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Saving Matrix Method and Nearest Neighbor Method for Garbage Transport Route Problems

Evi Yuliza[a)], Bambang Suprihatin[b)], Putra Bahtera Jaya Bangun[c)], Fitri Maya Puspita[d)], Sisca Octarina[e)] and Nuraina[f)]

Department of Mathematics, Universitas Sriwijaya, Jl. Raya Palembang-Prabumulih KM 32 Indralaya, Ogan Ilir 30862, Indonesia.

[a)] *Corresponding author: eviyuliza@mipa.unsri.ac.id*
[b)] *bambangs@unsri.ac.id*
[c)] *putra5978@unsri.ac.id*
[d)] *fitrimayapuspita@unsri.ac.id*
[e)] *sisca_octarina@unsri.ac.id*
[e)] *nurainamath18@gmail.com*

Abstract. Transporting waste vehicle routes can be viewed as a Vehicle Routing Problem (VRP). Nowadays, the problem of garbage transport vehicles in Ilir Barat I District is an important responsibility of the city government. In solving the problem of garbage collection vehicle routes, we propose a waste collection vehicle routing problem with time windows that pay attention to service time and rest time so that the distance traveled and travel time are optimal. This model is solved using the saving matrix and nearest neighbor method. The route of transporting waste from the Temporary Landfill (TL) to the Landfill (LF) is carried out randomly, causing insufficient travel time and distance. The working time of the waste transportation process in Ilir Barat I District is carried out in two sessions, namely session 1: at 07.00-11.00 West Indonesian Time (WIT) and session 2: 16.00-20.00 WIT. Garbage collectors have a break of 5 hours. The calculation of the waste transportation routes using the saving matrix method is obtained by grouping several TL into one route and sorting using the nearest neighbor method. The results show that the garbage collection vehicle at work session 1 serves Region 1, Region 2, Region 3, Region 4, and Region 5 with a total distance of 126.31 km with a total travel time of 5.67 hours. As for the working time of session 2, the garbage collection vehicle serves Region 6, Region 7, Region 8, and Region 9 with a total distance of 151.91 km and a total travel time of 6.3 hours. We found that the total travel time of the waste transporting vehicle exceeded the working time, thus cutting the rest time of the garbage transporter.

INTRODUCTION

The problem of waste is a problem faced in big cities, especially in Indonesia [1][2][3][4]. Due to the non-biodegradable nature of waste, waste is a somewhat complicated problem. If the management is not good, the intensity and presence will continue to increase. Waste problems need to be overcome by taking actions such as optimizing waste transportation routes so that the distance and travel time are minimum. Ilir Barat I District is a sub-district located in Palembang City. The location of Ilir Barat 1 District is quite strategic because of the many shopping centers, schools, and residential areas.

Garbage transport process from the Temporary Landfill (TL) to the Landfill (LF) is carried out by the Palembang City DLKH officers using waste transport vehicles such as Containers, Dump Trucks, or Amrol. The working time in carrying out the waste transportation process is divided into two sessions. Session 1 working time is from 07.00 – 11.00 WIT, and session 2 working time is from 16.00 – 20.00 WIT. This study will also discuss the time off from the officers. Paying attention to the working time which has two sessions, shows that there is a duration of 5 hours between the working time of session 1 and session 2, which the officers can use to rest. Garbage transport vehicles

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will pick up waste from several TL and take it to the LF. Garbage transport routes are carried out randomly, so the time and distance traveled are not optimal.

Determining the Ilir Barat 1 District route can be categorized as a Vehicle Routing Problem (VRP). The problem of garbage transport vehicles in Ilir Barat I District is important to the city government's responsibility and the city's environmental and sanitation services. VRP has been a combinatorial optimization problem for decades [5][6]. VRP can be implemented in the case of logistics, distribution, transportation and waste collection [7][8][9][10]. In this study, VRP discussed the problem of transporting waste. VRP on the garbage transport process is a vehicle with an available vehicle and their capacity that is responsible for transporting waste at several TL by paying attention to service time [11][12][13]. Several heuristic methods can be used to solve VRP in the case of waste transportation problems [14][15].

Saving Matrix is one way to minimize travel distance and time by connecting existing nodes to form a route based on the largest saving matrix value. The principle of the Nearest Neighbor method is to focus on the closest distance to the current position. The saving matrix and nearest neighbor methods include the heuristic method [16][17][18]. Garbage collection vehicle routes can be determined with robust counterpart open capacitated vehicle routing problems with time windows which is solved by the nearest neighbor method [16]. A saving matrix is a method used to determine the distance, route, time, or cost of shipping goods by selecting the path that must be passed [19]. The savings matrix will enable these savings by combining multiple stores into just one route [20]. After combining several TL using the saving matrix method, then the routing is done using the nearest neighbor method. The saving matrix method and the nearest neighbor method are implemented on the problem of waste transportation routes in Ilir Barat 1 District, Palembang City, to optimize the route of waste transport vehicles to minimize distance and travel time.

METHOD

The determination of route of the waste vehicle in Ilir Barat 1 District, Palembang City, will be determined using the saving matrix method and the Nearest Neighbor method. VRP can be viewed as a weighted directed graph. The set of all TL and LF can be expressed as nodes, and the journey from TL i to FDA j can be expressed as arc, written $G=(V,A)$ where $G=\{1,2,\ldots,n\}$ and $V=\{(k,l)|k=1,2,\ldots,n;\ l=1,2,\ldots,n\}$.

Some assumptions in this study are as follows: the average speed of garbage transporting vehicles is 40 km/hour, traffic jams are ignored, traffic lights are ignored, engine damage is neglected, the distance from TL i to TL j is considered the same or the matrix is symmetrical, the service time is about 5 minutes, and the capacity of the garbage vehicle is assumed to be 8 tons.

Saving Matrix

A saving matrix is a method to minimize the distance and time used by connecting existing nodes and making it a route based on the largest saving matrix value. The saving matrix value is the distance saved between the source node and the destination node. The saving matrix algorithm combines more than one vehicle to be allocated into one route. This algorithm can be used in vehicle scheduling, where the maximum vehicle capacity is taken into account. The following steps are carried out in the process of determining the route of the waste transport vehicle: 1) Set distance, service time, and garbage heap data; 2) Create a matrix; 3) Calculate the value of the saving matrix using the equation $S(i,j)=d(\text{origin},i)+d(\text{origin},j)-d(i,j)$ with $S(i,j)$ is the distance saved between customer i and customer j, d(origin, i) is the distance from the origin to TL i or otherwise; d(origin, j) is the distance from the origin to TL j or otherwise and $d(i,j)$ is the distance from TL i to TL j or otherwise; 4) Sort the largest saving matrix value to the one with the smallest saving matrix value; 5) Form the first route grouping (t = 1) and determine the first TL assigned to the first route grouping; 6) Counting the total pile of garbage at a selected TL. If the total pile of the garbage still meets the vehicle capacity, proceed to step 7. If not, then continue to step 8; 7) Select the next customer to be assigned based on the last pool of selected customers that has the largest saving matrix value, then repeat step 5. 8) The last selected customer is removed from the saving matrix; 9) Allocate all selected customers into one route. The route grouping (t) has been arranged. If customers still have not been selected, proceed to step 10. The saving matrix method work process will be completed when all customers have been selected; and 10) Create a new route grouping (t_new = t_old + 1), then go back to step 5.

Nearest Neighbor

The nearest neighbor is a fairly simple method that can be used in sequencing a route. The fundamental of the nearest neighbor method is to focus on the distance closest to the current position [18]. The initial step for the Nearest neighbor method is to prioritize the closest distance from the current position to the goal, and the next work system is to see the closest distance from the current position to the next destination. The following are the steps to determine the route of the garbage transport vehicle: 1) Determine the origin node that will be the center point; 2) The distance closest to the origin will be selected as the next trip then the two distances are combined; 3) The last visited point will be the starting point, the next point selection is done by selecting the point that has the minimum distance from the starting point; 4) If all points have been visited then go to step 5. If not then repeat step 3; and 5) Connect the points that have been obtained from the first point to the last point in order to obtain a route.

After sorting the route using the nearest neighbor method, the total distance traveled and the total time taken in transporting waste to the landfill will be calculated. The total distance traveled is calculated by looking at the route sequence and then calculating the distance based on the known distance table. The total travel time is solved by adding up the total travel time with the total service time. Service time is defined as the time required by garbage collectors to transport and remove waste from the vehicle, the service time is assumed to be 5 minutes. The formula for calculating the total travel time is expressed by Equation (1).

$$\text{Travel Time} = \frac{\text{Total Distance}}{\text{Average Speed of Vehicle}} \tag{1}$$

Suppose the number of TL is represented by n and node 1 represents FDA; then m (number of nodes) is $m = n + 1$. The formula for calculating the total service time is expressed by Equation (2).

$$\text{Total Service Time} = m \times \text{Service Time} \tag{2}$$

RESULT AND DISCUSSION

Garbage transportation in Ilir Barat 1 Subdistrict, Palembang City, is divided into several regions, each with one operational vehicle for transporting waste. The division of the waste transportation region in Ilir Barat 1 District, Palembang City, aims to make it easier for officers to carry out waste transportation. Ilir Barat 1 Subdistrict Palembang City has 9 Regions, as shown in Table 1, with the working time divided into two sessions. Total travel time is obtained from total travel time and service time. This study uses distance data from the Palembang City Environment and Hygiene Office in 2019. Table 1, Table 2, and Table 3 show data on waste transportation, piles of garbage in a region, and distance matrix in a region.

TABLE 1. Data.

Region	1	2	3	4	5	6	7	8	9
Total of TL	1	7	2	5	6	3	7	3	7

TABLE 2. Pile of garbage in the region 9.

	TL 1	**TL 2**	**TL 3**	**TL 4**	**TL 5**	**TL 6**
Pile of trash (Kg)	3300	5300	4100	3500	4200	3000

The saving value in region 9 is calculated based on the data in Table 3 using $S(i,j) = d(\text{origin}, i) + d(\text{origin}, j) - d(i,j)$ with $S(i,j)$, the results are as in Table 4. Then combine the TL into one vehicle and sort the route. The first route is TL1 – TL6 – FDA. TL1 and TL6 both have a distance of 17 km to the FDA, so for the ordering of route 1 this may be from TL 1 – TL 6 – FDA it may also be from TL6 – TL1 – FDA. The second route is TL4 – TL5 – FDA. TL4 and TL5 both have a distance of 16 km to the FDA, so the ordering of route 2 may be from TL4 – TL5 – FDA and from TL5 – TL 4 – FDA. The third route is TL2 – TL3 – FDA. TL2 has the closest distance to the FDA, so TL2 will be the first destination, then proceed to TL3 and finally to the FDA.

TABLE 3. Distance matrix (km).

	TL1	TL2	TL3	TL4	TL5	TL6	FDA
TL1	0						
TL2	2.8	0					
TL3	2.7	0.4	0				
TL4	0.75	1.4	1	0			
TL5	0.55	1.2	0.85	0.16	0		
TL6	0.9	1.6	1.2	0.19	0.35	0	
FDA	17	12	15	16	16	17	0

TABLE 4. Saving matrix in 9th region (km).

	TL1	TL2	TL3	TL4	TL5	TL6
TL1	0					
TL2	26,2	0				
TL3	29,3	26,6	0			
TL4	32,25	26,6	30	0		
TL5	32,45	26,8	30,15	31,84	0	
TL6	33,1	27,4	30,8	32,81	32,65	0

TABLE 5. Results using saving matrix and nearest neighbor method.

Region	Route	Total distance (km)	Total travel time (hour)
1	TL1-FDA	9.5	0.41
2	TL 1 - TL 6 - TL 5 - TL 7 - TL 2 - TL 3 - TL 4 - FDA	23.41	1.25
3	TL 2 - TL 1 – FDA	27	0.93
4	TL 2 - TL 5 - FDA	9.35	0.48
	TL 1 - TL 4 - FDA	9.05	0.48
	TL 3 – FDA	8	0.37
5	TL 4 - TL 2 - FDA	17.6	0.69
	TL 1 - TL 6 - FDA	12.7	0.57
	TL 5 - TL 3 - FDA	13.5	0.59
6	TL 3 - TL 2 - FDA	14.5	0.61
	TL 1 - FDA	12	0.47
7	TL 1 - TL 3 - FDA	12.35	0.56
	TL 2 - TL 4 - FDA	12	0.55
	TL 6 - TL 5 - FDA	11.5	0.54
	TL 7 - FDA	8.4	0.38
8	TL 2 - TL 1 - FDA	25.1	0.88
	TL 3 – FDA	6.6	0.33
9	TL 1 - TL 6 - FDA	17.9	0.7
	TL 4 - TL 5 - FDA	16.16	0.66
	TL 2 - TL 3 – FDA	15.4	0.63

Based on calculations using the saving matrix method with route ordering using the nearest neighbor method, three routes are obtained in Region 9, that can be seen in Table 5. The total distance traveled on route 1 is 17.9 km; based on Equations (1) and (2) the total travel time is obtained, respectively, is $\frac{17.9 \text{ km}}{40 \text{ km/hour}} = 0.4475 \text{ hour}$, and the total service time is $3 \times 5 \text{ minutes} = 15 \text{ minutes}$, so the total time taken to transport waste on route 1 is $(0.4475 \times 60) + 15 = 41.85 \text{ minutes}$ or 0.6975 hour. The total distance covered on route 2 is 16.16 km; based on

Equations (1) and (2), respectively, the total travel time $\frac{16.16\text{ km}}{40\text{ km/hour}} = 0.404\text{ hour}$, total service time $3 \times 5\text{ minutes} = 15\text{ minutes}$, so the total time taken to transport waste on route 2 is (0.404 × 60) + 15 = 39.24 minutes or 0.654 hours. The total distance covered on route 3 is 15.4 km; based on Equations (1) and (2), respectively, the total travel time $\frac{15.4\text{ km}}{40\text{ km/hour}} = 0.385\text{ hour}$, and the total service time $3 \times 5\text{ minutes} = 15\text{ minutes}$, so the total time taken to transport waste on route 3 is (0.385 × 60) + 15 = 38.1 minutes or 0.635 hour.

During session 1 working hours (07.00 – 11.00 WIB), waste transport vehicles can serve Region 1, Region 2, Region 3, Region 4, and Region 5 with a total distance of 126.31 km and a total travel time of 5.67 hours. Meanwhile, during working session 2 (16.00 – 20.00 WIB) the waste transport vehicle can serve Region 6, Region 7, Region 8, and Region 9 with a total distance of 151.91 km and a travel time of 6.3 hours. We found that the total travel time of the waste transport vehicle exceeded the working time.

CONCLUSION

The saving matrix method and the nearest neighbor method can be applied to the problem of transporting garbage vehicles. The total travel time for waste transport vehicles in Ilir Barat District 1 exceeds the working time. This can be due to the large pile of garbage in each region which is limited by vehicle capacity and service time. Even though the total travel time exceeds the working time, the garbage collectors have sufficient time to rest.

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