model, the congestion can be modeled as the ratio of the freight flow and the link capacity.

Integration with other network improvement. Within the network improvement scenario, only the development of new railway connections were considered. Within the national development plan, there are also several planning on port development, addition of new ships and road construction. However, since this model do not consider the port and maritime capacity, the maritime improvement was not added to the model. And the road transport developments are on regional level, hence it is not within the spatial resolution of the model. By improving the spatial resolution of the model and adding the network capacity constraints, it is possible to integrate the other network improvement plans to the model.

Modeling the network improvement effect on freight flow. In this research, the demand was assumed to be exogenous. There is no causal relation within the model that would affect the demand in the future. Therefore this model could not project the effect of the scenarios to the demand change in the future. By modeling the demand based on the actions taken on the network, the model could be extended to give recommendations with the objective to solve the demand imbalance problem.

8.3 Reflections

Working on this research I learned a lot working in a field that I am really new into it. I started with few technical knowledges in transport and logistics. This posed a big challenge for myself. In order to deliver a good quality research I have to catch up with the required knowledge. I took classes on transportation modeling and advanced transportation modeling. I read many research articles to understand the techniques, I asked many people for guidance and helps.

Before the kickoff meeting, the challenge is to write a good research proposal. The main problem for me is to understand the aspects and techniques in freight transport network design and optimization. I also need to gain understanding on the practical problems in Indonesia. With the help of my supervisors and my colleagues, I could obtains good references on research articles and able to deliver a good research proposal.

Later on during the research period, I found that data collection posed the biggest challenge. Not all data are available freely on the web. And sometimes, the data need to be calibrated and some data are not that extensive. The unavailability of several data also required me to adjust the research framework. For instance, the unavailability of the network capacity data made be unable to use a stochastic model that can calculate the delays in the network. In the end, several assumptions were made to cope with the data limitations.

I also faced hard time programming the model. I found the AIMMS software to be a really good software for working with multidimensional data. Inputting and checking the calculation result was really easy. However, the problem came on the programming phase. With my lack of knowledge on programming, I struggled to make the model work. Fortunately, the software comes with a good documentation and program examples. Hence, learning from all of them, I could make the program work.

In the end of the research process, I felt that there are still many rooms for improvement. The result of this thesis is not perfect. But I feel satisfied that I could finish this research even though the process was delayed. I faced one big challenge of doing something that I am really new into it. I started from zero and now I can deliver this result. With the result from this research I hope that my work could benefit my country and the people as a whole through a better transportation and logistics system. In the future I would strive to learn more about transport and logistics, honing my knowledge and implementing it for the good purpose of making a better nation for its people.

References

Asian Development Bank. (2015). *Fossil fuel subsidies in indonesia: Trends, impacts, and reforms.*

Askolani. (2010). Increasing the momentum of fossil-fuel subsidy reform : Developments and opportunities. IISD.

Bahagia, S., Sandee, H., & Meeuws, R. (2013). State of logistics indonesia 2013. *Collaboration Center of Logistics and Supply Chain Studies*.

Banomyong, R., & Beresford, A. K. (2001). Multimodal transport: the case of laotian garment exporters. *International Journal of Physical Distribution & Logistics Management Int Jnl Phys Dist & Log Manage*, *31*(9), 663685. doi: 10.1108/09600030110408161

BAPPENAS. (2015). Inter-island maritime highway development for long term planning 2015-2019 and its implementation in 2014. *Badan Pembangunan Indonesia*.

Ben-Akiva, M., & Bierlaire, M. (1999). Discrete choice methods and their applications to short term travel decisions. *International Series in Operations Research and Management Science Handbook of Transportation Science*, 533.

Indoneia Infrastructure Inititatives. (2010, Aug). Future indonesian railways: An interface report towards the national railway masterplan. *Australia Indonesia Partnership*.

Indonesia Investment Coordinating Board. (2015). Infrastructure projects and special economic zones in indonesia. *Deputy Chairman for Investment Planning*.

Indonesian Central Statistics Bureau. (2015, Sep). *Kepadatan penduduk menurut provinsi, 2000-2014.* Retrieved from `https://www.bps.go.id/linkTableDinamis/view/id/842`

Indonesian Central Statistics Bureau. (2016a, Feb). *Jumlah penduduk miskin menurut provinsi, 2013-2016.* Retrieved from `https://www.bps.go.id/linkTableDinamis/view/id/1119`

Indonesian Central Statistics Bureau. (2016b, Oct). *Produk domestik regional bruto atas dasar harga berlaku menurut provinsi, 2010-2015 (miliar rupiah).* Retrieved from `https://www.bps.go.id/linkTableDinamis/view/id/955`

Indonesian Ministry of National Development Planning. (2014). *Rencana pembanguna jangka menegah nasional (rpjmn) 2015-2019.*

Ministry of Transportation and Infrastructure and Australian Aid. (2014). *Pengembangan perkeretaapian dalam renstra perhubungan dan rpjm 2015 - 2019.*

Open Government Indonesia. (n.d.). *Indonesia geospatial database.* Retrieved from http://tanahair.indonesia.go.id/home/

PT Kereta Api Indonesia. (2016). *Annual report 2015.*

Trading Economics. (n.d.). *Indonesia interest rate: Forecast 2016-2020.* Retrieved from http://www.tradingeconomics.com/indonesia/interest-rate/forecast

Bisschop, J., & Roelofs, M. (2006). *Aimms optimization modeling.* Paragon Decision Technology.

Burns, L. D. (1979). *Transportation, temporal, and spatial components of accessibility.* Lexington Books.

Cascetta, E. (2001). *Transportation systems engineering: theory and methods.* Kluwer Academic.

Christiansen, M., Fagerholt, K., Nygreen, B., & Ronen, D. (2007). Chapter 4 maritime transportation. *Transportation Handbooks in Operations Research and Management Science*, 189284. doi: 10.1016/s0927-0507(06)14004-9

Coordinating Ministry for Economic Affairs and Ministry of National Development Planning. (2011). Master plan acceleration and expansion of indonesia, economic development 2011/2025.

Crainic, T., & Laporte, G. (1997). Planning models for freight transportation. *European Journal of Operational Research*, *97*(3), 409–438. doi: 10.1016/S0377-2217(96)00298-6

Crainic, T. G., & Bektas, T. (2007). Brief overview of intermodal transportation. *Logistics Engineering Handbook*. doi: 10.1201/9781420004588.ch28

Crainic, T. G., & Kim, K. H. (2007). Chapter 8 intermodal transportation. *Transportation Handbooks in Operations Research and Management Science*, 467537. doi: 10.1016/s0927-0507(06)14008-6

de Baat, M., den Hertog, V., de Jong, S., de Regt, K., & Wijgergangs, K. (2015). *Setting up a freight transportation model for java in indonesia.*

Dikun, S. (2010). Future indonesian railways. an interface report towards the national railway master plan. *Indonesia Infrastructure Initiative*.

Direktorat Jenderal Perhubungan Darat, . (2005). Masterplan transportasi darat. *Departemen Perhubungan*.

Enserink, B., Hermans, L., Kwakkel, J., Koppenjan, J., & Bots, P. (2010). *Policy analysis of multi-actor systems*. Lemma.

Faisal, A. (2015). *Designing national freight maritime network in indonesia: A supporting study for maritime highway policy (kebijakan tol laut) in some future scenarios* (Unpublished doctoral dissertation).

Ferdian, A. (2005). *Evaluasi sistem dry port gedebage* (Unpublished doctoral dissertation).

Friesz, T. L., Cho, H.-J., Mehta, N. J., Tobin, R. L., & Anandalingam, G. (1992). A simulated annealing approach to the network design problem with variational inequality constraints. *Transportation Science*, *26*(1), 1826. doi: 10.1287/trsc.26.1.18

Geurs, K., & Eck, J. R. v. (2001). *Accessibility measures: review and applications: evaluation of accessibility impacts of land-use transport scenarios, and related social and economic impacts*. Rijksinstituut voor Volksgezondheid en Milieu.

Glover, F., & Laguna, M. (1997). Tabu search principles. *Tabu Search*, 125151.

Gulat, J., Florian, M., & Crainic, T. G. (1990). A multimode multiproduct network assignment model for strategic planning of freight flows. *Transportation Science*, *24*(1), 2539. doi: 10.1287/trsc.24.1.25

Hermans, L. M., & Thissen, W. A. (2009). Actor analysis methods and their use for public policy analysts. *European Journal of Operational Research*, *196*(2), 808818. doi: 10.1016/j.ejor.2008.03.040

Indonesian Ministry of National Development Planning. (2014). Pengembangan tol laut dalam rpjmn 2015-2019 dan implementasi 2015. *Directorate of Transportation*.

Indonesia Port Corporation II. (2012). Annual report of indonesia port corporation ii 2011. *Indonesia Port Corporation II*.

Janic, M. (2007). Modelling the full costs of an intermodal and road freight transport network. *Transportation Research Part D: Transport and Environment*, *12*(1), 3344. doi: 10.1016/j.trd.2006.10.004

Johnson, D. S., Lenstra, J. K., & Kan, A. H. G. R. (1978). The complexity of the network design problem. *Networks*, *8*(4), 279285. doi: 10.1002/net.3230080402

Kamar Dagang Indonesia. (2013, Jan). Subsidi energi dan bbm, pengaruhnya terhadap industri. *Policy Paper*, *13*.

Kawaguchi, H., Wachi, T., & Yagi, S. (2010). Freight flow analysis and estimation of pavement cost reduction by overloaded trucks utilising weight bridge survey in the central java region. *12th WCTR 11 15 July 2010*.

Kirkpatrick, S., Gelatt, C. D., & Vecchi, M. P. (1983). Optimization by simulated annealing. *Science*, *220*(4598), 671680.

Leblanc, L. J. (1975). An algorithm for the discrete network design problem. *Transportation Science*, *9*(3), 183199. doi: 10.1287/trsc.9.3.183

Liao, C.-H., Tseng, P.-H., & Lu, C.-S. (2009). Comparing carbon dioxide emissions of trucking and intermodal container transport in taiwan. *Transportation Research Part D: Transport and Environment*, *14*(7), 493496. doi: 10.1016/j.trd.2009.05.002

Lim, H., & Thill, J.-C. (2008). Intermodal freight transportation and regional accessibility in the united states. *Environment and Planning A*, *40*(8), 20062025. doi: 10.1068/a38336

Lino, R. J. (2013, Oct). *From serving to driving indonesia's growth: Delivering lasting transformation at ipc.* World Bank.

Lubis, H., Isnaeni, M., Sjafruddin, A., & Dharmowijoyo, D. (2005). Multimodal transport in indonesia: Recent profile and strategy development. *Proceedings of the Eastern Asia Society for Transportation Studies*, *5*.

Magnanti, T. L., & Wong, R. T. (1984). Network design and transportation planning: Models and algorithms. *Transportation Science*, *18*(1), 155. doi: 10.1287/trsc.18.1.1

Martalia, L. (2016). *The opportunities for establishment of logistics clusters in indonesia.*

Mcnally, M. G. (2007). The four-step model. *Handbook of Transport Modelling Handbooks in Transport*, 3553. doi: 10.1108/9780857245670-003

Metropolis, N., Rosenbluth, A. W., Rosenbluth, M. N., Teller, A. H., & Teller, E. (1953). Equation of state calculations by fast computing machines. *The Journal of Chemical Physics*, *21*(6), 10871092.

Ministry of Economic Affair. (2011). Acceleration and expansion of indonesia economic development and nationan connectivity enhancement. *MP3EI*.

Ministry of National Development Planning. (2015). Infrastructure development priority 2016.

Ministry of Trade. (2014). Analysis of inter-island logistics performance.

Ministry of Transportation. (2014). Penelitian asal tujuan transportasi national: Tabel asal dan tujuan barang antar provinsi. *Research and Development Agency*.

Murray-Webster, R., & Simon, P. (2006, Nov). Making sense of stakeholder mapping. *PM World Today*, *8*(11).

Muslihati. (2012, Oct). Analisis biaya operasional kapal pada berbagai load faktor angkutan perintis. *ILTEK*, *7*(14), 10131018.

Mutohar, I., Tomonori, S., & Sutomo, H. (2010). The implementation and impacts of pso, imp and tac schemes on national railways reform in indonesia. *Journal of the Eastern Asia Society for Transport Studies*, *8*.

Nugroho, H. (2009). Apakah persoalannya pada subsidi bbm? tinjauan terhadap masalah subsidi bbm, ketergantungan pada minyak bumi, manajemen energi nasional, dan pembangunan infrastruktur energi. *National Development Agency of Indonesia*.

of Connectiviy, T. I. M. (2010). Rencana strategis kementerian perhubungan 2010-2014. *Directorate General of Railway*.

Ortuuzar, J. D., & Willumsen, L. G. (2011). *Modelling transport* (4th ed.). John Wiley and Sons.

Pearman, A. (1979). The structure of the solution set to network optimisation problems. *Transportation Research Part B: Methodological*, *13*(1), 8190. doi: 10.1016/0191-2615(79)90008-0

Poorzahedy, H., & Turnquist, M. A. (1982). Approximate algorithms for the discrete network design problem. *Transportation Research Part B: Methodological*, *16*(1), 4555. doi: 10.1016/0191-2615(82)90040-6

Rodrigue, J.-P., Comtois, C., & Slack, B. (2006). *The geography of transport systems*. Routledge.

Ross, S. A., Westerfield, R., & Jaffe, J. F. (2005). *Corporate finance*. McGraw-Hill/Irwin.

Russ, B. F., Yamada, T., Castro, J., & Yasukawa, H. (2005). Optimising the design of multimodal freight transport network in indonesia. *Journal of the Eastern Asia Society for Transportation Studies*, *6*, 28942907.

Sheffi, Y. (1984). *Urban transportation networks: equilibrium analysis with mathematical programming methods*. Prentice-Hall.

Southworth, F., & Peterson, B. E. (2000). Intermodal and international freight network modeling. *Transportation Research Part C: Emerging Technologies*, *8*(1-6), 147166. doi: 10.1016/s0968-090x(00)00004-8

Steadieseifi, M., Dellaert, N., Nuijten, W., Woensel, T. V., & Raoufi, R. (2014). Multimodal freight transportation planning: A literature review. *European Journal of Operational Research*, *233*(1), 115. doi: 10.1016/j.ejor.2013.06.055

Steenbrink, P. A. (1974). *Optimization of transport networks*. Wiley.

Sun, Y., Lang, M., & Wang, D. (2015). Optimization models and solution algorithms for freight routing planning problem in the multi-modal transportation networks: A review of the state-of-the-art. *TOCIEJ The Open Civil Engineering Journal*, *9*(1), 714723. doi: 10.2174/1874149501509010714

Tavasszy, L., Minderhoud, M., Perrin, J.-F., & Notteboom, T. (2011). A strategic network choice model for global container flows: specification, estimation and application. *Journal of Transport Geography*, *19*(6), 1163–1172. Retrieved from http://linkinghub.elsevier.com/retrieve/pii/S0966692311000524 doi: 10.1016/j.jtrangeo.2011.05.005

Tavasszy, L. A. (1996). *Modeling european transport flows* (Unpublished doctoral dissertation).

The Asia Foundation. (2008, Apr). The cost of moving goods: Road transportation, regulations and charges in indonesia. *The Cost of Moving Goods Road Transportation, Regulations and Charges in Indonesia*.

Trading Economics. (n.d.). *Indonesia gdp annual growth rate.* Retrieved from http://www.tradingeconomics.com/indonesia/gdp-growth-annual/forecast

UNCTAD. (2015). Key satistics and trends in international trade 2015: The trade slowdown. Retrieved 9 May 2016, from http://unctad.org/en/PublicationsLibrary/ditctab2015d1_en.pdf

Wijaya, H., Purnawan, & Gunawan, H. (2014). *Penentuan tarif angkutan barang moda kereta api jalur padang-solok* (Unpublished doctoral dissertation).

World Bank. (2013). State of logistics indonesia 2013. *center of Logistics and Supply Chain Studies, Asosiasi Logistik Indonesia, Panteia, STC-Group, TheWorld Bank Office Jakartas*.

World Economic Forum. (2015). Global competitiveness report 2015-2016. *World Economic Forum*.

Xiong, Y., & Schneider, J. (1992). transportation network design using a cumulative genetic algorithm and neural network. *Transportation Research Record*, *1364*, 3744.

Yamada, T. (2013). Network design for freight transport and supply chain. *Urban Transportation and Logistics Health, Safety, and Security Concerns*, 167188. doi: 10.1201/b16346-8

Yang, H., & Bell, M. G. H. (1998). Models and algorithms for road network design: a review and some new developments. *Transport Reviews*, *18*(3), 257278. doi: 10.1080/01441649808717016

Yen, J. Y. (1971). Finding the k shortest loopless paths in a network. *Management Science*, *17*(11), 712716. doi: 10.1287/mnsc.17.11.712

Zhang, M., Wiegmans, B., & Tavasszy, L. (2013). Optimization of multimodal networks including environmental costs: A model and findings for transport policy. *Computers in Industry*, *64*(2), 136–145. Retrieved from http://dx.doi.org/10.1016/j.compind.2012.11.008 doi: 10.1016/j.compind.2012.11.008

Appendix A

OD Matrix 2011

Table A.1: OD Matrix 2011

	Aceh	Sumut	Sumbar	Riau	Jambi	Sumsel	Bengkulu	Lampung	Babel	Kepri	DKI	Jabar	Jateng	DIY
Aceh	38,685,881	47,040,807	8,916,035	6,936,864	2,893,548	5,984,110	2,029,796	5,335,520	808,226	1,202,025	5,405,222	24,002,314	17,630,709	1,777,238
Sumut	86,877,503	291,943,329	34,715,449	32,593,084	10,701,690	20,662,918	7,085,321	16,386,361	2,631,818	4,521,140	16,847,076	74,086,960	52,184,986	5,072,574
Sumbar	10,540,083	21,682,042	55,978,976	17,063,477	7,776,289	10,655,780	4,372,295	7,917,243	1,204,002	1,869,042	6,700,902	29,915,662	20,468,000	1,824,158
Riau	12,527,288	31,592,822	25,725,418	13,167,290	5,262,215	6,692,162	2,213,242	4,971,704	891,604	1,972,937	4,245,214	19,031,249	13,011,292	1,276,131
Jambi	3,408,135	6,814,842	7,662,124	3,342,670	3,357,576	5,727,801	1,881,837	3,212,996	587,431	696,844	2,504,193	10,513,783	6,724,690	660,321
Sumsel	6,657,962	11,858,576	10,094,768	4,023,440	5,474,662	44,501,787	6,300,950	17,855,539	2,212,930	1,219,198	10,221,751	41,523,922	21,529,708	2,239,946
Bengkulu	2,305,706	4,080,082	4,241,461	1,380,200	1,852,763	6,355,051	2,388,203	2,977,801	303,671	251,552	1,944,458	8,334,723	4,814,317	480,522
Lampung	9,393,688	16,629,018	11,759,709	4,731,967	4,776,180	29,671,343	4,743,163	24,836,032	1,271,759	638,742	15,872,564	50,668,900	22,678,886	2,067,213
Babel	874,927	1,574,860	1,086,708	510,332	520,405	2,163,972	277,853	735,590	758,612	218,984	1,821,078	7,364,255	4,710,479	434,674
Kepri	2,088,938	4,225,156	2,681,244	1,887,384	1,029,431	2,000,730	362,853	614,212	379,638	3,871,748	1,166,743	4,565,640	3,310,768	327,829
DKI	10,632,430	16,679,778	11,235,808	4,606,209	4,166,118	18,450,269	3,299,579	15,935,104	3,189,530	1,096,483	252,351,925	388,589,781	49,617,559	4,507,574
Jabar	46,133,424	73,210,120	49,254,425	20,288,776	17,711,683	71,166,190	14,037,914	54,710,606	12,980,175	3,630,248	341,537,447	1,961,544,047	730,462,472	35,209,567
Jateng	32,383,135	51,153,466	32,205,342	12,739,450	10,583,705	37,850,998	7,758,314	22,985,639	8,025,016	2,923,888	47,692,118	413,594,682	1,476,884,066	170,418,947
DIY	4,707,080	7,023,305	4,193,928	1,768,574	1,544,328	5,164,516	1,094,940	3,007,204	1,062,761	465,107	5,800,102	46,183,498	255,542,393	82,434,059
Jatim	34,363,962	52,643,332	30,899,614	12,755,299	10,119,995	33,977,384	7,286,560	18,628,920	7,127,481	2,946,599	32,284,745	220,005,246	769,860,220	84,648,095
Banten	33,703,881	20,489,338	14,241,672	5,671,795	5,290,039	23,594,760	4,602,339	26,656,970	3,995,358	1,481,530	110,966,030	236,768,649	120,842,593	10,664,033
Bali	509,689	1,345,883	594,071	581,582	372,546	801,990	281,426	772,533	167,227	156,520	345,415	2,667,216	4,650,644	435,373
NTB	560,138	1,492,959	660,534	673,930	397,831	866,598	305,174	806,868	167,943	166,604	347,667	2,564,842	4,176,398	387,486
NTT	507,846	1,252,991	533,116	522,694	309,513	646,133	240,021	578,522	124,074	137,662	240,563	1,728,076	2,414,771	261,541
Kalbar	973,671	2,717,162	1,249,373	1,348,599	850,765	1,678,334	535,850	1,379,667	477,229	477,766	516,644	3,442,777	3,871,086	330,949
Kalteng	573,206	1,602,469	694,378	723,500	452,973	1,001,087	315,107	877,521	241,209	217,926	351,097	2,624,251	3,719,645	318,457
Kalsel	965,610	2,603,850	1,146,372	1,141,802	697,015	1,479,067	504,598	1,339,803	338,580	321,318	692,341	4,140,686	6,176,733	558,676
Kaltim	409,265	1,088,726	455,928	463,644	262,280	538,481	188,811	467,672	118,011	136,023	226,005	1,378,056	1,764,573	155,934
Sulut	280,158	706,565	290,781	284,104	165,990	320,978	114,441	273,750	65,256	78,618	126,994	771,174	985,110	88,772
Sulteng	341,034	887,680	360,580	363,730	204,980	418,731	148,184	373,815	87,318	95,707	187,872	1,048,573	1,363,882	125,221
Sulsel	1,673,097	4,365,642	1,850,118	1,823,128	1,068,900	2,218,830	807,936	2,002,382	477,628	493,115	937,044	6,002,047	8,438,532	756,351
Sultra	372,731	992,272	407,982	402,539	230,824	482,280	170,894	443,228	95,411	107,552	174,581	1,252,897	1,690,994	154,968
Gorontalo	153,039	381,405	156,804	154,719	85,654	172,894	65,679	159,288	36,148	41,167	61,136	441,582	540,609	49,919
Sulbar	160,994	430,274	177,899	183,312	103,110	211,012	80,659	196,718	45,186	47,343	76,772	585,283	821,109	69,866

Continued: OD Matrix 2011

	Aceh	Sumut	Sumbar	Riau	Jambi	Sumsel	Bengkulu	Lampung	Babel	Kepri	DKI	Jabar	Jateng	DIY
Maluku	131,850	326,046	130,913	128,944	75,205	146,122	54,933	129,947	29,333	34,131	50,495	362,044	471,270	43,420
Maluku Utara	113,770	274,420	109,430	115,649	64,087	124,346	47,119	112,313	25,073	30,251	42,117	301,052	386,298	34,465
Papua	146,214	352,544	143,409	137,527	80,368	155,572	55,765	136,607	29,023	36,652	54,964	369,217	448,099	40,938
Papua Barat	70,414	169,088	67,309	67,039	37,876	75,620	27,594	67,391	15,156	16,721	25,916	176,912	221,929	20,304
Dd	343,226,746	679,630,852	313,921,675	152,583,256	98,520,544	335,957,847	73,679,353	236,885,467	49,969,816	31,601,145	861,819,191	3,566,549,998	3,312,414,818	407,875,521

Table A.2: OD Matrix 2011 part 2

	Jatim	Banten	Bali	NTB	NTT	Kalbar	Kalteng	Kalsel	Kaltim	Sulut	Sulteng	Sulsel	Sultra	Gorontalo
Aceh	17,828,872	20,748,054	1,360,151	1,644,972	1,490,869	2,811,781	1,024,334	1,739,912	1,302,166	736,564	888,026	2,800,219	933,432	413,654
Sumut	51,382,217	18,998,483	4,004,952	4,892,067	3,994,694	8,596,556	3,051,814	4,700,498	3,442,136	1,985,686	2,328,294	7,832,272	2,509,612	1,120,571
Sumbar	18,843,110	8,156,001	1,388,726	1,661,094	1,343,784	3,158,909	1,035,223	1,880,488	1,162,616	610,589	824,575	2,787,962	842,600	355,071
Riau	12,300,432	5,181,235	910,317	1,102,694	869,422	2,273,815	711,180	1,140,064	838,429	447,494	564,828	1,850,801	560,528	237,107
Jambi	6,028,384	2,999,949	442,952	501,670	390,226	1,073,740	341,063	551,076	359,592	198,580	246,366	828,571	249,579	106,102
Sumsel	19,470,636	12,727,546	1,334,323	1,525,102	1,154,943	3,120,761	1,038,517	1,609,806	1,038,689	521,117	755,276	2,416,141	733,413	284,982
Bengkulu	4,234,283	2,656,993	301,164	340,736	270,257	601,921	214,065	344,377	226,096	122,608	159,806	537,374	162,721	65,314
Lampung	17,377,012	22,617,535	1,110,424	1,279,505	922,599	2,190,500	829,240	1,317,337	811,454	406,642	528,186	1,883,481	579,704	228,652
Bangka Belitung	3,971,036	2,027,578	258,986	294,910	220,349	828,698	237,611	351,123	222,070	106,847	136,225	483,577	137,562	57,907
Kepri	3,178,622	1,185,102	226,731	272,378	214,398	750,488	207,483	320,734	219,640	111,024	146,924	484,831	147,684	64,274
DKI	33,779,731	107,876,133	1,781,765	2,015,343	1,267,602	2,803,049	1,215,193	1,946,968	1,151,547	531,800	769,447	2,843,288	840,961	314,587
Jabar	222,921,683	239,093,601	12,141,289	13,344,885	8,787,483	16,645,386	7,786,411	12,346,716	7,074,602	3,556,601	4,839,602	17,907,477	5,274,038	2,046,174
Jateng	704,785,836	100,009,830	26,026,491	25,274,588	14,514,243	22,893,020	13,484,464	22,585,107	11,351,495	5,309,804	7,773,114	30,765,832	8,365,012	3,158,722
DIY	120,630,772	14,458,366	4,496,854	4,429,675	2,886,557	3,604,653	2,027,083	3,414,926	1,833,158	857,056	1,295,514	4,969,636	1,380,566	526,137
Jatim	1,659,910,335	52,929,041	64,650,799	42,067,677	17,674,752	19,158,475	13,302,680	26,378,076	12,528,422	5,649,497	8,339,455	37,503,830	9,775,710	3,375,074
Banten	54,682,043	182,796,186	2,363,501	3,291,631	1,767,110	3,950,948	1,538,240	2,497,064	1,521,054	768,088	1,001,528	3,809,877	1,103,685	423,778
Bali	12,985,047	613,008	35,540,230	17,169,829	3,421,788	2,219,487	1,656,638	3,522,767	1,772,463	870,940	1,323,924	6,700,532	1,782,905	510,664
NTB	8,537,734	680,777	16,103,290	17,684,766	2,765,890	1,035,522	759,887	1,667,323	906,639	512,583	747,656	4,301,964	1,109,494	298,179
NTT	3,685,982	411,430	3,167,652	2,556,693	5,207,163	550,409	352,625	767,127	537,652	408,701	551,014	2,887,053	1,100,433	236,487
Kalbar	4,140,822	864,360	2,037,425	995,600	553,535	3,561,557	546,369	706,902	468,071	178,458	259,005	826,310	234,727	104,853
Kalteng	4,798,047	609,589	2,583,553	1,195,940	593,201	886,076	1,112,503	914,944	311,052	76,458	125,323	454,293	112,579	47,897
Kalsel	9,354,873	953,012	5,262,733	2,711,518	1,290,498	1,139,803	915,895	21,029,693	4,784,172	1,156,468	2,194,321	8,407,923	1,950,242	782,271
Kaltim	3,355,977	336,595	1,525,081	815,307	490,807	429,599	164,070	2,669,400	7,135,870	305,974	583,417	1,432,293	374,449	187,824
Sulut	1,290,462	185,243	891,392	540,321	463,235	194,669	48,598	738,090	358,933	20,369,103	2,255,923	4,137,495	1,714,883	2,339,118
Sulteng	1,907,193	247,822	1,330,223	764,304	594,786	266,705	80,410	1,366,550	669,270	2,375,414	877,122	965,060	310,033	242,001
Sulsel	13,247,245	1,337,730	10,396,660	6,841,421	4,634,928	1,369,756	473,444	7,996,092	2,697,496	6,575,828	1,615,181	156,634,718	17,761,692	4,093,047
Sultra	2,550,080	307,748	1,920,580	1,245,490	1,304,476	275,366	82,988	1,417,931	481,303	1,834,210	335,662	12,862,385	1,336,179	120,434
Gorontalo	767,979	103,038	519,099	308,909	255,515	113,890	30,251	465,925	227,677	2,154,557	219,402	2,395,988	101,537	4,069,067
Sulbar	1,203,218	128,752	839,679	501,558	337,749	141,900	49,016	1,003,383	349,036	642,184	185,509	8,146,792	144,360	567,052
Maluku	638,693	85,881	452,101	269,220	316,053	79,754	20,111	313,432	118,469	799,844	67,713	1,500,465	87,235	420,530
Maluku Utara	516,579	73,530	365,700	212,643	206,428	72,428	18,512	267,864	113,049	1,376,761	72,787	1,293,892	72,341	548,902
Papua	611,107	103,259	408,188	231,983	234,074	75,757	18,151	272,064	95,227	524,602	46,697	1,085,670	52,597	291,205
Papua Barat	301,351	42,102	205,431	124,106	125,393	40,557	9,557	145,391	54,011	377,375	28,964	631,214	32,756	184,660
Dd	3,021,217,393	301,545,507	206,348,441	158,108,537	80,564,809	106,915,932	54,383,622	128,389,151	66,163,553	62,459,458	42,086,786	334,369,216	61,875,246	27,822,295

Table A.3: OD Matrix 2011 part 3

	Sulbar	Maluku	Maluku Utara	Papua	Papua Barat	Oi

Continued: OD Matrix 2011 part 3

	Sulbar	Maluku	Maluku Utara	Papua	Papua Barat	Oi
Aceh	421,479	372,263	319,652	421,839	175,145	**226,081,676**
Sumut	1,140,535	1,015,973	847,637	1,087,154	454,956	**779,696,316**
Sumbar	370,932	326,142	265,880	355,284	147,119	**243,484,056**
Riau	264,311	216,041	176,767	236,332	96,195	**172,558,559**
Jambi	118,090	95,635	79,931	103,272	41,676	**71,851,698**
Sumsel	332,198	266,870	218,905	280,323	112,831	**234,657,517**
Bengkulu	75,422	63,418	50,473	67,477	27,104	**52,232,118**
Lampung	263,436	208,854	168,249	227,173	87,792	**252,776,939**
Bangka Belitung	66,571	51,408	41,185	52,945	22,351	**32,621,671**
Kepri	71,559	52,723	47,449	56,999	23,634	**36,294,991**
DKI	393,645	288,760	228,576	299,122	124,216	**944,829,879**
Jabar	2,435,240	1,798,002	1,451,611	1,896,291	752,336	**3,713,976,521**
Jateng	4,120,184	2,857,839	2,235,603	2,800,048	1,176,160	**3,336,686,160**
DIY	662,420	475,653	365,746	449,773	188,531	**588,944,869**
Jatim	4,784,014	2,933,315	2,332,784	2,759,020	1,205,633	**3,304,806,040**
Banten	491,995	392,465	300,741	393,835	160,830	**882,223,588**
Bali	755,713	481,650	364,035	444,901	187,465	**106,006,100**
NTB	454,578	281,929	208,249	249,661	109,275	**71,990,369**
NTT	289,389	323,067	193,175	243,898	105,055	**33,072,525**
Kalbar	117,075	77,628	69,374	80,832	34,605	**35,707,378**
Kalteng	71,551	34,055	29,451	30,948	13,401	**27,713,687**
Kalsel	1,403,505	507,860	445,549	450,263	210,101	**87,057,150**
Kaltim	251,076	104,284	97,996	93,043	41,178	**28,047,651**
Sulut	586,705	806,250	1,397,535	571,861	341,625	**43,784,134**
Sulteng	160,611	73,648	74,834	52,417	26,121	**18,391,834**
Sulsel	12,135,888	2,470,042	2,101,041	1,863,999	949,343	**288,110,300**
Sultra	145,606	100,155	78,073	63,468	32,164	**33,473,452**
Gorontalo	522,133	424,615	556,227	307,479	176,225	**16,219,555**
Sulbar	1,997,997	282,713	264,617	222,389	104,947	**20,302,390**
Maluku	244,152	368,667	111,863	124,807	77,859	**8,211,502**
Maluku Utara	222,063	125,386	540,958	64,135	48,900	**7,993,247**
Papua	179,220	114,868	58,264	1,361,828	133,922	**8,085,583**
Papua Barat	101,249	87,696	51,820	174,045	268,819	**4,045,762**
Dd	35,650,543	18,079,874	15,774,248	17,886,862	7,657,512	**15711935215**

Appendix B

Growth Factor Calculation

Table B.1: Growth Factor

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total Growth Factor 2030
Aceh	1,051	1,042	1,049	1,056	1,058	1,060	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	2,974
Sumut	1,062	1,060	1,061	1,061	1,067	1,072	1,076	1,081	1,081	1,081	1,081	1,081	1,081	1,081	1,081	1,081	1,081	1,081	1,081	3,971
Sumbar	1,064	1,062	1,058	1,054	1,060	1,064	1,070	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	3,743
Riau	1,035	1,026	1,036	1,046	1,049	1,051	1,058	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	1,068	2,957
Jambi	1,074	1,079	1,072	1,065	1,070	1,074	1,081	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	4,572
Sumsel	1,060	1,060	1,059	1,058	1,061	1,062	1,067	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	3,604
Bengkulu	1,066	1,062	1,061	1,059	1,067	1,073	1,077	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	1,084	4,127
Lampung	1,065	1,060	1,061	1,062	1,068	1,072	1,077	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	1,082	4,037
Bangka Belitung	1,057	1,053	1,054	1,055	1,061	1,068	1,071	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	3,578
Kepri	1,068	1,061	1,064	1,067	1,074	1,070	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	1,075	3,788
DKI	1,065	1,061	1,058	1,054	1,065	1,072	1,073	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	3,844
Jabar	1,063	1,061	1,058	1,055	1,066	1,071	1,078	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	3,770
Jateng	1,063	1,058	1,058	1,057	1,067	1,071	1,075	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	3,763
DIY	1,053	1,054	1,054	1,053	1,059	1,061	1,064	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,065	1,065	3,134
Jatim	1,073	1,065	1,064	1,062	1,066	1,071	1,073	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	3,939
Banten	1,062	1,059	1,054	1,049	1,056	1,064	1,068	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	1,077	3,631
Bali	1,067	1,060	1,068	1,075	1,073	1,078	1,083	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	4,377
NTB	0,989	1,057	1,047	1,037	1,081	1,083	1,087	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	1,090	4,062
NTT	1,054	1,056	1,058	1,060	1,062	1,068	1,076	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	1,095	4,524
Kalbar	1,058	1,061	1,060	1,059	1,060	1,062	1,072	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	1,079	3,786
Kalteng	1,067	1,074	1,067	1,061	1,070	1,075	1,082	1,087	1,087	1,087	1,087	1,087	1,087	1,087	1,087	1,087	1,087	1,087	1,087	4,393
Kalsel	1,057	1,052	1,051	1,050	1,062	1,068	1,076	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	4,030
Kaltim	1,040	1,016	1,030	1,045	1,056	1,056	1,064	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	1,070	3,039
Sulut	1,079	1,074	1,073	1,071	1,072	1,078	1,078	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	1,083	4,318
Sulteng	1,092	1,094	1,085	1,076	1,077	1,081	1,083	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	4,893
Sulsel	1,084	1,076	1,075	1,074	1,074	1,083	1,091	1,091	1,091	1,091	1,091	1,091	1,091	1,091	1,091	1,091	1,091	1,091	1,091	4,863
Sultra	1,104	1,073	1,075	1,078	1,080	1,082	1,101	1,103	1,103	1,103	1,103	1,103	1,103	1,103	1,103	1,103	1,103	1,103	1,103	5,729
Gorontalo	1,077	1,078	1,072	1,067	1,072	1,084	1,086	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	1,089	4,663

Continued: Growth Factor

	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	Total Growth Factor 2030
Sulbar	1,090	1,072	1,076	1,081	1,098	1,101	1,102	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104	1,104	5,935
Maluku	1,078	1,051	1,060	1,069	1,073	1,083	1,084	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	1,086	4,355
Maluku Utara	1,067	1,061	1,060	1,059	1,063	1,070	1,075	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	1,078	3,827
Papua	1,159	1,093	1,117	1,141	1,150	1,167	1,176	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	1,177	18,010
Papua Barat	1,011	1,148	1,114	1,079	1,103	1,147	1,164	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	1,166	12,972

Appendix C

OD Matrix 2030

Table C.1: OD Matrix 2030 part 1

	Aceh	Medan	Pekanbaru	Padang	Bengkulu	Jambi	Palembang	Lampung	Serang	Batam	P. Pinang	Jakarta	Bandung	Semarang	Yogyakarta
Aceh		516747388	74512307.5	62692411	13714336.4	20271584.3	39601559	55873657.5	200470682	12425002.1	5204064.94	63241694.2	274401607	192614887	27997711.8
Medan	373598089		250910193	172198779	32404013.6	54123474	94180810.9	132067664	162726323	33556192.1	12507541.7	132470796	581434774	406260831	55779090.6
Pekanbaru	41024614.8	192755501		100913402	8162501.56	19768552.7	23794621.8	27984853.7	33542995.8	11161989.1	3018104.26	27241119.7	119987823	75341106.4	10459346.2
Padang	66745437	259879849	192580476		31751575.2	57358657.2	75569430.1	88033180.5	106613156	20071795.6	8135096.8	84111261.2	368718623	241089189	31395745.9
Bengkulu	16753936.9	58482237.4	18268101.6	36088925.5		15532682.3	52008037.3	39150069	37987703.7	2994990.39	2293398.44	27234722.7	115868945	64037126.4	9037637.98
Jambi	26458602.6	97856251.8	48117694.2	71106389.7	16941663.9		50060312.9	43673388.2	48372114.9	9413117.45	4758586.45	38094982.3	161955630	96777400.4	14121335.8
Palembang	43133461.9	148938310	48237106.6	76806862.1	45807210.3	41285988.6		213871042	170071030	14421259.1	15597911.5	132989536	512965901	272829991	37225832.6
Lampung	43078986.8	132303480	40141534.5	63923820.3	24042762.7	25941730.7	144165622		215228379	4959149.32	5939155.04	128660034	441733436	185586051	24280164.1
Serang	150672367	137966982	37626129.6	59228881.4	19295086.4	21785629.7	92427441.6	164248540		8606210.21	14724274.2	783396474	1736297727	726271383	104996651
Batam	9106543.31	34252157.9	14946970.2	14159865	1905759.89	5279289.72	9236647.59	4839111.86	11224068.7		1659020.04	8306958.88	27502759.1	22151374.8	3523652.35
Pangkal Pinang	5783662.53	18833287.7	6380318.62	8615837.45	2173071.17	4203658.06	15835727	9100710.55	28590784.2	2716686.17		22824273.3	92886132.3	57427016.3	7605117.44
Jakarta	41555345.3	129520318	32637201.8	51516536.5	14948993.2	19252238.3	78584822.4	122028270	853106839	8969922.39	14000445.7		2625739893	366657006	44591183.5
Bandung	180977445	558615681	143495615	225564094	62843810.4	79273926.2	313090374	382043503	1785235613	34424927.8	55526484.5	2929966950		3118503906	348223572
Semarang	132688717	392744207	97922982.6	154042165	36232547.5	50610017.8	162032585	170681296	909461354	24916841.3	35451066.3	373421746	3239660561		1923212047
Yogyakarta	11139725	31794896.1	7998786.07	11433821	3011912.57	4138890.39	14039980.9	12957288.5	66842157	2054833.8	2724539.51	28253476.6	220693565	1068185963	
Surabaya	140455855	404789108	96902805	148446022	33357679.1	47491611.2	153389673	136896102	430785138	25041185.3	31283817.7	266116724	1756177016	5552302820	950329225
Ambon	3242409.52	8849124.08	1881717.22	2840693.47	552370.667	832982.607	2324434.94	1819116.46	3418373.85	459215.469	447764.921	2515098.56	15660596.5	24891776.2	4142936.54
Gorontalo	3857737.41	10450441.2	2211261.93	3311394.11	609116.045	989507.767	2657742.24	2132408.5	3952157.23	599414.797	540041.951	2933835.98	19082621	29458243.2	4906749.97
Palu	8690223.01	22784682	5527408.82	8069289.35	1563859.73	2410939.68	7391128	5168832.57	9800956.91	1437794.24	1333098	7529806.91	47360349.7	76067690.8	12677896.8
Mamuju	5002954.97	13538155.8	3137368.11	4402968.5	895261.986	1401723.55	3943188.36	3126987.48	5839978.22	849410.095	790202.304	4672565.49	28906297.3	48906580.4	7862920.08
Makassar	27234933.1	76176679.1	18000894.1	27115719	5226497.3	8058685.63	23499387.9	18318733.3	37054862.6	4715461.67	4703266.58	27653814.8	174168123	299228486	48334678.1
Kendari	10695260	28755134.7	6422529.28	9654509.06	1864457.6	2859671.46	8403442.13	6642244.5	12646019.8	1692164.78	1576183.72	9635730.12	60429926.7	95846310.5	15818522.6
Pontianak	21290802	65093121	17217323.5	23919261.5	4557746.26	8130358.11	23630400.6	16586462.5	29916577.1	5682693.86	6274901.99	21224683.3	126038863	173345946	27294432.1
Palangkaraya	8999798.83	26813235.3	6248430.3	9095470.4	1880773.64	2996578.49	9124410.34	7285699.93	13514976.2	1822946.79	2087646.16	10676683.6	68411405.4	118474501	17809947.7
Banjarmasin	104394.729	282029.886	68403.861	112829.277	20662.6463	33064.5674	96588.3319	79040.2497	149823.832	19244.0333	21067.3842	116818.061	740802.938	1355106.44	204895.546
Samarinda	7914563.37	20921300.9	5095969.15	7066377.08	1374209.68	2185597.25	6313149.81	4932018.79	9244965.87	1334974.45	1349739.84	6999105.7	42999428.1	68994386.6	11141935.9
Denpasar	11906759.3	35059354.1	7968910.97	12156910.8	2636388.37	3877603.86	11680659.5	9720651.64	20690090.4	1984799.35	2267159.71	15597567.7	106284841	227835903	39365461
Mataram	13363755	39743151.8	8958282.65	13494730.2	2768139.82	4075566.05	12389928.8	10394694.8	26741213.7	2212797.35	2395852.74	16372643.4	108413848	205330753	35986682.6
Kupang	13489378.4	36143987.3	7866529.29	12158556.1	2445288.86	3530765.17	10449926	8347675.12	15988811.6	1939869.75	1993722.2	11469266.9	79509144.6	131324873	26117567.3

Continued: OD Matrix 2030 part 1

	Aceh	Medan	Pekanbaru	Padang	Bengkulu	Jambi	Palembang	Lampung	Serang	Batam	Pangkal Pinang	Jakarta	Bandung	Semarang	Yogyakarta
Sofifi	2446613.51	6487815.8	1352975.18	2035042.55	386317.276	611794.583	1675502.59	1287780.65	2301874.56	363171.393	315232.447	1749517.79	11110629.4	17111306.5	2799420.46
Manado	6360968.38	17148386.5	3864559.07	5273044.17	1058843.98	1714940.19	4500364.51	3511761.21	6633207.83	958803.22	922731.748	4592625.74	30714808.8	45855469	7401533.81
Manokwari	10942503.6	28200775.8	6130449.34	9216078.66	1750351.26	2678869.95	7271573.46	5892860.66	10216091.8	1478561.98	1373388.54	7759237.62	49189778.7	72633237.1	11667100.4
Jayapura	6308707.02	16387525.8	3464959.69	5299209.95	976286.731	1501162.96	4064162.03	3162262.63	5793104.05	851301.457	805094.477	4474256.93	27099156.9	42365270.4	6790901.35

Table C.2: OD Matrix 2030 part 2

	Surabaya	Ambon	Gorontalo	Palu	Mamuju	Makassar	Kendari	Pontianak	Palangkaraya	Banjarmasin	Samarinda	Denpasar	Mataram	Kupang	Sofifi
Aceh	204396848	784241	910273	2028471	957592	9951580	2217004	5791393	3409429	5743446	2434311	3031632	3331699	3020666	676704
Medan	418093339	2589457	3029122	7049952	3417239	34671927	7880625	21579703	12726806	20679778	8646660	10689002	11857081	9951252	2179445
Pekanbaru	75434838	762576	915009	2151102	1084109	10781979	2380615	7975616	4278778	6752617	2741992	3439473	3985622	3091214	683949
Padang	231314511	980017	1173831	2699301	1331755	13849986	3054152	9352803	5198114	8581742	3413077	4447213	4944755	3990904	819190
Bengkulu	60143269	453419	542115	1223114	665761	6668706	1410561	4422906	2600893	4164955	1558448	2322886	2518910	1981137	388922
Jambi	92537233	687678	783221	1874339	942839	9774025	2110657	7779394	4141989	6373502	2398287	3406563	3637764	2830185	586007
Palembang	244908983	1053249	1246220	3018212	1520977	15993330	3476274	12097435	7215836	10661115	3881371	5780742	6246440	4657326	896288
Lampung	150409902	1049190	1286093	3018182	1588297	16167232	3578624	11139431	7085105	10817568	3775984	6237433	6514650	4670989	906815
Serang	384370698	623666	748265	1799684	934996	9714598	2234867	6276981	4426834	6920771	2444350	4451661	4943799	2987803	533972
Batam	22323438	258576	311878	725076	358673	3735842	814816	3619553	1651009	2434307	1030513	1185795	1262191	1042924	229181
Pangkal Pinang	51004253	209903	258674	624851	323352	3417908	682759	3415049	1726092	2422881	844484	1196676	1201800	887871	179421
Jakarta	248205123	388206	470017	1444359	590225	7203990	1342180	3971956	2699232	5322715	1737523	2655548	2672867	1849446	323799
Bandung	1658839556	2729809	3329525	7906244	4413036	45255433	9446842	25958542	19786856	31220775	10390540	20110812	19338910	13029694	2269933
Semarang	5793968012	3546778	4068625	10264573	6179666	63508395	12726419	29133795	27994048	46486093	13280177	35000744	31431573	18173568	2907282
Yogyakarta	530574258	272157	312892	784888	437919	4740805	971337	2074390	1996087	3501782	977396	2728920	2428760	1639338	216028
Surabaya		5031621	6050138	15024869	9478948	104361794	20089529	32621392	37799011	73697686	26438388	102296199	67260271	29038163	4069611
Ambon	25549175		3698394	641477	2462431	21514065	872352	676136	296618	4423460	908315	4195174	2455603	2813914	1092114
Gorontalo	31475939	3921863		2256903	5288326	38171757	1123167	977855	446689	7295455	1751644	4762451	2780820	2205474	5119062
Palu	81609903	662639	2147067		1815393	15806162	3284790	2534624	1226410	21473625	5709323	12955916	7316565	5392223	712291
Mamuju	56786245	2898079	6197722	1906451		144052992	1728344	1389676	849314	16659608	2980276	8970317	5395846	3435051	2635894
Makassar	364762255	14593521	23303379	9386172	79235698		125099558	8036692	4418455	81775461	13930481	65169375	41840902	28079474	12584396
Kendari	112010082	999544	1163409	3552359	1654080	203513464		2689501	1289934	22345873	4290434	20428528	12712585	12608764	828878
Pontianak	145067971	603899	862373	2019493	1074468	10371792	2085075		6709364	8630589	3252927	16805955	7840974	4167696	548424
Palangkaraya	116877349	176696	265781	706484	430650	4159675	729130	4800396		8047049	1441522	14555225	6676363	3098160	162642
Banjarmasin	1582685	18806	27956	81993	60203	479766	85076	42414	54897		160164	211366	100039	46028	16072
Samarinda	76147749	720057	1383819	4067824	2121444	16395379	2925362	2844937	1890575	29078195		10773028	5510550	3267846	687110
Denpasar	565953097	3957688	4544192	11644773	7350553	91012359	16812760	17835616	22616421	46069964	13350559		140968200	27729628	3201340
Mataram	341757806	2187147	2509579	6209205	4074660	55579701	10118364	8088257	9715817	22028373	6623555	139487691		20770574	1727508
Kupang	159921154	2859651	2311903	5381622	3055956	41936829	11802895	5008384	5367284	11676429	4440823	30960342	25025775		1867762
Sofifi	17855126	856198	4257359	572779	2025380	16081365	597567	530989	225414	3410232	750060	2786324	1593938	1478563	
Manado	48789053	6907452	18606758	20514072	5545897	56788848	15840239	1541162	660293	9987254	2642393	7521442	4426663	3529541	11889707
Manokwari	71568985	3237498	7976009	1359704	5768764	48352137	1646365	2096780	802802	11679822	2413533	11540737	6476206	6326705	1663659
Jayapura	43426895	2804494	6347621	940870	3780189	34195329	1158546	1246456	482706	7567820	1483234	6752479	3936093	3784082	1761370

Table C.3: OD Matrix 2030 part 3

	Manado	Manokwari	Jayapura
Aceh	1666382	869678	418824
Medan	5611543	2799901	1342901
Pekanbaru	1680193	813336	396469

Continued: OD Matrix 2030 part 3

	Manado	Manokwari	Jayapura
Padang	2176786	1073560	503875
Bengkulu	944599	460287	227757
Jambi	1517813	734883	346334
Palembang	2313607	1121365	545066
Lampung	2210255	1102969	544117
Serang	1345235	749865	305741
Batam	595613	277677	126675
Pangkal Pinang	466973	207689	108456
Jakarta	976331	422565	199241
Bandung	5814654	2783895	1333913
Semarang	7413935	3372393	1670234
Yogyakarta	556426	256602	127265
Surabaya	10166263	4814298	2374044
Ambon	7022440	1000501	763833
Gorontalo	21814617	2715780	1722136
Palu	22076463	456981	283438
Mamuju	6964188	2127336	1201831
Makassar	40241275	10559223	6139186
Kendari	19649129	602652	375316
Pontianak	1474032	573628	307094
Palangkaraya	426978	159476	83969
Banjarmasin	44285	16324	8723
Samarinda	2181592	578791	328279
Denpasar	7803242	3573282	1798344
Mataram	4389571	1884629	1008233
Kupang	4191349	2117901	1134560
Sofifi	10696736	445952	396629
Manado		4530466	3259012
Manokwari	14834082		4514731
Jayapura	12305338	4823866	

Appendix D

Distance Matrix

Table D.1: Origin and Destination Distance Table

Origin	Destination	Distance [km]	Origin	Destination	Distance [km]
Aceh	Port_Aceh	33.5	Makassar	Sul-2	514
Aceh	Medan	603	Kendari	Port_Kendari	17
Aceh	Padang	1247	Kendari	Palu	826
Medan	Port_Medan	26	Kendari	Sul-2	507
Medan	Aceh	603	Pontianak	Port_Pontianak	3
Medan	Pekanbaru	661	Pontianak	Palangkaraya	1077
Medan	Padang	752	Pontianak	Samarinda	1315
Pekanbaru	Medan	661	Palangkaraya	Pontianak	1077
Pekanbaru	Padang	311	Palangkaraya	Banjarmasin	192
Pekanbaru	Jambi	452	Banjarmasin	Port_Banjarmasin	5
Padang	Port_Padang	9	Banjarmasin	Palangkaraya	192
Padang	Aceh	1247	Banjarmasin	Samarinda	603
Padang	Medan	752	Samarinda	Port_Samarinda	23
Padang	Pekanbaru	311	Samarinda	Pontianak	1315
Padang	Bengkulu	538	Samarinda	Banjarmasin	603
Bengkulu	Padang	538	Samarinda	Tanjung Selor	616
Bengkulu	Jambi	426	Tanjung Selor	Samarinda	616
Bengkulu	Palembang	436	Denpasar	Port_Denpasar	10.5
Bengkulu	Lampung	581	Mataram	Port_Mataram	24
Bengkulu	Port_Bengkulu	20	Kupang	Port_Kupang	13
Jambi	Port_Jambi	9	Sofifi	Port_Sofifi	4
Jambi	Pekanbaru	452	Manado	Port_Manado	3
Jambi	Bengkulu	426	Manado	Gorontalo	470
Jambi	Palembang	276	Manokwari	Port_Sorong	468
Palembang	Port_Palembang	3	Manokwari	Jayapura	1230
Palembang	Bengkulu	436	Jayapura	Port_Jayapura	12
Palembang	Jambi	276	Jayapura	Manokwari	1230
Palembang	Lampung	370	Port_Bengkulu	Bengkulu	20
Lampung	Port_Lampung	138	Port_Palembang	Palembang	3
Lampung	Bengkulu	581	Term_Serang	Serang	2
Lampung	Palembang	370	Term_Jakarta	Jakarta	10
Serang	Port_Banten	36	Term_Port_Jakarta	Jakarta	16.5
Serang	Jakarta	85	Term_Port_Serang	Serang	36
Serang	Bandung	238	Term_Bandung	Bandung	12
Serang	Term_Serang	2	Term_Cirebon	Cirebon	4
Serang	Term_Port_Serang	36	Term_Semarang	Semarang	5.5
Batam	Port_Batam	17	Term_Yogyakarta	Yogyakarta	1
Pangkal Pinang	Port_PangkalPinang	5	Term_Surabaya	Surabaya	3
Jakarta	Port_Jakarta	16.5	Term_Port_Surabaya	Surabaya	6
Jakarta	Serang	85	Port_Aceh	Aceh	33.5
Jakarta	Bandung	160	Port_Medan	Medan	26
Jakarta	Cirebon	193	Port_Batam	Batam	17
Jakarta	Term_Jakarta	10.3	Port_Padang	Padang	9
Jakarta	Term_Port_Jakarta	16.5	Port_Jambi	Jambi	9
Bandung	Serang	238	Port_PangkalPinang	Pangkal Pinang	5
Bandung	Jakarta	160	Port_Lampung	Lampung	138
Bandung	Cirebon	125	Port_Banten	Serang	36
Bandung	Yogyakarta	369	Port_Jakarta	Jakarta	16.5
Bandung	Term_Bandung	12	Port_Semarang	Semarang	8
Cirebon	Jakarta	193	Port_Surabaya	Surabaya	8.5
Cirebon	Bandung	125	Port_Pontianak	Pontianak	3
Cirebon	Semarang	223	Port_Banjarmasin	Banjarmasin	5
Cirebon	Yogyakarta	364	Port_Samarinda	Samarinda	23
Cirebon	Term_Cirebon	4	Port_Manado	Manado	3
Semarang	Port_Semarang	8	Port_Makassar	Makassar	10
Semarang	Cirebon	223	Port_Kendari	Kendari	17
Semarang	Yogyakarta	105	Port_Denpasar	Denpasar	10.5
Semarang	Surabaya	309	Port_Mataram	Mataram	24
Semarang	Term_Semarang	5.5	Port_Kupang	Kupang	13
Yogyakarta	Bandung	369	Port_Sofifi	Sofifi	4
Yogyakarta	Cirebon	364	Port_Ambon	Ambon	8
Yogyakarta	Semarang	105	Port_Sorong	Manokwari	468
Yogyakarta	Surabaya	312	Port_Jayapura	Jayapura	12
Yogyakarta	Term_Yogyakarta	1	Port_Aceh	Aceh	33.5
Surabaya	Port_Surabaya	8.5	Port_Medan	Medan	26

Continued: Origin and Destination Distance Table

Origin	Destination	Distance [km]	Origin	Destination	Distance [km]
Surabaya	Semarang	309	Port_Batam	Batam	17
Surabaya	Yogyakarta	312	Port_Padang	Padang	9
Surabaya	Term_Surabaya	3	Port_Jambi	Jambi	9
Surabaya	Term_Port_Surabaya	6	Port_P.Pinang	Pangkal Pinang	5
Ambon	Port_Ambon	8	Port_Lampung	Lampung	138
Gorontalo	Sul-1	440	Port_Banten	Serang	36
Gorontalo	Manado	470	Port_Jakarta	Jakarta	16.5
Sul-1	Gorontalo	440	Port_Semarang	Semarang	8
Sul-1	Palu	212	Port_Surabaya	Surabaya	8.5
Palu	Sul-1	212	Port_Pontianak	Pontianak	3
Palu	Mamuju	399	Port_Banjarmasin	Banjarmasin	5
Palu	Sul-2	437	Port_Samarinda	Samarinda	23
Palu	Kendari	826	Port_Manado	Manado	3
Mamuju	Palu	399	Port_Makassar	Makassar	10
Mamuju	Sul-2	413	Port_Kendari	Kendari	17
Mamuju	Makassar	440	Port_Denpasar	Denpasar	10.5
Sul-2	Palu	437	Port_Mataram	Mataram	24
Sul-2	Mamuju	413	Port_Kupang	Kupang	13
Sul-2	Makassar	514	Port_Sofifi	Sofifi	4
Sul-2	Kendari	507	Port_Ambon	Ambon	8
Makassar	Port_Makassar	10	Port_Sorong	Manokwari	468
Makassar	Mamuju	440	Port_Sorong	Manokwari	468

Table D.2: Origin and Destination Distance Table : Maritime

Origin	Destination	Distance [km]	Origin	Destination	Distance [km]
Port_Aceh	Port_Medan	580	Port_Pontianak	Port_Jakarta	909
Port_Aceh	Sum-1	200	Port_Banjarmasin	Port_Surabaya	607
Port_Medan	Port_Aceh	580	Port_Banjarmasin	Port_Samarinda	669
Port_Medan	Port_Batam	895	Port_Samarinda	Port_Banjarmasin	669
Port_Batam	Port_Medan	895	Port_Manado	Port_Kendari	848
Port_Batam	Port_Jambi	250	Port_Manado	Port_Sofifi	393
Port_Batam	Port_PangkalPinang	785	Port_Manado	Port_Ambon	1020
Port_Batam	Port_Pontianak	726	Port_Makassar	Port_Surabaya	963
Port_Batam	Sum-3	455	Port_Makassar	Port_Kendari	615
Port_Padang	Sum-1	1245	Port_Makassar	Port_Denpasar	613
Port_Jambi	Port_Batam	250	Port_Makassar	Port_Mataram	550
Port_PangkalPinang	Port_Batam	785	Port_Makassar	Port_Kupang	1176
Port_PangkalPinang	Port_Jambi	535	Port_Kendari	Port_Manado	848
Port_PangkalPinang	Port_Palembang	472	Port_Kendari	Port_Makassar	615
Port_PangkalPinang	Port_Jakarta	535	Port_Kendari	Port_Ambon	854
Port_Lampung	Port_Banten	137	Port_Denpasar	Port_Surabaya	545
Port_Lampung	Port_Jakarta	396	Port_Denpasar	Port_Makassar	613
Port_Banten	Port_Lampung	137	Port_Mataram	Port_Surabaya	495
Port_Banten	Port_Jakarta	330	Port_Mataram	Port_Makassar	550
Port_Jakarta	Port_PangkalPinang	535	Port_Kupang	Port_Makassar	1176
Port_Jakarta	Port_Lampung	396	Port_Sofifi	Port_Manado	393
Port_Jakarta	Port_Banten	330	Port_Sofifi	Port_Ambon	695
Port_Jakarta	Port_Semarang	389	Port_Sofifi	Port_Sorong	892
Port_Jakarta	Port_Surabaya	811	Port_Ambon	Port_Manado	1020
Port_Jakarta	Port_Pontianak	909	Port_Ambon	Port_Kendari	854
Port_Jakarta	Sum-3	455	Port_Ambon	Port_Sofifi	695
Port_Semarang	Port_Jakarta	389	Port_Ambon	Port_Sorong	915
Port_Semarang	Port_Surabaya	526	Port_Sorong	Port_Sofifi	892
Port_Surabaya	Port_Jakarta	811	Port_Sorong	Port_Ambon	915
Port_Surabaya	Port_Semarang	526	Port_Sorong	Port_Jayapura	1330
Port_Surabaya	Port_Banjarmasin	607	Port_Jayapura	Port_Sorong	1330
Port_Surabaya	Port_Makassar	963	Sum-1	Port_Aceh	200
Port_Surabaya	Port_Denpasar	545	Sum-1	Port_Padang	1245
Port_Surabaya	Port_Mataram	495	Sum-3	Port_Batam	455
Port_Pontianak	Port_Batam	726	Sum-3	Port_Jakarta	455

Table D.3: Origin and Destination Distance Table : Railway

Origin	Destination	Distance [km]	Origin	Destination	Distance [km]
Port_Aceh	Port_Medan	580	Port_Pontianak	Port_Jakarta	909
Port_Aceh	Sum-1	200	Port_Banjarmasin	Port_Surabaya	607
Port_Medan	Port_Aceh	580	Port_Banjarmasin	Port_Samarinda	669
Port_Medan	Port_Batam	895	Port_Samarinda	Port_Banjarmasin	669
Port_Batam	Port_Medan	895	Port_Manado	Port_Kendari	848
Port_Batam	Port_Jambi	250	Port_Manado	Port_Sofifi	393
Port_Batam	Port_PangkalPinang	785	Port_Manado	Port_Ambon	1020
Port_Batam	Port_Pontianak	726	Port_Makassar	Port_Surabaya	963
Port_Batam	Sum-3	455	Port_Makassar	Port_Kendari	615
Port_Padang	Sum-1	1245	Port_Makassar	Port_Denpasar	613
Port_Jambi	Port_Batam	250	Port_Makassar	Port_Mataram	550
Port_PangkalPinang	Port_Batam	785	Port_Makassar	Port_Kupang	1176
Port_PangkalPinang	Port_Jambi	535	Port_Kendari	Port_Manado	848
Port_PangkalPinang	Port_Palembang	472	Port_Kendari	Port_Makassar	615
Port_PangkalPinang	Port_Jakarta	535	Port_Kendari	Port_Ambon	854
Port_Lampung	Port_Banten	137	Port_Denpasar	Port_Surabaya	545
Port_Lampung	Port_Jakarta	396	Port_Denpasar	Port_Makassar	613
Port_Banten	Port_Lampung	137	Port_Mataram	Port_Surabaya	495
Port_Banten	Port_Jakarta	330	Port_Mataram	Port_Makassar	550
Port_Jakarta	Port_PangkalPinang	535	Port_Kupang	Port_Makassar	1176
Port_Jakarta	Port_Lampung	396	Port_Sofifi	Port_Manado	393

Continued: Origin and Destination Distance Table : Railway

Origin	Destination	Distance [km]	Origin	Destination	Distance [km]
Port_Jakarta	Port_Banten	330	Port_Sofifi	Port_Ambon	695
Port_Jakarta	Port_Semarang	389	Port_Sofifi	Port_Sorong	892
Port_Jakarta	Port_Surabaya	811	Port_Ambon	Port_Manado	1020
Port_Jakarta	Port_Pontianak	909	Port_Ambon	Port_Kendari	854
Port_Jakarta	Sum-3	455	Port_Ambon	Port_Sofifi	695
Port_Semarang	Port_Jakarta	389	Port_Ambon	Port_Sorong	915
Port_Semarang	Port_Surabaya	526	Port_Sorong	Port_Sofifi	892
Port_Surabaya	Port_Jakarta	811	Port_Sorong	Port_Ambon	915
Port_Surabaya	Port_Semarang	526	Port_Sorong	Port_Jayapura	1330
Port_Surabaya	Port_Banjarmasin	607	Port_Jayapura	Port_Sorong	1330
Port_Surabaya	Port_Makassar	963	Sum-1	Port_Aceh	200
Port_Surabaya	Port_Denpasar	545	Sum-1	Port_Padang	1245
Port_Surabaya	Port_Mataram	495	Sum-3	Port_Batam	455
Port_Pontianak	Port_Batam	726	Sum-3	Port_Jakarta	455

Appendix E

Transshipment Cost Matrix

Table E.1: Transshipment Cost between Trucks and Maritime Mode

Origin	Destination	Cost [€]	Origin	Destination	Cost [€]
Port_Banten	Serang	96.93	Mataram	Port_Mataram	96.93
Port_Jakarta	Jakarta	96.93	Kupang	Port_Kupang	96.93
Port_Surabaya	Surabaya	96.93	Sofifi	Port_Sofifi	125.17
Term_Port_Jakarta	Jakarta	96.93	Manokwari	Port_Sorong	125.17
Term_Port_Serang	Serang	96.93	Jayapura	Port_Jayapura	125.17
Aceh	Port_Aceh	69.71	Port_Aceh	Aceh	69.71
Medan	Port_Medan	69.71	Port_Medan	Medan	69.71
Padang	Port_Padang	69.71	Port_Batam	Batam	69.71
Bengkulu	Port_Bengkulu	69.71	Port_Padang	Padang	69.71
Jambi	Port_Jambi	69.71	Port_Bengkulu	Bengkulu	69.71
Palembang	Port_Palembang	69.71	Port_Jambi	Jambi	69.71
Lampung	Port_Lampung	69.71	Port_Palembang	Palembang	69.71
Serang	Port_Banten	96.93	Port_PangkalPinang	Pangkal Pinang	69.71
Serang	Term_Port_Serang	96.93	Port_Lampung	Lampung	69.71
Serang	Term_Serang	96.93	Port_Semarang	Semarang	96.93
Batam	Port_Batam	69.71	Port_Pontianak	Pontianak	48.93
Pangkal Pinang	Port_PangkalPinang	69.71	Port_Banjarmasin	Banjarmasin	48.93
Jakarta	Port_Jakarta	96.93	Port_Samarinda	Samarinda	48.93
Jakarta	Term_Port_Jakarta	96.93	Port_Manado	Manado	125.17
Jakarta	Term_Jakarta	96.93	Port_Makassar	Makassar	75.00
Bandung	Term_Bandung	96.93	Port_Kendari	Kendari	75.00
Cirebon	Term_Cirebon	96.93	Port_Denpasar	Denpasar	96.93
Semarang	Port_Semarang	96.93	Port_Mataram	Mataram	96.93
Semarang	Term_Semarang	96.93	Port_Kupang	Kupang	96.93
Yogyakarta	Term_Yogyakarta	96.93	Port_Sofifi	Sofifi	125.17
Surabaya	Port_Surabaya	96.93	Port_Sorong	Manokwari	125.17
Surabaya	Term_Port_Surabaya	96.93	Port_Jayapura	Jayapura	125.17
Surabaya	Term_Surabaya	96.93	Term_Serang	Serang	96.93
Ambon	Port_Ambon	125.17	Term_Jakarta	Jakarta	96.93
Makassar	Port_Makassar	75.00	Term_Bandung	Bandung	96.93
Kendari	Port_Kendari	75.00	Term_Cirebon	Cirebon	96.93
Pontianak	Port_Pontianak	48.93	Term_Semarang	Semarang	96.93
Banjarmasin	Port_Banjarmasin	48.93	Term_Yogyakarta	Yogyakarta	96.93
Samarinda	Port_Samarinda	48.93	Term_Surabaya	Surabaya	96.93
Denpasar	Port_Denpasar	96.93			

Table E.2: Transshipment Cost between Railway and Maritime Mode

Origin	Destination	Cost [€]	Origin	Destination	Cost [€]
Port_Banten	Term_Port_Serang	96.93	Term_Port_Jakarta	Port_Jakarta	96.93
Port_Jakarta	Term_Port_Jakarta	96.93	Term_Port_Serang	Port_Banten	96.93
Port_Surabaya	Term_Port_Surabaya	96.93	Term_Port_Surabaya	Port_Surabaya	96.93

Appendix F

Fuel Subsidy Iteration

Table F.1: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
1	0	0	0	0.060	0.143	0.797	91.03	9.55	14.83	173.27	-0.03	-5.35
2	0.05	0	0	0.060	0.143	0.797	90.12	9.53	14.79	173.27	-0.03	-5.35
3	0.1	0	0	0.060	0.143	0.797	89.20	9.51	14.76	173.27	-0.03	-5.35
4	0.15	0	0	0.060	0.143	0.797	88.29	9.49	14.72	173.28	-0.03	-5.35
5	0.2	0	0	0.063	0.143	0.794	95.24	9.47	14.50	185.68	-0.03	-5.48
6	0.25	0	0	0.063	0.143	0.794	94.27	9.45	14.47	185.68	-0.03	-5.48
7	0.3	0	0	0.063	0.143	0.794	93.29	9.43	14.43	185.69	-0.03	-5.48
8	0.35	0	0	0.063	0.143	0.794	92.31	9.41	14.39	185.70	-0.03	-5.48
9	0.4	0	0	0.068	0.142	0.789	103.96	9.38	14.04	210.86	-0.03	-5.76
10	0	0.05	0	0.060	0.143	0.797	86.38	5.72	12.01	173.27	-0.03	-5.35
11	0.05	0.05	0	0.060	0.143	0.797	85.47	5.70	11.97	173.27	-0.03	-5.35
12	0.1	0.05	0	0.063	0.143	0.794	92.23	5.68	11.76	185.67	-0.03	-5.48
13	0.15	0.05	0	0.063	0.143	0.794	91.25	5.66	11.72	185.68	-0.03	-5.48
14	0.2	0.05	0	0.063	0.143	0.794	90.27	5.64	11.68	185.68	-0.03	-5.48
15	0.25	0.05	0	0.063	0.143	0.794	89.29	5.61	11.65	185.69	-0.03	-5.48
16	0.3	0.05	0	0.063	0.143	0.794	88.32	5.59	11.61	185.70	-0.03	-5.48
17	0.35	0.05	0	0.063	0.143	0.794	87.34	5.57	11.58	185.70	-0.03	-5.48
18	0.4	0.05	0	0.068	0.142	0.789	98.89	5.55	11.22	210.87	-0.02	-5.76
19	0	0.1	0	0.063	0.143	0.794	89.21	1.89	9.01	185.67	-0.02	-5.48
20	0.05	0.1	0	0.063	0.143	0.794	88.23	1.87	8.97	185.67	-0.02	-5.48
21	0.1	0.1	0	0.063	0.143	0.794	87.25	1.85	8.94	185.68	-0.02	-5.48
22	0.15	0.1	0	0.063	0.143	0.794	86.27	1.82	8.90	185.68	-0.02	-5.48
23	0.2	0.1	0	0.063	0.143	0.794	85.30	1.80	8.87	185.69	-0.02	-5.48
24	0.25	0.1	0	0.063	0.143	0.794	84.32	1.78	8.83	185.70	-0.02	-5.48
25	0.3	0.1	0	0.063	0.143	0.794	83.34	1.76	8.79	185.70	-0.02	-5.48
26	0.35	0.1	0	0.063	0.143	0.794	82.37	1.74	8.76	185.71	-0.02	-5.48
27	0.4	0.1	0	0.068	0.142	0.789	93.83	1.71	8.41	210.88	-0.02	-5.76
28	0	0.15	0	0.063	0.143	0.794	84.24	-1.95	6.19	185.67	-0.02	-5.47
29	0.05	0.15	0	0.063	0.143	0.794	83.26	-1.97	6.16	185.68	-0.02	-5.47
30	0.1	0.15	0	0.063	0.143	0.794	82.28	-1.99	6.12	185.68	-0.02	-5.47
31	0.15	0.15	0	0.063	0.143	0.794	81.30	-2.01	6.08	185.69	-0.02	-5.47
32	0.2	0.15	0	0.063	0.143	0.794	80.32	-2.03	6.05	185.69	-0.02	-5.47
33	0.25	0.15	0	0.063	0.143	0.794	79.35	-2.05	6.01	185.70	-0.02	-5.47
34	0.3	0.15	0	0.063	0.143	0.794	78.37	-2.07	5.98	185.71	-0.02	-5.47
35	0.35	0.15	0	0.063	0.143	0.794	77.39	-2.10	5.94	185.72	-0.02	-5.47
36	0.4	0.15	0	0.068	0.142	0.789	88.76	-2.12	5.59	210.89	-0.02	-5.76
37	0	0.2	0	0.063	0.143	0.794	79.26	-5.77	3.37	185.68	-0.01	-5.47
38	0.05	0.2	0	0.063	0.143	0.794	78.28	-5.80	3.33	185.68	-0.01	-5.47
39	0.1	0.2	0	0.063	0.143	0.794	77.31	-5.82	3.30	185.69	-0.01	-5.47
40	0.15	0.2	0	0.063	0.143	0.794	76.33	-5.84	3.26	185.69	-0.01	-5.47
41	0.2	0.2	0	0.063	0.143	0.794	75.35	-5.86	3.23	185.70	-0.01	-5.47
42	0.25	0.2	0	0.063	0.143	0.794	74.37	-5.88	3.19	185.71	-0.01	-5.47
43	0.3	0.2	0	0.063	0.143	0.794	73.40	-5.90	3.15	185.72	-0.01	-5.47
44	0.35	0.2	0	0.063	0.143	0.794	72.42	-5.92	3.12	185.73	-0.01	-5.47
45	0.4	0.2	0	0.068	0.142	0.789	83.70	-5.95	2.77	210.90	-0.01	-5.76
46	0	0.25	0	0.063	0.143	0.794	74.29	-9.61	0.55	185.68	0.00	-5.47
47	0.05	0.25	0	0.063	0.143	0.794	73.31	-9.63	0.52	185.69	0.00	-5.47
48	0.1	0.25	0	0.063	0.143	0.794	72.33	-9.65	0.48	185.70	0.00	-5.47
49	0.15	0.25	0	0.063	0.143	0.794	71.36	-9.67	0.44	185.70	0.00	-5.47
50	0.2	0.25	0	0.063	0.143	0.794	70.38	-9.69	0.41	185.71	0.00	-5.47
51	0.25	0.25	0	0.063	0.143	0.794	69.40	-9.71	0.37	185.72	0.00	-5.47
52	0.3	0.25	0	0.063	0.143	0.794	68.43	-9.74	0.34	185.73	0.00	-5.47
53	0.35	0.25	0	0.063	0.143	0.794	67.45	-9.76	0.30	185.74	0.00	-5.47
54	0.4	0.25	0	0.068	0.142	0.789	78.63	-9.78	-0.04	210.91	0.00	-5.76
55	0	0.3	0	0.063	0.143	0.794	69.32	-13.42	-2.30	185.69	0.03	-5.49
56	0.05	0.3	0	0.063	0.143	0.794	68.34	-13.44	-2.34	185.70	0.03	-5.49
57	0.1	0.3	0	0.063	0.143	0.794	67.36	-13.46	-2.37	185.70	0.03	-5.49
58	0.15	0.3	0	0.063	0.143	0.794	66.39	-13.48	-2.41	185.71	0.03	-5.49
59	0.2	0.3	0	0.063	0.143	0.794	65.41	-13.51	-2.44	185.72	0.03	-5.49
60	0.25	0.3	0	0.063	0.143	0.794	64.43	-13.53	-2.48	185.73	0.03	-5.49
61	0.3	0.3	0	0.063	0.143	0.794	63.46	-13.55	-2.52	185.74	0.03	-5.49
62	0.35	0.3	0	0.063	0.143	0.794	62.48	-13.57	-2.55	185.75	0.03	-5.49
63	0.4	0.3	0	0.068	0.142	0.789	73.57	-13.59	-2.89	210.93	0.03	-5.77

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
64	0	0.35	0	0.063	0.143	0.794	64.35	-17.26	-5.12	185.70	0.04	-5.49
65	0.05	0.35	0	0.063	0.143	0.794	63.37	-17.28	-5.15	185.71	0.04	-5.49
66	0.1	0.35	0	0.063	0.143	0.794	62.39	-17.30	-5.19	185.71	0.04	-5.49
67	0.15	0.35	0	0.063	0.143	0.794	61.42	-17.32	-5.22	185.72	0.04	-5.49
68	0.2	0.35	0	0.063	0.143	0.794	60.44	-17.34	-5.26	185.73	0.04	-5.49
69	0.25	0.35	0	0.063	0.143	0.794	59.46	-17.36	-5.30	185.74	0.04	-5.49
70	0.3	0.35	0	0.063	0.143	0.794	58.49	-17.38	-5.33	185.75	0.04	-5.49
71	0.35	0.35	0	0.063	0.143	0.794	57.52	-17.41	-5.37	185.77	0.04	-5.49
72	0.4	0.35	0	0.068	0.142	0.789	68.51	-17.43	-5.71	210.94	0.04	-5.77
73	0	0.4	0	0.063	0.143	0.794	59.38	-21.09	-7.92	185.71	0.04	-5.47
74	0.05	0.4	0	0.063	0.143	0.794	58.40	-21.11	-7.95	185.72	0.04	-5.47
75	0.1	0.4	0	0.063	0.143	0.794	57.42	-21.13	-7.99	185.73	0.04	-5.47
76	0.15	0.4	0	0.063	0.143	0.794	56.45	-21.16	-8.02	185.74	0.04	-5.47
77	0.2	0.4	0	0.063	0.143	0.794	55.47	-21.18	-8.06	185.75	0.04	-5.47
78	0.25	0.4	0	0.063	0.143	0.794	54.50	-21.20	-8.09	185.76	0.04	-5.47
79	0.3	0.4	0	0.063	0.143	0.794	53.52	-21.22	-8.13	185.77	0.04	-5.47
80	0.35	0.4	0	0.063	0.143	0.794	52.55	-21.24	-8.17	185.79	0.05	-5.47
81	0.4	0.4	0	0.068	0.142	0.789	63.45	-21.26	-8.50	210.96	0.05	-5.75
82	0	0	0.05	0.060	0.142	0.797	88.03	8.28	12.53	173.27	-0.03	-5.08
83	0.05	0	0.05	0.060	0.142	0.797	87.12	8.26	12.50	173.27	-0.03	-5.08
84	0.1	0	0.05	0.060	0.142	0.797	86.20	8.24	12.46	173.28	-0.03	-5.08
85	0.15	0	0.05	0.060	0.142	0.797	85.29	8.22	12.43	173.28	-0.03	-5.08
86	0.2	0	0.05	0.060	0.142	0.797	84.37	8.20	12.39	173.29	-0.03	-5.08
87	0.25	0	0.05	0.060	0.142	0.797	83.46	8.18	12.36	173.29	-0.03	-5.08
88	0.3	0	0.05	0.063	0.142	0.795	90.32	8.16	12.14	185.69	-0.03	-5.21
89	0.35	0	0.05	0.063	0.142	0.795	89.34	8.14	12.10	185.70	-0.03	-5.21
90	0.4	0	0.05	0.063	0.142	0.795	88.36	8.12	12.07	185.71	-0.03	-5.21
91	0	0.05	0.05	0.060	0.142	0.797	83.38	4.45	9.71	173.27	-0.02	-5.08
92	0.05	0.05	0.05	0.060	0.142	0.797	82.47	4.43	9.67	173.28	-0.02	-5.08
93	0.1	0.05	0.05	0.060	0.142	0.797	81.55	4.41	9.64	173.28	-0.02	-5.08
94	0.15	0.05	0.05	0.060	0.142	0.797	80.64	4.39	9.61	173.29	-0.02	-5.08
95	0.2	0.05	0.05	0.063	0.142	0.795	87.30	4.37	9.39	185.69	-0.02	-5.21
96	0.25	0.05	0.05	0.063	0.142	0.795	86.32	4.35	9.36	185.69	-0.02	-5.21
97	0.3	0.05	0.05	0.063	0.142	0.795	85.34	4.33	9.32	185.70	-0.02	-5.21
98	0.35	0.05	0.05	0.063	0.142	0.795	84.37	4.30	9.29	185.71	-0.02	-5.21
99	0.4	0.05	0.05	0.063	0.142	0.795	83.39	4.28	9.25	185.72	-0.02	-5.21
100	0	0.1	0.05	0.060	0.142	0.797	78.74	0.62	6.89	173.28	-0.02	-5.07
101	0.05	0.1	0.05	0.060	0.142	0.797	77.82	0.60	6.85	173.28	-0.02	-5.07
102	0.1	0.1	0.05	0.063	0.142	0.795	84.28	0.58	6.65	185.68	-0.02	-5.20
103	0.15	0.1	0.05	0.063	0.142	0.795	83.30	0.56	6.61	185.69	-0.02	-5.20
104	0.2	0.1	0.05	0.063	0.142	0.795	82.33	0.53	6.58	185.69	-0.02	-5.20
105	0.25	0.1	0.05	0.063	0.142	0.795	81.35	0.51	6.54	185.70	-0.02	-5.20
106	0.3	0.1	0.05	0.063	0.142	0.795	80.37	0.49	6.50	185.71	-0.02	-5.20
107	0.35	0.1	0.05	0.063	0.142	0.795	79.40	0.47	6.47	185.72	-0.02	-5.20
108	0.4	0.1	0.05	0.063	0.142	0.795	78.42	0.45	6.43	185.73	-0.02	-5.20
109	0	0.15	0.05	0.060	0.142	0.797	74.09	-3.21	4.07	173.28	-0.02	-5.07
110	0.05	0.15	0.05	0.063	0.142	0.795	80.29	-3.23	3.87	185.68	-0.02	-5.20
111	0.1	0.15	0.05	0.063	0.142	0.795	79.31	-3.26	3.83	185.69	-0.02	-5.20
112	0.15	0.15	0.05	0.063	0.142	0.795	78.33	-3.28	3.79	185.69	-0.02	-5.20
113	0.2	0.15	0.05	0.063	0.142	0.795	77.35	-3.30	3.76	185.70	-0.02	-5.20
114	0.25	0.15	0.05	0.063	0.142	0.795	76.38	-3.32	3.72	185.71	-0.02	-5.20
115	0.3	0.15	0.05	0.063	0.142	0.795	75.40	-3.34	3.69	185.71	-0.02	-5.20
116	0.35	0.15	0.05	0.063	0.142	0.795	74.42	-3.36	3.65	185.72	-0.01	-5.20
117	0.4	0.15	0.05	0.063	0.142	0.795	73.45	-3.38	3.62	185.73	-0.01	-5.20
118	0	0.2	0.05	0.063	0.142	0.795	76.29	-7.04	1.08	185.68	-0.01	-5.20
119	0.05	0.2	0.05	0.063	0.142	0.795	75.31	-7.06	1.04	185.69	0.00	-5.20
120	0.1	0.2	0.05	0.063	0.142	0.795	74.34	-7.08	1.01	185.69	0.00	-5.20
121	0.15	0.2	0.05	0.063	0.142	0.795	73.36	-7.10	0.97	185.70	0.00	-5.20
122	0.2	0.2	0.05	0.063	0.142	0.795	72.38	-7.13	0.94	185.71	0.00	-5.20
123	0.25	0.2	0.05	0.063	0.142	0.795	71.40	-7.15	0.90	185.71	0.00	-5.20
124	0.3	0.2	0.05	0.063	0.142	0.795	70.43	-7.17	0.86	185.72	0.00	-5.20
125	0.35	0.2	0.05	0.063	0.142	0.795	69.45	-7.19	0.83	185.73	0.00	-5.20
126	0.4	0.2	0.05	0.063	0.142	0.795	68.48	-7.21	0.79	185.75	0.00	-5.20
127	0	0.25	0.05	0.063	0.142	0.795	71.32	-10.87	-1.74	185.69	0.00	-5.20
128	0.05	0.25	0.05	0.063	0.142	0.795	70.34	-10.90	-1.77	185.69	0.00	-5.20
129	0.1	0.25	0.05	0.063	0.142	0.795	69.36	-10.92	-1.81	185.70	0.00	-5.20
130	0.15	0.25	0.05	0.063	0.142	0.795	68.39	-10.94	-1.84	185.71	0.00	-5.20
131	0.2	0.25	0.05	0.063	0.142	0.795	67.41	-10.96	-1.88	185.71	0.00	-5.20
132	0.25	0.25	0.05	0.063	0.142	0.795	66.43	-10.98	-1.92	185.72	0.00	-5.20
133	0.3	0.25	0.05	0.063	0.142	0.795	65.46	-11.00	-1.95	185.73	0.00	-5.20
134	0.35	0.25	0.05	0.063	0.142	0.795	64.48	-11.02	-1.99	185.74	0.00	-5.20
135	0.4	0.25	0.05	0.063	0.142	0.795	63.51	-11.05	-2.02	185.76	0.00	-5.20
136	0	0.3	0.05	0.063	0.142	0.795	66.35	-14.71	-4.55	185.69	0.01	-5.20
137	0.05	0.3	0.05	0.063	0.142	0.795	65.37	-14.73	-4.59	185.70	0.01	-5.20
138	0.1	0.3	0.05	0.063	0.142	0.795	64.39	-14.75	-4.63	185.71	0.01	-5.20
139	0.15	0.3	0.05	0.063	0.142	0.795	63.42	-14.77	-4.66	185.72	0.01	-5.20
140	0.2	0.3	0.05	0.063	0.142	0.795	62.44	-14.79	-4.70	185.72	0.01	-5.20
141	0.25	0.3	0.05	0.063	0.142	0.795	61.46	-14.81	-4.73	185.73	0.01	-5.20
142	0.3	0.3	0.05	0.063	0.142	0.795	60.49	-14.84	-4.77	185.75	0.01	-5.20
143	0.35	0.3	0.05	0.063	0.142	0.795	59.51	-14.86	-4.80	185.76	0.01	-5.20
144	0.4	0.3	0.05	0.063	0.142	0.795	58.54	-14.88	-4.84	185.77	0.01	-5.20
145	0	0.35	0.05	0.063	0.142	0.795	61.38	-18.52	-7.40	185.70	0.04	-5.21
146	0.05	0.35	0.05	0.063	0.142	0.795	60.40	-18.54	-7.44	185.71	0.04	-5.21
147	0.1	0.35	0.05	0.063	0.142	0.795	59.42	-18.56	-7.47	185.72	0.04	-5.21
148	0.15	0.35	0.05	0.063	0.142	0.795	58.45	-18.59	-7.51	185.73	0.04	-5.21
149	0.2	0.35	0.05	0.063	0.142	0.795	57.47	-18.61	-7.55	185.74	0.04	-5.21
150	0.25	0.35	0.05	0.063	0.142	0.795	56.49	-18.63	-7.58	185.75	0.04	-5.21
151	0.3	0.35	0.05	0.063	0.142	0.795	55.52	-18.65	-7.62	185.76	0.04	-5.21
152	0.35	0.35	0.05	0.063	0.142	0.795	54.55	-18.67	-7.65	185.77	0.04	-5.21
153	0.4	0.35	0.05	0.063	0.142	0.795	53.57	-18.69	-7.69	185.79	0.04	-5.21
154	0	0.4	0.05	0.063	0.142	0.795	56.41	-22.36	-10.22	185.72	0.05	-5.21

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
155	0.05	0.4	0.05	0.063	0.142	0.795	55.43	-22.38	-10.25	185.72	0.05	-5.21
156	0.1	0.4	0.05	0.063	0.142	0.795	54.45	-22.40	-10.29	185.73	0.05	-5.21
157	0.15	0.4	0.05	0.063	0.142	0.795	53.48	-22.42	-10.33	185.74	0.05	-5.21
158	0.2	0.4	0.05	0.063	0.142	0.795	52.50	-22.44	-10.36	185.75	0.05	-5.21
159	0.25	0.4	0.05	0.063	0.142	0.795	51.53	-22.46	-10.40	185.76	0.05	-5.21
160	0.3	0.4	0.05	0.063	0.142	0.795	50.55	-22.48	-10.43	185.78	0.05	-5.21
161	0.35	0.4	0.05	0.063	0.142	0.795	49.58	-22.51	-10.47	185.79	0.05	-5.21
162	0.4	0.4	0.05	0.063	0.142	0.795	48.61	-22.53	-10.50	185.81	0.05	-5.21
163	0	0	0.1	0.060	0.142	0.798	85.03	7.01	10.23	173.27	-0.02	-4.79
164	0.05	0	0.1	0.060	0.142	0.798	84.12	6.99	10.20	173.27	-0.02	-4.79
165	0.1	0	0.1	0.060	0.142	0.798	83.20	6.97	10.16	173.28	-0.02	-4.79
166	0.15	0	0.1	0.060	0.142	0.798	82.29	6.95	10.13	173.28	-0.02	-4.79
167	0.2	0	0.1	0.060	0.142	0.798	81.37	6.93	10.09	173.29	-0.02	-4.79
168	0.25	0	0.1	0.060	0.142	0.798	80.46	6.91	10.06	173.29	-0.02	-4.79
169	0.3	0	0.1	0.060	0.142	0.798	79.54	6.89	10.02	173.30	-0.02	-4.79
170	0.35	0	0.1	0.060	0.142	0.798	78.63	6.87	9.99	173.31	-0.02	-4.79
171	0.4	0	0.1	0.060	0.142	0.798	77.72	6.85	9.95	173.32	-0.02	-4.79
172	0	0.05	0.1	0.060	0.142	0.798	80.38	3.18	7.41	173.27	-0.02	-4.78
173	0.05	0.05	0.1	0.060	0.142	0.798	79.47	3.16	7.38	173.28	-0.02	-4.78
174	0.1	0.05	0.1	0.060	0.142	0.798	78.55	3.14	7.34	173.28	-0.02	-4.78
175	0.15	0.05	0.1	0.060	0.142	0.798	77.64	3.12	7.31	173.29	-0.02	-4.78
176	0.2	0.05	0.1	0.060	0.142	0.798	76.72	3.10	7.27	173.29	-0.02	-4.78
177	0.25	0.05	0.1	0.060	0.142	0.798	75.81	3.08	7.24	173.30	-0.02	-4.78
178	0.3	0.05	0.1	0.060	0.142	0.798	74.90	3.06	7.20	173.31	-0.02	-4.78
179	0.35	0.05	0.1	0.063	0.142	0.795	81.40	3.04	7.00	185.71	-0.02	-4.91
180	0.4	0.05	0.1	0.063	0.142	0.795	80.42	3.02	6.96	185.72	-0.02	-4.91
181	0	0.1	0.1	0.060	0.142	0.798	75.74	-0.65	4.59	173.28	-0.02	-4.78
182	0.05	0.1	0.1	0.060	0.142	0.798	74.82	-0.67	4.56	173.28	-0.02	-4.78
183	0.1	0.1	0.1	0.060	0.142	0.798	73.91	-0.69	4.52	173.29	-0.02	-4.78
184	0.15	0.1	0.1	0.060	0.142	0.798	72.99	-0.71	4.49	173.29	-0.02	-4.78
185	0.2	0.1	0.1	0.060	0.142	0.798	72.08	-0.73	4.45	173.30	-0.02	-4.78
186	0.25	0.1	0.1	0.063	0.142	0.795	78.38	-0.75	4.25	185.70	-0.02	-4.91
187	0.3	0.1	0.1	0.063	0.142	0.795	77.40	-0.78	4.21	185.71	-0.02	-4.91
188	0.35	0.1	0.1	0.063	0.142	0.795	76.43	-0.80	4.18	185.72	-0.02	-4.91
189	0.4	0.1	0.1	0.063	0.142	0.795	75.45	-0.82	4.14	185.73	-0.02	-4.91
190	0	0.15	0.1	0.060	0.142	0.798	71.09	-4.48	1.77	173.28	-0.01	-4.78
191	0.05	0.15	0.1	0.060	0.142	0.798	70.17	-4.50	1.74	173.29	-0.01	-4.78
192	0.1	0.15	0.1	0.060	0.142	0.798	69.26	-4.52	1.70	173.29	-0.01	-4.78
193	0.15	0.15	0.1	0.063	0.142	0.795	75.36	-4.54	1.50	185.69	-0.01	-4.91
194	0.2	0.15	0.1	0.063	0.142	0.795	74.38	-4.57	1.47	185.70	-0.01	-4.91
195	0.25	0.15	0.1	0.063	0.142	0.795	73.41	-4.59	1.43	185.71	-0.01	-4.91
196	0.3	0.15	0.1	0.063	0.142	0.795	72.43	-4.61	1.40	185.72	-0.01	-4.91
197	0.35	0.15	0.1	0.063	0.142	0.795	71.45	-4.63	1.36	185.73	-0.01	-4.91
198	0.4	0.15	0.1	0.063	0.142	0.795	70.48	-4.65	1.32	185.74	-0.01	-4.91
199	0	0.2	0.1	0.060	0.142	0.798	66.44	-8.31	-1.05	173.29	-0.01	-4.78
200	0.05	0.2	0.1	0.063	0.142	0.795	72.34	-8.33	-1.24	185.69	-0.01	-4.91
201	0.1	0.2	0.1	0.063	0.142	0.795	71.36	-8.36	-1.28	185.69	-0.01	-4.91
202	0.15	0.2	0.1	0.063	0.142	0.795	70.39	-8.38	-1.31	185.70	-0.01	-4.91
203	0.2	0.2	0.1	0.063	0.142	0.795	69.41	-8.40	-1.35	185.71	-0.01	-4.91
204	0.25	0.2	0.1	0.063	0.142	0.795	68.43	-8.42	-1.38	185.72	-0.01	-4.91
205	0.3	0.2	0.1	0.063	0.142	0.795	67.46	-8.44	-1.42	185.73	-0.01	-4.91
206	0.35	0.2	0.1	0.063	0.142	0.795	66.48	-8.46	-1.46	185.74	-0.01	-4.91
207	0.4	0.2	0.1	0.063	0.142	0.795	65.51	-8.48	-1.49	185.75	-0.01	-4.91
208	0	0.25	0.1	0.063	0.142	0.795	68.35	-12.14	-4.03	185.69	0.00	-4.91
209	0.05	0.25	0.1	0.063	0.142	0.795	67.37	-12.16	-4.06	185.70	0.00	-4.91
210	0.1	0.25	0.1	0.063	0.142	0.795	66.39	-12.18	-4.10	185.70	0.00	-4.91
211	0.15	0.25	0.1	0.063	0.142	0.795	65.42	-12.20	-4.13	185.71	0.00	-4.91
212	0.2	0.25	0.1	0.063	0.142	0.795	64.44	-12.23	-4.17	185.72	0.01	-4.91
213	0.25	0.25	0.1	0.063	0.142	0.795	63.46	-12.25	-4.21	185.73	0.01	-4.91
214	0.3	0.25	0.1	0.063	0.142	0.795	62.49	-12.27	-4.24	185.74	0.01	-4.91
215	0.35	0.25	0.1	0.063	0.142	0.795	61.51	-12.29	-4.28	185.75	0.01	-4.91
216	0.4	0.25	0.1	0.063	0.142	0.795	60.54	-12.31	-4.31	185.77	0.01	-4.91
217	0	0.3	0.1	0.063	0.142	0.795	63.38	-15.97	-6.84	185.70	0.01	-4.90
218	0.05	0.3	0.1	0.063	0.142	0.795	62.40	-16.00	-6.88	185.70	0.01	-4.90
219	0.1	0.3	0.1	0.063	0.142	0.795	61.42	-16.02	-6.91	185.71	0.01	-4.90
220	0.15	0.3	0.1	0.063	0.142	0.795	60.44	-16.04	-6.95	185.72	0.01	-4.90
221	0.2	0.3	0.1	0.063	0.142	0.795	59.47	-16.06	-6.99	185.73	0.01	-4.90
222	0.25	0.3	0.1	0.063	0.142	0.795	58.49	-16.08	-7.02	185.74	0.01	-4.90
223	0.3	0.3	0.1	0.063	0.142	0.795	57.52	-16.10	-7.06	185.75	0.01	-4.90
224	0.35	0.3	0.1	0.063	0.142	0.795	56.55	-16.12	-7.09	185.77	0.01	-4.90
225	0.4	0.3	0.1	0.063	0.142	0.795	55.57	-16.14	-7.13	185.78	0.01	-4.90
226	0	0.35	0.1	0.063	0.142	0.795	58.41	-19.81	-9.66	185.71	0.02	-4.90
227	0.05	0.35	0.1	0.063	0.142	0.795	57.43	-19.83	-9.69	185.71	0.02	-4.90
228	0.1	0.35	0.1	0.063	0.142	0.795	56.45	-19.85	-9.73	185.72	0.02	-4.90
229	0.15	0.35	0.1	0.063	0.142	0.795	55.48	-19.87	-9.77	185.73	0.02	-4.90
230	0.2	0.35	0.1	0.063	0.142	0.795	54.50	-19.89	-9.80	185.74	0.02	-4.90
231	0.25	0.35	0.1	0.063	0.142	0.795	53.53	-19.91	-9.84	185.75	0.02	-4.90
232	0.3	0.35	0.1	0.063	0.142	0.795	52.55	-19.93	-9.87	185.77	0.02	-4.90
233	0.35	0.35	0.1	0.063	0.142	0.795	51.58	-19.95	-9.91	185.78	0.02	-4.90
234	0.4	0.35	0.1	0.063	0.142	0.795	50.61	-19.98	-9.94	185.80	0.02	-4.90
235	0	0.4	0.1	0.063	0.142	0.795	53.44	-23.62	-12.51	185.72	0.05	-4.92
236	0.05	0.4	0.1	0.063	0.142	0.795	52.46	-23.64	-12.54	185.73	0.05	-4.92
237	0.1	0.4	0.1	0.063	0.142	0.795	51.48	-23.66	-12.58	185.74	0.06	-4.92
238	0.15	0.4	0.1	0.063	0.142	0.795	50.51	-23.69	-12.61	185.75	0.06	-4.92
239	0.2	0.4	0.1	0.063	0.142	0.795	49.53	-23.71	-12.65	185.76	0.06	-4.92
240	0.25	0.4	0.1	0.063	0.142	0.795	48.56	-23.73	-12.68	185.77	0.06	-4.92
241	0.3	0.4	0.1	0.063	0.142	0.795	47.59	-23.75	-12.72	185.79	0.06	-4.92
242	0.35	0.4	0.1	0.063	0.142	0.795	46.61	-23.77	-12.76	185.80	0.06	-4.92
243	0.4	0.4	0.1	0.063	0.142	0.795	45.64	-23.79	-12.79	185.82	0.06	-4.92
244	0	0	0.15	0.060	0.142	0.798	82.03	5.74	7.93	173.27	-0.02	-4.47
245	0.05	0	0.15	0.060	0.142	0.798	81.12	5.72	7.90	173.28	-0.02	-4.47

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
246	0.1	0	0.15	0.060	0.142	0.798	80.20	5.70	7.86	173.28	-0.02	-4.47
247	0.15	0	0.15	0.060	0.142	0.798	79.29	5.68	7.83	173.29	-0.02	-4.47
248	0.2	0	0.15	0.060	0.142	0.798	78.37	5.66	7.79	173.29	-0.02	-4.47
249	0.25	0	0.15	0.060	0.142	0.798	77.46	5.64	7.76	173.30	-0.02	-4.47
250	0.3	0	0.15	0.060	0.142	0.798	76.54	5.62	7.72	173.31	-0.02	-4.47
251	0.35	0	0.15	0.060	0.142	0.798	75.63	5.60	7.69	173.31	-0.02	-4.47
252	0.4	0	0.15	0.060	0.142	0.798	74.72	5.58	7.66	173.32	-0.02	-4.47
253	0	0.05	0.15	0.060	0.142	0.798	77.38	1.91	5.11	173.28	-0.02	-4.47
254	0.05	0.05	0.15	0.060	0.142	0.798	76.47	1.89	5.08	173.28	-0.02	-4.47
255	0.1	0.05	0.15	0.060	0.142	0.798	75.55	1.87	5.04	173.29	-0.02	-4.47
256	0.15	0.05	0.15	0.060	0.142	0.798	74.64	1.85	5.01	173.29	-0.02	-4.47
257	0.2	0.05	0.15	0.060	0.142	0.798	73.73	1.83	4.97	173.30	-0.02	-4.47
258	0.25	0.05	0.15	0.060	0.142	0.798	72.81	1.81	4.94	173.30	-0.02	-4.47
259	0.3	0.05	0.15	0.060	0.142	0.798	71.90	1.79	4.90	173.31	-0.02	-4.47
260	0.35	0.05	0.15	0.060	0.142	0.798	70.99	1.77	4.87	173.32	-0.02	-4.47
261	0.4	0.05	0.15	0.060	0.142	0.798	70.07	1.75	4.84	173.33	-0.02	-4.47
262	0	0.1	0.15	0.060	0.142	0.798	72.74	-1.93	2.29	173.28	-0.01	-4.47
263	0.05	0.1	0.15	0.060	0.142	0.798	71.82	-1.95	2.26	173.29	-0.01	-4.47
264	0.1	0.1	0.15	0.060	0.142	0.798	70.91	-1.97	2.22	173.29	-0.01	-4.47
265	0.15	0.1	0.15	0.060	0.142	0.798	69.99	-1.99	2.19	173.30	-0.01	-4.47
266	0.2	0.1	0.15	0.060	0.142	0.798	69.08	-2.00	2.15	173.30	-0.01	-4.47
267	0.25	0.1	0.15	0.060	0.142	0.798	68.17	-2.02	2.12	173.31	-0.01	-4.47
268	0.3	0.1	0.15	0.060	0.142	0.798	67.25	-2.04	2.08	173.32	-0.01	-4.47
269	0.35	0.1	0.15	0.060	0.142	0.798	66.34	-2.06	2.05	173.33	-0.01	-4.47
270	0.4	0.1	0.15	0.063	0.142	0.796	72.48	-2.08	1.85	185.74	-0.01	-4.60
271	0	0.15	0.15	0.060	0.142	0.798	68.09	-5.76	-0.53	173.29	-0.01	-4.47
272	0.05	0.15	0.15	0.060	0.142	0.798	67.17	-5.78	-0.56	173.29	-0.01	-4.47
273	0.1	0.15	0.15	0.060	0.142	0.798	66.26	-5.80	-0.60	173.30	-0.01	-4.47
274	0.15	0.15	0.15	0.060	0.142	0.798	65.35	-5.82	-0.63	173.30	-0.01	-4.47
275	0.2	0.15	0.15	0.060	0.142	0.798	64.43	-5.84	-0.67	173.31	-0.01	-4.47
276	0.25	0.15	0.15	0.060	0.142	0.798	63.52	-5.85	-0.70	173.32	-0.01	-4.47
277	0.3	0.15	0.15	0.063	0.142	0.796	69.46	-5.88	-0.90	185.72	-0.01	-4.60
278	0.35	0.15	0.15	0.063	0.142	0.796	68.48	-5.90	-0.93	185.74	-0.01	-4.60
279	0.4	0.15	0.15	0.063	0.142	0.796	67.51	-5.92	-0.97	185.75	-0.01	-4.60
280	0	0.2	0.15	0.060	0.142	0.798	63.44	-9.59	-3.35	173.29	0.00	-4.46
281	0.05	0.2	0.15	0.060	0.142	0.798	62.53	-9.61	-3.38	173.30	0.00	-4.46
282	0.1	0.2	0.15	0.060	0.142	0.798	61.61	-9.63	-3.42	173.30	0.00	-4.46
283	0.15	0.2	0.15	0.060	0.142	0.798	60.70	-9.65	-3.45	173.31	0.00	-4.46
284	0.2	0.2	0.15	0.063	0.142	0.796	66.44	-9.67	-3.64	185.71	0.00	-4.59
285	0.25	0.2	0.15	0.063	0.142	0.796	65.46	-9.69	-3.68	185.72	0.00	-4.59
286	0.3	0.2	0.15	0.063	0.142	0.796	64.49	-9.71	-3.71	185.73	0.00	-4.59
287	0.35	0.2	0.15	0.063	0.142	0.796	63.51	-9.73	-3.75	185.75	0.00	-4.59
288	0.4	0.2	0.15	0.063	0.142	0.796	62.54	-9.75	-3.78	185.76	0.00	-4.59
289	0	0.25	0.15	0.060	0.142	0.798	58.80	-13.42	-6.16	173.30	0.00	-4.46
290	0.05	0.25	0.15	0.060	0.142	0.798	57.88	-13.44	-6.20	173.30	0.00	-4.46
291	0.1	0.25	0.15	0.063	0.142	0.796	63.42	-13.46	-6.39	185.71	0.00	-4.59
292	0.15	0.25	0.15	0.063	0.142	0.796	62.45	-13.48	-6.42	185.71	0.00	-4.59
293	0.2	0.25	0.15	0.063	0.142	0.796	61.47	-13.50	-6.46	185.72	0.00	-4.59
294	0.25	0.25	0.15	0.063	0.142	0.796	60.49	-13.52	-6.49	185.73	0.00	-4.59
295	0.3	0.25	0.15	0.063	0.142	0.796	59.52	-13.54	-6.53	185.75	0.00	-4.59
296	0.35	0.25	0.15	0.063	0.142	0.796	58.55	-13.56	-6.56	185.76	0.00	-4.59
297	0.4	0.25	0.15	0.063	0.142	0.796	57.57	-13.58	-6.60	185.77	0.00	-4.59
298	0	0.3	0.15	0.063	0.142	0.796	60.41	-17.24	-9.13	185.70	0.02	-4.59
299	0.05	0.3	0.15	0.063	0.142	0.796	59.43	-17.26	-9.17	185.71	0.02	-4.59
300	0.1	0.3	0.15	0.063	0.142	0.796	58.45	-17.28	-9.21	185.72	0.02	-4.59
301	0.15	0.3	0.15	0.063	0.142	0.796	57.48	-17.30	-9.24	185.72	0.02	-4.59
302	0.2	0.3	0.15	0.063	0.142	0.796	56.50	-17.33	-9.28	185.73	0.02	-4.59
303	0.25	0.3	0.15	0.063	0.142	0.796	55.52	-17.35	-9.31	185.75	0.02	-4.59
304	0.3	0.3	0.15	0.063	0.142	0.796	54.55	-17.37	-9.35	185.76	0.02	-4.59
305	0.35	0.3	0.15	0.063	0.142	0.796	53.58	-17.39	-9.38	185.77	0.02	-4.59
306	0.4	0.3	0.15	0.063	0.142	0.796	52.61	-17.41	-9.42	185.79	0.02	-4.59
307	0	0.35	0.15	0.063	0.142	0.796	55.44	-21.07	-11.95	185.71	0.02	-4.59
308	0.05	0.35	0.15	0.063	0.142	0.796	54.46	-21.09	-11.99	185.72	0.02	-4.59
309	0.1	0.35	0.15	0.063	0.142	0.796	53.48	-21.12	-12.02	185.73	0.02	-4.59
310	0.15	0.35	0.15	0.063	0.142	0.796	52.51	-21.14	-12.06	185.74	0.02	-4.59
311	0.2	0.35	0.15	0.063	0.142	0.796	51.53	-21.16	-12.09	185.75	0.02	-4.59
312	0.25	0.35	0.15	0.063	0.142	0.796	50.56	-21.18	-12.13	185.76	0.02	-4.59
313	0.3	0.35	0.15	0.063	0.142	0.796	49.58	-21.20	-12.16	185.78	0.03	-4.59
314	0.35	0.35	0.15	0.063	0.142	0.796	48.61	-21.22	-12.20	185.79	0.03	-4.59
315	0.4	0.35	0.15	0.063	0.142	0.796	47.64	-21.24	-12.24	185.81	0.03	-4.59
316	0	0.4	0.15	0.063	0.142	0.796	50.47	-24.89	-14.79	185.72	0.06	-4.60
317	0.05	0.4	0.15	0.063	0.142	0.796	49.49	-24.91	-14.83	185.73	0.06	-4.60
318	0.1	0.4	0.15	0.063	0.142	0.796	48.52	-24.93	-14.87	185.74	0.06	-4.60
319	0.15	0.4	0.15	0.063	0.142	0.796	47.54	-24.95	-14.90	185.75	0.06	-4.60
320	0.2	0.4	0.15	0.063	0.142	0.796	46.57	-24.97	-14.94	185.77	0.06	-4.60
321	0.25	0.4	0.15	0.063	0.142	0.796	45.59	-24.99	-14.97	185.78	0.06	-4.60
322	0.3	0.4	0.15	0.063	0.142	0.796	44.62	-25.01	-15.01	185.80	0.06	-4.60
323	0.35	0.4	0.15	0.063	0.142	0.796	43.65	-25.03	-15.05	185.81	0.06	-4.60
324	0.4	0.4	0.15	0.063	0.142	0.796	42.68	-25.06	-15.08	185.83	0.06	-4.60
325	0	0	0.2	0.060	0.141	0.799	79.33	4.46	5.63	173.74	-0.02	-4.14
326	0.05	0	0.2	0.060	0.141	0.799	78.41	4.44	5.59	173.75	-0.02	-4.14
327	0.1	0	0.2	0.060	0.141	0.799	77.50	4.42	5.56	173.75	-0.02	-4.14
328	0.15	0	0.2	0.060	0.141	0.799	76.59	4.40	5.52	173.76	-0.02	-4.14
329	0.2	0	0.2	0.060	0.141	0.799	75.67	4.38	5.49	173.76	-0.02	-4.14
330	0.25	0	0.2	0.060	0.141	0.799	74.76	4.36	5.46	173.77	-0.02	-4.14
331	0.3	0	0.2	0.060	0.141	0.799	73.84	4.34	5.42	173.78	-0.02	-4.14
332	0.35	0	0.2	0.060	0.141	0.799	72.93	4.32	5.39	173.79	-0.02	-4.14
333	0.4	0	0.2	0.060	0.141	0.799	72.02	4.30	5.35	173.80	-0.02	-4.14
334	0	0.05	0.2	0.060	0.141	0.799	74.38	0.63	2.81	173.28	-0.01	-4.13
335	0.05	0.05	0.2	0.060	0.141	0.799	73.47	0.61	2.78	173.28	-0.01	-4.13
336	0.1	0.05	0.2	0.060	0.141	0.799	72.55	0.59	2.74	173.29	-0.01	-4.13

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
337	0.15	0.05	0.2	0.060	0.141	0.799	71.64	0.57	2.71	173.29	-0.01	-4.13
338	0.2	0.05	0.2	0.060	0.141	0.799	70.73	0.55	2.67	173.30	-0.01	-4.13
339	0.25	0.05	0.2	0.060	0.141	0.799	69.81	0.53	2.64	173.31	-0.01	-4.13
340	0.3	0.05	0.2	0.060	0.141	0.799	68.90	0.51	2.60	173.32	-0.01	-4.13
341	0.35	0.05	0.2	0.060	0.141	0.799	67.99	0.49	2.57	173.33	-0.01	-4.13
342	0.4	0.05	0.2	0.060	0.141	0.799	67.08	0.48	2.53	173.34	-0.01	-4.13
343	0	0.1	0.2	0.060	0.141	0.799	69.74	-3.20	-0.01	173.28	-0.01	-4.13
344	0.05	0.1	0.2	0.060	0.141	0.799	68.82	-3.22	-0.04	173.29	-0.01	-4.13
345	0.1	0.1	0.2	0.060	0.141	0.799	67.91	-3.24	-0.08	173.29	-0.01	-4.13
346	0.15	0.1	0.2	0.060	0.141	0.799	66.99	-3.26	-0.11	173.30	-0.01	-4.13
347	0.2	0.1	0.2	0.060	0.141	0.799	66.08	-3.28	-0.15	173.31	-0.01	-4.13
348	0.25	0.1	0.2	0.060	0.141	0.799	65.17	-3.30	-0.18	173.32	-0.01	-4.13
349	0.3	0.1	0.2	0.060	0.141	0.799	64.25	-3.32	-0.22	173.33	-0.01	-4.13
350	0.35	0.1	0.2	0.060	0.141	0.799	63.34	-3.34	-0.25	173.34	-0.01	-4.13
351	0.4	0.1	0.2	0.060	0.141	0.799	62.43	-3.36	-0.29	173.35	-0.01	-4.13
352	0	0.15	0.2	0.060	0.141	0.799	65.09	-7.03	-2.83	173.29	0.00	-4.13
353	0.05	0.15	0.2	0.060	0.141	0.799	64.17	-7.05	-2.86	173.29	0.00	-4.13
354	0.1	0.15	0.2	0.060	0.141	0.799	63.26	-7.07	-2.90	173.30	0.00	-4.13
355	0.15	0.15	0.2	0.060	0.141	0.799	62.35	-7.09	-2.93	173.31	0.00	-4.13
356	0.2	0.15	0.2	0.060	0.141	0.799	61.43	-7.11	-2.97	173.31	0.00	-4.13
357	0.25	0.15	0.2	0.060	0.141	0.799	60.52	-7.13	-3.00	173.32	0.00	-4.13
358	0.3	0.15	0.2	0.060	0.141	0.799	59.61	-7.15	-3.04	173.33	0.00	-4.13
359	0.35	0.15	0.2	0.060	0.141	0.799	58.70	-7.17	-3.07	173.35	0.00	-4.13
360	0.4	0.15	0.2	0.060	0.141	0.799	57.79	-7.19	-3.11	173.36	0.00	-4.13
361	0	0.2	0.2	0.060	0.141	0.799	60.44	-10.86	-5.65	173.29	0.00	-4.13
362	0.05	0.2	0.2	0.060	0.141	0.799	59.53	-10.88	-5.68	173.30	0.00	-4.13
363	0.1	0.2	0.2	0.060	0.141	0.799	58.61	-10.90	-5.72	173.31	0.00	-4.13
364	0.15	0.2	0.2	0.060	0.141	0.799	57.70	-10.92	-5.75	173.31	0.00	-4.13
365	0.2	0.2	0.2	0.060	0.141	0.799	56.79	-10.94	-5.79	173.32	0.00	-4.13
366	0.25	0.2	0.2	0.060	0.141	0.799	55.88	-10.96	-5.82	173.33	0.00	-4.13
367	0.3	0.2	0.2	0.060	0.141	0.799	54.97	-10.98	-5.85	173.34	0.00	-4.13
368	0.35	0.2	0.2	0.062	0.141	0.796	60.55	-11.00	-6.04	185.75	0.00	-4.26
369	0.4	0.2	0.2	0.062	0.141	0.796	59.57	-11.02	-6.08	185.77	0.00	-4.26
370	0	0.25	0.2	0.060	0.141	0.799	55.80	-14.69	-8.47	173.30	0.01	-4.12
371	0.05	0.25	0.2	0.060	0.141	0.799	54.88	-14.71	-8.50	173.31	0.01	-4.12
372	0.1	0.25	0.2	0.060	0.141	0.799	53.97	-14.73	-8.54	173.31	0.01	-4.12
373	0.15	0.25	0.2	0.060	0.141	0.799	53.06	-14.75	-8.57	173.32	0.01	-4.12
374	0.2	0.25	0.2	0.060	0.141	0.799	52.15	-14.77	-8.60	173.33	0.01	-4.12
375	0.25	0.25	0.2	0.062	0.141	0.796	57.52	-14.79	-8.79	185.74	0.01	-4.25
376	0.3	0.25	0.2	0.062	0.141	0.796	56.55	-14.81	-8.82	185.75	0.01	-4.25
377	0.35	0.25	0.2	0.062	0.141	0.796	55.58	-14.83	-8.86	185.77	0.01	-4.25
378	0.4	0.25	0.2	0.062	0.141	0.796	54.61	-14.85	-8.89	185.78	0.01	-4.25
379	0	0.3	0.2	0.060	0.141	0.799	51.15	-18.51	-11.28	173.31	0.02	-4.12
380	0.05	0.3	0.2	0.060	0.141	0.799	50.24	-18.53	-11.32	173.32	0.02	-4.12
381	0.1	0.3	0.2	0.060	0.141	0.799	49.33	-18.55	-11.35	173.33	0.02	-4.12
382	0.15	0.3	0.2	0.062	0.141	0.796	54.51	-18.57	-11.53	185.73	0.02	-4.25
383	0.2	0.3	0.2	0.062	0.141	0.796	53.53	-18.60	-11.57	185.74	0.02	-4.25
384	0.25	0.3	0.2	0.062	0.141	0.796	52.56	-18.62	-11.60	185.75	0.02	-4.25
385	0.3	0.3	0.2	0.062	0.141	0.796	51.58	-18.64	-11.64	185.77	0.02	-4.25
386	0.35	0.3	0.2	0.062	0.141	0.796	50.61	-18.66	-11.67	185.78	0.02	-4.25
387	0.4	0.3	0.2	0.062	0.141	0.796	49.64	-18.68	-11.71	185.80	0.02	-4.25
388	0	0.35	0.2	0.060	0.141	0.799	46.51	-22.34	-14.11	173.32	0.03	-4.12
389	0.05	0.35	0.2	0.062	0.141	0.796	51.49	-22.36	-14.28	185.72	0.03	-4.25
390	0.1	0.35	0.2	0.062	0.141	0.796	50.51	-22.38	-14.31	185.73	0.03	-4.25
391	0.15	0.35	0.2	0.062	0.141	0.796	49.54	-22.40	-14.35	185.74	0.03	-4.25
392	0.2	0.35	0.2	0.062	0.141	0.796	48.56	-22.42	-14.39	185.76	0.03	-4.25
393	0.25	0.35	0.2	0.062	0.141	0.796	47.59	-22.44	-14.42	185.77	0.03	-4.25
394	0.3	0.35	0.2	0.062	0.141	0.796	46.62	-22.47	-14.46	185.78	0.03	-4.25
395	0.35	0.35	0.2	0.062	0.141	0.796	45.64	-22.49	-14.49	185.80	0.03	-4.25
396	0.4	0.35	0.2	0.062	0.141	0.796	44.67	-22.51	-14.53	185.82	0.03	-4.25
397	0	0.4	0.2	0.062	0.141	0.796	47.50	-26.17	-17.06	185.73	0.04	-4.24
398	0.05	0.4	0.2	0.062	0.141	0.796	46.52	-26.19	-17.09	185.74	0.04	-4.24
399	0.1	0.4	0.2	0.062	0.141	0.796	45.55	-26.21	-17.13	185.75	0.04	-4.24
400	0.15	0.4	0.2	0.062	0.141	0.796	44.57	-26.23	-17.16	185.76	0.04	-4.24
401	0.2	0.4	0.2	0.062	0.141	0.796	43.60	-26.25	-17.20	185.77	0.04	-4.24
402	0.25	0.4	0.2	0.062	0.141	0.796	42.62	-26.28	-17.24	185.79	0.04	-4.24
403	0.3	0.4	0.2	0.062	0.141	0.796	41.65	-26.30	-17.27	185.81	0.04	-4.24
404	0.35	0.4	0.2	0.062	0.141	0.796	40.68	-26.32	-17.31	185.82	0.04	-4.24
405	0.4	0.4	0.2	0.062	0.141	0.796	39.71	-26.34	-17.34	185.85	0.04	-4.24
406	0	0	0.25	0.060	0.141	0.799	78.17	3.19	3.44	176.71	-0.01	-3.68
407	0.05	0	0.25	0.060	0.141	0.799	77.26	3.17	3.41	176.71	-0.01	-3.68
408	0.1	0	0.25	0.060	0.141	0.799	76.34	3.15	3.37	176.72	-0.01	-3.68
409	0.15	0	0.25	0.060	0.141	0.799	75.43	3.13	3.34	176.72	-0.01	-3.68
410	0.2	0	0.25	0.060	0.141	0.799	74.51	3.11	3.31	176.73	-0.01	-3.68
411	0.25	0	0.25	0.060	0.141	0.799	73.60	3.09	3.27	176.74	-0.01	-3.68
412	0.3	0	0.25	0.060	0.141	0.799	72.69	3.07	3.24	176.74	-0.01	-3.68
413	0.35	0	0.25	0.060	0.141	0.799	71.78	3.05	3.20	176.75	-0.01	-3.68
414	0.4	0	0.25	0.060	0.141	0.799	70.86	3.03	3.17	176.76	-0.01	-3.68
415	0	0.05	0.25	0.060	0.141	0.799	71.67	-0.64	0.50	173.75	-0.01	-3.77
416	0.05	0.05	0.25	0.060	0.141	0.799	70.75	-0.66	0.47	173.75	-0.01	-3.77
417	0.1	0.05	0.25	0.060	0.141	0.799	69.84	-0.68	0.43	173.76	-0.01	-3.77
418	0.15	0.05	0.25	0.060	0.141	0.799	68.92	-0.70	0.40	173.76	-0.01	-3.77
419	0.2	0.05	0.25	0.060	0.141	0.799	68.01	-0.72	0.36	173.77	-0.01	-3.77
420	0.25	0.05	0.25	0.060	0.141	0.799	67.10	-0.74	0.33	173.78	-0.01	-3.77
421	0.3	0.05	0.25	0.060	0.141	0.799	66.19	-0.76	0.30	173.79	-0.01	-3.77
422	0.35	0.05	0.25	0.060	0.141	0.799	65.27	-0.78	0.26	173.80	-0.01	-3.77
423	0.4	0.05	0.25	0.060	0.141	0.799	64.36	-0.80	0.23	173.81	-0.01	-3.77
424	0	0.1	0.25	0.060	0.141	0.799	67.01	-4.47	-2.31	173.75	0.00	-3.77
425	0.05	0.1	0.25	0.060	0.141	0.799	66.10	-4.49	-2.35	173.76	0.00	-3.77
426	0.1	0.1	0.25	0.060	0.141	0.799	65.18	-4.51	-2.38	173.76	0.00	-3.77
427	0.15	0.1	0.25	0.060	0.141	0.799	64.27	-4.53	-2.42	173.77	0.00	-3.77

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
428	0.2	0.1	0.25	0.060	0.141	0.799	63.36	-4.55	-2.45	173.78	0.00	-3.77
429	0.25	0.1	0.25	0.060	0.141	0.799	62.45	-4.57	-2.49	173.79	0.00	-3.77
430	0.3	0.1	0.25	0.060	0.141	0.799	61.53	-4.59	-2.52	173.80	0.00	-3.77
431	0.35	0.1	0.25	0.060	0.141	0.799	60.62	-4.61	-2.56	173.81	0.00	-3.77
432	0.4	0.1	0.25	0.060	0.141	0.799	59.71	-4.63	-2.59	173.82	0.00	-3.77
433	0	0.15	0.25	0.060	0.141	0.799	62.09	-8.30	-5.13	173.29	0.00	-3.77
434	0.05	0.15	0.25	0.060	0.141	0.799	61.18	-8.32	-5.17	173.30	0.00	-3.77
435	0.1	0.15	0.25	0.060	0.141	0.799	60.26	-8.34	-5.20	173.30	0.00	-3.77
436	0.15	0.15	0.25	0.060	0.141	0.799	59.35	-8.36	-5.24	173.31	0.00	-3.77
437	0.2	0.15	0.25	0.060	0.141	0.799	58.44	-8.38	-5.27	173.32	0.00	-3.77
438	0.25	0.15	0.25	0.060	0.141	0.799	57.52	-8.40	-5.31	173.33	0.00	-3.77
439	0.3	0.15	0.25	0.060	0.141	0.799	56.61	-8.42	-5.34	173.34	0.00	-3.77
440	0.35	0.15	0.25	0.060	0.141	0.799	55.70	-8.44	-5.38	173.35	0.00	-3.77
441	0.4	0.15	0.25	0.060	0.141	0.799	54.79	-8.46	-5.41	173.37	0.00	-3.77
442	0	0.2	0.25	0.060	0.141	0.799	57.44	-12.13	-7.95	173.30	0.01	-3.76
443	0.05	0.2	0.25	0.060	0.141	0.799	56.53	-12.15	-7.99	173.30	0.01	-3.76
444	0.1	0.2	0.25	0.060	0.141	0.799	55.62	-12.17	-8.02	173.31	0.01	-3.76
445	0.15	0.2	0.25	0.060	0.141	0.799	54.70	-12.19	-8.06	173.32	0.01	-3.76
446	0.2	0.2	0.25	0.060	0.141	0.799	53.79	-12.21	-8.09	173.33	0.01	-3.76
447	0.25	0.2	0.25	0.060	0.141	0.799	52.88	-12.23	-8.12	173.34	0.01	-3.76
448	0.3	0.2	0.25	0.060	0.141	0.799	51.97	-12.25	-8.16	173.35	0.01	-3.76
449	0.35	0.2	0.25	0.060	0.141	0.799	51.06	-12.27	-8.19	173.37	0.01	-3.76
450	0.4	0.2	0.25	0.060	0.141	0.799	50.15	-12.28	-8.23	173.38	0.01	-3.76
451	0	0.25	0.25	0.060	0.141	0.799	52.80	-15.96	-10.77	173.30	0.02	-3.76
452	0.05	0.25	0.25	0.060	0.141	0.799	51.88	-15.98	-10.80	173.31	0.02	-3.76
453	0.1	0.25	0.25	0.060	0.141	0.799	50.97	-16.00	-10.84	173.32	0.02	-3.76
454	0.15	0.25	0.25	0.060	0.141	0.799	50.06	-16.02	-10.87	173.33	0.02	-3.76
455	0.2	0.25	0.25	0.060	0.141	0.799	49.15	-16.04	-10.91	173.34	0.02	-3.76
456	0.25	0.25	0.25	0.060	0.141	0.799	48.24	-16.05	-10.94	173.35	0.02	-3.76
457	0.3	0.25	0.25	0.060	0.141	0.799	47.33	-16.07	-10.98	173.37	0.02	-3.76
458	0.35	0.25	0.25	0.060	0.141	0.799	46.42	-16.09	-11.01	173.38	0.02	-3.76
459	0.4	0.25	0.25	0.062	0.141	0.797	51.64	-16.12	-11.19	185.79	0.02	-3.89
460	0	0.3	0.25	0.060	0.141	0.799	48.15	-19.78	-13.59	173.31	0.02	-3.76
461	0.05	0.3	0.25	0.060	0.141	0.799	47.24	-19.80	-13.62	173.32	0.02	-3.76
462	0.1	0.3	0.25	0.060	0.141	0.799	46.33	-19.82	-13.66	173.33	0.02	-3.76
463	0.15	0.3	0.25	0.060	0.141	0.799	45.42	-19.84	-13.69	173.34	0.02	-3.76
464	0.2	0.3	0.25	0.060	0.141	0.799	44.51	-19.86	-13.73	173.35	0.02	-3.76
465	0.25	0.3	0.25	0.060	0.141	0.799	43.60	-19.88	-13.76	173.37	0.02	-3.76
466	0.3	0.3	0.25	0.062	0.141	0.797	48.62	-19.90	-13.93	185.78	0.02	-3.89
467	0.35	0.3	0.25	0.062	0.141	0.797	47.64	-19.93	-13.97	185.79	0.03	-3.89
468	0.4	0.3	0.25	0.062	0.141	0.797	46.67	-19.95	-14.01	185.81	0.03	-3.89
469	0	0.35	0.25	0.060	0.141	0.799	43.51	-23.61	-16.40	173.33	0.03	-3.75
470	0.05	0.35	0.25	0.060	0.141	0.799	42.60	-23.63	-16.44	173.33	0.03	-3.75
471	0.1	0.35	0.25	0.060	0.141	0.799	41.69	-23.65	-16.47	173.34	0.03	-3.75
472	0.15	0.35	0.25	0.060	0.141	0.799	40.78	-23.67	-16.51	173.36	0.03	-3.75
473	0.2	0.35	0.25	0.062	0.141	0.797	45.60	-23.69	-16.68	185.76	0.03	-3.88
474	0.25	0.35	0.25	0.062	0.141	0.797	44.62	-23.71	-16.71	185.78	0.03	-3.88
475	0.3	0.35	0.25	0.062	0.141	0.797	43.65	-23.74	-16.75	185.79	0.03	-3.88
476	0.35	0.35	0.25	0.062	0.141	0.797	42.68	-23.76	-16.79	185.81	0.03	-3.88
477	0.4	0.35	0.25	0.062	0.141	0.797	41.71	-23.78	-16.82	185.83	0.03	-3.88
478	0	0.4	0.25	0.060	0.141	0.799	38.87	-27.44	-19.22	173.34	0.05	-3.75
479	0.05	0.4	0.25	0.060	0.141	0.799	37.96	-27.46	-19.26	173.35	0.05	-3.75
480	0.1	0.4	0.25	0.062	0.141	0.797	42.58	-27.48	-19.42	185.76	0.05	-3.88
481	0.15	0.4	0.25	0.062	0.141	0.797	41.60	-27.50	-19.46	185.77	0.05	-3.88
482	0.2	0.4	0.25	0.062	0.141	0.797	40.63	-27.52	-19.50	185.78	0.05	-3.88
483	0.25	0.4	0.25	0.062	0.141	0.797	39.66	-27.54	-19.53	185.80	0.05	-3.88
484	0.3	0.4	0.25	0.062	0.141	0.797	38.69	-27.56	-19.57	185.82	0.05	-3.88
485	0.35	0.4	0.25	0.062	0.141	0.797	37.72	-27.58	-19.60	185.84	0.05	-3.88
486	0.4	0.4	0.25	0.062	0.141	0.797	36.75	-27.60	-19.64	185.86	0.05	-3.88
487	0	0	0.3	0.060	0.140	0.800	75.12	1.91	1.12	176.71	-0.01	-3.30
488	0.05	0	0.3	0.060	0.140	0.800	74.21	1.89	1.09	176.71	-0.01	-3.30
489	0.1	0	0.3	0.060	0.140	0.800	73.29	1.87	1.05	176.72	-0.01	-3.30
490	0.15	0	0.3	0.060	0.140	0.800	72.38	1.85	1.02	176.73	-0.01	-3.30
491	0.2	0	0.3	0.060	0.140	0.800	71.46	1.83	0.98	176.73	-0.01	-3.30
492	0.25	0	0.3	0.060	0.140	0.800	70.55	1.81	0.95	176.74	-0.01	-3.30
493	0.3	0	0.3	0.060	0.140	0.800	69.64	1.79	0.91	176.75	-0.01	-3.30
494	0.35	0	0.3	0.060	0.140	0.800	68.73	1.77	0.88	176.76	-0.01	-3.30
495	0.4	0	0.3	0.060	0.140	0.800	67.82	1.75	0.84	176.77	-0.01	-3.30
496	0	0.05	0.3	0.060	0.140	0.800	70.42	-1.91	-1.69	176.71	0.00	-3.29
497	0.05	0.05	0.3	0.060	0.140	0.800	69.50	-1.93	-1.73	176.72	0.00	-3.29
498	0.1	0.05	0.3	0.060	0.140	0.800	68.59	-1.95	-1.76	176.72	0.00	-3.29
499	0.15	0.05	0.3	0.060	0.140	0.800	67.67	-1.97	-1.80	176.73	0.00	-3.29
500	0.2	0.05	0.3	0.060	0.140	0.800	66.76	-1.99	-1.83	176.74	0.00	-3.29
501	0.25	0.05	0.3	0.060	0.140	0.800	65.85	-2.01	-1.87	176.75	0.00	-3.29
502	0.3	0.05	0.3	0.060	0.140	0.800	64.94	-2.03	-1.90	176.76	0.00	-3.29
503	0.35	0.05	0.3	0.060	0.140	0.800	64.03	-2.05	-1.94	176.77	0.00	-3.29
504	0.4	0.05	0.3	0.060	0.140	0.800	63.12	-2.07	-1.97	176.78	0.00	-3.29
505	0	0.1	0.3	0.060	0.140	0.800	64.01	-5.74	-4.63	173.76	0.00	-3.38
506	0.05	0.1	0.3	0.060	0.140	0.800	63.09	-5.76	-4.66	173.76	0.00	-3.38
507	0.1	0.1	0.3	0.060	0.140	0.800	62.18	-5.78	-4.69	173.77	0.00	-3.38
508	0.15	0.1	0.3	0.060	0.140	0.800	61.27	-5.80	-4.73	173.78	0.00	-3.38
509	0.2	0.1	0.3	0.060	0.140	0.800	60.35	-5.82	-4.76	173.78	0.00	-3.38
510	0.25	0.1	0.3	0.060	0.140	0.800	59.44	-5.84	-4.80	173.79	0.00	-3.38
511	0.3	0.1	0.3	0.060	0.140	0.800	58.53	-5.86	-4.83	173.80	0.00	-3.38
512	0.35	0.1	0.3	0.060	0.140	0.800	57.62	-5.88	-4.87	173.82	0.00	-3.38
513	0.4	0.1	0.3	0.060	0.140	0.800	56.71	-5.90	-4.90	173.83	0.00	-3.38
514	0	0.15	0.3	0.060	0.140	0.800	59.35	-9.57	-7.44	173.76	0.01	-3.38
515	0.05	0.15	0.3	0.060	0.140	0.800	58.44	-9.59	-7.48	173.77	0.01	-3.38
516	0.1	0.15	0.3	0.060	0.140	0.800	57.53	-9.61	-7.51	173.77	0.01	-3.38
517	0.15	0.15	0.3	0.060	0.140	0.800	56.61	-9.63	-7.55	173.78	0.01	-3.38
518	0.2	0.15	0.3	0.060	0.140	0.800	55.70	-9.65	-7.58	173.79	0.01	-3.38

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
519	0.25	0.15	0.3	0.060	0.140	0.800	54.79	-9.67	-7.62	173.80	0.01	-3.38
520	0.3	0.15	0.3	0.060	0.140	0.800	53.88	-9.69	-7.65	173.82	0.01	-3.38
521	0.35	0.15	0.3	0.060	0.140	0.800	52.97	-9.71	-7.69	173.83	0.01	-3.38
522	0.4	0.15	0.3	0.060	0.140	0.800	52.06	-9.73	-7.72	173.84	0.01	-3.38
523	0	0.2	0.3	0.059	0.141	0.800	54.44	-13.40	-10.26	173.30	0.02	-3.38
524	0.05	0.2	0.3	0.059	0.141	0.800	53.53	-13.42	-10.29	173.31	0.02	-3.38
525	0.1	0.2	0.3	0.059	0.141	0.800	52.62	-13.44	-10.33	173.32	0.02	-3.38
526	0.15	0.2	0.3	0.059	0.141	0.800	51.71	-13.46	-10.36	173.33	0.02	-3.37
527	0.2	0.2	0.3	0.059	0.141	0.800	50.79	-13.48	-10.40	173.34	0.02	-3.37
528	0.25	0.2	0.3	0.059	0.140	0.800	49.88	-13.50	-10.43	173.35	0.02	-3.37
529	0.3	0.2	0.3	0.059	0.140	0.800	48.97	-13.52	-10.47	173.36	0.02	-3.37
530	0.35	0.2	0.3	0.060	0.140	0.800	48.06	-13.53	-10.50	173.38	0.02	-3.37
531	0.4	0.2	0.3	0.060	0.140	0.800	47.16	-13.55	-10.54	173.39	0.02	-3.37
532	0	0.25	0.3	0.059	0.141	0.800	49.80	-17.23	-13.08	173.31	0.02	-3.37
533	0.05	0.25	0.3	0.059	0.141	0.800	48.89	-17.25	-13.11	173.32	0.02	-3.37
534	0.1	0.25	0.3	0.059	0.141	0.800	47.97	-17.26	-13.15	173.33	0.02	-3.37
535	0.15	0.25	0.3	0.059	0.141	0.800	47.06	-17.28	-13.18	173.34	0.02	-3.37
536	0.2	0.25	0.3	0.059	0.141	0.800	46.15	-17.30	-13.22	173.35	0.02	-3.37
537	0.25	0.25	0.3	0.059	0.141	0.800	45.24	-17.32	-13.25	173.36	0.02	-3.37
538	0.3	0.25	0.3	0.059	0.141	0.800	44.33	-17.34	-13.29	173.37	0.02	-3.37
539	0.35	0.25	0.3	0.060	0.141	0.800	43.42	-17.36	-13.32	173.39	0.02	-3.37
540	0.4	0.25	0.3	0.060	0.141	0.800	42.52	-17.38	-13.35	173.41	0.03	-3.37
541	0	0.3	0.3	0.059	0.141	0.800	45.16	-21.05	-15.90	173.32	0.03	-3.37
542	0.05	0.3	0.3	0.059	0.141	0.800	44.24	-21.07	-15.93	173.33	0.03	-3.37
543	0.1	0.3	0.3	0.059	0.141	0.800	43.33	-21.09	-15.96	173.34	0.03	-3.37
544	0.15	0.3	0.3	0.059	0.141	0.800	42.42	-21.11	-16.00	173.35	0.03	-3.37
545	0.2	0.3	0.3	0.059	0.141	0.800	41.51	-21.13	-16.03	173.36	0.03	-3.37
546	0.25	0.3	0.3	0.059	0.141	0.800	40.60	-21.15	-16.07	173.37	0.03	-3.37
547	0.3	0.3	0.3	0.059	0.141	0.800	39.69	-21.17	-16.10	173.39	0.03	-3.37
548	0.35	0.3	0.3	0.060	0.141	0.800	38.78	-21.19	-16.14	173.41	0.03	-3.37
549	0.4	0.3	0.3	0.060	0.141	0.800	37.88	-21.21	-16.17	173.43	0.03	-3.37
550	0	0.35	0.3	0.059	0.141	0.800	40.51	-24.88	-18.71	173.33	0.04	-3.36
551	0.05	0.35	0.3	0.059	0.141	0.800	39.60	-24.90	-18.75	173.34	0.04	-3.36
552	0.1	0.35	0.3	0.059	0.141	0.800	38.69	-24.92	-18.78	173.35	0.04	-3.36
553	0.15	0.35	0.3	0.059	0.141	0.800	37.78	-24.94	-18.82	173.36	0.04	-3.36
554	0.2	0.35	0.3	0.059	0.141	0.800	36.87	-24.96	-18.85	173.38	0.04	-3.36
555	0.25	0.35	0.3	0.059	0.141	0.800	35.96	-24.98	-18.88	173.39	0.04	-3.36
556	0.3	0.35	0.3	0.059	0.141	0.800	35.05	-25.00	-18.92	173.41	0.04	-3.36
557	0.35	0.35	0.3	0.062	0.140	0.798	39.71	-25.02	-19.09	185.83	0.04	-3.49
558	0.4	0.35	0.3	0.062	0.140	0.798	38.75	-25.04	-19.12	185.85	0.04	-3.49
559	0	0.4	0.3	0.059	0.141	0.800	35.87	-28.71	-21.53	173.35	0.05	-3.36
560	0.05	0.4	0.3	0.059	0.141	0.800	34.96	-28.73	-21.56	173.36	0.05	-3.36
561	0.1	0.4	0.3	0.059	0.141	0.800	34.05	-28.75	-21.60	173.37	0.05	-3.36
562	0.15	0.4	0.3	0.059	0.141	0.800	33.14	-28.77	-21.63	173.38	0.05	-3.36
563	0.2	0.4	0.3	0.059	0.141	0.800	32.23	-28.79	-21.67	173.40	0.05	-3.36
564	0.25	0.4	0.3	0.062	0.140	0.798	36.69	-28.81	-21.83	185.81	0.05	-3.49
565	0.3	0.4	0.3	0.062	0.140	0.798	35.72	-28.83	-21.86	185.83	0.05	-3.49
566	0.35	0.4	0.3	0.062	0.140	0.798	34.75	-28.85	-21.90	185.85	0.06	-3.49
567	0.4	0.4	0.3	0.062	0.140	0.798	33.78	-28.87	-21.93	185.88	0.06	-3.48
568	0	0	0.35	0.060	0.140	0.800	72.07	0.64	-1.19	176.71	0.00	-2.86
569	0.05	0	0.35	0.060	0.140	0.800	71.16	0.62	-1.23	176.72	0.00	-2.86
570	0.1	0	0.35	0.060	0.140	0.800	70.24	0.60	-1.26	176.72	0.00	-2.86
571	0.15	0	0.35	0.060	0.140	0.800	69.33	0.58	-1.30	176.73	0.00	-2.86
572	0.2	0	0.35	0.060	0.140	0.800	68.42	0.56	-1.33	176.74	0.00	-2.86
573	0.25	0	0.35	0.060	0.140	0.800	67.50	0.54	-1.36	176.75	0.00	-2.86
574	0.3	0	0.35	0.060	0.140	0.800	66.59	0.52	-1.40	176.76	0.00	-2.86
575	0.35	0	0.35	0.060	0.140	0.800	65.68	0.50	-1.43	176.77	0.00	-2.86
576	0.4	0	0.35	0.060	0.140	0.800	64.77	0.48	-1.47	176.78	0.00	-2.86
577	0	0.05	0.35	0.060	0.140	0.800	67.37	-3.19	-4.02	176.72	0.00	-2.88
578	0.05	0.05	0.35	0.060	0.140	0.800	66.45	-3.21	-4.06	176.72	0.00	-2.88
579	0.1	0.05	0.35	0.060	0.140	0.800	65.54	-3.23	-4.09	176.73	0.00	-2.88
580	0.15	0.05	0.35	0.060	0.140	0.800	64.63	-3.25	-4.13	176.74	0.00	-2.88
581	0.2	0.05	0.35	0.060	0.140	0.800	63.71	-3.27	-4.16	176.74	0.00	-2.88
582	0.25	0.05	0.35	0.060	0.140	0.800	62.80	-3.29	-4.20	176.75	0.00	-2.88
583	0.3	0.05	0.35	0.060	0.140	0.800	61.89	-3.31	-4.23	176.77	0.00	-2.88
584	0.35	0.05	0.35	0.060	0.140	0.800	60.98	-3.33	-4.26	176.78	0.00	-2.88
585	0.4	0.05	0.35	0.060	0.140	0.800	60.07	-3.35	-4.30	176.79	0.00	-2.87
586	0	0.1	0.35	0.060	0.140	0.800	62.66	-7.01	-6.84	176.72	0.01	-2.87
587	0.05	0.1	0.35	0.060	0.140	0.800	61.75	-7.03	-6.87	176.73	0.01	-2.87
588	0.1	0.1	0.35	0.060	0.140	0.800	60.84	-7.05	-6.91	176.74	0.01	-2.87
589	0.15	0.1	0.35	0.060	0.140	0.800	59.92	-7.07	-6.94	176.74	0.01	-2.87
590	0.2	0.1	0.35	0.060	0.140	0.800	59.01	-7.09	-6.98	176.75	0.01	-2.87
591	0.25	0.1	0.35	0.060	0.140	0.800	58.10	-7.11	-7.01	176.76	0.01	-2.87
592	0.3	0.1	0.35	0.060	0.140	0.800	57.19	-7.13	-7.04	176.78	0.01	-2.87
593	0.35	0.1	0.35	0.060	0.140	0.800	56.28	-7.15	-7.08	176.79	0.01	-2.87
594	0.4	0.1	0.35	0.060	0.140	0.800	55.37	-7.17	-7.11	176.80	0.01	-2.87
595	0	0.15	0.35	0.059	0.140	0.801	56.35	-10.84	-9.76	173.77	0.02	-2.96
596	0.05	0.15	0.35	0.059	0.140	0.801	55.43	-10.86	-9.79	173.77	0.02	-2.96
597	0.1	0.15	0.35	0.059	0.140	0.801	54.52	-10.88	-9.83	173.78	0.02	-2.96
598	0.15	0.15	0.35	0.059	0.140	0.801	53.61	-10.90	-9.86	173.79	0.02	-2.96
599	0.2	0.15	0.35	0.059	0.140	0.801	52.70	-10.92	-9.90	173.80	0.02	-2.96
600	0.25	0.15	0.35	0.059	0.140	0.801	51.79	-10.94	-9.93	173.81	0.02	-2.96
601	0.3	0.15	0.35	0.059	0.140	0.801	50.88	-10.96	-9.97	173.82	0.02	-2.96
602	0.35	0.15	0.35	0.059	0.140	0.801	49.97	-10.98	-10.00	173.84	0.02	-2.96
603	0.4	0.15	0.35	0.059	0.140	0.801	49.06	-11.00	-10.04	173.86	0.02	-2.96
604	0	0.2	0.35	0.059	0.140	0.801	51.69	-14.67	-12.58	173.77	0.02	-2.96
605	0.05	0.2	0.35	0.059	0.140	0.801	50.78	-14.69	-12.61	173.78	0.02	-2.96
606	0.1	0.2	0.35	0.059	0.140	0.801	49.87	-14.71	-12.64	173.79	0.02	-2.96
607	0.15	0.2	0.35	0.059	0.140	0.801	48.96	-14.73	-12.68	173.80	0.02	-2.96
608	0.2	0.2	0.35	0.059	0.140	0.801	48.05	-14.75	-12.71	173.81	0.02	-2.96
609	0.25	0.2	0.35	0.059	0.140	0.801	47.14	-14.77	-12.75	173.82	0.02	-2.96

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
610	0.3	0.2	0.35	0.059	0.140	0.801	46.23	-14.78	-12.78	173.84	0.02	-2.95
611	0.35	0.2	0.35	0.059	0.140	0.801	45.32	-14.80	-12.82	173.85	0.02	-2.95
612	0.4	0.2	0.35	0.059	0.140	0.801	44.41	-14.82	-12.85	173.87	0.03	-2.95
613	0	0.25	0.35	0.059	0.140	0.801	46.80	-18.49	-15.39	173.31	0.03	-2.95
614	0.05	0.25	0.35	0.059	0.140	0.801	45.89	-18.51	-15.43	173.32	0.03	-2.95
615	0.1	0.25	0.35	0.059	0.140	0.801	44.98	-18.53	-15.46	173.33	0.03	-2.95
616	0.15	0.25	0.35	0.059	0.140	0.801	44.07	-18.55	-15.50	173.34	0.03	-2.95
617	0.2	0.25	0.35	0.059	0.140	0.801	43.16	-18.57	-15.53	173.36	0.03	-2.95
618	0.25	0.25	0.35	0.059	0.140	0.801	42.25	-18.59	-15.56	173.37	0.03	-2.95
619	0.3	0.25	0.35	0.059	0.140	0.801	41.34	-18.61	-15.60	173.39	0.03	-2.95
620	0.35	0.25	0.35	0.059	0.140	0.801	40.43	-18.63	-15.63	173.40	0.03	-2.95
621	0.4	0.25	0.35	0.059	0.140	0.801	39.52	-18.65	-15.67	173.42	0.03	-2.95
622	0	0.3	0.35	0.059	0.140	0.801	42.16	-22.32	-18.21	173.32	0.04	-2.95
623	0.05	0.3	0.35	0.059	0.140	0.801	41.25	-22.34	-18.24	173.33	0.04	-2.95
624	0.1	0.3	0.35	0.059	0.140	0.801	40.34	-22.36	-18.28	173.34	0.04	-2.95
625	0.15	0.3	0.35	0.059	0.140	0.801	39.42	-22.38	-18.31	173.36	0.04	-2.95
626	0.2	0.3	0.35	0.059	0.140	0.801	38.51	-22.40	-18.35	173.37	0.04	-2.95
627	0.25	0.3	0.35	0.059	0.140	0.801	37.61	-22.42	-18.38	173.39	0.04	-2.95
628	0.3	0.3	0.35	0.059	0.140	0.801	36.70	-22.44	-18.42	173.40	0.04	-2.95
629	0.35	0.3	0.35	0.059	0.140	0.801	35.79	-22.46	-18.45	173.42	0.04	-2.95
630	0.4	0.3	0.35	0.059	0.140	0.801	34.89	-22.48	-18.48	173.45	0.04	-2.94
631	0	0.35	0.35	0.059	0.140	0.801	37.52	-26.15	-21.02	173.34	0.05	-2.94
632	0.05	0.35	0.35	0.059	0.140	0.801	36.61	-26.17	-21.06	173.35	0.05	-2.94
633	0.1	0.35	0.35	0.059	0.140	0.801	35.69	-26.19	-21.09	173.36	0.05	-2.94
634	0.15	0.35	0.35	0.059	0.140	0.801	34.78	-26.21	-21.13	173.37	0.05	-2.94
635	0.2	0.35	0.35	0.059	0.140	0.801	33.88	-26.23	-21.16	173.39	0.05	-2.94
636	0.25	0.35	0.35	0.059	0.140	0.801	32.97	-26.25	-21.20	173.40	0.05	-2.94
637	0.3	0.35	0.35	0.059	0.140	0.801	32.06	-26.27	-21.23	173.42	0.05	-2.94
638	0.35	0.35	0.35	0.059	0.140	0.801	31.15	-26.29	-21.27	173.45	0.05	-2.94
639	0.4	0.35	0.35	0.059	0.140	0.801	30.25	-26.31	-21.30	173.47	0.06	-2.94
640	0	0.4	0.35	0.059	0.140	0.801	32.88	-29.98	-23.84	173.35	0.06	-2.93
641	0.05	0.4	0.35	0.059	0.140	0.801	31.97	-30.00	-23.87	173.36	0.07	-2.93
642	0.1	0.4	0.35	0.059	0.140	0.801	31.06	-30.02	-23.91	173.38	0.07	-2.93
643	0.15	0.4	0.35	0.059	0.140	0.801	30.15	-30.04	-23.94	173.39	0.07	-2.93
644	0.2	0.4	0.35	0.059	0.140	0.801	29.24	-30.06	-23.98	173.41	0.07	-2.93
645	0.25	0.4	0.35	0.059	0.140	0.801	28.33	-30.08	-24.01	173.43	0.07	-2.93
646	0.3	0.4	0.35	0.059	0.140	0.801	27.43	-30.10	-24.05	173.45	0.07	-2.93
647	0.35	0.4	0.35	0.059	0.140	0.801	26.52	-30.11	-24.08	173.47	0.07	-2.93
648	0.4	0.4	0.35	0.062	0.140	0.798	30.82	-30.14	-24.24	185.90	0.07	-3.06
649	0	0	0.4	0.020	0.142	0.838	-4.39	-0.65	-1.14	-7.56	0.00	0.34
650	0.05	0	0.4	0.022	0.142	0.836	-0.46	-0.65	-1.25	0.01	0.00	0.24
651	0.1	0	0.4	0.060	0.139	0.801	67.19	-0.68	-3.60	176.73	0.00	-2.41
652	0.15	0	0.4	0.060	0.139	0.801	66.28	-0.70	-3.63	176.73	0.00	-2.41
653	0.2	0	0.4	0.060	0.139	0.801	65.37	-0.72	-3.67	176.74	0.00	-2.41
654	0.25	0	0.4	0.060	0.139	0.801	64.46	-0.74	-3.70	176.75	0.00	-2.41
655	0.3	0	0.4	0.060	0.139	0.801	63.55	-0.76	-3.74	176.76	0.00	-2.41
656	0.35	0	0.4	0.060	0.139	0.801	62.63	-0.78	-3.77	176.78	0.00	-2.41
657	0.4	0	0.4	0.060	0.139	0.801	61.73	-0.80	-3.81	176.79	0.01	-2.41
658	0	0.05	0.4	0.020	0.142	0.838	-8.31	-4.48	-3.97	-7.56	0.01	0.34
659	0.05	0.05	0.4	0.022	0.142	0.836	-4.51	-4.48	-4.09	0.01	0.01	0.25
660	0.1	0.05	0.4	0.060	0.139	0.801	62.49	-4.51	-6.41	176.73	0.01	-2.41
661	0.15	0.05	0.4	0.060	0.139	0.801	61.58	-4.53	-6.45	176.74	0.01	-2.41
662	0.2	0.05	0.4	0.060	0.139	0.801	60.67	-4.54	-6.48	176.75	0.01	-2.41
663	0.25	0.05	0.4	0.060	0.139	0.801	59.75	-4.56	-6.52	176.76	0.01	-2.41
664	0.3	0.05	0.4	0.060	0.139	0.801	58.84	-4.58	-6.55	176.77	0.01	-2.41
665	0.35	0.05	0.4	0.060	0.139	0.801	57.93	-4.60	-6.58	176.79	0.01	-2.41
666	0.4	0.05	0.4	0.060	0.139	0.801	57.03	-4.62	-6.62	176.80	0.01	-2.41
667	0	0.1	0.4	0.020	0.142	0.838	-12.22	-8.30	-6.81	-7.56	0.02	0.35
668	0.05	0.1	0.4	0.022	0.142	0.836	-8.56	-8.30	-6.92	0.02	0.02	0.25
669	0.1	0.1	0.4	0.060	0.139	0.801	57.79	-8.33	-9.22	176.74	0.02	-2.41
670	0.15	0.1	0.4	0.060	0.139	0.801	56.88	-8.35	-9.26	176.75	0.02	-2.41
671	0.2	0.1	0.4	0.060	0.139	0.801	55.96	-8.37	-9.29	176.76	0.02	-2.41
672	0.25	0.1	0.4	0.060	0.139	0.801	55.05	-8.39	-9.33	176.77	0.02	-2.41
673	0.3	0.1	0.4	0.060	0.139	0.801	54.14	-8.41	-9.36	176.78	0.02	-2.41
674	0.35	0.1	0.4	0.060	0.139	0.801	53.23	-8.43	-9.40	176.80	0.02	-2.40
675	0.4	0.1	0.4	0.060	0.139	0.801	52.33	-8.45	-9.43	176.82	0.02	-2.40
676	0	0.15	0.4	0.020	0.142	0.838	-16.14	-12.12	-9.67	-7.55	0.02	0.34
677	0.05	0.15	0.4	0.022	0.142	0.836	-12.60	-12.13	-9.77	0.03	0.02	0.24
678	0.1	0.15	0.4	0.060	0.139	0.801	53.09	-12.15	-12.05	176.75	0.02	-2.42
679	0.15	0.15	0.4	0.060	0.139	0.801	52.17	-12.17	-12.09	176.76	0.02	-2.42
680	0.2	0.15	0.4	0.060	0.139	0.801	51.26	-12.19	-12.12	176.77	0.02	-2.42
681	0.25	0.15	0.4	0.060	0.139	0.801	50.35	-12.21	-12.16	176.78	0.03	-2.42
682	0.3	0.15	0.4	0.060	0.139	0.801	49.44	-12.23	-12.19	176.80	0.03	-2.42
683	0.35	0.15	0.4	0.060	0.139	0.801	48.54	-12.25	-12.23	176.81	0.03	-2.42
684	0.4	0.15	0.4	0.060	0.139	0.801	47.63	-12.27	-12.26	176.83	0.03	-2.42
685	0	0.2	0.4	0.020	0.142	0.838	-20.05	-15.95	-12.51	-7.55	0.03	0.34
686	0.05	0.2	0.4	0.022	0.142	0.836	-16.65	-15.95	-12.61	0.03	0.03	0.24
687	0.1	0.2	0.4	0.060	0.139	0.801	48.39	-15.98	-14.87	176.76	0.03	-2.41
688	0.15	0.2	0.4	0.060	0.139	0.801	47.47	-16.00	-14.90	176.77	0.03	-2.41
689	0.2	0.2	0.4	0.060	0.139	0.801	46.56	-16.02	-14.94	176.78	0.03	-2.41
690	0.25	0.2	0.4	0.060	0.139	0.801	45.65	-16.04	-14.97	176.79	0.03	-2.41
691	0.3	0.2	0.4	0.060	0.139	0.801	44.75	-16.06	-15.00	176.81	0.03	-2.41
692	0.35	0.2	0.4	0.060	0.139	0.801	43.84	-16.08	-15.04	176.83	0.03	-2.41
693	0.4	0.2	0.4	0.060	0.139	0.801	42.93	-16.10	-15.07	176.85	0.04	-2.41
694	0	0.25	0.4	0.020	0.142	0.838	-25.44	-19.77	-15.45	-10.51	0.04	0.26
695	0.05	0.25	0.4	0.021	0.142	0.837	-22.16	-19.78	-15.54	-2.92	0.04	0.16
696	0.1	0.25	0.4	0.059	0.140	0.801	42.21	-19.80	-17.78	173.81	0.04	-2.50
697	0.15	0.25	0.4	0.059	0.140	0.801	41.30	-19.82	-17.82	173.82	0.04	-2.50
698	0.2	0.25	0.4	0.059	0.140	0.801	40.39	-19.84	-17.85	173.83	0.04	-2.50
699	0.25	0.25	0.4	0.059	0.140	0.801	39.48	-19.86	-17.89	173.85	0.04	-2.50
700	0.3	0.25	0.4	0.059	0.140	0.801	38.58	-19.88	-17.92	173.86	0.04	-2.50

Continued: Subsidy Heuristic Iteration

	Subsidy Rate			Modal Share			Logistics Cost Difference [%]			Flow Difference [%]		
n	R	M	T	R	M	T	R	M	T	R	M	T
701	0.35	0.25	0.4	0.059	0.140	0.801	37.67	-19.90	-17.95	173.88	0.04	-2.50
702	0.4	0.25	0.4	0.059	0.140	0.801	36.76	-19.92	-17.99	173.91	0.04	-2.50
703	0	0.3	0.4	0.020	0.142	0.838	-29.53	-23.60	-18.29	-10.97	0.05	0.26
704	0.05	0.3	0.4	0.021	0.142	0.837	-26.38	-23.60	-18.38	-3.37	0.05	0.16
705	0.1	0.3	0.4	0.059	0.140	0.801	37.34	-23.63	-20.60	173.35	0.05	-2.49
706	0.15	0.3	0.4	0.059	0.140	0.801	36.43	-23.65	-20.63	173.37	0.05	-2.49
707	0.2	0.3	0.4	0.059	0.140	0.801	35.52	-23.67	-20.67	173.38	0.05	-2.49
708	0.25	0.3	0.4	0.059	0.140	0.801	34.61	-23.69	-20.70	173.40	0.05	-2.49
709	0.3	0.3	0.4	0.059	0.140	0.801	33.71	-23.71	-20.73	173.42	0.05	-2.49
710	0.35	0.3	0.4	0.059	0.140	0.801	32.80	-23.73	-20.77	173.44	0.06	-2.49
711	0.4	0.3	0.4	0.059	0.140	0.801	31.90	-23.75	-20.80	173.46	0.06	-2.49
712	0	0.35	0.4	0.020	0.142	0.838	-33.39	-27.43	-21.13	-10.97	0.07	0.27
713	0.05	0.35	0.4	0.021	0.142	0.837	-30.37	-27.43	-21.22	-3.36	0.07	0.17
714	0.1	0.35	0.4	0.059	0.140	0.801	32.70	-27.46	-23.41	173.37	0.07	-2.49
715	0.15	0.35	0.4	0.059	0.140	0.801	31.79	-27.48	-23.45	173.38	0.07	-2.49
716	0.2	0.35	0.4	0.059	0.140	0.801	30.88	-27.50	-23.48	173.40	0.07	-2.49
717	0.25	0.35	0.4	0.059	0.140	0.801	29.97	-27.52	-23.52	173.42	0.07	-2.49
718	0.3	0.35	0.4	0.059	0.140	0.801	29.07	-27.54	-23.55	173.44	0.07	-2.49
719	0.35	0.35	0.4	0.059	0.140	0.801	28.16	-27.56	-23.58	173.46	0.07	-2.48
720	0.4	0.35	0.4	0.059	0.140	0.801	27.26	-27.58	-23.62	173.49	0.07	-2.48
721	0	0.4	0.4	0.020	0.142	0.838	-37.24	-31.25	-23.97	-10.96	0.08	0.28
722	0.05	0.4	0.4	0.021	0.142	0.837	-34.35	-31.26	-24.05	-3.34	0.08	0.18
723	0.1	0.4	0.4	0.059	0.140	0.801	28.06	-31.28	-26.23	173.39	0.08	-2.48
724	0.15	0.4	0.4	0.059	0.140	0.801	27.15	-31.30	-26.26	173.40	0.08	-2.48
725	0.2	0.4	0.4	0.059	0.140	0.801	26.25	-31.32	-26.30	173.42	0.08	-2.48
726	0.25	0.4	0.4	0.059	0.140	0.801	25.34	-31.34	-26.33	173.44	0.08	-2.48
727	0.3	0.4	0.4	0.059	0.140	0.801	24.43	-31.36	-26.36	173.47	0.08	-2.48
728	0.35	0.4	0.4	0.059	0.140	0.801	23.53	-31.38	-26.40	173.49	0.08	-2.48
729	0.4	0.4	0.4	0.059	0.140	0.801	22.63	-31.40	-26.43	173.52	0.08	-2.48