International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 12 (2019), pp. 2997-3005


# Clustering on Freight Distribution System in Archipelagic Region with Deterministic Allocation Model

**Windra Priatna Humang**[1], **Sigit Pranowo Hadiwardoyo***, **Nahry**

*Department of Civil Engineering, Faculty of Engineering, Universitas Indonesia, Depok 16242, Indonesia*

*[1]ORCID: 0000-0002-7549-9147*

**Abstract**

The ship operational costs in Indonesia tend to suffer losses because of its geographical shape with clustering islands, overlapping shipping networks, and small size of cargo.This condition causes the government to provide subsidies/Public Service Obligation (PSO) to guarantee the availability of goods in remote, outer and border islands. The clustering system is believed to be capable of optimizing the network so that there is no overlap in the operational area of the ship. The port clustering model will form port clusters that will be used in the integration model organization of the freight transportation on the Sea Tollway, Pelni and Pioneer ship network. The method used is a deterministic allocation model with R-tools.

The results of the clustering implementation in the freight distribution system on Maluku Province shows that the implementation of the 3 clusters system increases the profit by 15.7% (compared to the current system which does not use clustering), whereas the income earned is actually lower with the 9 clusters system. These results indicate that the clustering system does not always increase profits from PSO transportation services. The more clusters formed, the higher the operational costs of the ship and the less cargo can be transported, hence the reduced revenue.

**Keywords:** clustering, allocation model, freight distribution

## I. INTRODUCTION

As a country with 16,056 islands (Badan Pusat Statistik, 2018), Indonesia has around 2,342 small islands located in remote, outerand border areas that have not been served optimally. With these archipelagic regions, the problems on freight distribution faced by Indonesia are the vast service area, the large number of ports that must be served and the insufficient number of available ships. On the other hand, each port must be served by ships with high frequency to avoid scarcity of freight in the destination area. This condition currently causes the inefficiency in freight distribution because the distribution time is very long, and there is an overlap in the network served by 2 or more ships.

This paper is part of a research to develop a sea transportation networking integration model for the freight distribution in Indonesian archipelago, by taking the case of ships that are subsidized through the Public Service Obligation (PSO) from the government. Currently, there are 13 Sea Tollway ship routes, serviced by 3000 DWT - 3650 DWT ships with an estimated capacity of 115 Teus or 2,600 tons. Pelni serves 20 routes with an estimated capacity of 3,084 passengers, 500 tons and 98 TEUs. While the Pioneer serves 96 routes, served by 500-1000 DWT/1,200-2,000 GT ships, and is capable of carrying cargo up to 1,000 tons. The costs of PSO incurred by the government is unequal to the effectiveness of sea transportation services. In 2018, the cost of Sea Tollway PSO reached 447 billion, Pelni reached 1.86 trillion and Pioneer reached 1.1 trillion (Ministry of Transportation, 2018). This research is expected to maximize the income of ship operators so that the provided PSO can be lower.

Freight distribution services (especially Pioneer ship) currently do not consider shipping distances, only the origin of freight distribution destinations based on the existence of the cargo that will be transported from local government recommendations. Sea Tollway and Pelni ships transport freights from the main port and then distribute them collector ports. Pioneer ships transport freights from the collector port and then distribute it to the feeder port. Freight distribution system of Sea Tollway, Pelni and Pioneer is a back and forth system where ships returning to their original port must go through the previous port. This condition is inefficient because the cost of PSO for freight distribution becomes higher.

The purpose of this paper is to form an optimal port cluster for the shipping network so that there is no overlap on ship operational areas. The development of this model is believed to be able to reduce the travel time of the shipswhich will minimize costs and maximize revenue.

In section 2, the literature review discusses the allocation model and variables used by previous papers and their differences with this paper. Section 3 discusses the problem definition and assumptions regarding the proposed clustering system and its assumptions. Section 4 discusses the proposed allocation model about the mathematical model used and the algorithm. Section 5 discusses the results and discussion about the implementation with an example of applying the clustering model in Maluku Province, which is an archipelago that has the most ports in Indonesia.

## II. RELATED WORK

Past literature has discussed a lot about the allocation problem on freight distribution using ships. The issue of distribution allocation is an operational problem that aims to streamline the freight distribution which includes optimization of the shipping network by ships, referring to Christiansen et al [1] and Meng et al [2]. However, this paper focuses on developing a port clustering model which is then used as a limitation in ship routes creation to make freight distribution more effective.

To solve the allocation problem on freight distribution, mathematical programming has been widely used in various applications, including healthcare by Brailsford and Vissers [3], freight by Andrew Lim, et al [4], manufacturing by Klein & Kolb [5], hospital facilities by Liping Zhou, et al [6], seat allocation for passenger rail by Xinchang Wang [7], and Berth Allocation by Roberto Cruz, et al [8]. There is not much literature that focuses on maximizing the objective function on the allocation problem. One of them is Campbell's study [9], which introduced an allocation model that maximizes demand covering, based on the number of facilities to be found. Hwang and Lee [10] propose a heuristic algorithm for a single p-hub maximum allocation problem. Whereas Peker and Kara [11] expand the scope of the definition and introduce distance variables. They developed an integer programming formulation for single and multiple allocation versions.

The variables used in the clustering formulation of this study refer to previous studies including demand variables that have been used in paper that covers location problems, such as Zheng, J. et al [12], Karimi, H. [13], Berman, O. et al [14], Taherkhani, G et al [15], Kartal, Z et al [16], Blanquero, R. et al [17], Petrovic, D. et al [18], Raghavan, S. et al [19], Zhang, B. et al [20], and Colombo, F. et al [21]. Demand is the amount of goods that will be unloaded and loaded at each port. Cargo is important because the revenue depends on the amount of cargo carried by the ship. The higher the cargo, the higher the profit.

Variable distance between ports becomes a determinant in covering optimization, as shown in the researches by Ye, L. et al [22], Berman, O. et al [14], and Raghavan, S. et al [19]. Distance will affect distribution costs because the further the port, the higher the transport costs. The problem freight distribution has in archipelagic region is the distance between one island to another, resulting in long distribution time, hence the high transportation costs.

In the covering problem, time variable will determine the allocation structure that will be chosen. Karimi, H. et al [13] state that in addition to demand, the service time variable will determine the simulation model of the pickup and delivery system. In addition, Zhang, B. et al [20] also include a time variable in determining covering allocation for emergency facilities with uncertain environmental variables. In maritime transport, there are 2 time variables that affect the freight distribution: duration in the sea and duration in the port. Duration in the sea is strongly influenced by the distance between ports and environmental conditions (weather and waves). However, in modeling the clustering system these variables are ignored. The duration in the port is affected by the amount of cargo to be unloaded/loaded and the loading/unloading equipment. The more cargo to be unloaded/loaded, the longer the time spent at the port. Furthermore, the faster the loading/unloading equipment, the faster it will take to do the loading and unloading activities.

Variable costs include Transportation Costs $(C_t)$ plus Handling Costs $(C_h)$ plus Inventory Costs $(C_i)$. According to Jinca, M.Y. [23], Transportation cost $(\boldsymbol{C_t}) = (\boldsymbol{D^m_i . C_s}) + \boldsymbol{C_p}$. Where $D^m{}_i$ is the voyage distance between ports $i$ and $i+1$ on route $R$ (sea mile), $C_s$ is ship operation costin sea per TEus or per ton and $C_p$ is the ship operation cost in port. Ship operation cost in sea includes daily operational costs (ship depreciation, crew members, docking, insurance, capital cost and fuel cost. Ship operation cost in the port includes costs during the piloting period (daily operational costs during piloting, fuel, scout fees and delay fees), costs when a ship at a dock (daily operating costs in the dock, boat mooring costs and fuel), costs for the berth period in wharf (daily operating costs during berth, anchoring costs and fuel)

Handling costs include Terminal Handling Charge (THC), loading and unloading costs, storage costs for goods in container yards or in warehouses, Overbrengen costs (OB) or container moving costs from one container terminal to another, container weighing fees, ccontainer certification fees, etc. But in this clustering model, handling costs are focused on the costs of loading and unloading of goods and storage. Handling cost is $(\boldsymbol{C_h}) = \boldsymbol{C_{BM}} + \boldsymbol{C_{SR}}$, where: $C_{BM}$ is the cost for loading and unloading goods and $C_{SR}$ is the storage cost.

Inventory costs consist of the goods value, the time to money value, the time length used by the goods/cargo at the time of transit or terminal and corporate income tax. In the short term the owner will add up the inventory costs before taxing them. Inventory costs are positively correlated with payload volume, payload value, and length of storage time. But in this paper inventory cost focuses on inventory costs that associated with the calculated container shipping process, and involves waiting costs and shipping costs. Waiting costs are costs related to sailing frequency due to schedule delays, whether waiting from the loading port or at the place of production or origin. Inventory cost $(C_i) = \boldsymbol{C_{wt}} + \boldsymbol{C_{st}}$, Where: $C_{wt}$ is the cost of waiting time for containers or general cargo per round voyage, $C_{st}$ is the cost of shipping a container or general cargo per round voyage.

Waiting time cost $(C_{wt}) = \frac{365T}{12f} \sum_i \sum_j Q^m{}_{ij},$ Where: $T$ is the cost of time per day, $F$ is the shipping frequency in 1 year, $Q^m{}_{ij}$ is the charge from port $i$ to port $j$ per TEUs or general cargo year). Sailing time cost $(C_{st})$ by Hsu, C.I. [24] $= T \sum_i \sum_j \sum_k Q^m{}_{ij}(W_k + \frac{D^m_k}{V_t}) + \frac{T}{f} \sum_i \sum_j \sum_k \sum_l \frac{Q^m_{ij}\,\delta^m_{ijk}}{R_k}(Q^m{}_{kl} + Q^m{}_{lk})$, where $Q^m{}_{ij}$ is the load demand from port $i$ to port $j$ on route $R$ per year (TEUs or general cargo), $Q^m{}_{kl}$ = load demand from port $k$ to port $l$ on route $R$ per year (TEUs or general cargo), $W_k$ is the duration a ship will take from arrival to departure at port k (days), $D^m{}_k$ is the sailing distance between port k and k +1 on the $R$ route (sea mile), $V_t$ is the average speed of ship service (sea mile), $R_k$ is the handling average per Teus at Port $i$ (TEUs or general cargo/day).

In addition to the variables above, Humang, et. Al [25] found that, based on the findings in the field, the factors that influence the integration of the distribution network in the islands are time, cost, port, ship, environment (waves and weather), policy and cargo. These factors are then derived into variables that will be used to form the clustering model.

## III. PROBLEM DEFINITION AND ASSUMPTIONS

The optimized distribution system in this case is a distribution system served by 3 ships with different networks. The three ships are Sea Tollway ships, Pelni ships and Pioneer ships. The proposed clustering system that will be developed refers to the number of destination ports that must be served. Clustering is focused on ports served by Pioneer ships, but still accommodates ports served by Sea Tollway ships and Pelni ships.

The objective function of this clustering is to maximize profit, the profit is revenue reduced by costs, not profit from shipping operators. By maximizing profits, it is expected that the burden on subsidized PSO can be minimized. The assumptions of the proposed allocation model for clustering are described as follows:

- All feeder ports have the same potential to be included in the same one cluster.
- The objective function of the model (equation 1) is to maximize profit (profit), which is to maximize (income - costs) or can be mathematically expressed in the form of minimizing (- profit) or minimizing (cost - income).
- The objective function represents all ports, whether it's the main port, the collector level and the feeder level
- Pioneer ships only serve vessel trips between the collector port and the feeder port, while the Sea Tollway and Pelni ships only serve shipping between the main port and the collecting port.
- Pioneer ships only sail between ports in one cluster, while Sea Tollway and Pelni ships can sail between ports in different clusters.

## IV. PROPOSED ALLOCATION MODEL

The mathematical form of the deterministic allocation model for clustering is as follows:

***Objective Function: Maximum Profit (Z) = Revenue – Costs***

$$= \left[ \sum_{u\in U}\sum_{p\in P} w^{up}.\Phi_{TL}\left(\sum_{p\in P}\alpha^{up}\right) - \begin{pmatrix} \sum_{u\in U}\sum_{p\in P}\alpha^{up}.B^{p}_{TL}.C^{p}_{bmTL} + \sum_{u\in U}\sum_{p\in P}\alpha^{up}\left\{S^{p}.C^{p}_{st}\right\} + \\ T_k\sum_{u\in U}\sum_{p\in P}\alpha^{up}\left\{t^{p}_{TL} + \frac{w^{up}}{V_{TL}}\right\} + T_k\sum_{u\in U}\sum_{p\in P}\frac{\alpha^{up}}{C^{p}_{bmTL}} \end{pmatrix} \right] + \sum_{u\in U}\sum_{p\in P} w^{up}.\varphi_{PL}\left(\sum_{p\in P}\beta^{up}\right) -$$

$$\begin{pmatrix} \sum_{u\in U}\sum_{p\in P}\beta^{up}.B^{p}_{PL}.C^{p}_{bmPL} + \sum_{u\in U}\sum_{p\in P}\beta^{up}\left\{S^{p}.C^{p}_{st}\right\} + \\ T_k\sum_{u\in U}\sum_{p\in P}\beta^{up}\left\{t^{p}_{PL} + \frac{w^{up}}{V_{PL}}\right\} + T_k\sum_{u\in U}\sum_{p\in P}\frac{\beta^{up}}{C^{p}_{bmPL}} \end{pmatrix} - \begin{pmatrix} \sum_{u\in U}\sum_{u'\in U'}\gamma^{uu'}.B^{u'}_{PL}.C^{u}_{bmPL} + \sum_{u\in U}\sum_{u'\in U'}\gamma^{uu'}\left\{S^{u'}.C^{u'}_{st}\right\} \\ + T_k\sum_{u\in U}\sum_{u'\in U'}\gamma^{uu'}\left\{t^{u'}_{PL} + \frac{x^{uu'}}{V_{PL}}\right\} + T_k\sum_{u\in U}\sum_{u'\in U}\frac{\gamma^{uu'}}{C^{u}_{bmPL}} \end{pmatrix} +$$

$$\left[ \sum_{p\in P}\sum_{r\in R} z^{pr}.\Psi_{PR}\left(\sum_{r\in R}\sigma^{pr}\right) - \begin{pmatrix} \sum_{p\in P}\sum_{r\in R}\sigma^{pr}.B^{r}_{PR}.C^{r}_{bmPR} + \sum_{p\in P}\sum_{r\in R}\sigma^{pr}\left\{S^{r}.C^{r}_{st}\right\} + \\ T_g\sum_{p\in P}\sum_{r\in R}\sigma^{pr}\left\{t^{r}_{PR} + \frac{z^{pr}}{V_{PR}}\right\} + T_g\sum_{p\in P}\sum_{r\in R}\frac{\sigma^{pr}}{C^{r}_{bmPR}} \end{pmatrix} \right] \quad \text{...............................(1)}$$

**Set:**

| | |
|---|---|
| $U$ | = main port cluster($u$), $-u = \{1,2,3,\ldots n\}$ |
| $U'$ | = main port cluster ' ($u'$), $-u' = \{1,2,3,\ldots m\}$ |
| $P$ | =collector port cluster, ($p$), $-p = \{1,2,3,\ldots p\}$ |
| $R$ | = feeder port cluster, ($r$), $-r = \{1,2,3,\ldots r\}$ |
| $TL$ | = Sea Tollway ship |
| $PL$ | = Pelni ship |
| $PR$ | = Pioneer ship |

**Decision Variable:**

| | |
|---|---|
| $\alpha^{up}$ | = quantity of goods that move from -u to -p using the Sea Tollway ship *(Teus)* |
| $\beta^{up}$ | = quantity of goods that move from -u to -p using the Pelni ship *(Teus)* |
| $\gamma^{uu'}$ | = quantity of goods that move from -*u* ke–*u*' using the Pelni ship *(Teus)* |
| $\sigma^{pr}$ | = quantity of goods that move from -*p* ke –*r* using the Pioneer ship *(ton)* |

**Input parameters:**

| | |
|---|---|
| $\Phi_{TL}$ | = cost per distance unit to move goods using Sea Tollway ship *(Rp/mile/Teus)* |
| $\varphi_{PL}$ | = cost per distance unit to move goods usingPelni ship *(Rp/mile/Teus)* |
| $\Psi_{PR}$ | = cost per distance unit to move goods using Pioneer ship *(Rp/mile/ton)* |
| $w^{up}$ | = Distance from port-*u* to port-*p* *(mile)* |
| $z^{pr}$ | = Distance from port-*p* to port-*r* *(mile)* |
| $D^{u}$ | = Total demand (cargo) from port-*u* to port-*p* *(Teus)* |
| $D^{p}$ | = Total demand (cargo) from port-*p* to port-*r* *(Ton)* |
| $t^{p}_{TL}$ | = Docking time average for Sea Tollway ship in port-*p* *(hour)* |
| $t^{p}_{PL}$ | = Docking time average for Pelni ship at port-*p(hour)* |
| $t^{r}_{PR}$ | = Docking time average for Perintis ship at port-*r(hour)* |
| $B^{p}_{TL}$ | = loading and unloading time of Sea Tollway ship at port-*p* per *unit (hour /Teus)* |
| $B^{p}_{PL}$ | = loading and unloading time of Pelni ship at port-*p* per unit*(hour /Teus)* |

$B_{PL}^{u'}$ = loading and unloading time of Pelni ship at port -*u*' per unit *(hour /Teus)*
$B_{PR}^{r}$ = loading and unloading time of Pioneer ship at port -*r* per unit *(hour /ton)*
$S^{u'}$ = goods storage time at port-*u'(day)*
$S^{p}$ = goods storage time at port-*p(day)*
$S^{r}$ = goods storage time at port-*r(day)*
$C_{bmTL}^{p}$ = loading and *unloading* cost of Sea Tollway ship at port-*p (Rp/Teus)*
$C_{bmPL}^{u'}$ = loading and *unloading* cost of Pelni ship at port-*u (Rp/Teus)*
$C_{bmPL}^{p}$ = loading and *unloading* cost of Pelni ship at port-*p (Rp/Teus)*
$C_{bmPR}^{r}$ = loading and *unloading* cost of Pioneer ship at port-*r (Rp/ton)*
$C_{st}^{u}$ = goods storage cost at port -*u (Rp/Teus)*
$C_{st}^{u'}$ = goods storage cost at port -*u'(Rp/Teus)*
$C_{st}^{p}$ = goods storage cost at port -*p(Rp/Teus)*
$C_{st}^{r}$ = goods storage cost at port -*r(Rp/ton)*
$T_k$ = container goods inventory cost *(Rp/Teus/ day)*
$T_g$ = general cargo goods inventory cost*(Rp/Ton/day)*
$V_{TL}$ = Sea Tollway ship speed average *(mile/hour)*
$V_{PL}$ = Pelni ship speed average *(mile/hour)*
$V_{PR}$ = Pioneer ship speed average *(mile/hour)*

**subject to:**

$$D^u = \sum_{p\in P}(\alpha^{up} + \beta^{up}) + \sum_{u'\in U'}\gamma^{uu'} \quad \forall\, u \in U \ldots\ldots \quad (2)$$

$$D^p = \sum_{r\in R}\alpha^{pr} \quad \forall\, p \in P \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

$$\alpha_{up} \geq 0 \quad \forall\, u \in U,\ \forall\, p \in \ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4)$$

$$\beta_{up} \geq 0 \quad \forall\, u \in U,\ \forall\, p \in P\ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

$$\gamma_{uu'} \geq 0 \quad \forall\, u \in U,\ \forall\, u' \in U'\ldots\ldots\ldots\ldots\ldots \quad (6)$$

$$\sigma_{pr} \geq 0 \quad \forall\, p \in P,\ \forall\, r \in R\ldots\ldots\ldots\ldots\ldots\ldots \quad (7)$$

The descriptions of the allocation model are as follows:

- The 1st and 2nd term of the objective function representthe Sea Tollway ships.
- The 3rd to 6th term represent thePelniships.
- The 7th and 8th term represent Pioneer ships.
- Equation 2 is the load constraint, where the total load demand from the main port is the total load from the collector and feeder ports.
- Equation 3 is the load constraint, where the total load demand from the collector port is the total load from the feeder port.
- Equations 4 - 7 are constraint which states that the number of cargo requests at each port must be ≥ 0.

**Algorithm**

The tools used in simulating the clustering model optimization are R-tools. The steps for completing the algorithm are explained below:

Step 0: (initialization) the network given is G = (N, A), then the unit cost of each variable is determined in equation 1

Step 1: (data set) determine the data set of each network from the main port (u), main port '(u'), collector port (p) and feeder port (r) covering each of the Sea Tollway, Pelni and Pioneer networks.

Step 2: define routes based on the allocation model traversed by each of the Sea Tollway, Pelni and Pioneer networks based on the problems in Equations 2-7.

Step 3: calculate the profit earned from each formed route. Each route represents port covering.

Step 4: if the maximum profit has been found from the selected allocation model then the process is stopped; otherwise return to step 2

## IV. RESULT AND DISCUSSION

Simulations were carried out to implement the model that had been built with a case example of Maluku Province, Indonesia. The simulations were done with 3 models to know the comparison between three simulation models. Each simulation is explained as follows:

- Simulation 1 shows the current conditions without clustering. It consists of 3 main ports: Port of Tanjung Priok, Port of Tanjung Perak and Port of Makassar. Collector ports are 3 ports: Port of Ambon, Port of Tual and Port of Saumlaki. There are 76 feeder ports.
- Simulation 2, by forming 3 clusters with three home base ports, which are Port of Ambon, Port of Tual and Port of Saumlaki. The three ports are designated as homebase port because the three ports are visited by all types of ships, both by the Sea Tollway and Pelni ships.
- Simulation 3, by forming 9 clusters with nine home base ports, which are Port of Ambon, Port of Tual, Port of Saumlaki, Port of Namlea, Port of Namrole, Port of Kisar, Port of Moa, Port of Banda Neira and Port of Dobo. The addition of six ports as home base port is because the six ports are gateway ports for goods to Maluku Province aside from Ambon, Tual and Saumlaki.

### IV.I Computational Results

The clustering model is implemented on R tools with Intel (R) Core (TM) i5 CPU, 2.40GHz, 8.00GB RAM. Simulation results have been manually validated to ensure that the developed model is able to explain the process and the obtained results. The results of simulating clustering models for each simulation with a case example can be described as follows:

- **Simulation 1**
  The result of running the R program with the first simulation data input shows that the profit value reaches Rp. 19.102.274.423,- with the current condition of the ship service network (without clustering)

- **Simulation 2**
  Running the R program with the second simulation data input raises 50 alternative cluster iterations. The optimization results show that the most maximum profit value that can be generated is Rp. 22.652.202.087,-

- **Simulation 3**
  Running the R program with the 3rd simulation data input raises 50 alternative cluster iterations. The optimization

results show that the most optimal profit value is Rp. 10.140.814.814,-.

### IV.II Interpretation of Simulation Results

The port clustering simulations in Maluku Province use real data from 2017. The results of the simulation with the clustering model show several different findings between one simulation to another. The interpretation is explained below.

**1. Simulation 1**

There are 3 Pioneer homebase ports in the existing conditions of Maluku Province: Ambon, Tual and Saumlaki. The Pioneer sea transport network is distributed from these ports to other nearby ports. Currently there is no definite system/regulation regarding the freight distribution. The destination port is determined by the government through the Ministry of Transportation based on recommendations from local government. The nature of the network goes back and forth (the ship must return to the previous port if it wants to return to the homebase port), so it feels inefficient. The current pioneering transport routes/networks are shown in Figure 1 below.

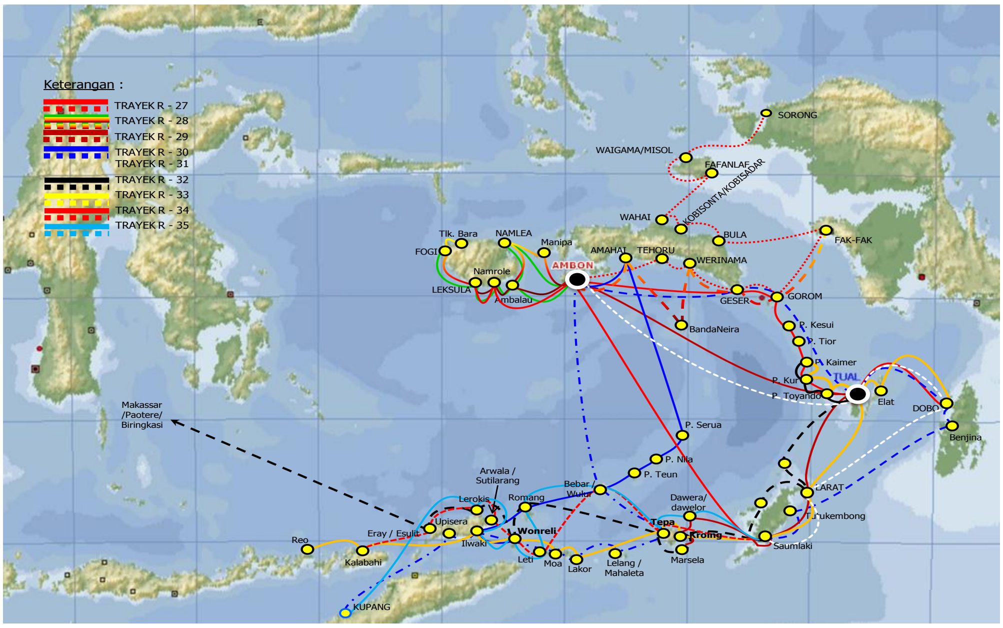


**Fig. 1.** Pioneer routes / networks for the current freight distribution in Maluku Province (simulation – 1)

The results of the analysis with equation 1 show the total profit (revenue minus costs) earned by the shipping company with the existing conditions without clustering, which is Rp. 19.102.274.423, - for all routes in Maluku Province. This small income, if not subsidized by the government, will burden the people with very high freight costs. Therefore, to ensure the continued freight distribution in remote, outermost and border areas, the government through the Ministry of Transportation provided a very large subsidy of Rp. 1.1 trillion in 2018 for 96 Pioneer routes.

**2. Simulation 2**

The profit value is obtained randomly from the 50 iterations that have the highest value. Each simulation alternative represents a cluster that can be formed from a collection of collector ports and feeder ports. The comparison of the clustering profit values on simulation 2 can be seen in the Figure 2.

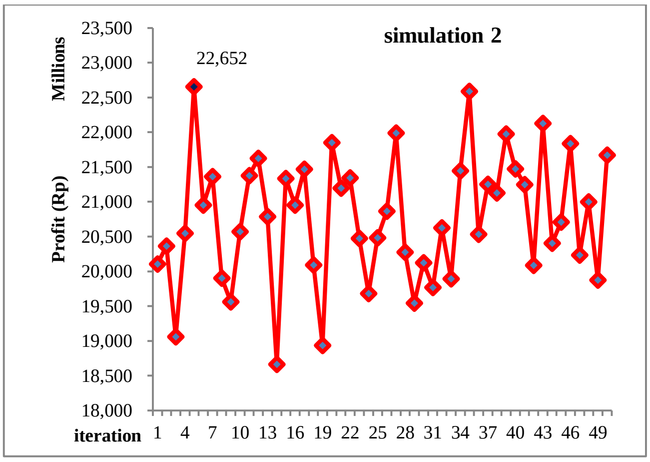


**Fig. 2.** Comparison of the clustering profit values on simulation 2

The 5th iteration alternative as the most maximized alternative is explained by the following ports:

- Cluster A, also referred as North Cluster with homebase node of Port of Ambon, consists of 20 ports, which are

Namlea, Namrole, Ambalau, Wamsisi, Leksula, Tifu, Waemulang, Fogi, Manipa, Kelang, Buano, Taniwel, Wahai, Kobisadar, Bula, Kelimoi, Geser Island, Kelimuri, Werinama and Amahai.

- Cluster B, also referred as Eastern Cluster with homebase node of Port of Tual, consists of 26 ports, which are Dobo Port, Manawoka Island, Gorom, Kailakat, Kesui Island, Kasiui, Tior Island, Kaimer, Mangur, Fadol, Kur Island, Toyando, Tam, Banda Neira, Holat, Weduar, Elat, Mun, Banda Eli, Benjina, Tabarfane, Jerol, Meror, Longgar, Marlasi and Lelam Kojabi.
- Cluster C, also referred as South Cluster with homebase node of Port of Saumlaki, consists of 30 ports, which are Kisar, Larat, Sofyanin/Rumayaan, Rumean, Wunlah, Seira, Nurkat, Molu, Tutukembong, Adault/Lingat, Marsela, Tepa, Dawera/Dawelor, Kroing, Lewa/Dai, Moa, Serua, Nila, Teon, Wulur, Bebar, Eray, Ilwaki, Romang, Arwala/Sutilirang, Kisar1, Leti Island, Lakor, Luang Island and Lelang.

The illustration of clustering from the highest (optimal) profit value, which is the 5th iteration, is shown in the following figure 3.

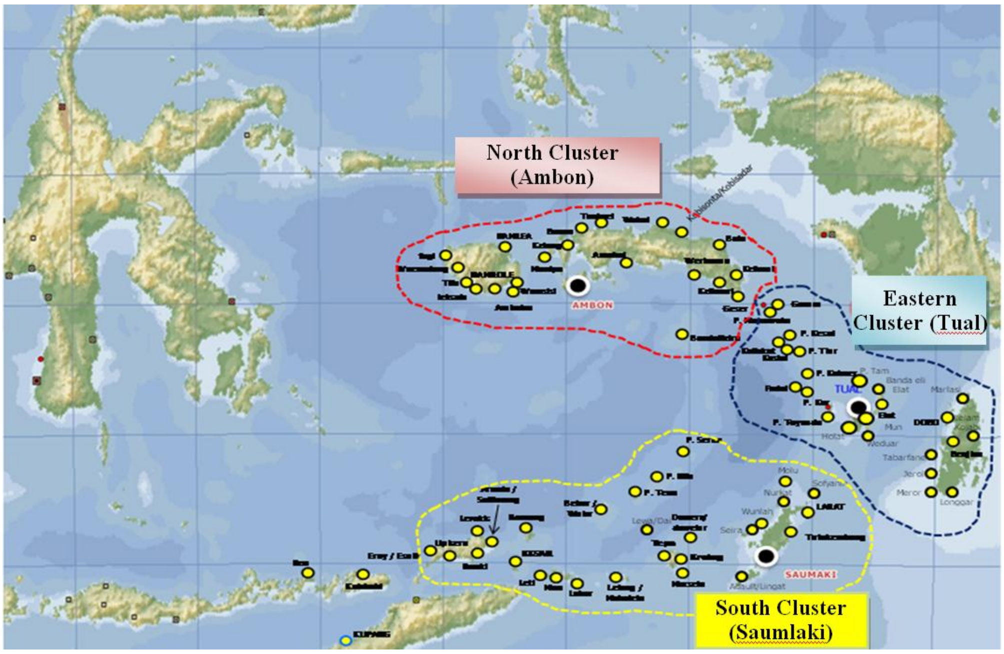


**Fig. 3.** Port Clustering from the highest Profit Value (simulation - 2)

### 3. Simulation 3

The profit value is obtained randomly from the 50 iterations that have the highest value. Each simulation alternative represents a cluster that can be formed from a collection of collector ports and feeder ports. The comparison of the clustering profit values on simulation 3 can be seen in Figure 4.

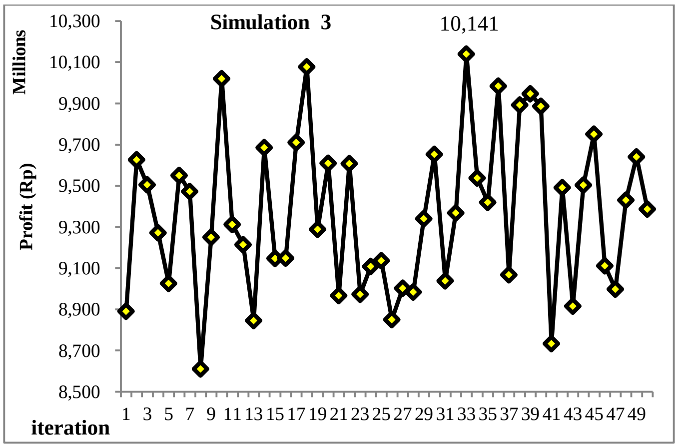


**Fig. 4.** Comparison of the clustering profit values on simulation 3

The 33rd alternative as the alternative with the most maximum profit is described by the following ports:

- Cluster A with homebase of Port of Namlea consists of 3 ports: Fogi, Kelang and Manipa
- Cluster B with homebase of Port of Namrole consists of 5 ports: Wamsisi, Ambalau, Tifu, Leksula, and Waemulang Ports.
- Cluster C with homebase of Port of Ambon consists of 10 ports: Werinama, Bula, Kobisadar, Wahai, Amahai, Taniwel, Buano, Kelimuri, Kelimoi and Geser Island ports.
- Cluster D with homebase of Port of Banda Neira consists of 6 ports: Tioor Island, Kesui Island, Kasiui, Kailakat, Gorom Island, and Manawoka Island
- Cluster E with homebase of Port of Tual consists of 12 ports: Weduar, Mun, Banda Eli, Elat, Holat, Tayandu, Tam Island, Mangur, Fadol, Kur Island, and Kaimer Ports
- Cluster F with homebase of Port of Dobo consists of 7 ports: Marlasi, Lelam Kojabi, Longgar, Meror, Jerol, Tabarfane, and Benjina Ports
- Cluster G with homebase of Port of Saumlaki consists of 13 ports: Dawera/Dawelor, Kroing, Marsela,

Adault/Lingat, Seira, Tutukembong, Wunlah, Rumean, Sofyanin, Nurkat, Molu, Larat, and Lewa/Dai,

- Cluster H with homebase of Port of Moa consists of 10 ports: Leti Island, Lakor, Bebar, Wulur, Teon, Nila Island, Serua Island, Lelang, Luang Island, and Tepa
- Cluster I with homebase of Port of Kisar consists of 4 ports: Eray, Ilwaki, Arwala/Sutilirang, and Kisar1 Ports

The illustration of clustering from the highest (optimal) profit value in simulation 3, the 33rd iteration, is shown in Figure 5 below.

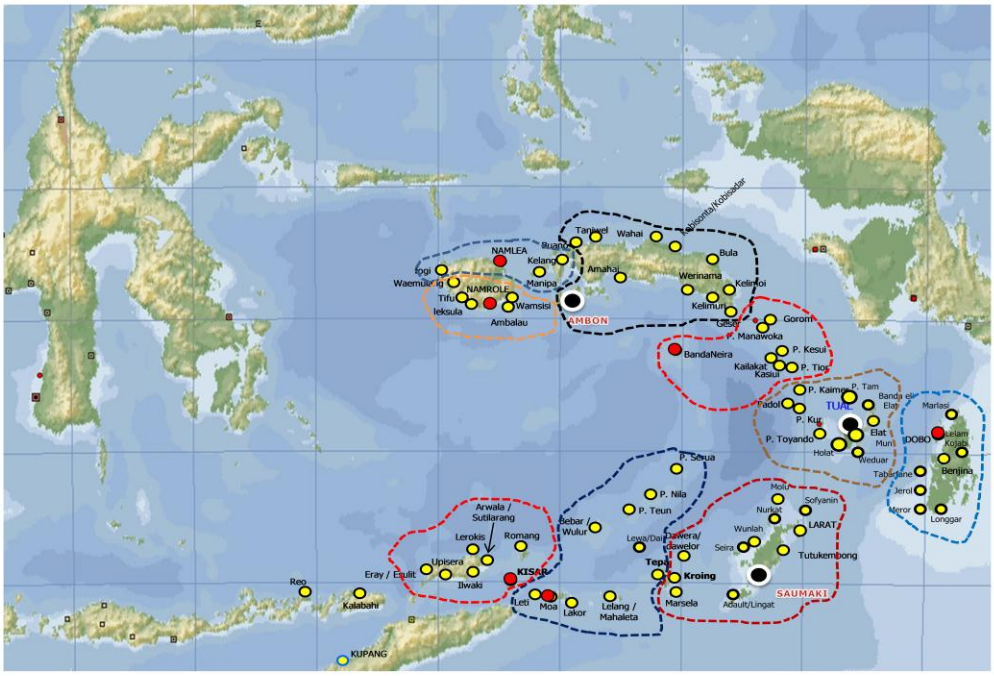

**Fig. 5.** Port Clustering from the highest Profit Value (simulation - 3)

The results comparison of deterministic allocation model optimization in the three simulations show that there is a difference in profit value. Simulation 2 with the 3 cluster system has the highest profit value and is 15.7% more profitable than simulation 1 (currently). Simulation 2 has a better profit value of 55.2% than simulation 3. Although using clusters is better than not using it, the excessive number of clusters also results in inefficiency. Simulation 3, which used 9 clusters, actually received lower profit value because the number of ports served by each cluster is small, so the transportation demand is small, resulting in reduced revenue. The comparison of profits between the 3 simulations can be seen in Figure 6.

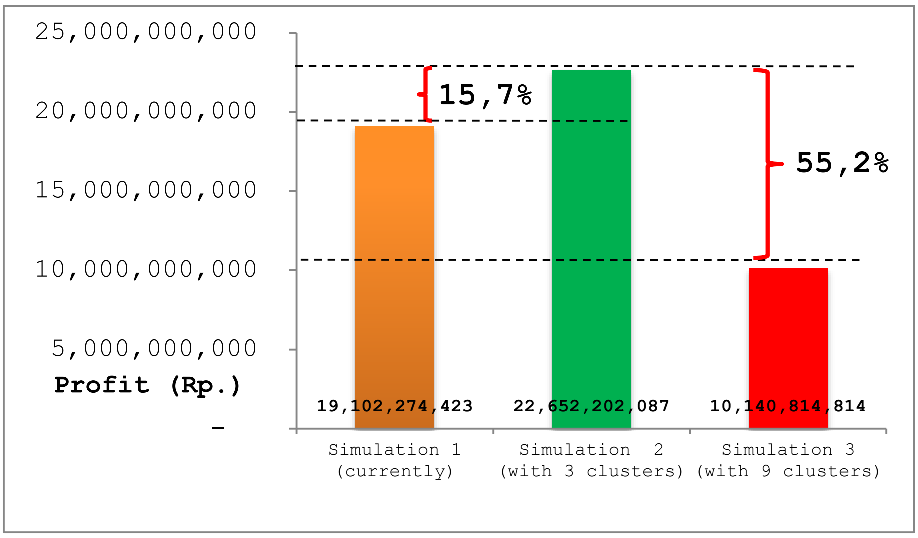


**Fig. 6.** The profit comparison of the Clustering Optimization Model

## V. CONCLUSION

This paper has modeled efficient port clustering in order to increase profits and reduce subsidies/PSO. The cost efficiency that is assumed with the maximum profit through the implementation of a clustering system in the freight distribution system on archipelagic area is highly possible. The comparison of profit optimization resultswith the allocation model between the existing condition and the implementation of the 3 cluster system shows that there is an 15.7% increase in profit, whereas with the 9 cluster profit system the profit is lower. These results indicate that the clustering system does not necessarily increase profit from subsidized/PSO transport services. The more clusters formed, the higher the operational costs of the ship and the less cargo can be transported because the number of ports served is increasingly limited. These result in reduced income. Adopting the current geographical and demand conditions in the Indonesian Maluku province will form 3 optimal clusters: the 1st cluster with homebase of Port of Ambon that consists of 20 ports, the 2nd cluster with homebase of Port of Tual port that consists of 26 ports, and the 3rd cluster with the homebase of Port of Saumlaki that consists of 23 ports. Furthermore, the cluster will be used in integrating the sea transportation network in order to optimize the freight distribution network in Indonesia.

## ACKNOWLEDGMENTS

This research is supported and funded by DRPM Universitas Indonesia through the Research Grant funding under ‘Hibah Kompetitif Publikasi Internasional Terindeks Tugas Akhir Doktor (TADok) year 2019’ by contract No: NKB-0176/UN2.R3.1/HKP.05.00/2019.

## REFERENCES

[1] Christiansen, M., Fagerholt, K., Nygreen, B., and Ronen, D. (2013). Ship routing and scheduling in the new millennium. European Journal of Operational Research, 228(3):467 – 483.

[2] Meng, Q., Wang, S., Andersson, H., and Thun, K. (2014). Containership routing and scheduling in liner shipping: Overview and future research directions. Transportation Science, 48(2):265–280.

[3] Brailsford, S., & Vissers, J. (2011). OR in healthcare: A European perspective. *European Journal of Operational Research*, *212*, 223-234. doi:10.1016/j.ejor.2010.10.026

[4] Andrew Lim, Hu Qin, Zhou Xu. (2012). *The freight allocation problem with lane cost balancing constraint.* European Journal of Operational Research 217 (2012) 26–35

[5] Klein, R., & Kolb, J. (2015). *Maximizing customer equity subject to capacity constraints*. *Omega*, *55*, 111-125. doi:10.1016/j.omega.2015.02.008.

[6] Liping Zhou , Na Geng , Zhibin Jiang , Xiuxian Wang, (2016) *Combining revenue and equity in capacity allocation of imaging facilities*, European Journal of Operational Research, doi: 10.1016/j.ejor.2016.06.046

[7] Xinchang Wang, Hua Wang, Xiaoning Zhang, (2016). *Stochastic seat allocation models for passenger rail transportation under customer choice.* Transportation Research Part E 96 (2016) 95–112

[8] Roberto Cruz, Andre Bergsten Mendes, Laura Bahiense, Yue Wu, (2018). *Integrating Berth Allocation Decisions in a Fleet Composition and Periodic Routing Prob-lem of Platform Supply Vessels,* European Journal of Operational Research, doi:https://doi.org/10.1016/j.ejor.2018.11.030

[9] Campbell, J. F., (1994). *Integer programming formulations of discrete hub location problems*. European Journal of Operational Research 72 (2), 387–405.

[10] Hwang, Y. H., Lee, Y. H., (2012). *Uncapacitated single allocation p-hub maximal covering problem*. Computers & Industrial Engineering 63 (2), 382–389

[11] Peker, M., Kara, B. Y., (2015). *The p-hub maximal covering problem and extensions for gradual decay functions.* Omega 54, 158–172

[12] Zheng, J., Qi, J., Sun, Z. and Li, F., (2018). *Community structure based global hub location problem in liner shipping.* Transportation Research Part E: Logistics and Transportation Review, 118, pp.1-19.

[13] Karimi, H., (2018). *The capacitated hub covering location-routing problem for simultaneous pickup and delivery systems.* Computers & Industrial Engineering, 116, pp.47-58.

[14] Berman, O., Kalcsics, J. and Krass, D., (2016). *On covering location problems on networks with edge demand.* Computers & Operations Research, 74, pp.214-227.

[15] Taherkhani, G. and Alumur, S.A., (2019). *Profit maximizing hub location problems*. Omega, 86, pp.1-15.

[16] Kartal, Z., Hasgul, S. and Ernst, A.T., (2017). *Single allocation p-hub median location and routing problem with simultaneous pick-up and delivery*. Transportation Research Part E: Logistics and Transportation Review, 108, pp.141-159.

[17] Blanquero, R., Carrizosa, E. and Boglárka, G., (2016). *Maximal covering location problems on networks with regional demand*. Omega, 64, pp.77-85.

[18] Petrović, D. Batanović, V and Petrović, R., (2009). *Fuzzy logic based algorithms for maximum covering location problems.* Information Sciences, 179(1-2), pp.120-129.

[19] Raghavan, S., Sahin, M. and Salman, F.S., (2019). *The capacitated mobile facility location problem.* European Journal of Operational Research, 277(2), pp.507-520.

[20] Zhang, B., Peng, J. and Li, S., (2017). *Covering location problem of emergency service facilities in an uncertain environment.* Applied Mathematical Modelling, 51, pp.429-447.

[21] Colombo, F., Cordone, R. and Lulli, G., (2016). *The multimode covering location problem*. Computers & Operations Research, *67*, pp.25-33.

[22] Ye, L., Ye, C. and Chuang, Y.F., (2011). *Location set covering for waste resource recycling centers in Taiwan.* Resources, Conservation and Recycling, 55(11), pp.979-985.

[23] Jinca, M.Y., (2011). *Transportasi Laut Indonesia, Analisis Sistem dan Studi Kasus*. Brilian Internasional, Surabaya

[24] Hsu, C.I. and Hsieh, Y.P., (2007). *Routing, ship size, and sailing frequency decision-making for a maritime hub-and-spoke container network.* Mathematical and Computer Modelling, 45(7-8), pp.899-916.

[25] Humang, W.P. Hadiwardoyo, S.P. and Nahry, (2019). *Factors Influencing the Integration of Freight Distribution Networks in the Indonesian Archipelago: A Structural Equation Modeling Approach.* Advances in Science, Technology and Engineering Systems Journal (ASTESJ). Volume 4, Issue 3, Page No 278-286