An Optimization Model for Container Capacity in New Sorong-Papua Port

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Abstract— ***The issue of the logistics system is an important issue for the state of Indonesia as an archipelago. Effort to distribute commodities to destinations across the island and attempted export of transport costs become cheaper and faster is a thing to be achieved by all parties including the government of Indonesia. Logistical problems in eastern Indonesia are more complex than the western part of Indonesia. For example, the cost of transport from eastern Indonesia is more expensive than the western part of Indonesia. Therefore, PELINDO II as the company seeks to make the country a new facility in the form of New-port that will replace the port of Sorong Sorong. New-Sorong port will be the largest port in Eastern Indonesia. This paper makes an optimization model with the goal of optimizing shipping container and determines how much capacity should be made to the port of New-Sorong.***

Keywords— Optimization Model, Container Capacity, and Hub-and-Spoke.

I. INTRODUCTION

Marine logistics is an important issue for Indonesia as an archipelago country with a diversity of natural resources and other commodities. Indonesia marine logistic performance is still not optimal compared with other ASEAN countries such as Singapore, Malaysia, Thailand, and Vietnam. The World Bank reports that Indonesia was ranked 75th out of 155 countries based on the logistic performance index in 2010 showed [1]. Indonesia's logistics cost is more expensive compared with other countries in ASEAN that nearly 27% of Indonesia's GDP product.

Logistics costs in eastern part of Indonesia are the highest (50%-60%) compared with the western (eg, Sumatera) and the central part of Indonesia that is only 30% (eg Bali and Makassar) [2]. Many experts believe that the constraints of infrastructure and facilities in eastern part of Indonesia are the main constraint. Especially in Papua, one of the problems is the geographical conditions of the land that comprises many mountains and tropical forest that do not support the use of ground transportation.

Based on data from the Directorate of Resource Potential Development and Infrastructure 2010 [3], there are some commodities that increase in the future, such as cashew nuts, cocoa, corn, coconut, oil palm, and others. From these commodities there are three potential export commodities namely oil palm, cocoa, and coffee.

Efforts to reduce the cost of ocean freight logistics especially in eastern Indonesia, the government in this case, played by PT. Pelabuhan Indonesia II will make New Sorong Port become the biggest port in eastern Indonesia with the capacity until 500.000 TEUs [4].

The existence of this new port is expected to not only increase the potential for inter-island trade commodities in Papua. But also consolidate container to offshore destination such as Australia, Papua New Guinea, and Timor-Timur. Therefore, the design of logistics network for New Sorong port is important to be studied. In this paper, the New-Sorong port is designed as the hub and feeders ports and comodity-producing districts is a spoke in logistics system.

Logistics network with hub-and-spoke system is a new and innovative system and can reduce logistics cost [5]. In the context of the research, hub-and-spoke system is also in accordance with the logistical flow phenomenon whereby New Sorong port as its hub and feeder ports and some commodity-prodicing region as its spokes. The determination of how much the optimal capacity of New Sorong port based on the number of containers received and sent by considering the costs of transportation and the possibility route from commodity location to the nearest port with its capacity and the possibility route from feeder port to the hub port become important to know for Pelindo and Marine Transportation Department.

Several researchers have conducted a study about hub-and-spoke system to develop and apply his theory to several different areas. For example, O'Kelly (1987) [6] is first expert that make hub-and-spoke system formula using quadrate-integer programming. Campbell (1994) [7] solve p-hub median problem to help selecting p-hub facility from existing facility set. Most of the researchers used a variety mathematical model such as path-programming, linear programming, and integer programming [8].

Hub-and-spoke system widely apllied in several transportation areas such as airport, trade party logistics, ports, etc. Baird (2006) [9] optimizes the container shipping in Europe with respect to the location of the hub. Arnold et al (2004) [10] made an integer programming formulation model for road and rail. Racunica and Wynter (2005) [11] optimize hub-and-spoke models to increase the market of railway transportation. Loureiro and Balston (1996) [12] made a bilevel model for diverse commodities as the basis for determining the investment policy in freight network.

Lim, et al (2012) [13] discussed the problem of

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allocating the amount of cargo for all paths to the shipping company to minimize transportation costs. Optimization method used is a mixed integer programming which is then followed by a tabu search algorithm as a comparison to help companies optimize the delivery to 2000 retail outlets spread across 33 countries. Holguin-Veras and Jara-Diaz, (1999) [14] conducted a study to determine the optimal allocation of the containers at the port. The problem is formulated by considering the physical properties required by each container and the capacity of the port using integer programming.

This study uses a hub-and-spoke system to conduct optimization model with the goal of optimizing the capacity of New Sorong port (hubs) that has been determined by taking into the cheapest transportation costs.

Efforts to determine these optimal logistic network route from the commodities locations to feeder port and to New Sorong port is important information to know. How government policies are needed for the development of ports in Papua region is expected to be based on the results of this study. The results of this study can be refered for local and central government to make the logistics cost in Papua can be reduced.

II. METHODE AND MODEL

Hub-and-spoke system is used to develop logistics system because relatively relevant between nature of problems. Integer programming is used to develop model to optimize transportation costs. The optimization of shipping costs was selected because the New Sorong port will be developed in order to optimize the shipping costs in Papua in the future.

Logistics network mapping has been used to model the hub and spoke network in Papua. The New Sorong port is the hub and the feeder ports are Manokwari, Fakfak, Biak, Jayapura, Merauke, and Nabire as spokes. The source is from an existing location in Papua's commodities to be shipped to other Island particularly Java. Hub and spoke systems in Papua are shown in Figures 1.

An optimization to minimize transportation costs can be formulated as follows:

Minimize :

$$\sum_{i=1}^{m}\sum_{j=1}^{n} d_{ij}\, x_{ij} + \sum_{j=1}^{n}\sum_{k=1}^{o} d_{jk}\, y_{jk} + \sum_{l=1}^{t}\sum_{k=1}^{o} d_{lk}\, z_{lk} \quad (1)$$

Subject to

$$\sum_{j=1}^{6} x_{ij} = p_i \quad (2)$$

$$\sum_{i=1}^{15} x_{ij} \le q_i \quad (3)$$

$$\sum_{k=1}^{1} y_{jk} \le q_j \quad (4)$$

$$\sum_{j=1}^{6} y_{jk} + \sum_{l=1}^{3} z_{lk} \le r_k \quad (5)$$

$$\sum_{k=1}^{1} z_{lk} \le s_l \quad (6)$$

$$\sum_{i=1}^{15} x_{ij} = \sum_{k=1}^{1} y_{jk} \quad (7)$$

$$x_{ij} \ge 0 \text{ and integer} \quad (8)$$

$$y_{jk} \ge 0 \text{ and integer}$$

Decision variables

i = Commodity-producing regions
j = Feeder port
k = Hub port
l = Outer Island
p = Number of commodity production by regio (TEUs)
q = Capacity of feeder port (TEUs)
r = Capacity of hub port (TEUs)
s = Number of container from outer island (TEUs)
x_{ij} = Number of containers which shipped from regions to feeder port (TEUs)
d_{ij} = Destinations of container shipping from regions to feeder port (km)
y_{jk} = Number of containers which shipped from feeder port to hub port (New Sorong) (TEUs)
d_{jk} = Destinations of container shipping which shipped from regions to feeder port (km)
z_{lk} = Number of container which shipped from outer island to hub port (TEUs)
d_{lk} = Destinations of container shipping which shipped from Outler Island to hub port (km)

Verification of the model has been done by looking at the absence of errors in the software Lingo. Data input used for the number of commodities in Papua as a source to be transported obtained from forecasting. As for commodities transported for delivery to outer islands and exports are (1) palm oil, (2) coffee and (3) cocoa. Linear regression method is used because no trend or seasonal pattern is found from data.

Increased commodity in the future is determined by calculating the projected third-commodity development projects such as MIPEE (Merauke Integrated Food and Energy Estate) project. The results are a basis for the input of three commoditites for the future. The MIFEE project is allocated on a land area of 1.2 million hectares which consists of 10 clusters Agricultural Production Center (KSSP) with a phased implementation. Commodity that needs shipping is only palm oil containers.

Running for the model optimization has been done using the software Lingo verified after the model (see table 1 and 2. The model was started years running from 2014 until 2024. Sensitivity analysis is done to know the factors that are sensitive to the model output. In this study, the factors tested by sensitivity analysis are port capacity factor and the distance factor delivery. For the capacity factor will be raised and lowered by 5% and 10%. As for the distance factor will be increased 10% and 20% annually.

III. RESULT AND DISCUSSION

A. Reciprocating Compressor Cycle

From the results of forecasting the amount of production of cocoa, coffee, and palm oil that has been converted in the number of containers transported a number of commodity areas. Amount of container increases from year to year because of the additional containers of commodities results for MIFEE project. If seen from the results of commodity forecasting, projections MIFEE project and also container from outside Papua has increased from year to year.

The amounts of palm oil container are more than the number of containers of coffee and cocoa commodity. Coffee and cocoa commodity only forecasting results obtained from the palm while the addition of forecasting also get extra from MIFEE projections starting in 2014. Starting in 2014 the amount of container oil palm has increased continuously with the addition of palm oil which started production in 2014 after the cropping

period. With the commodity of the project MIFEE will automatically increase the amount of container that can be sent from the territory of Papua. It will also affect the construction of facilities at ports, especially the port of New Sorong.

Running the optimization model is calculated starting in 2014 because in that year the Port of New Sorong will begin operation. Running the optimization model has produced good number of container shipments of commodity-producing region to the port of the feeder and feeder ports to the ports collection. Results showed that container shipments increased from 2014 until 2024.

From 2014 until 2017, the allocation of container shipments of commodity-producing region to the feeder ports showed the same results from the origin districts and destination ports. But in 2018, the allocation of delivery of the commodity-producing region to the port of collectors will be different with the allocation results in previous years. This is reflected in the allocation of container shipments from the Telukbintuni district.

In the range of 2014 to 2018, in the earlier years of the Telukbintuni district, containers sent only to the Manokwari Port. Whereas in 2018, sent also to the Manokwari Port, the container is also sent to the Fakfak port. In 2018, the amount of container port capacity while the more particularly Manokwari Harbor was not able to accommodate all of the container, so the container the rest will be allocated to the Fakfak Port, the nearest port after the Manokwari Port.

After that in 2019, running the model is done by increasing the feeder port capacity to be doubled due to the capacity of the port because it is not able to accommodate feeder container from Papua. In 2019 and 2020, the results of the allocation of container show the same results from the district of origin and destination ports. While starting in 2021, the allocation results showed different results as was the case in 2018. Results showed that the total container to the Port of New Sorong, both from outside the territory of Papua and Papua has yet to reach 500,000 TEUs.

This phenomenon can be used as an illustration to the port manager to manage the container shipping activities in the future especially for the feeder manager ports in Papua. The existence of additional projections of commodity container MIFEE implicates the rise in commodity production in Papua the feeder port should also consider about the addition of capacity to containers.

Feeder ports should have a development plan within a certain time. However this is not the case at ports in Papua. Therefore, the results of this study can be used as the basis for the port managers to plan the development of the port, such as an increase in material handling processes to increase speed of loading and unloading containers, expansion port for increasing lean ship, BOR increased with an increase in hours effective ports and other efforts.

B. The sensitivity analysis

Sensitivity analysis was conducted to test two factors such as (1) the container shipping capacity and (2) container shipping distances. Based on results of sensitivity analysis, the sensitivity of factors can be identified.

Increasing and decreasing each factors were setted for 5% dan 10%. If the port container capacity is increased 5%, the results of sensitivity analysis indicate that the allocation of container transportation from Commodity-producing regions to feeder port don't change in 2014 until 2017. Whereas in 2018, the results of allocations indicates that the destination transportation changed. The shipping transportation from Telukbintuni districts become two feeder ports such as Manokwari and Fakfak Ports. If the port capacity is increased 10%, the result is the allocation of container transportation also changed to Manokwari port (see table 3). If the port capacity is increased 10%, the result is the allocation of container shipping was changed become only Manokwari Port.

In 2018, the containers shipping to the Manokwari Port from Telukbintuni district become increase if port capacity in feeder ports also increases. Whereas, container shipping to Fakfak port from Telukbintuni district become decreases. Containers shipping to the Fakfak Port can be delivered when the capacity of Fakfak port also is increased. This is due to the increasing of the capacity of the port, including the Manokwari and New-Sorong (hub) Port.

When the port capacity reduced by 5% and 10%, the results of shipping container allocation change exactly in Manokwari and Fakfak Port. In 2018, containers transportation from Telukbintuni district to Manokwari Port will increase if the container port capacity is increased. The amount of containers shipping to the Fakfak Port will decrease if the port capacity is increased. This is due to the increasing of the port capacity, including the Manokwari and New-Sorong Port. The amount of container in Telukbintuni district was not able to be accommodated by the Manokwari Port and should be sent to the Fak-fak Port.

If the port capacity is reduced by 5% and 10%, shipping container allocation results is also change in Manokwari and Fakfak Port. In 2018, container transportation to the Manokwari Port that is delivered from Telukbintuni districts will increase if the increasing in the number of container port capacity is increased. While shipping containers to the Port Fakfak will decrease using the increasing in port capacityf factor. This is due to the increase of the port capacity, including the Port of Manokwari Port and New-Sorong Port.

If the port capacity reduced by 10 % by 2022, there is excess feeder ports capacity in Biak Port. This happens because the amount of container are not all able to be accommodated nearby feeder port with the capacity reductions of 10% .There is a feeder to the delivery to the port of distances Big M. It is also happened in the year 2023. Whereas in 2024, when the capacity was reduced by 5 % also found the results of the allocation of containers to the port with the distance Big M. This is caused by the reduced capacity will be an imbalance between the number of containers shipped to the port capacity, where the number of containers shipped remains but the port capacity will be reduced . The sheer number of containers will exceed the capacity of the port and will not obtain a feasible solution because there will be no terkirimkan containers. This violates or is not in accordance with the defined limits.

Port capacity factor is a sensitive factor because the output of the container shipping allocation changes if port capacity factor is increased or decreased by 5%.

The results of the sensitivity analysis pointed out that the sensitivity does not happen in all feeder ports. The container shipping allocation will change at the feeder ports that have a few port capacities and the amount of container shipping is a lot of container that should be delivered from comodity-producing districts to hub ports. Manokwari and Fakfak ports have a few port capacitites and many containers that should be shipped to hub port. In 2018, the sensitivy will be happen because the comodities will increase significanly and many containers from comodity-producing districts should be delivered to hub ports.

For container shipping distance factor is also analysed using the sensitivity analysis. The change of rutes for logistics system from the commodity-producing region to the feeder port and change of rutes of logistics system from feeder ports to the hub ports (New-Sorong port) are analysed using condition by the shipping distance factor is increased 5%, 10%, and 20%. The sensitivity results showed that the allocations and the route of containers shipping from comodity-producting regions until New-Sorong Port do not change.

The sensitivity analysis also conducted if the shipping distance factor is decreased 5%, 10%, and 20%. The sensitivity results showed that the allocations and the route of containers shipping from comodity-producting regions until New-Sorong Port also do not change.

Due to the sensitivity analysis for shipping distance factor does not affect significantly for the allocations and the route of containers. Its means that shipping distance factor is not sensitive to change the allocations and the route of container shipping from commodity-producing region to the port of feeders and from feeder ports to the hub ports (New-Sorong).

IV. Conclusion

From the research that has been done, then a number of conclusions that support the goals of the research are obtained. Conclusions will be divided into two main points, including the optimization model formulation and determination of a new facility in the logistics network to New Sorong port.

First, the optimization model of container shipments to the New Sorong port used a hub-and-spoke system approach. Based of hub-and-spoke system, the model is then constructed consisting of two stages, namely the delivery of containers of commodity-producing region to the feeder port and from the feeder port and also from outside Papua deliver to the hub port. Sea and land logistics network mapping to New Sorong port is made before the model is built. Optimal number of container shipments from commodity-producing region to the feeder port and from feeder ports to the ports collection will vary each year. From year to year the number of shipping containers at the feeder port is constantly increasing. Running the model made up to the year 2024 when the feeder port capacity cannot accommodate all the containers at this year.

Second, due to this phenomenon, then build new facilities or increased port capacity, especially in a feeder port, the Port of Port Fakfak Manokwari and precisely in the year 2019 and 2024 are needed to do. The new facility can be built such as increased BOR of port, add material handling facilities, expansion of ports, and so on.

As for some suggestions that can used by the port management or local government, which can make the results of this research to help make decisions in establishing a policy that would direct the delivery of the container in accordance with the results of running the allocation. Besides the port manager can make planning in the development of port capacity and also the addition of new facilities after getting an idea of the condition of the development of the container shipping from Papua so that all commodity-producing regions can be sent.

For the future research, the interval estimation for forecasting may be considered in this model. The selections of appropriate forecasting model are also considered such as regression methods, ARIMA model and others forecasting methods. This gradual rise can be accommodated by adding interval estimation so that later forecasting results obtained will be better

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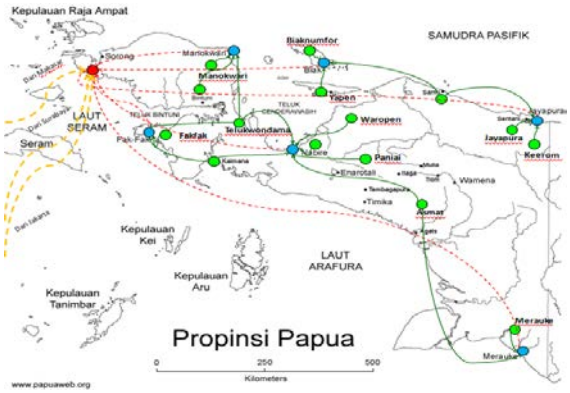

Figure 1. Papua's logistics networks from comodities location until New Sorong-Papua

TABLE 1.
THE RESULTS OF THE ALLOCATION FOR CONTAINER SHIPPING FROM COMODITY-PRODUCING DISTRICTS TO FEEDER PORTS IN 2014

No	Comodity-producting districts	Feeder ports					
		Jayapura	Manokwari	Fakfak	Biak	Merauke	Nabire
1	Manokwari		3322				
2	Telukbintuni		3210				
3	Keerom	8052					
4	Asmat						2079
5	Merauke					4204	
6	Fakfak			74			
7	Kaimana			28			
8	Telukwondama			37			
9	Biaknumfor				21		
10	Jayapura	591					
11	Yapen				63		
12	Nabire						159
13	Sarmi				64		
14	Waropen						66
15	Paniai						65

TABLE 2.
THE RESULTS OF THE ALLOCATION FOR CONTAINER SHIPPING FROM FEEDER PORTS TO HUB (NEW-SORONG) PORT IN 2014

Feeder Ports	New Sorong (Hub) ports
Jayapura	8643
Manokwari	6532
Fakfak	139
Biak	148
Merauke	4204
Nabire	2369
Makasar	7180
Surabaya	38294
Jakarta	2393

TABLE 3.
THE RESULTS OF THE SENSITIVITY ANALYSIS FOR CONTAINER SHIPPING CAPACITY

	Ports	New-Sorong (Hub) Port				
		(-) 10%	(-) 5%	0%	(+) 5%	(+) 10%
1	Jayapura	8643	8643	8643	8643	8643
2	Manokwari	6532	6532	6532	6532	6532
3	Fakfak	139	139	139	139	139
4	Biak	148	148	148	148	148
5	Merauke	4204	4204	4204	4204	4204
6	Nabire	2369	2369	2369	2369	2369
7	Makasar	7180	7180	7180	7180	7180
8	Surabaya	38294	38294	38294	38294	38294
9	Jakarta	2393	2393	2393	2393	2393