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Analysis of Intermodal Freight Transport Efficiency: Study of the Java-Sumatera Route

Faris Nofandi[1], Alwi Sina Khaqiqi[2], Rizki Adi Pratama[3]
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***Abstract*— As an archipelagic country, Indonesia has abundant natural resources and the potential to develop various industries. In this case, the Ministry of Industry still relies on Java as a location to encourage industrial activities in Indonesia. One of the largest industrial areas in Indonesia is located in the western area of Java Island, namely in the Pulogadung, Karawang, and Bekasi areas. Geographically, Indonesia, an archipelagic country, has good inter-island connectivity. The maritime transportation sector is a strategic component forming the national transportation system. Apart from that, the competitiveness of Indonesian commodities, goods, and services is developed due to national logistics prices, which are partly determined by transportation costs. The many commodities produced on Java Island have resulted in a high demand for goods from Java Island. The cost of shipping goods plays a significant role in the buyer's price. In this research, several options were analyzed for sending goods from Java to Sumatera, namely by using a truck and then crossing by ship from Merak Port to Bakauheni Port or sending by ship to Panjang Port, from Tanjung Priok Port or Ciwandan Port. This research was conducted to select a mode of transportation with a minimum unit cost to support delivery activities. Then, this research was carried out using an optimization method to make the shipping costs incurred more optimal. The results of this research will provide an analysis of the efficiency of intermodal transportation in transporting goods on the Java-Sumatera route.**

Keywords— Industrial Estate, Minimum Unit Cost, Optimization Method, Sea Transportation

I. INTRODUCTION

The Republic of Indonesia is an archipelago with a considerable area, part of which is a marine area with a total area of 3,347,357 km2. Therefore, an effective and efficient means of transportation is needed. The sea transportation sector has excellent potential for Indonesia if developed optimally [1]. Minister of Transportation Budi Karya Sumadi said the sea transportation sector plays an essential role in increasing competitiveness and strengthening Indonesia's maritime position. Currently, one of the largest industrial areas in Indonesia is located in the western region of Java Island, namely in Pulogadung, Karawang, and Bekasi. Various factories produce products from automotive, pharmaceutical, food, and household appliances [6]. More details regarding the distribution map of industrial areas in DKI Jakarta and its surroundings can be seen in figure 1.

From the picture above, it can be seen the distribution map of industrial areas in DKI Jakarta and its surroundings. By looking at the condition of the distribution of the industry, sea transportation, and ports play an essential role [8]. Shipping goods have been dominated by sea transportation and the port as a place of loading and unloading. However, there are still many problems that must be solved related to shipping goods.

The first is non-conducive government regulations, low land value chain efficiency, low maritime value chain efficiency, non-optimal port operations, infrastructure, and unbalanced supply-demand [3].

This results in shipping problems such as damage to goods, loss of goods, and delays [5]. Immaterial losses experienced by consumers in the event of delayed goods have not been reimbursed.

Therefore, there are several options for modes of transportation to transport goods from Java to Sumatera to meet the demand for freight transportation [2]. Among the options for sending goods from Java to Sumatera are using trucks and crossing by ship from Merak Port to Bakauheni Port or sending by ship to Panjang Port, from Tanjung Priok Port or Ciwandan Port. More details regarding the route of shipping goods from the Island to Sumatera can be seen in the picture below [15]. From the picture above, it can be explained that each route can be used to deliver goods from Java Island to Sumatera Island and vice versa [10]. With several alternative routes and conveyances, this causes competition between modes in it. Therefore, it is necessary to research to determine the effective mode of transportation to deliver goods from Java to Sumatera Island and vice versa. The purpose of this study is to determine the current condition of shipping goods from Java to Sumatera, determine the most optimal unit cost for shipping goods from Java to Sumatera on each route, and determine the comparison of the characteristics of shipping goods from Java to Sumatera among several choices of modes and routes available [13]. The limitations of the problem in this study are the modes of transportation used with Trul-Ro ships and General Cargo, port regulations, service for each mode, and tariffs considered in the analysis, and the route used is Tanjung Priok - Panjang, Merak-Bakauheni, Ciwandan-Panjang [4].

Faris Nofandi, politeknik pelayaran Surabaya, Indonesia, e-mail: farisnofandi@gmail.com
Alwi Sina Khaqiqi, politeknik pelayaran Surabaya, Indonesia
Rizki Adi Pratama, politeknik pelayaran Surabaya, Indonesia

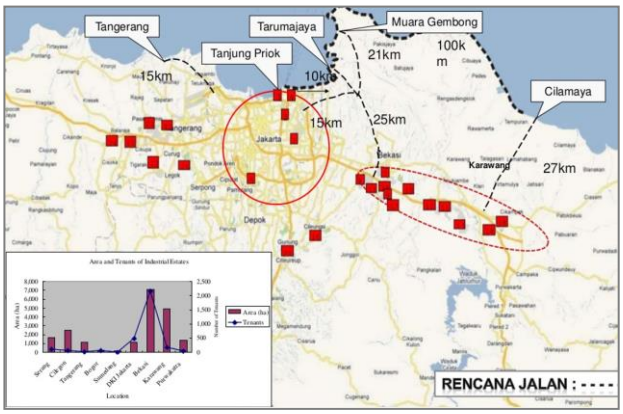

Figure 2. Map of Distribution of Industrial Areas in DKI Jakarta and Surrounding Areas

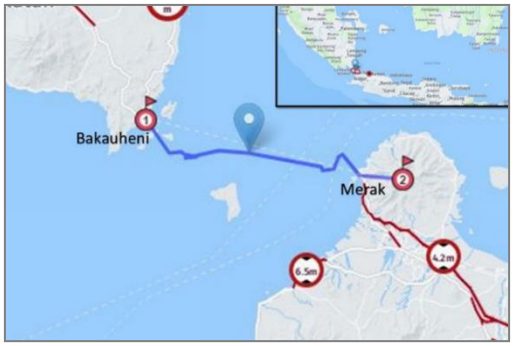

Figure 2. Route I Merak - Bakauheni

Figure 3. Route II Tanjung Priok - Panjang

Figure 1. Route III Ciwandan – Panjang

II. RESEARCH METHOD

The research method consists of 3 stages: problem identification, data collection, and processing. At the problem identification stage, the author identifies the current conditions in the delivery of goods on each route and with different conveyances so that the obstacles caused can be known. This study can discuss the efficiency level of various types of intermodal transportation in the transportation of goods. The data collection method in the research is direct (primary) and indirect (secondary). This data collection is based on data from related companies through direct surveys and data that the public can access directly. The stages of work consist of identifying existing conditions, analyzing existing conditions, analyzing alternative delivery of goods with new modes, and minimizing unit cost.

III. ANALYSIS AND DISCUSSION

A. Analysis of Existing Conditions

The Java - Sumatera ferry transportation route is one of the critical crossing routes in Indonesia because it connects two large islands, namely Java and Sumatera. To go through the route, the mode of transportation used is land transportation. The distance traveled by trucks to cross Java Island to Sumatera Island if using the Merak - Bakauheni route is 38.6 km. The distance traveled through the Tanjung Priok - Panjang route is 222.2 km. Meanwhile, if through the Ciwandan - Panjang route, the route traveled is 103.7 km. As explained in the previous section, for each port of origin, there is a market share of each port. It will be connected to the sea transportation mode, namely ships serving inter-island crossing routes. From the number of ship visits at each port, the results show that most of the ships heading to the island of Sumatera, especially Lampung, still go through the Merak - Bakauheni route with a magnitude of 95% of the total number of ships in 3 ports.

A.1. Route 1 Analysis

On the first route, Merak to Bakauheni, trucks load at factories in their respective industrial areas and travel overland to the port of origin, Merak Port. The journey from Merak to Bakauheni is 20 nautical miles, which takes 2 hours with an average speed of 5 knots. After the cargo arrives at Bakauheni Port, it will be taken to Bandar Lampung as the final destination. The distance covered is 85 kilometers with a truck speed of 30 km/h, so the time taken is almost 3 hours. Meanwhile, with an average speed of 30 km/h, the time taken for the truck to reach the port of origin, Merak Port, can be seen in the table below:

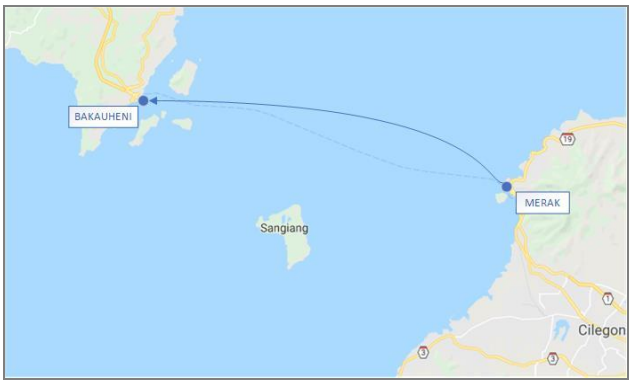

Figure 3. Route of Merak – Bakauheni.

TABLE 1.
TRAVEL TIME FROM INDUSTRIAL AREA TO MERAK PORT

No.	Origins	Destinations	Time (Hours)
1	Ciwandan	Merak	0,67
2	Cilegon	Merak	0,47
3	Cikande	Merak	1,83
4	Kw. Industri Milenium	Merak	2,57
5	Cikupa	Merak	2,57
6	Tangerang	Merak	3,43

The table above explains the travel time from the Industrial Estate to Merak Port. The mode of transportation used to transport passengers and vehicles on the crossing route is the Roro Ship. Below are the specifications of the selected Ro-Ro ship for the Merak to Bakauheni route. The main specifications of the Roro ship include payload, dead weight tonnage, length, width, height, laden and ship speed. Based on the results of the solver that has been carried out, this model considers the volume of cargo transported per year and the lowest unit cost generated if using a ro-ro ship with a length of 85 meters, width of 22.4 meters, height of 11.5 meters, and 8.6 meters laden.

Currently, users of crossing services on the Merak route - Bakauheni and Tanjung Priok - Panjang are divided into three: passengers, two-wheeled vehicles, and four-wheeled vehicles. Two-wheeled vehicles consist of class I, class II, and class III. Meanwhile, passenger vehicles are divided into IV A, V A, and VI A. For goods vehicles, it is divided into several groups,

namely group IV B, group V B, group VI B, group VII, group VIII, and group IX.

The land transportation mode chosen for the calculation analysis follows the sea transportation mode used. The mode used for ro-ro ships and general cargo is tronton trucks. More details regarding the tronton vehicles' specifications can be seen in the table below:

TABLE 2.
TRONTON SPESIFICATIONS

No.	Informations	Unit	Value
1	Long	m	5,6
2	Wide	m	2,0
3	Tall	m	1,8
4	Volume	m3	20,3
5	Capacity	kg	14.000,0
		ton	14,0
6	Speed	km/h	20,0

From the table above, the specifications of the tronton vehicle used to deliver cargo can be explained. Look at the specifications of the tronton used to transport export cargo using general cargo and roro ships. This tronton has a capacity of 14 tons with a loading space volume of 20,3 m.

Priok Port. The journey from Tanjung Priok to Panjang is 120 nautical miles, which takes 9 hours with an average speed of 13 knots. After the truck arrives at the destination port, Panjang Port, the truck will head to Bandar Lampung City, 7.8 kilometers away. With an average truck speed of 30 km/h, the time traveled from

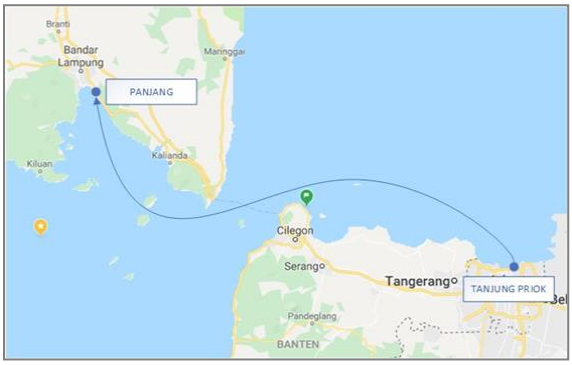

Figure 6 Tanjung Priok Harbor – Panjang Harbor crossing route

A.2. Route II Analysis

On the following route, Tanjung Priok to Panjang, trucks carry out the loading process at factories in their respective industrial areas and travel overland to the port of origin, namely Tanjung Priok Port. Industrial area, and travel by road to the port of origin, namely Tanjung Panjang Port to Bandar Lampung is 0.26 hours.

Meanwhile, with an average speed of 30 km/h, the time taken for the truck to reach the port of origin namely Tanjung Priok Port, can be seen in the table below.

TABLE 3.
TRAVEL TIME FOR TRUCKS FROM THE INDUSTRIAL ESTATE TO TANJUNG PRIOK PORT

No.	Origins	Destinations	Time (Hours)
1	Jakarta Industrial Estate	Tanjung Priok	0,60
2	Kawasan Berikat Nusantara	Tanjung Priok	0,43
3	Marunda Industrial Park	Tanjung Priok	0,33
4	Cibinong	Tanjung Priok	1,80
5	Citeureup	Tanjung Priok	1,53
6	Cikarang	Tanjung Priok	1,93
7	Karawang	Tanjung Priok	2,43

From the table above, it can be explained the travel time of trucks from the Industrial Estate to Tanjung Priok Port. The following is the specifications of the roro ship selected for the Tanjung Priok to Panjang route. The main specifications of the Roro ship include payload, dead weight tonnage, length, width, height, laden and ship speed.

TABLE 4.
MAIN SIZE SPECIFICATIONS FOR THE TANJUNG PRIOK - PANJANG PORT ROUTE

No.	Informations	Unit	Value
1	Rute	Tanjung Priok - Panjang	
2	Payload	SUP	4.598,00
3	DWT	ton	7.403,00
4	LPP	meter	90,56
5	B	meter	16,87
6	H	meter	11,26
7	T	meter	7,66
8	Vs	knot	12,00

The table above shows the results of the best roro ship specifications for the Tanjung Priok to Panjang route based on the results of the survey that has been carried out. This model considers the volume of cargo transported per year and the lowest unit cost generated when using a roro ship with a length of 90.56 meters, 16.87 meters wide, 11.26 meters high, and 7.66 meters laden. The land transportation mode chosen for the calculation analysis is the sea transportation mode used.

The mode used for roro ships and general cargo is tronton trucks. The following are the specifications of the tronton truck..

TABLE 5
TRONTON SPESIFICATIONS

No.	Informations	Unit	Value
1	Long	m	5,6
2	Wide	m	2,0
3	Tall	m	1,8
4	Volume	m3	20,3
5	Capacity	kg	14.000,0
		ton	14,0
6	Speed	km/h	20,0

The table above explains the tronton vehicle's specifications for delivering cargo. The specifications of the tronton used to transport export cargo using general cargo and roro ships. This tronton has a capacity of 14 tons with a loading space volume of 20,3 m^3.

A.3. Route III Analysis

On the last route, Ciwandan to Panjang, trucks perform the loading process at factories in their respective industrial area, and travel by road to the port of origin, Ciwandan Port. The journey from Ciwandan to Panjang is 56 nautical miles and takes 6 hours at 10 knots. After the truck arrives at the destination port, Panjang Port, the truck will head to Bandar Lampung City, which is 7.8 kilometers away. With an average truck speed of 30 km/h, the time taken from Panjang Port to Bandar Lampung is 0.26 hours.

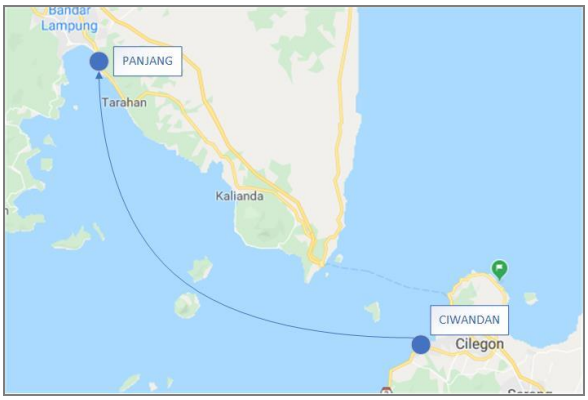

Figure 4. Ciwandan Harbor - Panjang Harbor Crossing Route

TABLE 6.
TRAVEL TIME FOR TRUCKS TO CIWANDAN PORT

No.	Origins	Destinations	Time (Hour)
1	Ciwandan	Ciwandan	0,10
2	Cilegon	Ciwandan	0,27
3	Cikande	Ciwandan	1,87
4	Kawasan Industri Milenium	Ciwandan	2,63
5	Cikupa	Ciwandan	2,60
6	Tangerang	Ciwandan	3,47

Meanwhile, with an average speed of 30 km/h, the time taken for the truck to reach the port of origin, Ciwandan Port, can be seen in the table below.

The table above explains the travel time of trucks to Ciwandan Port. The following are the specifications of the selected general cargo ship for the Ciwandan to Panjang route. The main specifications of the Roro ship include payload, dead weight tonnage, length, width, height, laden and ship speed. The best general cargo ship specifications for the Tanjung Priok to Panjang route are based on the solver results that have been carried out.

This model considers the volume of cargo transported per year and the lowest unit cost generated when using a general cargo ship with a length of 109.2 meters, a width of 17.7 meters, a height of 8.4 meters, and a laden ship of 4.3 meters. The land transportation mode chosen for the calculation analysis is the sea transportation mode used. The mode used for roro ships and general cargo is tronton trucks. The following are the specifications of the tronton truck.

TABLE 7.

TRONTON SPESIFICATIONS

No.	Informations	Unit	Value
1	Long	m	5,6
2	Wide	m	2,0
3	Tall	m	1,8
4	Volume	m3	20,3
5	Capacity	kg	14.000,0
		ton	14,0
6	Speed	km/jam	20,0

The table above explains the tronton vehicle's specifications for delivering cargo. The specifications of the tronton used to transport export cargo using general cargo and roro ships. This tronton has a capacity of 14 tons with a loading space volume of 20,3 m^3.

B. Analysis of Alternative Cargo Delivery

B.1. Scenario I

In this scenario, the mode used is a Container Ship on the Tanjung Priok to Panjang route. The cargo will be carried using trucks from the factory, loaded with containers, and transported using ships. Then, from the cargo flow in scenario 1, calculations are carried out and obtained for the optimum ship size. The results of the best container ship specifications for the Tanjung Priok to Panjang route are based on the results of the survey that has been carried out. This model considers the volume of cargo transported per year and the lowest unit cost generated when using a container ship with a length of 104.3 meters, a width of 14.9 meters, a height of 6.13 meters, and a vessel laden of 4.6 meters.

B.2. Scenario II

Meanwhile, for the Ciwandan to Panjang route, the alternative sea transportation mode that can be considered is the Container Ship. The cargo will be carried using trucks from the factory, loaded with containers, and transported using ships. The results of the best container ship specifications for the Tanjung Priok to Panjang route are based on the solver results that have been carried out. This model considers the volume of cargo transported per year and the lowest unit cost generated when using a container ship with a length of 102.4 meters, a width of 14.7 meters, a height of 6.72 meters, and a vessel laden of 5.27 meters.

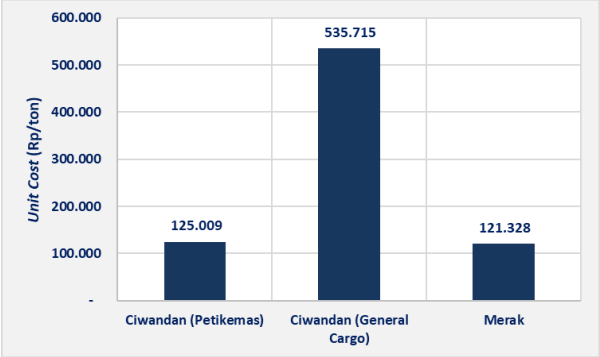

Figure 6. Comparison of Door - Port Costs from the Banten Industrial Area to the Port

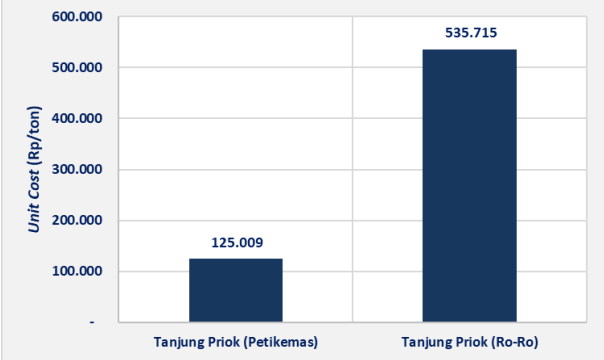

Figure 6. Comparison of Door to Port Costs from DKI Jakarta & West Java Industrial Areas to the Port

C. Transportation Cost Analysis

C.1. Door to Port Cost Analysis

The components of land transportation costs consist of fixed costs and variable costs. Fixed costs are specific to exist even if there is no shipping activity, such as truck rental fees and driver fees. Meanwhile, variable costs exist due to shipping, such as fuel, parking, etc.

The figure above shows the cost of shipping goods from each industrial area to each port of origin. Based on the calculations that have been made, the minimum cost per unit for cargo is the cheapest from Banten Province by shipping cargo from Merak Port at Rp121,328 per ton. Meanwhile, for the scenario of shipping by container ship, the minimum unit cost is in the industrial area in Banten to Ciwandan at Rp125,009 per ton.

C.2. Port to Port Cost Analysis

The cost component of sea transportation consists of several components, namely capital cost, operational cost, voyage cost, and cargo handling cost. The calculation of port-to-port costs is obtained from the total cost of shipping divided by the cargo to be sent to Bakauheni Port and Panjang Port, and vice versa.

The graph above shows that the Ro-Ro ship with the current route has a unit cost of Rp37,213 per ton, the minimum cost for sea transportation modes. Compared to other routes, the Bakauheni Port - Merak Port route is the closest route for crossing from Sumatera Island to Java Island.

TABLE 8.
CAPITAL COST

No.	Informations	Unit	Capital Cost
1	Route 1	Billion IDR/Year	2,18
2	Route 2	Billion IDR/Year	11,77
3	Route 3	Billion IDR/Year	12,99
4	Scenario 1	Billion IDR/Year	25,15
5	Scenario 2	Billion IDR/Year	6,77

The table above shows that the cheaper capital cost is Ro-Ro, which costs 2.18 billion/year. This is due to the size and number of vessels that affect capital costs.

TABLE 9.
OPERATIONAL COST

No.	Informations	Unit	Operasional Cost
1	Route 1	Billion IDR/Year	12,88
2	Route 2	Billion IDR/Year	15,81
3	Route 3	Billion IDR/Year	18,63
4	Scenario 1	Billion IDR/Year	76,26
5	Scenario 2	Billion IDR/Year	17,97

The table above shows that the cheapest operational cost value is on the Merak - Bakauheni route, with a cost of 12.88 billion/year.

TABLE 10.
VOYAGE COST

No.	Informations	Unit	Voyage Cost
1	Route 1	Billion IDR/Year	6,97
2	Route 2	Billion IDR/Year	334,85
3	Route 3	Billion IDR/Year	68,19
4	Scenario 1	Billion IDR/Year	46,84
5	Scenario 2	Billion IDR/Year	65,38

The table above shows that the cheapest voyage cost value is the roro ship from Merak, which costs 6.97 billion / year. It is caused by the frequency of ships serving cargo, affecting fuel costs, where fuel costs are the most influential cost in the total cost of the voyage..

TABEL 11.
CARGO HANDLING COST

No.	Informations	Unit	Cargo Handling Cost
1	Route 1	Billion IDR/Year	-
2	Route 2	Billion IDR/Year	-
3	Route 3	Billion IDR/Year	447,39
4	Scenario 1	Billion IDR/Year	1.092,67
5	Scenario 2	Billion IDR/Year	666,56

The table above shows that the cheapest cargo handling cost is for General Cargo ships with the Ciwandan - Panjang route, which is 447.39 billion / year. In comparison, Ro-Ro ships do not have cargo handling costs because there is no special cargo handling for this type of ship.

C.3. Port to Door Cost Anlysis

It can be seen in the figure above that the minimum unit cost from the destination port to the final destination, namely Bandar Lampung, is found in the new scenario, namely from Panjang Port to Bandar Lampung, which was initially carried out by sea using a container ship from Ciwandan Port. The cheapest unit cost for shipping goods from Java Island to Sumatera Island is through the route in scenario two, starting from the industrial area to Ciwandan Port and crossing to Sumatera Island through Panjang Port, which is IDR 315,466 per ton. Meanwhile, the most expensive unit cost is found on route 3, namely with the sea transportation mode of General Cargo ships from Ciwandan to Panjang, IDR 1,128,792 per ton. The time needed to travel from the industrial area to Merak and then proceed to Bakauheni is 8.6 hours, while from the industrial area to Ciwandan and proceed to Panjang for 9.4 hours, and the last route is from the industrial area to Tanjung Priok and proceed to Panjang for 12.2 hours. Meanwhile, for alternative routes in the new scenario using container ships, the route from Tanjung Priok to Panjang is 15.6 hours, and Ciwandan to Panjang is 9.4 hours. From this time comparison, the best alternative route is the first route, namely the Merak - Bakauheni route, because it has a faster travel time when compared to other routes.

IV. CONLUSIONS

From this paper, several things related to financing and weakening policy performance can be explained. From these conclusions, the results of this research can produce several suggestions and input for the government and society, including:

1. The Merak still dominates the current condition of cargo delivery from Java to Sumatera - Bakauheni crossing route with the truck transportation mode and then transported using the Ro-Ro ship. This is evidenced by the market share on the route dominating as much as 95% of the three existing routes. From the calculation of unit costs for cargo with current conditions, the following are obtained:
   a. Shipping on the Merak Port - Bakauheni Port route using ro-ro and tronton ships. Minimum cost with a unit cost of Rp324,721/ton.
   b. Shipments with the route Ciwandan Port - Panjang Port using general cargo ships and tronton. The minimum cost with the result is a unit cost of Rp1,128,792/ton.
   c. Shipping with the Tanjung Priok Port - Panjang Port route using roro and tronton ships. The minimum cost with the result is a unit cost of Rp667,489/ton.
2. In the new scenario created by looking at the potential of the port owned, an analysis of cargo delivery with a new mode is carried out, namely by Container Ship; the results obtained are as follows:
   a. Shipping on the Tanjung Priok Port – Panjang Port route uses container ships and trailers. The resulting minimum cost is a unit cost of Rp674,561/ton.
   b. Shipping on the Ciwandan Port – Panjang Port route uses container ships and trailers. The resulting minimum cost is a unit cost of Rp315,466/ton.
3. Based on the optimization that has been carried out, shipping cargo using scenario 2, namely on the Ciwandan Port route to Panjang by container ship, is the most effective compared to other routes for goods transportation because it has the minimum unit costs.

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