Logistics System of Exported Fishery Product: a Case Study of Fisheries Centre in Natuna

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Abstract. As one of potential fishery areas in Natuna, the Integrated Marine and Fisheries Center (SKPT) has been producing the fishery commodities of 350,000 kg per month. Currently, SKPT Natuna is cooperating with Japan to export one of fishery products, which is frozen octopus. However, the existing export logistics system is considered ineffective and inefficient due to the higher logistics cost and higher lead time. This study aims to develop logistics system model with respect to obtain the optimum travel duration and the schedule of ship arrival at each transit point by considering minimum unit cost. The method used is the Shortest Path Problem [1] to optimize 24 cargo delivery schedules for one year so that the optimum routes defined are different for each delivery schedule depending on the availability of ship. The result shows the total duration of the delivery required is 32 days and the total shipping cost is Rp. 31.3 million/TEU. Thus, the optimum route obtained is able to reduce the shipping cost of frozen octopus by 45% and shorten the lead time by 15% compared to the current logistics system.

Key words: Cold Chain Logistics, Frozen Octopus, Logistics Cost, Shortest-Path Problem

1. Introduction

Natuna Regency as one of the largest potential fishery areas in Indonesia produced 2.687.8 tons of fishery products in 2017. There were nine types of fishery products with the largest number during 2017, namely grouper fish (301.9 tons), kurisi bali (233.1 tons), red snapper (208.9 tons), kurisi (252 tons), sea catfish (318.1 tons), octopus (138.5 tons), squids (237.9 tons), tuna (311.2 tons), and flying fish (451.7 tons) [2]. Due to this area has the highest potential fishery resources, the Ministry of Marine Affairs and Fisheries in Natuna Regency had established the Integrated Marine and Fisheries Center (SKPT) in this area. The establishment of SKPT Natuna has purpose to increase the economy of fishermen in Natuna regency after facing economic problem[3].

The main export commodity at SKPT Natuna is frozen octopus, where Japan is the biggest importing country, which imports it regularly in every month [2]. During the distribution process of frozen product, the cold chain logistics should take into account to keep the product in cold temperature until the end customer received [4] [5]. Thus, it effects on the higher logistics cost and the higher lead time from Natuna to Japan. In order to solve this problems, optimization of logistics system is required to create the optimum route under several constraints, such as: ship schedule, ship capacity, product quality in term of handling the cargo, etc dan to obtain the minimum of total logistics cost[6].

2. Problem definition and datasets

SKPT Natuna is collaborating with the Indonesian Public Fisheries Company (Perum Perindo) for exporting product to Nagoya, Japan. This collaboration has been established since 2020 and will be continuing for the next few years. Japan is currently the main importer of frozen octopus product from
SKPT Natuna. This shipment is scheduled in twice a month, while the export volume of frozen octopus in one shipment is 15 tons. Moreover, reefer container trucks and container ships are used during this shipments because frozen octopus products can only be transported in reefer container to keep the standard temperature of frozen octopus in -18°C. Those trucks are used in the delivery of cargo from SKPT Natuna to the Selat Lampa Maritime Highway Port, while container ships are used in the delivery of cargo from Natuna to Japan which passes through several transit points. The existing route of fishery product shipments from Natuna to Japan is SKPT Natuna - Lampa Strait Maritime Highway Port – Tanjung Priok - Tanjung Pelepas - Hong Kong - Shanghai - Kobe – Nagoya. Transportation cost from each port affects on the total logistics cost significantly, whilst storage cost and cargo handling cost are the parameter of port competitiveness[7]. Hereby, the datasets used in this study as below:

Table 1. Locations (Nodes).

| Code | Location       | Code | Location |
|------|----------------|------|----------|
| T1   | SKPT Natuna    | T11  | Nansha   |
| T2   | Pel. Tol Laut  | T12  | Yantian  |
| T3   | Pontianak      | T13  | Gwangyang|
| T4   | Belawan        | T14  | Tokyo    |
| T5   | Jakarta        | T15  | Shanghai |
| T6   | Tj. Pelepas    | T16  | Port Klang|
| T7   | PSA            | T17  | Xiamen   |
| T8   | Laem Chabang   | T18  | Kobe     |
| T9   | Hongkong       | T19  | Yokohama |
| T10  | Kaohsiung      | T20  | Nagoya   |

Table 2. Cost Component Belawan – PSA.

| Cost Component          | Value (IDR/trip) |
|-------------------------|------------------|
| Capital Cost            | 37,882,340       |
| Operating Cost          | 307,625,678      |
| Voyage Cost             | 1,103,792,019    |
| Cargo Handling Cost     | 2,090,400,000    |
| **Total Cost**          | **3,539,700.038**|
| **Unit Cost**           | **3,403.557**    |

Table 1 and Table 2 present the locations used in the analysis including the code of each location and cost components in the route of Belawan – PSA in IDR per trip, respectively. In addition, Table 3 depicts the name of vessel used in every route, which will use in the model to calculate the unit cost by considering the load factor of 70% for each vessel [8].

Table 3. Vessels and the routes.

| Route | Vessel       | Route | Vessel        | Route | Vessel   | Route | Vessel |
|-------|--------------|-------|---------------|-------|----------|-------|--------|
| T2 - T3 | KM. Logistik Nusantara 4 | T4 - T7 | MV. Meratus Medan 5 | T9 - T11 | MV. Nordmaas | T14 - T19 | MV. TS Tokyo |
| T2 - T4 | KM. Logistik Nusantara 4 | T4 - T16 | MV. Newark | T9 - T12 | MV. MCC Qingdao | T15 - T18 | MV. Kuo Chang |
| T2 - T5 | KM. Logistik Nusantara 4 | T6 - T7 | MV. Tove Maersk | T9 - T15 | MV. JPO Pisces | T16 - T20 | MV. Bomar Renaissance |
| T3 - T7 | MV. Lintas Bengkulu | T6 - T9 | MV. PL Germany | T10 - T11 | MV. Filotimo | T17 - T20 | MV. Areopolis |
| T5 - T6 | MV. CMA CGM Bellini | T7 - T8 | MV. Nordlion | T11 - T9 | MV. Maersk Songkla | T18 - T20 | MV. One Olympus |
| T5 - T17 | MV. Bellavia | T7 - T10 | MV. Kmarin Azur | T11 - T14 | MV. MCC Cebu | T19 - T20 | MV. APL Pusan |
| T4 - T6 | MV. Kmarin Atlantica | T7 - T16 | MV. Lucky Merry | T12 - T13 | MV. Chesapeake Bay | T13 - T19 | MV. Merkur Horizon |

3. Research Methodology

3.1. Stages of study

There are six stages needed to solve the problems in this study as follows:
Identify the main problem
The first step is to identify the main problems occurred in the distribution of fishery export products from Natuna to Japan. Based on the data showed the problems are high logistics cost and long lead time during the distribution process.

Analyze the current situation
This stage should be conducted in order to find the current logistic system in Natuna, the existing route, the number of fishery products exported, the type of modes used, the initial logistic cost and the current lead time.

Define the alternative routes
Due to inefficiency occurred in the current route, thus alternative routes should be defined to obtain the minimum unit cost and the shorten lead time.

Determine the optimum route
There are three factors considered in the analysis, such as: logistic costs, delivery time and quality of product. The type of fishery export product is frozen octopus, so that the theory of cold chain logistic should take into account when builds up the model. Optimum route will be determined by minimizing the unit cost of distribution. Afterwards, total cost can be calculated by considering the number of export products and the amount of unit cost.

Compare the results
After determining the optimum route, the results should be compared by the current situation with respect to total logistic cost and lead time.

Provide conclusion and future research
The conclusion will provide the optimum route selected and the comparison between current situation and the model result. Moreover, the suggestion regarding future research will be add in this stage.

3.2. Mathematical model
This study focuses to obtain optimum solution for octopus product shipment. Mathematical model for the optimization is as below:

Objective Function:

\[
\text{Min } Z = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{k=1}^{K} X_{ijk} \cdot C_{ijk} + X_{ijk} \cdot \left(D_{ijk} - A_{ijk}\right) \cdot AC_{ijk} 
\]

Subject to:

\[
\sum_{k=1}^{K} \sum_{j=1}^{J} X_{ijk} = 1 
\]

\[
\sum_{k=1}^{K} \sum_{i=1}^{I} X_{ijk} = 1 
\]

\[
\sum_{k=1}^{K} \sum_{i=1}^{I} X_{ijk} = 0, \quad j = 1, 2, ..., J 
\]

\[
\sum_{k=1}^{K} \sum_{j=1}^{J} \sum_{i=1}^{I} D_{ijk} - A_{ijk} \geq 0
\]

\[
C_{ijk} = \frac{CC_{ijk} + OC_{ijk} + VC_{ijk} + CHC_{ijk}}{Q_{ijk}}
\]
Where:

- \( X_{ijk} \): Path of origin \( i \) destination \( j \) transportation mode \( k \) (1 = path is chosen, 0 = path is not chosen)
- \( C_{ijk} \): Cost of origin \( i \) destination \( j \) transportation mode \( k \) (IDR/TEU)
- \( AC_{ijk} \): Container stacking cost (IDR/day)
- \( D_{ijk} \): Departure time transportation mode \( k \) from origin \( i \) destination \( j \)
- \( A_{ijk} \): Arrival time transportation mode \( k \) from origin \( i \) destination \( j \)
- \( CC_{ijk} \): Capital Cost of origin \( i \) destination \( j \) transportation mode \( k \) (IDR)
- \( OC_{ijk} \): Operating Cost (IDR)
- \( VC_{ijk} \): Voyage Cost (IDR)
- \( CHC_{ijk} \): Cargo Handling Cost (IDR)
- \( Q_{ijk} \): Vessel Capacity x load factor (TEU)

Equation 1 represents the objective function to minimize the unit cost. Equation 2 and 3 depicts the cargo must be shipped from the origin and must be delivered to the destination, respectively. Equation 4 presents for each destination selected must be chosen for the origin in the next trip. Equation 5 means the arrival of vessel must be defined before the departure of the next vessel used. Equation 6 shows the formula to determine the unit cost, which consists of capital cost, operating cost, voyage cost and cargo handling cost[9] [10].

4. Results and discussion
The optimization model solves the problem in SKPT Natuna, when the first shipment of frozen octopus is shipped on January, 1st 2020. The optimum routes is SKPT Natuna - Maritime Highway Port – Belawan - Port Klang – Nagoya. The details of this solution are as below:

| No. | Location                  | ETA    | ETD    | Transportation mode |
|-----|----------------------------|--------|--------|---------------------|
| 1   | SKPT Natuna               | 1/1/2020 | 1/1/2020 | Container truck     |
| 2   | Maritime Highway Port     | 1/1/2020 | 1/11/2020 | KM. Logistik Nusantara 4 |
| 3   | Belawan                   | 1/13/2020 | 1/15/2020 | MV. Newark          |
| 4   | Port Klang                | 1/19/2020 | 1/26/2020 | MV. Bomar Renaissance |
| 5   | Nagoya                    | 4/2/2020 | -      | -                   |

The total cost of this optimal solution is 32,605,806 IDR/TEU and lead time is 34.6. The details can be seen in Table 5 as below:

| Route                      | ETA cargo | ETD cargo | Waiting time (day) | Transport Time (day) | Total Waiting Cost (IDR) | Logistics Cost (IDR) |
|----------------------------|-----------|-----------|--------------------|----------------------|--------------------------|----------------------|
| SKPT Natuna - Pelabuhan Tol Laut | 1/1/2020 | 1/1/2020 | -                  | 0.3                  | 4,380,000                |                      |
| Pelabuhan Tol Laut - Belawan    | 1/1/2020 | 1/11/2020 | 9.7                | 2.6                  | 483,183                  | 6,491,764            |
| Belawan - Port Klang           | 1/13/2020 | 1/15/2020 | 1.5                | 3.9                  | 97,350                   | 4,068,135            |
| Port Klang - Nagoya            | 1/19/2020 | 1/26/2020 | 6.9                | 9.7                  | 840,451                  | 16,244,922           |
| **Total:**                    | **18.1**  | **16.5**  | **1,420,985**      | **31,184,821**       | **32,605,806**           |                      |

4
Therefore, this model is conducted repeatedly for every shipment in 2020. The results for every shipment can be seen in Table 6 as below:

| Shipment Schedule | Lead Time (day) | Total Cost (Mio - IDR) |
|-------------------|-----------------|------------------------|
| January 01/01/2020 | 34.74           | 32.61                  |
| January 15/01/2020 | 31.3            | 25.88                  |
| February 01/02/2020| 30.74           | 32.38                  |
| February 14/02/2020| 31.74           | 32.47                  |
| Maret 01/03/2020   | 26.3            | 25.57                  |
| Maret 15/03/2020   | 30.74           | 32.47                  |
| April 01/04/2020   | 40.74           | 32.88                  |
| April 15/04/2020   | 26.74           | 32.47                  |
| May 01/05/2020     | 35.3            | 26.09                  |
| May 15/05/2020     | 24.74           | 32.02                  |
| June 01/06/2020    | 35.74           | 32.63                  |
| June 15/06/2020    | 35.74           | 32.6                   |
| July 01/07/2020    | 33.74           | 32.47                  |
| July 15/07/2020    | 25.98           | 25.98                  |
| August 01/08/2020  | 35.3            | 26.14                  |
| August 15/08/2020  | 38.74           | 32.99                  |
| September 01/09/2020| 28.74          | 31.95                  |
| September 15/09/2020| 34.74          | 32.47                  |
| October 01/10/2020 | 32.74           | 32.29                  |
| October 15/10/2020 | 32.74           | 32.29                  |
| November 01/11/2020| 37.74           | 32.79                  |
| November 15/11/2020| 36.74           | 32.53                  |
| Desember 01/12/2020| 34.74           | 32.47                  |
| Desember 15/12/2020| 20.74           | 35.58                  |
| **Mean**           | **32.38**       | **31.25**              |

Table 6 shows the mean of lead time of proposed model is 32.38 and total cost of proposed model is 31.25 Mio-IDR. Compare to the current condition in shipment frozen octopus product from SKPT Natuna, the proposed model has better results than the current condition. The details of the comparison results can be seen as below:

![Figure 1](image_url)

**Figure 1.** Comparison results of current condition and proposed model.

Figure 1 illustrates the comparison of the total cost and lead time for current condition and proposed model. Total cost of current condition is 57.29 Mio – IDR, while the total cost of proposed model is
significantly more efficiency (45%) than the current condition cost. On the other hand, the current lead time is 38.10 days, while the lead time of proposed model obtains 15% more efficiency than current condition.

5. Conclusion
Logistics system of fishery product is important especially for the Natuna fishermen. The proposed model can obtain significant efficiency in term of total cost and lead time. This study provides the mathematical model based on the shortest-path problem. The current total cost is 57.29 Mio-IDR and total lead time is 38.10 days whereas the average of total cost obtained by the model is 31.25 Mio-IDR and lead time is 32.28 days. Overall, this model gains the efficiency on total cost by 45% and shorten lead time by 15%. For the future research is important to conduct the stochastic problem optimization because the schedule of the vessel shows the stochastic properties.

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