New Era of Local Potential Distribution: Design of The Optimal Ship Route for Transportation of The Major Commodities Of Biak Numfor Using The Vehicle Routing Problem (VRP)

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***Abstract*— The problem of price disparity that occurred in Indonesia needs to be overcome by sea transportation planning. The development of the sea toll road is a solution in tackling the disparity of the price of needs in eastern Indonesia. The program can be maximized by transporting the potential commodities of a region to fill the vessels that are often empty without any cargo when returning from small regional port. The research parameters are ship capacity, time windows, and commodity. The case study of this research is Biak Numfor District, which has a wealth of natural resources in the agriculture sector. Using the Vehicle Routing problem (VRP), it can be determined that the purpose of the research is to improve the route to be more efficient. The result of the research is the optimal route and framework of scheduling of one port of origin, which is Biak, to nine destination ports.**

Keywords*— *Price Disparity; Vehicle Routing Problem (VRP); Routes and Scheduling

I. Introduction

Indonesia as the largest archipelagic country in the world has a great potential in various aspects, including marine, forestry, and agriculture. Logistics is the part of the supply chain process that plans, implements and controls the efficient, effective flows and storage of goods, services and related information from the point of origin to the point of consumption in order to meet customers' requirements [1]. Given the important and strategic role of traffic and transportation for the livelihood of the public, the interest of the public as the transportation service user needs to get prioritized and get an optimal service from both the government and the transportation service providers [2]. Right now it can be seen that the marine transportation in Indonesia is used by approximately 90% of domestic and international trade so that the capacity development and the connectivity of ports is critical to the reduction of logistics costs and an even distribution of the national growth [3].

Although Indonesia has the potential to run a sea transportation program, there are still some constraints on the logistics activities sector that are considered less efficient and irregular in the system. Moreover, the problems like the slow procurement and improvement of the facilities and infrastructure of the sea transportation or the limited infrastructure availability, delay, and also water and air pollution are some of the many problems faced when talking about the sea transportation problems [4]. This leads to price gaps in basic materials and building materials between the production centers and other areas that are far from the production site. In addition, the inefficient logistics system in Indonesia causes the price of the product to be high. Currently, Indonesia has logistics costs of 26.4% of GDP that are considered higher than other countries such as Malaysia which is only 15%, South Korea 16.3%, Japan 10.6% and the United States 9.9 % [5].

The geography of Indonesia, especially the eastern part of Indonesia, which is the archipelago and waters region, becomes one of the challenges in transportation activities or the process of the distribution of the basic needs and building materials. Sea transportation is one of the models that is very suitable to the geographical conditions in Indonesia as a means of distribution. In assisting the transport, there are four types of vessels commonly used for commodity distribution, including carrier, tanker, container and general cargo. Some large capacity fleet is required to operate properly and efficiently. The geographical aspect of Indonesia as an archipelago and a marine country that has a far enough distance is one thing to note. Therefore, logistics management on the transportation side in the form of large ships to transport the demand of regions that are able to reach the ports at each point of the island is needed.

One of the flagship programs of Nawacita by President Joko Widodo which is related to the transportation is the construction of the sea toll road. The connectivity index ranking of Indonesia in the marine transportation sector in 2014 increased to the 77th rank, compared to the year 2012 where it occupied the 104th rank [6]. The realization of sea toll road program is expected to be a driver of the country's economy, efficiency and evenly. In addition, the program is expected to cope with the disparity of the price of basic needs and building materials between the western and eastern Indonesia. The idea of a sea toll road is an effort to realize the first Nawacita, which is to strengthen the identity as a maritime country and the third Nawacita, which is to develop Indonesia from the periphery, by strengthening the regions and villages within the framework of the unitary state. In addition, the program will boost commerce within the country, while positioning Indonesia as a hub for international trade in the broader ASEAN and Indo-Pacific regions [7]. Thus, on the economic and development aspects, the presence of sea tolls can strengthen the economic equity through the distribution of basic needs in a systematic way.

One of the reasons why the inefficient distribution of the basic needs occurs is because some regions through the regional governments do not send materials or basic needs that become a superior potential in the area, so the problems that occur to the current sea toll road vessels is the many empty cargo once the sea toll road vessels return from the remote ports to Surabaya or Jakarta [8]. This resulted in the uneven distribution of the basic needs in the remote areas. Then it will have an impact on the wastage of fuel on the way back to the production center, whereas eastern Indonesia has the potential to help the equitable distribution of basic needs from the agriculture, plantation, and fishery. From the potentials, there are 16 active ports passed by vessels for commodity distribution to eastern Indonesia, which is found in six provinces, which are NTB, NTT, Maluku, North Maluku, Papua and West Papua.

Biak Numfor is one of the regencies in Papua Province, which consists of two main islands, Biak island and Numfor island, and about 42 small islands. Biak Numfor Regency has a total area of 260,199 km2 consisting of land and sea covering 19 District Areas with 185 Villages and 14 Subdistricts and 63 Preparation Villages [9]. Biak Numfor Regency is located in the Cenderawasih Bay with an altitude of 0-1000 meters above sea level. The regency is directly adjacent to the Pacific Ocean. This position makes the Biak Numfor Regency one of the strategic and important places to connect with the outside world, especially countries in the Pacific region, Australia or Philippines. This geographical position provides an opportunity to build an industrial area, including the tourism industry.

The abundant natural resources come from various sectors including fishery, plantation, and agriculture. The commodities of the food crops that have a high production amounts are corn and tubers. In 2014, corn production reaches 537.6 tons, while tuber crops such as cassava, taro and tubers reach 8,948 tons. In addition to agriculture, the plantation sector of Biak Numfor Regency also has the potential to meet the needs of basic commodities for production such as coconut, cocoa, and coffee, with the width of the coconut plantation area that reached 3,722.89 Ha and the production of 987.63 tons in 2014. In the cocoa plantation sector with a total planting area of 510.22 Ha, it only produces cocoa as much as 45.49 tons, while the plantation sector for coffee reached 265 kg per Ha by the end of 2014. In addition, there is an area nut plantation that produced 39.90 tons during the year with a 227.92 Ha planting area [10]. Commodities in the agricultural sector have been sufficient for the internal needs of Biak Numfor Regency itself, and some commodities have a surplus, so it needs to be distributed to other areas. From the potential owned by Biak Numfor Regency, it is expected to be a supplier of basic needs and meet the needs of industries in areas that have a high demand.

Although the Biak Numfor Regency has various potentials in terms of natural wealth, it still has problems with the aspect of economic growth. Regional economic growth can be seen based on the growth rate of the Regional Gross Domestic Product (GDP) of the region. In Table 1 it can be seen that the GDP of Biak Numfor Regency in 2016 was only at 4.07 %, while the previous year (2015), the GDP growth value reached 6.62 %. This shows a substantial decrease, one of which is contributed from the agriculture, forestry, and the fishery categories. This economic growth was not aligned with the developments that occurred in Papua which increased 9.21 % in 2016 or an increase from the previous year which was at the number of 7.47 %. This inequality occurs because the management of regional government budget in each fiscal year always experience delays and result in the delay in the disbursement of funds. This is likely to have a significant impact on the decrease in production [11]. Therefore, some of solution are needed, especially in relation to integrating regional potentials with national programs through the Nawacita platform.

TABLE I. GROWTH RATE OF THE REGIONAL GROSS DOMESTIC PRODUCT (GDP) OF BIAK NUMFOR REGENCY IN 2015-2016

Kategori	Uraian	2015	2016
A	Pertanian, Kehutanan, dan Perikanan	1,14	-3,35
B	Pertambangan dan Penggalian	8,77	15,03
C	Industri Pengolahan	4,43	8,78
D	Pengadaan Listrik dan Gas	-0,81	17,44
E	Pengadaan Air, Pengelolaan Sampah, Limbah dan Daur Ulang	3,74	2,48
F	Konstruksi	6,77	16,06
G	Perdagangan Besar dan Eceran; Reparasi Otomotif	10,04	4,82
H	Transportasi dan Pergudangan	2,29	4,29
I	Penyediaan Akomodasi dan Makan Minum	0,19	4,76
J	Informasi dan Komunikasi	8,28	13,79
K	Jasa Keuangan dan Asuransi	3,53	-2,56
L	Real Estate	6,25	0,68
M,N	Jasa Perusahaan	-3,47	-8,57
O	Administrasi Pemerintahan, Pertahanan dan Jaminan Sosial	18,58	10,99
P	Jasa Pendidikan	6,74	4,84
Q	Jasa Kesehatan dan Kegiatan Sosial	8,88	3,64
R,S,T,U	Jasa lainnya	2,31	-4,87
	PRODUK DOMESTIK REGIONAL BRUTO	6,62	4,07
	PRODUK DOMESTIK REGIONAL BRUTO TANPA MIGAS	6,62	4,07

(Source: BPS Kab. Biak Numfor, 2017)

From the production of the agricultural sector, corn and coffee commodities are considered to have potential that can support the fulfillment of corn and coffee needs in other areas. The selection of corn commodities refers to the reason that it is considered one of the most prominent regional products compared to other agricultural and plantation products. Corn, in addition to human consumption, is also used for other industrial uses such as animal feed. The price of animal feed in Indonesia is the highest in ASEAN with the price of local corn above Rp4,000 and it is less competing with Brazilian corn, which is only Rp2,500 per kg [12].While coffee produced in Biak is the robusta coffee, one of the most popular types of coffee. The number of Biak's robusta coffee production in December 2014 reached 13 tons [13], so that a well-planned distribution from a corn and coffee producing region like Biak Numfor to other locations with a high demand of corn in Indonesia is needed. The study of commodity distribution in addition to strengthening the Nawacita program through the sea toll road is also capable of supporting the targets of Sustainable Development Goals (SDGs), especially the 12th objective relating to responsible consumption and production. One of the targets to be achieved on these pillars of SDGs is to achieve a sustainable and efficient management of resource use and reduce waste of food through appropriate supply chains. Each year, it is estimated that about one-third of the foodstuffs produced cannot be used because of decay or expiration caused by either improper planting practices or poor transport management [14], so the distribution of local commodities, especially food staples to various other areas in a systematic manner through sea transportation is needed.

The main question of this research is about how the route design and scheduling is optimized for the distribution of local commodities of Biak Numfor Region case study to other areas through efficient sea transportation planning. This research uses the Vehicle Routing Problem (VRP) approach with some limitations, which are: Commodities studied are general cargo with the main commodities of corn; The area under study is limited to, ports in Manokwari, Nabire, Fak-Fak, Kaimana, Saumlaki, Tual, Dobo, Merauke, Ambon, and Tanjung Perak. The assumptions used are; the number, type and capacity of the required vessel is available; capacity in the distribution center is limited; the speed of each vessel is assumed to be average. The study aims to build an optimal scheduling and route determination system for the distribution of commodities from the Biak Port distribution center to several ports in other parts of Indonesia with minimum cost.

The progress of infrastructure in developing country is the essential process that can be achieved by the integrated logistics system. Logistics is part of the supply chain process that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services, and related information between the point of origin and the point of consumption in order to meet customers' requirements [15]. Logistics also means ensuring the availability of the right goods, in the right amount, in the right condition, at the right place, at the right time for the right customer at the right cost [16]. Therefore, the management of logistics will follow the perspective that requires aligning activities in accurate space and time for successful logistics operations. The concept in logistics system of space and time will create the appropriate activities to fulfill various parameters and optimize given performance measurement. Minimizing total operational cost is one example of performance measurement in logistics system [17]. With the implementation of appropriate logistics system, it is expected to be a solution of the logistics system inefficiency problems in Indonesia, which still has a high cost.

The logistics system needs to consider the dynamics and complexities that occur in the real world. It is a common belief that logistics system, in the global business era, is vulnerable[18] and also open to many sources of threats [19], so it requires logistics planning activities that can provide a direction for logistics operations. Logistics planning involves making decisions regarding quantity, location, capacity, production technology, and warehouse [20]. Logistics planning considers the planning period, where the route selection and ship scheduling are included in medium-term planning [21]. Logistics planning will have an impact on logistics activities and target compliance with the overall logistics strategy. Logistics as a holistic context has key components to fulfill the certain operational process. The management of logistics system has five major aspects that follow the coordination process including inventory, transportation, warehousing, communication & order, also utilization [22]. Logistics services comprise physical activities (e.g. transport, storage) as well as non-physical activities (e.g. supply chain design, selection of contractors, freightage negotiations) [23]. Transportation is the essential aspect of logistics systems. Transportation is the movement of goods or passengers from one place to another, where the product is transferred to the destination is required. Transportation is a system consisting of infrastructure and / or facilities and service system that allows the movement of the entire region so that the mobility of the population is accommodated, the movement of goods is possible, and access to all areas is possible [24]. Systematic transportation planning is relevant to Indonesia as a major archipelago country.

Transportation decisions that need to be analyzed in designing and operating a supply chain include the transportation modes used, routes and network selection, as well as inhouse and outsourcing [25]. As one of the basic parts of logistics system, transportation is crucial apsect that has major influence in the system improvement. The cost of transportation, on average, accounted for 6.5% of market revenue and 44% of logistics costs [26]. The ratio highlighted the importance of transportation management to promote accuracy and value-added under the least cost principle. The transportation system, once put in place, must be effectively managed [27]. Thus it is necessary to plan the aspects of transportation such as routes and proper scheduling in order to achieve goals efficiently.

In the context of sea transportation, there is a difference between determining standard assignment and route determination and ship assignment (Baush et al., 1998). Among them is the marine routing problems that uses vessels that have different operational characteristics, including capacity size, speed, and others included in the cost structure. The purpose of the inclusion of heterogeneous vehicle factors is to know the proper use of vehicles in accordance with the route and demand in accordance with the customer to obtain the most minimal cost and not wasteful use of vehicle resources owned [28]. In addition, ship scheduling involves high uncertainty and usually longer delivery times [29]. The approach used to accommodate the existing limitations is the formulation of the mathematical model of a transportation system using certain optimization methods.

The problem in determining the route and scheduling in this research is the vehicle routing problem (VRP). The vehicle routing problem (VRP) is an operational research method that originally introduced by Dantzig and Ramser in 1959 [30]. The concept is an approach to search optimal solution in transportation. The VRP is a problem to design a set of vehicle reoutes in which a fixed fleet of delivery vehicles routes in which a fixed fleet of delivery vehicles from one or several depots to a number of customers have to be set with various constraints [31]. The concept has various types and develops into specific contexts that correspondent with real case or problem. VRP in general is also defined as the problem of determining the route for a number of vehicles that aim to minimize the total transportation costs and meet a number of restrictions that reflect the characteristics of the real situation [32]. The VRP variants considered in this study are single trip, single product, single time window, and heterogeneous fleet.

II. Research Methods

A. System Characterization

This research uses the logistics approach to the transportation aspect in the form of ship related to scheduling and determining the shipping route. The vessel is used to transport agricultural commodities in the form of coffee and corn delivered in the form of containers with large vessels. The vessel's route is the route that connects the port points passed by each ship. Meanwhile, the ship's schedule is the time interval of the ship's visit to every port point passed by its route.

This study focuses on the proposed route and more efficient schedule of depots and ports of consumer demand. The research data is in the form of lane and port based on existing route of T12 sea toll road, which is the Nawacita program in Indonesia. Data processing then modifies the travel route that is considered ineffective due to the empty charge behind the vessel. Data about the distance between ports can be taken from Netpas. The products distributed consist of corn and coffee chosen because it is the main agricultural commodity in Biak Regency which is produced in abundance. In this study, there are ten ports consisting of one supply depot and nine destination point customers.

Both products are distributed by three types of vessels, which are the KM Caraka for General Cargo ship type with a capacity of 6500 tons, Perintis Papua I ship with a capacity of 2000 tons, and the Perintis Papua V ship with a capacity of 1500 tons. With a numerical example of the number of demand and supply capability of each port, the number of commodity transport will be adjusted to the capacity of the vessel.

The average speed of ships used is 14 knots or approximately 25.9 km per hour. This average speed affects the time it takes the ship to travel between points.

B. Conceptual Model of Research

The research method is related to the problem of scheduling and determining the ship route. This model was developed using the liner shipping model. System modeling with the liner shipping is intended to operate general cargo vessels based on the published travel guidebooks, whereby the vessel operates according to the set schedule and route. The distribution system of the corn and coffe commodities from Biak Numfor Regency to several regions in Indonesia represents a similar system with the liner shipping model. The ultimate goal of the ship's scheduling and determining system is to find a proper set of routes and ship assignments that meet the conditions with reference to the conceptual model of research. The model to be developed in the distribution of this product has several limitations, among others are:

1. Heterogeneous Fleet, Ships owned have different capacities. Each vessel also has different limits, be it from the size of the load capacity, maximum mileage capability, and more.
2. Single Trip, One ship can serve one customer / route in a single product delivery tour.
3. Multiple Products, The vessels used have more than one type and the type of product is shipped over one kind of product. The products that are transported for distribution are the main commodities of corn and coffee.
4. The fixed costs for transporting corn and coffee differ for each ship. The number of ships is based on the ship's capacity.
5. The distance between ports is symmetrical 6.The speed of each ship is constant, 14 knots.

Multiple Time Windows, The mechanisms of opening and closing hours of the port are used as the basis for service time of port operators.

C. Model Formulation

The purpose function of this model is to minimize the total cost of the ship journey, which is formulated as follows:

- **Minimization of the total cost of ship's journey** Z = the total cost of the ship's journey k on the route x the binary number stating that the route r served by the ship k is present in the solution or not.

$$C_{ijk} = d_{ij} \times \beta_k$$

$$Z = \sum_{k \in K} a_k z_k + \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} C_{ijk} X_{ijk}$$

- **Contrain Function**

  The constraint guarantees that each route is served by only one ship. This constraint is expressed by the following equation:

$$\sum_{k=1}^{K} Y_{ik} = 1, \qquad i \neq 1$$

- **Vessel Constraint**

  This constraint guarantees that if ship k serves port i, then the same vessel must enter and exit the node except the depot. This constraint is expressed by the following equation:

$$\sum_{j=1}^{J} X_{ijk} = Y_{ik}, \forall i \in I; k \in K \ dimana \ i \neq j$$

- **Capacity Constraint**

  The limitation of this vessel's capacity is the limits that serve to guarantee the commodities transported from the supplier in accordance with the capacity of the ship. This constraint is expressed by the following equation:

$$\sum_{i=1}^{I} D_i . Y_{ik} \leq Q_k . z_k, \quad \forall k \in K$$

- **Service Time Constraint**

  These service timelines are constraints that serve to ensure that service must be between opening hours and harbor closing hours. This constraint uses the following equation:

$$a_i \leq \tau_i \leq b_i, \quad \forall i \in I$$

- **Time Window Constraint**

  Time window constraint is a constraint that serves to to guarantee the time of service settings in the port. This constraint is expressed by the following equation:

$$T_{ik} \geq \pi_k, \quad \forall k \in K$$

$$\tau_i \geq T_{ik}, \forall k \in K; \ i \in I; i \neq 1$$

$$T_{jk} \geq \pi_k + w_{ijk} - M(1 - X_{ijk}) \forall k \in K; \ \ j \neq 1$$

$$T_{jk} \geq \tau_i + s_i + w_{ijk} - M(1 - X_{ijk}), \quad \forall k \in K; j \neq 1$$

- **Binary Constraint**

  This constraint is binary to Xijk, Yik, zk, where it will be 1 if the port is served by the ship k contained in the solution and Xijk, Yik, zk will be 0 if the opposite condition occurs, formulated as follows:

$$X_{ijk} \in \{0,1\}, \quad i \in I, j \in J, k \in K$$

$$Y_{ik} \in \{0,1\}, \quad i \in i, k \in K$$

$$z_k \in \{0,1\}, \quad k \in K$$

- **Mathematical Model**

  Based on the function of the objectives and limiting functions that have been described, it can be formulated in the form of linear programming integers or integer linear programming (ILP). Here is the final model formulation: Objective Function:

$$Min \ Z = \sum_{k \in K} a_k z_k + \sum_{i \in I} \sum_{j \in J} \sum_{k \in K} d_{ij} \beta_k X_{ijk}$$

Constraint Function:

$$\sum_{k=1}^{K} Y_{ik} = 1, i \neq 1$$

$$\sum_{j=1}^{J} X_{ijk} = Y_{ik}, \quad \forall i \in I; \ k \in K; \ i \neq J$$

$$\sum_{i=1}^{I} D_i Y_{ik} \leq Q_k . z_k, \quad \forall k \in K$$

$$a_i \leq \tau_i \leq b_i, \quad \forall k \in K$$

$$T_{ik} \geq \pi_k, \quad \forall k \in K$$

$$\tau_i \geq T_{ik}, \quad \forall k \in K; i \in I; i \neq 1$$

$$T_{jk} \geq \pi_k + w_{ijk} - M(1 - X_{ijk}) \ \forall k \in K; j \neq 1$$

$$T_{jk} \geq \tau_i + s_i + w_{ijk} - M(1 - X_{ijk}), \forall k \in K; j \neq 1$$

$$X_{ijk} \in \{0,1\}, \quad i \in I, j \in J, k \in K$$

$$Y_{ik} \in \{0,1\}, \quad i \in I, k \in K$$

$$z_k \in \{0,1\}, \quad k \in K$$

Index:

i, j:port index k : ship index, k:1,2,... K

Parameter:

di, : distance between port i with port j limit (mil)

: vessel speed k (knot or namutical miles/hour)

αk: fixed cost of vehicle k (Rp)

: ship fuel costs k (Rp/mil)

: demand for corn and coffe at port i (ton)

wi,, : travel time from port i to port j by ship k (jam)

: service time at port i (jam)

: opening hour of port i

: closing hour of port iQk : maximum capacity of vehicle k (ton)

Variable:

T : minimum time of ship k for port i

: departure time of vessel k

: service time of port i

Ci : travel expenses of ship k from $i$to j

Xi : value 1, if port j visited after port i by ship k, value 0, for others

Y : value 1, if port i served by ship k, value 0, for others

: velue 1, if ship k used, value 0, for others : total ship

D. Data collection

The data used as supply and demand for corn and coffee commodities is a numerical example that can meet the needs at the depot location and ship destination. The example of the numerical data can be seen in table 2. Data related to mileage of the ship for each port can be obtained from the *Netpass database* for 2018. To clarify the distance between ports, it can be seen from table 3.

TABEL II. PICKUP AMOUNT AND DELIVERY AMOUNT

No.	Name of Port	Location	Pick Up amount	Delivery amount
1	Kaimana	Kaimana Regency	522	678
2	Fak-fak	Fak-fak Regency	391	547
3	Nabire	Nabire Regency	404	560
4	Merauke	Merauke Regency	487	643
5	Manokwari	Manokwari Regency	532	688
6	Tual	Tual City	320	476
7	Dobo	Kepulauan Aru Regency	479	635
8	Saumlaki	Maluku	438	594
9	Ambon	Ambon City	488	644
10	Tanjung Perak	Surabaya	713	869
	Jumlah		4774	6334

TABEL III. DISTANCE BETWEEN PORTS

No.	PORT	BK	KN	FK	NR	MR	MW	TL	DB	SL	AB	TP
1	BK	0	802	650	156	1271	127	781	823	910	673	1552
2	KN	802	0	196	858	557	698	144	155	348	391	1376
3	FK	650	196	0	706	703	546	199	247	366	310	1251
4	NR	156	858	706	0	1326	175	837	878	965	729	1608
5	MR	1271	557	703	1326	0	1167	591	466	609	850	1733
6	MW	127	698	546	175	1167	0	677	719	806	569	1448
7	TL	781	144	199	837	591	677	0	110	190	325	1303
8	DB	823	155	247	878	466	719	110	0	235	453	1347
9	SL	910	348	366	965	609	806	190	235	0	460	1191
10	AB	673	391	310	729	850	569	325	453	460	0	1008
11	TP	1552	1376	1251	1608	1733	1448	1303	1347	1191	1008	0

(Netpass database, 2018)

III. RESULTS

From the calculation and modeling, the solution in the form of optimal schedules and routes is presented in graphical form to provide an overview to make it easier to understand. The solution in this study was developed to obtain optimal solutions based on a relevant data. In determining the sea toll routes and scheduling, the mode of transportation used is the vessel. In liner shipping, every single vessel has only one clear route and only serves on one port only, where the predetermined route is the optimal and efficient route that sails from Biak to the destination points. In Figure 1, it gives an overview of the port location observed in this study. The port consists of one port of origin (depot) and nine ports of destination. The depot is located in Biak, serving as a shipping and distribution center of the region's main agricultural commodities that include corn and coffee to seven destination ports in Papua, West Papua, Maluku and East Java.

Fig 1. Ports considered in the Research

Selected trip routes consider several aspects, such as the capacity of the ship used, the number of main commodities transported, the mileage of the vessel, the average speed of the vessel, as well as the time windows of each port, serving at 08.00-21.00 with a working duration of approximately 13 hours per day. Then after processing the data, obtained the calculation results of three vessels that have different capacities, which can meet the purpose function, namely shorter ship mileage, shorter and more optimal ship travel time, shown in Figure 2. The description of the route of travel is as follows:

(1) KM Caraka Ship (*general cargo*), serves the Biak - Saumlaki - Dobo - Kaimana - Fak-Fak – Merauke route. On the first day of departure, KM Caraka started the journey at 06.00 and went to the port of Saumlaki with a total distance of 910 nautical miles. The journey takes travel time for 873.76 hours, or about 36 days. The vessel is served for approximately 8 hours to perform the loading and unloading of corn and coffee commodities. The ship continues the journey to Dobo harbor with a mileage of 1145 nautical miles, during 1099.12 hours journey within a period of approximately 45 days journey. KM Caraka ship arrived at Dobo harbor at 08.15, to get a service about 7 hours. Then the ship left the port at 15:24. After that KM Caraka sailed to the port of Kaimana with a mileage of 1300 nautical miles, for 1248 hours or during the period of 52 days journey. With a service time of about 8 hours, the ship continues the journey to the next port, the port of Fak-Fak with a distance of 1496 nautical miles, the estimated travel time to 71436.09 hours with a period of about 59 days journey. With a service time of approximately 6 hours for loading and unloading, KM Caraka leaves Fak-Fak at 6:33 am. Then it continues the final journey to Merauke with a mileage of 2199 nautical miles, for 2111.02 hours or in 87 days of journey. And it gets a service for about 7 hours for loading and unloading.

(2) The second ship serves the route Biak -Tual - Ambon. The 2nd ship with the capacity characteristics is sailing to the selected port, located in Papua Province and West Papua Province. The journey of Perintis Papua I ship from Biak Port to Tual Harbor with 781 nautical mile distance, takes 749.45 hours with 31 day travel period. The ship arrives at 11:45 then get

service for 4 hours and immediately leaves the port to Ambon. The journey has a distance of 1106 nautical miles for 1061 hours within a period of 44 days journey. It arrives at 16:48 then gets a service for 7 hours for loading and unloading. Then, the last trip to the port of Tanjung Perak with mileage 2114 nautical miles takes 2029.26 hours or a 84 days journey. With the loading and unloading time of corn and coffee commodities for approximately 11 hours

(3) Then the third ship serves the route from Biak - Manokwari - Nabire. The journey uses the Perintis Papua V ship and its first trip is to Manokwari harbor, with a mileage reaching 127 nautical miles for 121.55 hours or approximately 5 days, with a 8 hour service time to load and unload the goods. Then it continues the journey to the Nabire port with a distance of 302 nautical miles for 289.55 hours or approximately 12 days, with loading and unloading time of approximately 6 hours of service.

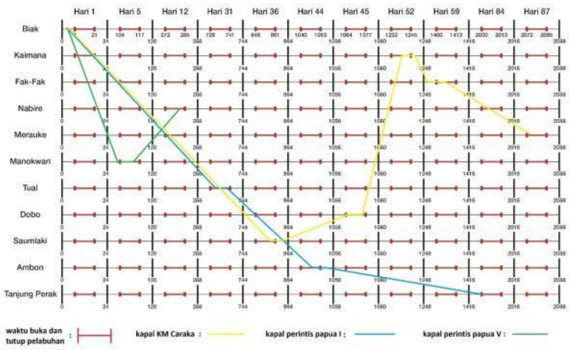

Fig 2. Result of the route determination and completion time.

With different demand of each commodity at each distribution point, the number of vessel will be adjusted with three types of vessels with different capacities. Therefore, the total supply of corn and coffee commodities can be transported for distribution. So the returning ship from Biak to Tanjung Perak is not empty. It can support the natural resources of Biak Numfor in order to have a selling value that can increase local income and support the economy of local communities. The suitability of ship capacity and demand for agricultural commodities is shown in Table 2.

Selected commodity distribution routes can provide minimum distance, as well as efficient transportation operational costs. In the cost function, there are several things that can affect the total cost, such as the large capacity of the ship used. The larger the capacity of the ship, the cost incurred will be greater, and vice versa. Distance or mileage of the ship is different because of different routes on each ship. Increased ship mileage will consume expenditure on fuel costs, which leads to an increase in overall costs. Thus the route has provided an optimal value function from the aspect of distance, time, and cost incurred in transit.

TABLE IV. TABLE OF THE SUPPLY AND DEMAND AND THE SHIP'S CAPACITY.

Ship	Destination Port	Supply (Ton)	Demand (Ton)	Ship Capacity (Ton)
1	Saumlaki	438	594	6500
	Dobo	487	635	
	Kaimana	522	678	
	Fak-Fak	391	547	
	Merauke	487	643	
	Total	**2325**	**3097**	
2	Tual	320	476	2000
	Ambon	488	644	
	Tanjung Perak	713	869	
	Total	**1521**	**1989**	
3	Manokwari	532	688	1500
	Nabire	404	560	
	Total	**936**	**1248**	

IV. DISCUSSION

With the results of the research that has been presented, this study is expected to contribute to the theoretical and practical aspects, so that this research can develop knowledge and deepen the study related to the model of sea transportation in Indonesia. In the theoretical sphere, the model of this study refers to some previous research that discusses the determination of VRP solutions with objective function in the form of route minimization and scheduling for the transportation of ships. The distribution of goods using ships in Indonesia has long been in operation, but there are still some facts that indicate the need for increased effectiveness in the field, related to the empty vessel loading to the original port after reaching the final destination port. The empty vessel loads, if filled, can give two advantages of being able to maximize the superior commodities of certain regions in eastern Indonesia and able to support the fulfillment of needs in other areas.

The research that refers to the problems of VRP for sea transportation began to be developed more. In the model developed by Arvian et al. (2014), the resulting solution is used to determine a more efficient voyage route, then determine ship scheduling, as well as minimize the travel expenses incurred. The parameters used are, (a) multiple trips, where one vehicle can serve more than one route in a shipping planning period, (b) Multiple products and multiple compartements, the type of product delivered and the vehicle used to ship the product has more than one compartment, (c) Multiple time windows, the mechanism of opening hours and closing hours is in accordance with customer more than one in the planning period, (d) Split delivery, product delivery to one customer can be shared by one or more vehicles, (e) Heterogeneous fleet, product deliveries are made using vehicles of different types and capacities. The developed model is the Heterogeneous Fleet Vehicle Routing Problem (HFVRP). The model is a new VRP variant that solves problems with different types and capacities of vehicles. With the limitations that the researcher gave, the optimal route determination and the cost minimization for the tanker being the mode of transporting the product are possible..

Next, there is a model developed by Fatma and Kartika (2017) [33], where this study provides scheduling solutions and route determination of vessels for the distribution of rice commodities from the port of origin in Surabaya to various ports in eastern Indonesia, by considering these limitations: (a) Single commodity, or commodities distributed is only rice, (b) Single trip, one vehicle that serves only one route in the context of delivery of goods, (c) Heterogenous fleet, use of different types of vehicles with different capacity. However, in this study, the parameters associated with time windows or opening hours of port cap are not clearly defined, so there is no known complete characteristic of the time parameter of windows and its impact on the purpose function. In addition, the aspect of travel expenses incurred in distribution activities is not explicitly stated.

Thus, on the theoretical aspect, this research developed a model approach done by Fatma and Kartika (2017) [33], with the determination of the vessel route based on the delivery route, the commodity needs (corn and coffee) at the destination location, the availability of the vessel, the carrying capacity of each vessel, the opening and closing time service in port of destination, and service time with activities in the form of loading and unloading of goods. The optimum solution developed in this study is able to fulfill the purpose function in the form of the minimum route of the vessel and the journey schedule and the arrival of each ship in each port. The selected objective function refers to the type of mediumterm planning on logistics systems [21]. The solution in this study was developed by not violating the boundaries of single trip, single time window, single commodity, and heterogenous fleet. Parameters and mathematical formulations include the use of branch & bound algorithms referring to the Fatma and Kartika model (2017) [33].

The difference between this study with previous one is the addition of the number of destination ports and the clarity of time windows values. In addition, this model fulfills the aspect that the ship does not return to its original port (Baush et al., 1998). The ship does not return to the port depot (Biak) because it will return to the port in the territory of Western Indonesia to fill the goods of the new route. The limitation of this research is that route modeling and ship scheduling have not fully described the real condition since not all parameters have been used. In addition, the data and parameters used in this study is still an example of numerical application and need an integrated validation. Theoretically, this research can be developed with the addition of more complete parameters such as variations of time windows that adjust the conditions directly at the port, the addition of the ship, the addition of the distribution destination point, and consider the integration with smaller ports. In addition to the aspect of determining cost efficiency, the costs involved can be added such as the cost components developed by Arvian et al. (2014) which covers the vehicle fixed costs referring to capacity differences, fuel costs per km, daily travel accommodation costs, crew salaries per route, travel fee fees, and loading and unloading costs.

In practical aspect, it is expected that this research can contribute to the optimization of sea toll agendas which become a part of the Nawacita program in Indonesia, where the rating of connectivity index in Indonesia still needs to be enhanced besides the challenge of benig the largest archipelago country in the world. The aim of the sea toll program is to reduce the price disparities, especially in eastern Indonesia. This study uses a case study of Biak Numfor area located in Papua Province which has a trend of Gross Regional Domestic Product (GDP) that tend to decrease (BPS, 2016). With abundant commodities in the agricultural sector in the form of coffee and corn, it is expected to support the strengthening of the regional economy, as well as to meet the demand from agricultural commodities in the regions. The results of this study can be a recommendation for the related ministries, particularly on improving the distribution of route network T12 which distributes goods from Surabaya to various ports in the eastern part of Indonesia. In this case, the relevant parties are the Directorate General of Sea Transportation and the Ministry of Transportation of Indonesia.

V. CONCLUSIONS

The issue of price disparity has become one of the obstacles in equitable economic development in Indonesia. Potential sea toll road program can be a solution to the key activities of distributing goods across remote areas. This can be done through a careful transport planning. Transportation in the sea usually uses a mode of ships with a variety of types and capacities. One that needs to be maximized in the aspect of the distribution of goods through maritime transport is the empty vessel load once the ship returns from a secluded port to a large port such as Surabaya and Jakarta. The selected case study is the Biak Numfor Regency with a consideration of economic growth that is not yet stable but on the other hand has a wealth of agricultural commodities such as corn and coffee. This study examines the shortest route and scheduling of marine vessels from Biak that carry agricultural commodities to other ports.

The results showed that there were three ships coming from Biak as the initial port of KM Caraka ship, Perintis Papua I Ship, and Perintis Papua V Ship. The most efficient route generated is for the KM Caraka ship serving the Biak-Saumlaki-Dobo-Kaimana-Fak-FakMerauke route with the total time of Caraka ship is 87 days, Perintis Papua I ship is 84 days, and Perintis Papua V ship is 12 days. While the Perintis Papua I Ship serves the Biak-Tual-Ambon route with the total time of . While the Papua V Pioneer Ship serves the Biak-ManokwariNabire route, with a total time of . Limitations or parameters considered in this study are ship capacity, time windows or port opening and closing hours, and commodity characteristics. This research contributes to maximizing the role of sea toll road in Indonesia through the distribution of local commodities. This study on theoretical aspects can be developed more fully and integrated with the addition of more detailed cost components and consideration of other relevant parameters.

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