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Determining Health Boat Route to Improve Health Care for Small Islands in Derawan Archipelago using Distance and Population Density Consideration

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Abstract. One of the methods to improve insufficient health services in Derawan Archipelago is by building a floating health infrastructure (Health Boat). It requires a method to decide optimal and effective route. Health Boat optimization uses a mathematical method, by considering distance and time shipping, number and condition of the patient based on total population, and optimization of the two variables. That's why from the three routes that are modeled in this study, a route which optimizes both constraint is chosen. To facilitate the discussion, researcher used alphabet in naming the islands. First alternative route is determined based on the distance of the island from Tanjung Batu and the result is: O-A-F-B-D-C-E-G-H-O with total distance is 256.07 nm. Second alternative is determined based on total population and the result is: O-E-F-C-G-A-H-B-D-O with distance is 442.16 nm. The last alternative is determined by a combination and the result is: O-F-E-C-D-B-A-G-H-O with distance is 328.29 nautical miles. Researcher chooses Route III as the optimal route considering distance and total population.

Introduction

The number of islands in Indonesia, according to data from Ministry of Home Affairs of the Republic of Indonesia in 2004, was as much as 17,504 islands. 7,870 of them have names, while 9,634 do not yet have a name. As a maritime country, Indonesia has a coastline of 95,181 km; making it the second country with the longest coastline in the world.

East Kalimantan itself has 363 small islands scattered in some areas and from the data of Directory Small Islands of Indonesia, the data collection of those islands are not finished yet, so the data obtained shows some islands are still uninhabited. From observations, Derawan Archipelago has 31 small islands, only 8 are populated by people, they are Derawan, Maratua, Kakaban, Sangalaki, Semama, Panjang, Balikukup and Kaniungan Besar Island.

The total population in Derawan District that consists of Derawan, Sangalaki and Panjang Island is 1,694 people, in Batu Putih District is 8,171 people, in Biduk-Biduk District is 5,836 people while in Maratua District that consists of Kakaban and Maratua Island is 3,555 people.

Distribution of medical facilities in Indonesia is uneven. Doctors, medical personnel and major hospitals only found in large cities so that citizens in remote island have difficulties to reach these facilities.

Data from the Central Bureau of Statistics District of Berau shows that Berau only have one hospital located in Tanjung Redeb named Abdul Rival hospital which is a Government Hospital in Berau District, type C with 6 types of basic health services and has 170 bed units. From the data of Department of Health of East Kalimantan, the number of people died in Abdul Rival hospital is 309 people in 2014. While the numbers of patients in the Derawan Islands are 777 people in 2013 with the numbers of health facilities are 10 units.

Therefore, it is necessary to build a health care floating facilities (health boat), which provides hospital standards care. This ship has a specific route determined by a mathematical method, Vehicle Routing Problem.

They are several studies on the method of vehicle routing problem, especially in the field of shipping route determination. Zhang, et al. (2015) [1] discuss VRP with the consideration of fuel cost, carbon emission cost, and vehicle usage cost into the traditional VRP problem and establish a low-carbon routing problem model. This research show that the route and vehicle arrangements based on fuel consumption and carbon emission are both economic and environmentally friendly.

Since our goal is to find optimal fixed routes for health boat operation on a regular schedule, our problem falls into the liner shipping category. We consider the strategic problem of creating long term routes that fulfill the demand with as few ships as possible. This problem is strongly reminiscent of the vehicle routing problem (VRP), and indeed most papers dealing with liner ship routing have formulated the problem as a variant of VRP (e.g., Fagerholt, 1999; Fagerholt & Lindstad, 2000; Sambracos, Paravantis, Tarantilis, & Kiranoudis, 2004; Karlaftis, Kepaptsoglou, & Sambracos, 2009).

Jiaotong (2015) has objective that is to determine a Danish tramp shipping company in the tanker business which orders to serve and to find the optimal route for each ship and the optimal sailing speed on each leg of the route so that the total profit is maximized.

Method

I. Research Location

The location used as a case study in this research is Derawan Archipelago. Berau District consists of thirteen (13) districts, including the District of Maratua and Derawan Districts.



Figure 1. Location of Derawan archipelago.

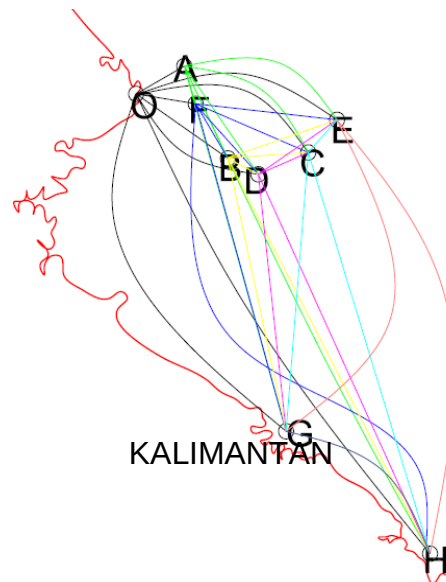


Figure 2. Research object.

The Derawan Archipelago consist of 31 islands and a few sand island (*gosong*) and atolls. From the 31 islands, taken 8 inhabited islands, they are Derawan, Maratua, Kakaban, Sangalaki, Semama, Panjang, Balikukup and Kaniungan Besar. Location of the islands can be seen in Fig. 1 and distances between islands are presented in Table 2. To facilitate the discussion, alphabet is used in naming the islands (Table 2) and provide redrawn map (Fig. 2) so that the operation area of Health Boat is clearly revealed.

II. Preparation of Data

The data needed are the number of population in each small island in East Kalimantan, as stated in Table 1.

Table 1. Total population in Derawan archipelago.

No	Island Name	Total Population (People)
1	Derawan,	1500
2	Maratua,	2818
3	Kakaban,	737
4	Sangalaki,	20
5	Semama	20
6	Panjang	174
7	Balikukup	600
8	Kaniungan Besar	60

However, it was difficult to gather data about number of ill and dead patients in Derawan Archipelago because of lack of information from East Kalimantan Health Ministry.

III. Distance Estimation

The distance between each small island to home base in Tanjung Batu is measured by using the google earth.

Table 2. Derawan archipelago distance matrix.

No	Alp.	Unit (Nm)	Distance Matrix									
		From - To	O	A	B	C	D	E	F	G	H	
0	O	Tanjung Batu	0.0	8.5	16.4	31.0	22.9	40.5	8.9	55.7	83.5	
1	A	Panjang	8.5	0.0	17.6	22.7	20.7	24.5	4.2	59.0	89.6	
2	B	Semama	16.4	17.6	0.0	12.2	6.2	17.0	12.1	45.4	77.0	
3	C	Kakaban	31.0	22.7	12.2	0.0	8.3	9.7	20.3	46.8	64.9	
4	D	Sangalaki	22.9	20.7	6.2	8.3	0.0	13.8	15.8	45.7	67.0	
5	E	Maratua	40.5	24.5	17.0	9.7	13.8	0.0	22.3	51.7	65.9	
6	F	Derawan	8.9	4.2	12.1	20.3	15.8	22.3	0.0	53.2	80.8	
7	G	Balikukup	55.7	59.0	45.4	46.8	45.7	51.7	53.2	0.0	38.3	
8	H	Kaniungan Besar	83.5	89.6	77.0	64.9	67.0	65.9	80.8	38.3	0.0	

IV. Mathematical Modeling

We make three routes for the health boat by taking into account the distance and shipping time, the number and condition of the patient, and the optimization of the two variables. The Health boat will return to its home base in Tanjung Batu to resupply equipments and medicines and to change medical personnel on board. We use mathematical models called TSP.

The purpose of the Traveling Salesman Problem (TSP) is to establish a minimum distance in one cycle in which each vertex is visited just once. If the distance is symmetric, the travel distance between locations is not dependent on the direction of travel; this problem is called symmetric TSP problem. Otherwise, the problem is called asymmetric TSP problem.

Mathematically the problem TSP can be described as a salesman who must travel out of town 1, 2, ..., n. Distance from town i to town j is d_{ij} , for $i \neq j = 1$ to n. The salesman wants to embark on a journey to several towns, visit each town exactly once and return to the origin town. The problem is to determine the optimal sequence of the journey, so the total distances will be small.

Suppose that the salesman begins from town 1. If he travels from town to town in order i to $i + 1$, $i = 1$ to $n - 1$, and then from town n to town 1, this route can be represented by the sequence 1, 2, ..., n; 1. That order is called a tour; it has to visit each town exactly once. So the beginning of the tour can be from any town because each town is connected to one vertex. For example, from town 1, salesman can go to town n - 1 or other. So there is n-1 different ways in which salesman can choose which town he wants to visit after town 1. From this town, salesman can go to n-2 remaining town.

So the number of possible tour in n TSP town is $(n-1)(n-2) \dots 1 = (n-1)!$. The mathematical model of the TSP can be formulated as follows:

$$x_{ij} = \begin{cases} 1, & \text{if } j \text{ town is visited from } i \text{ town} \\ 0, & \text{if not} \end{cases} \quad (1)$$

If d_{ij} is distance from i town to j town, the TSP mathematic model is:

$$\text{Minimize } z = \sum_{i=1}^n \sum_{j=1}^n d_{ij} x_{ij}, d_{ij} = \infty \text{ for all } i = j \quad (2)$$

Subject to:

$$\sum_{j=1}^n x_{ij} = 1, i = 1, 2, 3, \dots, n \quad (3)$$

$$\sum_{i=1}^n x_{ij} = 1, j = 1, 2, 3, \dots, n \quad (4)$$

$$x_{ij} = (1, 0) \quad i, j = 1, 2, \dots, n \quad (5)$$

In determining the optimal route of Health Boat, we need to pay attention to the distance and shipping time, the number and condition of the patient, and the optimization of these two variables.

Result and Discussion

I. Route I

Route I is determined based on the distance of the island from the town of Tanjung Batu which is the home base of the Health Boat. The mathematical model based on data in Table 2 is used to decide Route I. The Health Boat departs from home base in vertex O, and chooses the shortest route from O (the first island), resume to other island using the shortest route and so on.

$$\text{Minimize } \{X_{OA}, X_{OB}, X_{OC}, X_{OD}, X_{OE}, X_{OF}, X_{OG}, X_{OH}\}, \quad (6)$$

$$x_{ij} = 1, i \text{ and } j = 1, 2, 3, \dots, n$$

X_{OA} = distance from vertex O to vertex A

From this model, A island is chosen as the first destination, and A is eliminated from next mathematical model because A is the starting island (i),

$$\text{Minimize } \{X_{AB}, X_{AC}, X_{AD}, X_{AE}, X_{AF}, X_{AG}, X_{AH}\}, x_{ij} = 1, i \text{ and } j = 1, 2, 3, \dots, n \quad (7)$$

$$X_{AB} = \text{distance from vertex A to vertex B}$$

From this model, F island is chosen as the second destination, and F is eliminated from next mathematical model because F serves as the starting island (i), and so on until all the islands is visited exactly once and return to O. The Route I as a result from the calculation is: O-A-F-B-D-C-E-G-H-O and the route can be seen in Fig. 3(1). Total distance of this route is 256.07 nautical miles, the service speed of health boat is 10 knots, so the travelling time is 25.607 hours.

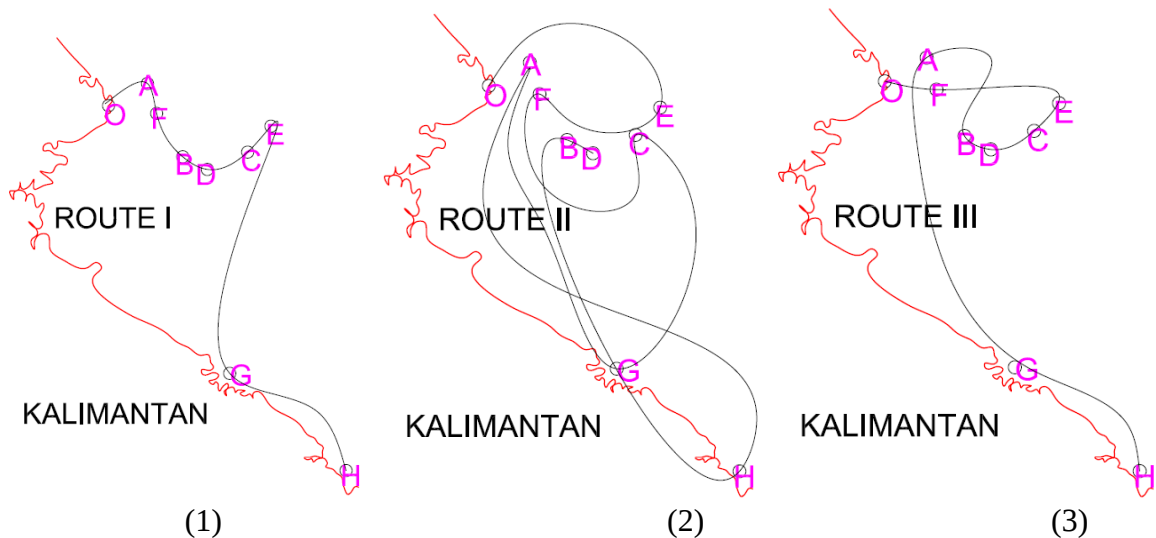


Figure 3. Result of the route.

II. Route II

Route II is determined based on the number and condition of patients. However, because of the data limitation from the Department of Health of East Kalimantan, we decide to use total population data of each island to decide the route. The Health Boat departs from and returns to O (see Table 2). The Route II as a result from the calculation is: O-E-F-C-G-A-H-B-D-O (see Fig. 3 (2)). Total distance is 442.16 nautical miles, the service speed of health boat is 10 knots, so the travelling time is 44.216 hours.

III. Route III

Route III is determined by a combination of distance and total population of each island. The decision of this route is based on premier data, site visit and interview result of people in Kaniungan Besar island. We got additional information that the time to travel from Kaniungan Besar to Biduk-Biduk District, is the same as the time needed to travel from Balikpapan to Batu Putih District, which is only about 30 minutes. Therefore, although Balikpapan took the 4th place in term of total population, we decide to visit this island last because of its distance. The Route III as a result from the calculation is: O-F-E-C-D-B-A-G-H-O (see Fig. 3 (3)). Total distance is 328.29 nautical miles, the service speed of health boat is 10 knots, so the travelling time is 32.829 hours.

Conclusions

Of the three routes that are modeled in this study, we have measured the distance for each route. We choose route III because it is the most optimum route in term of time and total population. The Route III has a total distance is 328.29 nautical miles, covering all of 5929 population in 8 islands. The service speed of health boat is 10 knots, so the travelling time is 32.829 hours.

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