Optimum Container Network Route in Papua Region

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Abstract. Indonesia is an archipelagic country which around 77\% of its area is covered by water. Thus, developing good logistic system is needed especially in water-based route to distribute goods to the entire country. To develop national logistic system, government establishes Sea Highyway concept. This new concept is expected to lower the logistic cost for Eastern side of Indonesia especially Papua. The existing routing system has not yet established to reach all the seaport at Papua. This issue will still force air-based and land-based distribution system to take over most of its distribution activity. The main discussion of this research is to determine the most optimal routing system for container shipment in Papua. The determination of optimal routing system applies Integer Linear Programming for its approach. The scope of this research would be the container shipment originated from Tanjung Perak and Makassar. The seaports taken into account for this research consist of 3 hub ports and 7 feeder ports. Based on the calculation, 54 alternatives routing are determined and 22 of these are the most optimal routing system for container shipment in Papua.

Keywords: Sea highway, Container Routing System Development, Integer Linear Programming.

1. Introduction

Indonesia is an archipelago with 17,000 islands. Total area of Indonesia approximately reach 7.9 million km\(^2\) with 1.8 million km\(^2\) for lands, 3.2 million km\(^2\) for territorial sea, and 2.9 million km\(^2\) for Exclusive Economic Zone. According to the facts above, 77\% of Indonesia is water or three times larger than lands [1]. By 2016, Logistic Performance Index (LPI) show that Indonesia has dropped from rank 53 to rank 63. Indonesian Institutes of Sciences (LIPI) states that Indonesia is one of country that has the highest logistic cost in ASEAN. It costs 25 to 30\% from Gross Domestic Product [2]. Current Indonesian logistic system has not yet efficient because of the high shipping cost. It causes price disparity and development gap between Western side and Eastern side of Indonesia. Government takes effort to give balance for the mentioned issue with the establishment of a programme called Tol-Laut. The idea of Tol-Laut is not to build a highway above the sea, but to increase sea connectivity by routinely order ships to travel from Western side to Eastern side of Indonesia [3]. This developing concept is expected to strengthen shipping route for Eastern side of Indonesia [4]. Currently, container domestic trading stream is still focused on Western side of Indonesia as portrayed below.

According to the Government Regulation Chapter 6 No. 20 Year 2010, sea transportation activities are commenced constantly and regularly, also able to be supplemented with incidental route. The domestic sea transportation activities performed in network route [5]. Currently, government has
developed shipment network route through Tol-Laut. Unfortunately, there are many seaports in Papua excluded from the network. The container shipment to Eastern side of Indonesia mostly done from Tanjung Perak port and Makassar port. Tol-Laut programme that supports container shipment to Papua are figured below by the red line.

![Domestic Trade Flows For Container Traffic in Indonesia](image1)

**Figure 1.** Overview of Trade Flows for Container Traffic in Indonesia.
(Source: Development of Sea highway in IDRJMN 2015-2019 and Implementation 2015)

![Mapping of Sea highway Route in Papua](image2)

**Figure 2.** Mapping of Sea highway Route in Papua.
(Source: Director General of Sea Transportation – Ministry of Transportation)

This research is different from any other existing route determination research. In example, [6] did route determination for medical help distribution. [7] did route determination for employee-serving bus. [3] did container route determination using hub and spoke system. [8] constructed sea transportation routes in Sumatra with Sumatran Ring. All of the research mentioned above was done for the same objectives, it is route determination. However, the object of this research differs from them. Little number of research discussing this topic is the main reason for this research. The objective is to develop optimal container shipment routes from 2 major seaports in Indonesia (Tanjung Perak port and Makassar port) to hub ports and feeder ports in Papua. By the result, it is expected to minimize the logistic cost so the commodity price in Papua would lower.

2. Methods
Structured and systematic flow of research should be conducted to gain a more comprehensive result. Collect data is the first step, followed by the formulation of mathematic model and constraints. Choices of alternative routes determination done after that and will be continued to the calculation of total shipping cost. Determination of optimal shipping route will be the last step.
2.1 Data Collection
Source of data for this research comes from primary and secondary data. Primary data collected by conducting interviews and will be a qualitative data. Existing applied sea routes and container shipment system are one of the questions to gain deeper knowledge about current condition. Meanwhile, secondary data is gathered from Ministry of Transportation, Research Center of Ministry of Transporation, official website of PT. Pelabuhan Indonesia, and application to determine distance among ports. Example of secondary data are goods distribution data through seaport in year 2016, seaport cost, distance among ports and seaports name. Table 1 shows the list of seaports taken into account in this research. The location of port members shown by picture 3.

Table 1. The Posts Member in Case Study.

| Major Port       | Hub Port in Papua | Feeder Port in Papua |
|------------------|-------------------|----------------------|
| Name             | Notation          | Name                 | Notation |
| Tanjung Perak    | A1                | Sorong               | B1       |
| Makassar         | A2                | Jayapura             | B2       |
|                  |                   | Merauke              | B3       |
|                  |                   | Fak-Fak              | C1       |
|                  |                   | Kaimana              | C2       |
|                  |                   | Manokwari            | C3       |
|                  |                   | Biak                 | C4       |
|                  |                   | Amamapare            | C5       |
|                  |                   | Nabire               | C6       |
|                  |                   | Serui                | C7       |

2.1.1 Mathematical Model and Constraints Formulation
To process data, adjusted mathematical model is constructed. It is the container shipment system in Indonesia. Next, constraints are constructed to support the mathematical model.

2.1.2 Route Alternatives Determination
Once the mathematical model and constraints has fully constructed, then route alternatives are determined. The determination is based on container shipment flow data and load capacity of the ship especially for the shipping from hub port to the feeder port and also from feeder port to the feeder port. Overload is not allowed, so if one ship has already reached its load limit, then the ship will travel back from the last feeder port to the hub port. Type of ship taken into account for this research is 1000 TEU ship traveling from major port to hub port and 700 TEU ship travelling from hub port to feeder port. Moreover, route alternatives determination also take concern to constraints.
2.1.3 Calculation of Total Shipping Cost
From the route alternatives, then total shipping cost calculation can be done. Total shipping cost consist of cost components. Hence, calculating all component of the cost should be done first. They are ship operational cost, travelling cost, port cost, main route cost, and hub route cost.

2.1.4 Optimal Shipping Route Decision
This step followed after the previous step has cleared. Determination of optimal shipping route is decided by comparing total cost from each of the alternatives. The chosen route is to have the lowest cost of total shipping cost.

2.2 Mathematical Framework
Optimal shipping route determination would be conducted in this research. The model used in this research developed from [9] to determine objective function and constraints in data processing.

\[ S_{tm} = \frac{DIS_{m}}{SpV} \times 24 \]  \hspace{1cm} (1)
\[ S_{tf} = \frac{DIS_{f}}{SpV} \times 24 \]  \hspace{1cm} (2)

Equation (1) explains the function of travelling time from major port to hub port, and equation (2) expresses the function of travelling time from hub port to feeder port and also from one feeder port to another feeder port. This calculation is influenced by distance between ports and speed of the ship.

\[ CV_{TV} = CV_{TV} \times L \times S_{tm} \]  \hspace{1cm} (3)
\[ CV_{TV} = CV_{TV} \times L \times S_{tf} \]  \hspace{1cm} (4)

Equation (3) expresses the function to determine total operational cost applied to the ship travelling from major port to hub port while equation (4) explains the total operational cost for the ship travelling from hub port to feeder port and among other feeder port. This calculation to determine operational costs is influenced by the amount of load and streaming time.

\[ SC_{m} = CV_{TV} \times S_{tm} \]  \hspace{1cm} (5)
\[ SC_{f} = CV_{TV} \times S_{tf} \]  \hspace{1cm} (6)

Equation (5) is expressing cost expenditure to travel from major port to hub port. Equation (6) is the function to determine cost expenditure to travel from hub port to feeder port and among other feeder port. This calculation to determine sea cost is influenced by the length of time to sail

\[ SC_{m} : \text{Sailing cost from major port to hub port (IDR/day)} \]
\[ SC_{f} : \text{Sailing cost from hub port to feeder port or feeder port to feeder port (IDR/day)} \]
\[ CV_{TV} : \text{Total vessel daily operating costs for ship 1000 TEU (IDR)} \]
\[ CV_{TV} : \text{Vessel daily operating cost for ship 700 TEU (IDR/TEU/day).} \]
\[ CV_{TV} : \text{Vessel daily operating cost for ship 700 TEU (IDR/TEU/day).} \]
\[ L : \text{Load (TEU)} \]
\[ S_{tm} : \text{Mainline streaming time (day).} \]
\[ S_{tf} : \text{Feeder streaming time (day).} \]
Equation (7) is the function describing the cost of loading activity in origin port and unloading activity in destination port. This calculation to determine port cost is influenced by origin port cost, destination port cost and the amount of load.

\[ PC = Port \ Cost \ (IDR) \]
\[ PC_a = Origin \ port \ cost \ (IDR/TEU) \]
\[ PC_t = Destination \ port \ cost \ (IDR/TEU) \]
\[ L = Load \ (TEU) \]

Equation (8) expresses the function of container shipping cost from major port to hub port.

\[ MC = SC_m + PC \] \quad (8) \]

Equation (9) is the function to determine container shipping cost from hub port to feeder port and also among other feeder port.

\[ FC = SC_f + PC \] \quad (9) \]

Equation (10) is the function to calculate the shipping cost for one route consisting of shipment from major port to hub port, hub port to feeder port and also among other feeder port.

\[ TC = MC + \sum FC \] \quad (10) \]

Minimum:
\[ \sum \sum \sum T_C abc X_{abc} \]

Constraints

- Ship will be allowed to travel to each feeder port only once for one container shipping route.
\[ \sum c = 1 \]

- Overload is not allowed when shipping container from major port to hub port in one shipping route.
\[ \sum d i \sum a \sum b \sum c X_{abc} \leq L \]

- Overload is not allowed when shipping container from hub port to feeder port in one shipping route.
\[ \sum d i \sum a \sum b \sum c X_{abc} \leq L \]

- Ship from the last feeder port will travel back to hub port if load has reached its limit.
\[ \sum a \sum b \sum c X_{abc} \sum a \sum b \sum c \geq L \]

- Binary number will be used for decision variable.
\[ Y_k \in [0,1] \]

\[ X_{abc} = 1, \ if \ travelling \ the \ route \]
\[ X_{abc} = 0, \ if \ not. \]
Whereas:
- $N_a$: The set of major ports $a$ in the total ports.
- $N_b$: The set of hub ports $b$ in the total ports.
- $N_c$: The set of feeder ports $c$ in the total ports.
- $TC_{abc}$: Total costs from major port $a$ via hub port $b$ to feeder port $c$ (IDR).
- $X_{abc}$: Flow fraction from major port $a$ via hub port $b$ to feeder port $c$.

### 3. Analysis and Results

In this research the optimal container shipping route will be designed based on the lowest minum total shipping cost. There are variable costs required for the total amount of shipping costs. Variables-variables cost are operating costs that according with needs, ports costs, major costs, port cost, origin post cost, destination port costs, feeder costs, and sailing costs. In this research, the development of the model from previous research is adding the charge to the mathematical equation in determining operational costs, and ports costs. For determination operating costs obtained by the ship to operate when travelling from one port to another. Operating costs are adjusted to the amount of cargo carried by the ship and also the length of the time to sail. Thus, the more cargo carried and also the longer the time to sail, it will affect the amount of operational costs of the ship needed. Whereas to determine port costs is the handling at the port both from the origin port and destination port. The intended container handling costs is the container loading costs at the port of origin when it wants to ship and the costs of container loading when arriving at the destination port. The results of the calculation port costs are influenced by the amount the cargo loaded and unloaded. To determine the optimum delivery route, alternative routes are first made. Alternatives routes are made based on the flow of container shipping and adjusted to the ships payload capacity. The load cannot be greater than the capacity of the ship. To conduct calculation, alternative routes are made and resulting in 54 route alternatives. Next, total shipping cost is calculated for each of the alternative route. Table below is the recapitulation of total shipping cost for each of the alternative.

#### Table 2. Recapitulation of Total Shipping Cost.

| No | Alternative          | Total Delivery Cost (IDR) | No | Alternative          | Total Delivery Cost (IDR) |
|----|----------------------|---------------------------|----|----------------------|---------------------------|
| 1  | a₁-b₁-c₁-c₅-c₆-b₁   | 2,411,456.146             | 28 | a₁-b₂-c₁-c₂-c₃-b₃   | 2,122,577.753             |
| 2  | a₁-b₁-c₃-c₅-b₁      | 2,481,038.147             | 29 | a₁-b₁-c₅-c₂-c₁-b₃   | 1,589,406.565             |
| 3  | a₁-b₁-c₃-c₇-b₁      | 2,358,813.160             | 30 | a₂-b₁-c₁-c₂-c₃-b₃   | 1,729,792.795             |
| 4  | a₁-b₁-c₄-c₅-b₁      | 2,225,711.531             | 31 | a₂-b₁-c₃-c₄-c₆-b₁   | 2,316,958.269             |
| 5  | a₁-b₁-c₄-c₇-b₁      | 2,396,880.592             | 32 | a₂-b₁-c₃-c₆-b₁      | 2,386,941.456             |
| 6  | a₁-b₁-c₄-c₃-b₁      | 2,398,882.193             | 33 | a₂-b₁-c₃-c₇-b₁      | 2,264,667.990             |
| 7  | a₁-b₁-c₆-c₇-c₄-b₁   | 1,873,387.057             | 34 | a₂-b₁-c₄-c₆-b₁      | 2,131,593.609             |
| 8  | a₁-b₁-c₆-c₄-b₁      | 1,875,574.321             | 35 | a₂-b₁-c₄-c₇-b₁      | 2,302,771.348             |
| 9  | a₁-b₁-c₆-c₃-b₁      | 2,748,544.172             | 36 | a₂-b₁-c₄-c₃-b₁      | 2,304,694.380             |
| 10 | a₁-b₁-c₇-c₆-b₁      | 2,184,585.290             | 37 | a₂-b₁-c₆-c₇-b₁      | 2,088,847.707             |
| 11 | a₁-b₁-c₇-c₄-b₁      | 2,134,888.091             | 38 | a₂-b₁-c₆-c₄-b₁      | 2,092,909.885             |
| 12 | a₁-b₁-c₇-c₃-b₁      | 2,769,819.317             | 39 | a₂-b₁-c₆-c₃-b₁      | 2,654,486.651             |
| 13 | a₁-b₂-c₃-c₄-c₅-b₂   | 3,176,158.589             | 40 | a₂-b₁-c₇-c₆-b₁      | 2,090,599.824             |
| 14 | a₁-b₂-c₃-c₇-c₆-b₂   | 3,218,375.952             | 41 | a₂-b₁-c₇-c₄-b₁      | 2,090,599.824             |
Optimal route determination is decided by comparing the total shipping cost of alternative that share the same route. The chosen route will be the route that yield lowest total shipping cost. After comparing all the total shipping cost, 22 container shipment routes synergized with container shipping stream is obtained. Table 3 is the recapitulation of the optimal container shipment route.

Table 3. Recapitulation of the optimum container network in Papua.

| Route 1 | Alternative 7 | Tanjung Perak-Sorong-Nabire-Serui-Biak-Jayapura | Route 12 | Alternative 39 | Makassar-Sorong-Nabire-Manokwari-Sorong |
|---------|---------------|-----------------------------------------------|----------|---------------|----------------------------------------|
| Route 2 | Alternative 8 | Tanjung Perak-Sorong-Nabire-Biak-Sorong        | Route 13 | Alternative 41 | Makassar-Sorong-Serui-Biak-Sorong       |
| Route 3 | Alternative 14| Tanjung Perak-Jayapura-Manokwari-Serui-Nabire  | Route 14 | Alternative 42 | Makassar-Sorong-Serui-Manokwari-Sorong  |
| Route 4 | Alternative 15| Tanjung Perak-Jayapura-Manokwari-Nabire-Jayapura| Route 15 | Alternative 49 | Makassar-Merauke-Amamapare-Serui-Merauke|
| Route 5 | Alternative 16| Tanjung Perak-Jayapura-Manokwari-Biak-Jayapura | Route 16 | Alternative 50 | Makassar-Merauke-Serui-Merauke          |
| Route 6 | Alternative 18| Tanjung Perak-Jayapura-Manokwari-Biak-Jayapura | Route 17 | Alternative 51 | Makassar-Merauke-Amamapare-Serui-Nabire |
| Route 7 | Alternative 31| Makassar-Sorong-Manokwari-Biak-Jayapura        | Route 18 | Alternative 52 | Makassar-Merauke-Serui-Nabire-Merauke  |
| Route 8 | Alternative 32| Makassar-Sorong-Manokwari-Nabire-Sorong        | Route 19 | Alternative 54 | Makassar-Merauke-Serui-Amamapare-Nabire|
| Route 9 | Alternative 33| Makassar-Sorong-Manokwari-Serui-Sorong         | Route 20 | Alternative 51 | Makassar-Merauke-Nabire-Nabire          |
Conclusions

1. The total shipping costs in the model are affected by mainline costs, feeder costs and port cost. Port cost for each route can be different because they are affected by ship’ load.

2. Based on the flow of container shipping and adjusted to the ship’s payload capacity, it is obtained 54 alternative routes.

3. Based on the minimum total shipping cost and also the shortest shipping route, 22 optimum container shipping routes are selected from these 54 alternatives.

Suggestions for the development of this research in the future are container shipments added from Tanjung Priuk Port and Belawan Port.

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