Design of transportation and distribution Oil Palm Trunk of (OPT) in Indonesia

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Abstract. This research initiated from the area of oil palm plantations in Indonesia 13 million hectares, triggering consternation of abundance of oil palm trunk when garden regeneration is done. If 4 percent of the area is rehabilitated every year, almost 100 million cubic feet of oil palm trunk will be trash. Biomass in the form of pellets can be processed from oil palm trunk. It is then disseminated back to the palm oil processing area into biomass. The amount of transportation cost of the used ships and trucks was defined as parameters. So the objective function determined the type and number of ship and truck trips that provide the minimum transportation cost. To optimize logistics transportation network in regional port cluster, combining hub-and-spoke transportation system among regional port with consolidation and dispersing transportation systems between ports and their own hinterlands, a nonlinear optimization model for two-stage logistics system in regional port cluster was introduced to simultaneously determine the following factors: the hinterlands serviced by individual ports and transportation capacity operated between each port and its hinterland, cargo transportation volume and corresponding transportation capacity allocated via a hub port from an original port to a destination port, cargo transportation volume and corresponding transportation capacity allocated directly from an original port to a destination port. Finally, a numerical example is given to demonstrate the application of the proposed model. It can be shown that the solution to the proposed non-linear model can be obtained by transforming it into linear programming models.

1. Introduction

Literature on port logistics has only developed over the last two decades or so, for example, UNCTAD defines ‘third generation’ ports as those offering value-added services (e.g. warehousing, packaging) in addition to cargo handling, and ‘fourth generation’ ports as those that are separated geographically but with common operators or administration, such as by global multi-port companies [1]. Distinguished between general logistics services (GLS) and value-added activities or logistics (VAL) in an effort to assess the logistics potential of ports [2], analyzed the components, functions, and optimization principles of port logistics [3], port logistics development strategies [4],[5], advocated the application of ‘agility’ to the port environment, proposing that ports should be proactive rather than reactive along supply chains in a modern globalized world economy [6]. Performed a simulation study for the logistics planning of a container terminal in view of supply chain management [7]. Furthermore, much of the other literature advocates the future of ports as logistics centers and highlights their nodal role in the changing patterns of maritime and intermodal transport [8-11]. Most of abovementionedstudies related to port logistics focus on qualitative analysis and are lacking in systematic theoretic study. In addition to that, these studies only consider internal logistics in a port terminal or a port’s overall logistics instead of systematically considering overall logistics network in regional port cluster.
Research positions.

| NO | Researchers | Years | Objection Function                                                                                                                                                                                                 | Methode                                      |
|----|--------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------|
| 1  | Adler        | 2001  | [12] Develop, evaluate and select network hub and spoke on the airlines                                                                                                                                       | Non linear Programming                       |
| 2  | Suprayogi    | 2002  | [13] Forming clusters of a set of ports. Determine the number of container container flows, ship size and number of ships and containers used                                                                   | Mathematical Model                           |
| 3  | Sasaki       | 2003  | [14] Presents a formulation of a hub and spoke model with a capacity involving limited arc capacity as a hub capacity constraint                                                                               | Branch and bound dan relaxasi lagrang       |
| 4  | Chaug-Ink    | 2007  | [15] Using hub and spoke networks in formulating two objective models to determine optimal ship routes, ship size and display frequency by minimizing shipping costs                                                                 | Pareto                                       |
| 5  | Wang         | 2008  | [16] Optimizing the transport network on the logistics network within the internal port                                                                                                                      |                                               |
| 6  | Defi         | 2011  | [17] Determine the number of ships and trucks in a certain time unit, and determine the number of travel modes transportnya. The combination of Wang (2008) and Suprayogi (2002) | Mathematical Model                           |
| 7  | Defi         | 2017  | Design of Transportation and Distribution Oil Palm Trunk                                                                                                                                                    | MILP                                         |

The system discussed is the delivery of goods from hinterland to certain ports. The hinterland consists of eight hinterland and five ports. At each hinterland, trucks are used as a means of transportation. Trucks of a certain type take goods from areas in their hinterlands. Then the goods are brought to the port. From the port the goods delivered to the destination port by using a ship with a certain type as well. The ABCD region is defined as hinterland 1. IJLK is defined as hinterland 2. The CDFE region is defined as hinterland 3, and the KLNM region is defined as hinterland 4. As the initial hinterland, hinterland 1,2,3,4 can be seen in Figure 1.
Trucks are required to collect items from IJLK. When the truck's capacity has not been met the truck is required to collect goods from the PO area until it reaches its trucking capacity, so that the IJLPOLK area is defined as hinterland 6. While the OPNM area is defined as hinterland 8.

Furthermore, if the truck picking up the goods from the CDFE area has also not reached the capacity, then the truck can take additional goods from the GH area, so the GHDFEC area is defined as hinterland 7. While the ABHG area is defined as hinterland 5. For that hinterland 5, 6, 7, 8 is called an alternative hinterland as shown in Figure 2.

2. Materials and Methods

Problem Formulation

The conceptual model can describe the whole system represented in the model. All parameters, decision variables are determined to produce a specific purpose function. In this study, the parameters are the number of goods taken from all hinterland with a certain type of truck with a certain capacity also to be brought to the nearest port. From that port the item is redistributed to the destination port by
using a particular type of vessel and a certain capacity as well. The amount of transportation cost of used ships and trucks is defined as parameters, so it can be determined the type and number of vessel and truck travel that gives minimum value to total transportation cost. The conceptual model can be seen in Figure 3.

**Figure 3. Conceptual Model**

Figure 3. shows clearly that the objective function to be achieved is the total transportation cost with the decision variable is the selected hinterland, the number and type of vessel, the number of vessel trips, the number and type of truck, and the number of truck trips on selected hinterland later.

**Identification of Model Variables**

After making the conceptual model above, then in this research identification of notation and related variables to minimize total transportation cost incurred.

**Notation of purpose function:**

- \( B \) : Total Transportation Cost [Rp/week]
- \( I, j \) : Index for ports
- \( (I, j) \) : The relationship index between ports \( i \) and \( j \)
- \( K \) : Index of ship type
- \( L \) : Index of truck type

**Set Notation**

- \( M \) : The set of ports
- \( N \) : The set of hinterland
- \( A_p \) : Number of alternative hinterland for \( p \in I \)
- \( E_p \) : Number of hinterland except region \( p, p \in I \)
- \( I \) : Number of all hinterland allowed
- \( I_i \) : Number of hinterland owned by port \( i \)
Parameter
CT_{lp} : Transportation cost of l type truck at hinterland p [Rp / travel]
CS_{kij} : Ship cost type from port i to j [Rp / travel]
CV_{kij} : Cost of ship type k from port i to j [Rp / ton]
CM_{kij} : Maintenance costs of ship type k from port i to j [Rp / ship]
D_{pj} : Number of goods distributed from hinterland p to port j [ton / week]
J_{Hi} : The distance between hinterland p and port i [km]
J_{ij} : Distance to port i with j (i,j) [mile]
JMK_{ijk} : Minimum number of ship type k on link i to j

\[ \text{JMK}_{ijk} = \emptyset \left( \frac{J_{ij}}{24v_k + \xi} \right), \forall i, j \in M; k \in K \]

Ø : Number of weeks in a year [52 weeks / yr]
S_k : Ship k capacity [ton / ship]
ST_{lp} : Truck l capacity on hinterland p [ton / truck]
v_k : Speed of speed k [knot or mile/hour]
ξ : Operating ports per week [7 day]
VT : Truck l type speed [km/hr]

Decision Variable:
If the selected hinterland is z_p = 1 instead z_p = 0
\[ R_{ijk} : \text{Frequency of ship k from port i to j [times/weeks]} \]
\[ JMT_{lp} : \text{Number of type l trucks required for each hinterland p [truck]} \]
\[ T_{lp} : \text{Number of trips of type l trucks operating at hinterland p [times/week]} \]
\[ x_{ij} : \text{The number of items distributed from port i to port j [ton/week]} \]
\[ Y_k : \text{Number of ship type k required [ship]} \]
\[ z_p : \text{The variable that is conditioned as binary.} \]
If the selected hinterland is z_p = 1 instead z_p = 0

Final Model
After identification of the index notation, parameter notation and decision variable notation, then compiled the model to be built.

Function Purpose:
Minimize total transportation costs between two ports and transportation costs at each hinterland.

Min B = Ship Cost + Truck Cost

\[ \text{MIN } B = \sum_{i=1}^{M} \sum_{j \neq i}^{M} CS_{kij} R_{ijk} + \sum_{i=1}^{M} \sum_{j \neq i}^{M} CV_{kij} x_{ij} + \sum_{i=1}^{M} \sum_{j \neq i}^{M} CM_{kij} Y_k \]
\[ + \sum_{p=1}^{L} \sum_{l=1}^{L} CT_{lp} T_{lp} Z_p + \sum_{p=1}^{L} \sum_{l=1}^{L} CT_{lp} JMT_{lp} Z_p \]

Subject to:
\[ x_{i1} + \sum_{j=1}^{M} x_{ij} = \sum_{j=1}^{M} \sum_{p=1}^{M} D_{pi} z_p, i, j = 1,2, ..., M, i \neq j \quad (1) \]
\[ x_{1i} + \sum_{j=1, j\neq i}^{M} x_{ji} = \sum_{j=1}^{M} \sum_{p=1}^{i} D_{pj} z_p, \quad i,j = 1,2,\ldots,M, \quad i \neq j \]  
\[ x_{ij} \leq \sum_{p=1}^{i} D_{pj} z_p, \quad i,j = 0,1,2,\ldots,M, \quad i \neq j \]  
\[ x_{ij} \leq \sum_{k=1}^{i} J M K^k R^k_{ij} S^k, \quad i,j = 1,2,\ldots,M, \quad \forall i,j \in M \]  
\[ Y^k = \sum_{i} \sum_{j} J M K^k R^k_{ij}, \quad \forall k \in K; \forall i,j \in M \]  
\[ \left( \sum_{\{i|\{i\cup j\}\in M\}} R^k_{ij} = \sum_{\{i|\{i\cup j\}\in M\}} R^k_{ji} \forall k \in K; \forall i,j \in M \right) \]  
\[ \sum_{i=1}^{M} D_{pi} z_p \leq \sum_{k=1}^{K_p} T_p^i S T_p^i, \quad p = 1,2,\ldots,l \]  
\[ J M T_p^i \geq \frac{T_p^i}{168 V T_i}, \quad \forall l, \forall p \]  
\[ \sum_{p=1}^{A_p} z_p = 1, \quad p = 1,2,\ldots,l \]  
\[ \sum_{p=1}^{E_p} z_p = 0, \quad p = 1,2,\ldots,l \]  
\[ \sum_{p=1}^{I} z_p = N \]  
\[ x_{ij} \geq 0, \quad i,j = 0,1,2,\ldots,M, \quad i \neq j \]  
\[ R^k_{ij}, Y^k, T_p^i J M T_p^i > 0, \text{ integers, } i,j = 0,1,2,\ldots,M, \quad p = 1,2,\ldots,l \]  
\[ z_p: \text{ If hinterland is selected } z_p = 1 \text{ otherwise } z_p = 0 \]

Constrains 1. is Ensure that the amount of goods distributed from port i to port hub plus total goods from each port i to port j equals the total number of items from the selected hinterland p to port i.
3. Results and Discussions

Data

The data used in this numerical example are data from Norita (2011) model and hypothetical data.

Data from Norita's model (2011).

The data from Norita (2011) model used are:

A. Data on the quantity of goods distributed (Dpj)

Within a week there is a total amount of goods that must be distributed from hinterland to port. In this case the port used is port 2, port 3, port 4, while port 1 is used as a hub port, as shown in Table 1 and Figure 1.

Table 1. Number of items distributed from hinterland to all ports [ton / week].

| H | Area | Port 1 | Port 2 | Port 3 | Port 4 | Port 5 |
|---|------|-------|-------|-------|-------|-------|
| 1 | ABCD | 0     | 1230  | 1290  | 1770  |
| 2 | IJLK | 1100  | 0     | 850   | 3180  |
| 3 | CDFE | 1160  | 1020  | 0     | 4290  |
| 4 | KLN  | 580   | 1550  | 2440  | 0     |
| 5 | ABGH | 0     | 560   | 670   | 910   |
| 6 | IJLPOK | 1400 | 0     | 2180  | 3650  |
| 7 | GHDFEC | 1160 | 1650  | 0     | 5200  |
| 8 | OPNM | 310   | 780   | 1250  | 0     |

a. Type and capacity of ship ( k dan V )

For delivery between ports used two types of ships with different capacity and speed. Can be shown with Table 2.

Table 2. Type, capacity and speed

| Ship | Capacity S (ton) | Speed V (knot) |
|------|-----------------|---------------|
| 1    | 5000            | 8.01          |
| 2    | 8000            | 10.25         |

b. Ship Cost

The cost of the vessel is the cost incurred when the vessel travels from the original port to the destination port, as shown in Table 3.

Table 3. Operating cost of ship from port of origin to destination port (0000000 IDR/week).

| Port | 2    | 3    | 4    | 5    | 1    |
|------|------|------|------|------|------|
| 1    | 0.75 | 0.90 | 0.60 | 0.70 | 0.80 |
| 2    | 0    | 1.5  | 2.0  | 2.5  | 1.8  |
| 3    | 1.2  | 0    | 0.9  | 1.5  | 2.5  |
| 4    | 1.5  | 2.0  | 1.3  | 1.8  | 0    |
| 5    | 0.8  | 1.2  | 1.6  | 2.0  | 2.5  |
| 1    | 0.75 | 0.90 | 0.60 | 0.70 | 0.80 |


c. Type, capacity and speed of truck (ST dan VT)

Type, capacity, and speed of truck can be seen in Table 4.

| Jenis Truk | Kapasitas truk V(ton) | Kecepatan truk VT(km/jam) |
|------------|------------------------|---------------------------|
| 1          | 3                      | 30                        |
| 2          | 5                      | 35                        |

| Truk | Hinterland | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|------|------------|----|----|----|----|----|----|----|----|
| 1    | 0,30       | 0,40 | 0,35 | 0,10 | 0,10 | 0,35 | 0,40 | 0,10 |
| 2    | 0,40       | 0,50 | 0,40 | 0,15 | 0,15 | 0,50 | 0,45 | 0,15 |

d. Truck cost (CT)

The cost of the truck is the cost incurred for truck operations starting from picking up the goods from the areas of a particular hinterland and delivering it to the nearest port within a week. The cost of the truck can be seen in Table 5.

| Truk | Hinterland | 1  | 2  | 3  | 4  | 5  | 6  | 7  | 8  |
|------|------------|----|----|----|----|----|----|----|----|
| 1    | 0,30       | 0,40 | 0,35 | 0,10 | 0,10 | 0,35 | 0,40 | 0,10 |
| 2    | 0,40       | 0,50 | 0,40 | 0,15 | 0,15 | 0,50 | 0,45 | 0,15 |

Hypothetical Data

There are some hypothetical data used are:

a. Distance between ports (I_p)

Distance between ports is the distance between the origin port, port hub and destination port in a cluster port. Distance between ports can be seen in Table 6.

| Port | 1   | 2   | 3   | 4   | 5   |
|------|-----|-----|-----|-----|-----|
| 1    | 0   | 236 | 392 | 794 | 521 |
| 2    | 236 | 0   | 189 | 591 | 677 |
| 3    | 392 | 189 | 0   | 458 | 823 |
| 4    | 236 | 794 | 591 | 0   | 1118|
| 5    | 521 | 677 | 823 | 1118| 0   |

b. The distance between hinterland to port

The distance between the hinterland to the port is the distance between the circumference of the hinterland through which the boundary moves toward the port can be seen in Table 7.

Table 7. The distance between hinterland to port(km)
Model Solutions

After the data obtained from research data Norita (2011) and hypothetical data, which is required to complete the model. Then the data input process into the model. The search for an optimal solution for this example is done using the V10 Lingo program where lingo programming is based on a research operational method of Branch and Bound Algorithm (ABB). The solution obtained is nonlinear integer. This model can be made in linear form in a way, the model is made 4 cases, where set combination of 8 hinterland which support certain part:

Table 8. Cases of possible hinterland selected

| Kasus | Hinterland |
|-------|------------|
| 1     | 12340000   |
| 2     | 10100101   |
| 3     | 01011010   |
| 4     | 00001111   |

So we get a solution that is global optimal.

Table 9. Comparison of calculation results from 4 cases

| Notation | Decision Variables | Hinterland selected |
|----------|--------------------|---------------------|
| B        | Total cost         | 1,515,150 1,659,000 | 1,440,500 1,583,900 |
| Y        | Ship type 1        | 3 4 5 6       |
|          | Ship type 2        | 2 2 1 1       |
| R_{ijk}  | Frequency of links | Ship type 1 with 1 trip |
|          | (1,2)              | Ship type 1 with 1 trip |
|          | Frequency of links | Ship type 2 with 1 trip |
|          | (1,3)              | Ship type 2 with 1 trip |
|          | Frequency of links | Ship type 2 with 1 trip |
|          | (1,4)              | Ship type 1 with 1 trip |

So we get a solution that is global optimal.


4. Conclusions

Of the four cases above which provide the minimum value is case 2, with the results are as follows: The solution is optimally global with transport costs being 1440,500. For the number of ships type one needed is 10 vessels and 2 units of ship type 2. Table 10. shows the frequency of ship trips per week in sending goods by ship of choice from the port of origin to the destination port with details as follows:

Ship type 1 as much as 1 unit sending goods as much as 2840 tons from port 1 to the port hub that sent 1 trip. Ship type 2 as much as 1 unit sending goods as much as 3760 tons from port 3 to port hub that sent 1 trip. Ship type 1 as much as 2 units sending goods as much as 3960 tons from port 4 to port hub that sent 2 trips. Ship type 1 as much as 2 times the journey sending goods as much as 9290 tons from port 5 to port hub.

Conversely from the port hub to port 2 items shipped as much as 2140 tons with 1 boat trip type 1. From the port hub to port 3 items shipped as much as 5130 tons with 1 trip with ship type 2. From the port hub to port 4 items shipped as much 8010 tons with 2 trips by ship type 1. From port hub to port 5 items shipped as much as 4570 tons with 2 trips by ship type1, as shown in Figure 2.

| links (1,5) | Frequency of links (2,1) | Frequency of links (3,1) | Frequency of links (4,1) | Frequency of links (5,1) |
|------------|--------------------------|--------------------------|--------------------------|--------------------------|
| ship type 1 with 1 trip | 2 trip | ship type 1 with 1 trip | 2 trip | ship type 1 with 1 trip | 2 trip |
| ship type 2 with 1 trip | 2 trip | ship type 2 with 1 trip | 2 trip | ship type 1 with 1 trip | 2 trip |
| ship type 1 with 2 trip | 2 trip | ship type 1 with 2 trip | 2 trip | ship type 1 with 2 trip | 2 trip |

| T2 | Type truck 2 | 54 | 54 | 65 | 27 |
| 65 | 82 | 91 | 27 | 91 |
| 82 | 30 | 101 | 1001 |

| JMT | Truck Frequency 2 | 858 | 858 | 1026 | 428 |
| Truck Frequency 2 | 1026 | 1294 | 914 | 1446 |
| Truck Frequency 2 | 1294 | 1446 | 428 | 1602 |
| Truck Frequency 2 | 914 | 468 | 1602 | 468 |

Table 10. Number of ship travel and ship type used for case 2
Next to the hinterland section can be seen in Table 10, where between hinterland 1 and hinterland 5 selected as supplier for port 2 is hinterland 5. For hinterland 2 and hinterland 6 selected as supplier for port 3 is hinterland 6. Next to hinterland 3 and hinterland 7 selected as a supplier for port 4 is hinterland 7. While hinterland 4 and hinterland 8 are selected as suppliers for port 5 is hinterland 8. 

There are similarities between the types of trucks used in transporting goods on selected hinterland ie truck type 2, with varying amounts. At hinterland 5 the number of trucks used is 27 trucks with 428 trips. At hinterland 6 the number of trucks used is 91 trucks with 1446 trips. At hinterland 7 the number of trucks used is 101 trucks with 1602 trips. At hinterland 8 the number of trucks used is 30 with 468 trips.

| NO | Hinterland of origin | Port of destination | Type truck | Number of trips | Number of trucks |
|----|----------------------|---------------------|------------|----------------|-----------------|
| 1  | 2                    | 3                   | 2          | 1026           | 65              |
| 2  | 4                    | 5                   | 2          | 914            | 58              |
| 3  | 5                    | 2                   | 2          | 428            | 27              |
| 4  | 7                    | 4                   | 2          | 1602           | 101             |

Table 11. Hinterland was selected and the number of trucks and truck trips for case 2

Table 11. explains that on hinterland 2 used type 2 truck of 65 units with the number of travel 1026 times. At hinterland 4 used type 2 truck as many as 58 units with the number of trips 914 times. At hinterland 5 used type 2 truck of 27 units with the number of trips 428 times. At hinterland 2 used type 2 truck counted 101 units with the number of trips 1602 times.

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