Desimal: Jurnal Matematika Vol 7 No 1 (2024) 73-86

Contents lists available at DJM

DESIMAL: JURNAL MATEMATIKA

p-ISSN: 2613-9073 (print), e-ISSN: 2613-9081 (online), DOI 10.24042/djm

http://ejournal.radenintan.ac.id/index.php/desimal/index

Analysis of optimization waste transportation using saving matrix and floyd warshall methods in Binjai

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ARTICLE INFO

Article History

Received : 09-02-2024

Revised : 19-03-2024

Accepted : 19-04-2024

Published : 30-04-2024

Keywords:

Optimization; Routing; Saving Matrix; Floyd Warshall.

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Doi: 10.24042/djm.v7i1.21887

ABSTRACT

Waste is defined as anything that is not utilized or discarded. Waste is not something that happens by itself; instead, it is a product of human activity. Unresolved problems are often caused by waste. Binjai City's waste problem is one example. In Binjai City, waste transportation is done once a day. The capacity of the truck is only 6–8 m³ or 3-5 tons, so if it is full, the waste is immediately transported to the landfill. Then the collection of waste at each TPS is not possible. Optimization of waste transportation routes using Floyd Warshall and Saving Matrix techniques is one way to overcome this problem. When scheduling cars, the Savings Matrix approach can be used to combine multiple delivery points and take into account the maximum capacity of the vehicle. The Floyd Warshall method is a dynamic programming component that is well suited to solving route optimization problems and can find every potential path between any two locations. Based on an analytical procedure that includes the Floyd Warshall algorithm and the Saving Matrix. These two routes of 29.46 kilometers were first used by the Environmental Agency of Binjai City. 20.63 km is the overall distance when using Saving Matrix, and 23.55 km is the overall distance when using Floyd Warshall. This shows that the Saving Matrix approach is more successful in reducing travel costs and distance.

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INTRODUCTION

In big cities such as Jakarta, Surabaya, Medan, Bandung, Yogyakarta, or Semarang, waste is often a problem. The increase in population is the cause of increased waste production (Ernawati, Budiastuti, & Masykuri, 2012). Waste itself is a major environmental problem that still requires special attention to date at all levels of society (Gusminto & Lesmana, 2023). According to SNI 19-2454-2002 (2002), municipal solid waste is considered solid waste that includes biological and inorganic elements that are thought to be unusable. Waste from various companies, households, factories, offices, hospitals, industries, shops, and markets accounts for the largest amount of waste (Muhaimin, Yundari, & Pasaribu, 2023). It must be managed carefully to avoid potential environmental damage and maintain the city's development expenditures. Among the factors that cause the accumulation of garbage around the house is the busyness of residents, so they do not have time to throw garbage in garbage shelters, especially if the location of the landfill (TPS) is far from the residential environment (Rozi & Multahadah, 2021). The volume of waste that increases and is not immediately managed will have a negative impact on the environment and people's lives (Kuka, Katili, & Payu, 2021). Unresolved problems are often caused by waste; Binjai City's waste problem is one example. In Binjai City, waste transportation is done once a day. Waste transportation is one of the waste management subsystems that targets bringing waste from the transfer site or from the waste source directly to the landfill (TPA) (Jannah, 2021). The landfill (TPA) will be the truck's immediate destination if it is fully loaded with garbage. Therefore, it is not possible to collect waste at every TPS in Binjai City. The truck can only carry 6–8 m3 (3-5 tons) of waste, and the amount of waste from each tank is too much to be transported in one trip. Therefore, the waste must be disposed of at each TPS.

As waste management is a costly endeavor, it requires more attention. The ultimate goal of waste transportation optimization is to minimize waste accumulation, which directly impacts public health and city aesthetics. This will make waste transportation simple, fast, and affordable. Waste transportation in Binjai is done irregularly, resulting in inefficiencies in both time and cost. There are more factors than distance used in finding the fastest path from city A to city B. To avoid traffic congestion, consider other options besides the fastest route, taking into account the actual traffic situation (Faro & Giordano, 2016). In mathematics, there is the study of how to find the fastest route from a location using graphs (Inayah, Resti, & Ilmiyah, 2023). In graph theory, several algorithms can be used to solve the shortest route problem, including the Dijkstra algorithm, the Bellman-Ford algorithm, the Greedy algorithm, the Floyd-Warshall algorithm, and others (Buako, Yahya, & Achmad, 2021). A graph is a set of nodes connected by weighted lines; alternatively, a graph can be thought of as several vertices connected by edges. Graphs are used to present discrete objects and the relationships between them (Panjaitan & Aprilia, 2023).

The shortest paths can be found using various techniques, such as the Floyd-Warshal method and the savings matrix. By calculating the required route and the number of transportation options based on the capacity of each mode to find the most reliable and efficient route, the Saving Matrix method helps businesses determine the cost, time, distance, and route of delivering goods to customers and the ideal transportation cost from the place of business to the project site (Pattiasina, Setyoadi, & Wijayanto, 2018). By combining many delivery places, matrix savings can be utilized to overcome vehicle problems by taking into account the maximum capacity of the vehicle (Indrawati, Eliyati, & Lukowi, 2016). This saving matrix has the advantage of being easy to update when there are delivery schedules, vehicle volumes, the number of vehicles, or other limits. This makes it a superior alternative for completing delivery schedules quickly and realistically. The savings matrix method is also one of the techniques used to schedule a limited number of vehicles from facilities that have maximum capacity (Perdana, Hunusalela, & Prasasty, 2021). In addition, this method applies the merging of points in one way and pays attention to the capacity of the vehicle (Suyitno & Rosyida, 2020). The Saving Matrix method aims to form an optimal delivery plan by considering the capacity of a large number of customers' transport vehicles to minimize transportation costs (Yusnindi & Handayani, 2022). To determine the shortest path or route, Warshall developed the Floyd Warshall algorithm. This algorithm was invented by Warshall (Ningrum & Andrasto, 2016). Floyd Warshall's algorithm compares all possible trajectories for each pair of points in the graph and then performs tests of those acquired point combinations (Rifanti & Arifwidodo, 2019). The Floyd-Warshall algorithm is a method of solving problems by viewing the solutions obtained as interrelated decisions (Ridwan & Agustin, 2020).

Fitri Armanda and Rina Filia Sari conducted research on route determination in 2023 using the saving matrix approach. The saving matrix method can shorten travel time and reduce costs. According to the research findings, three routes were used so that a total distance of 100.73 km was obtained, compared to the original four routes of 144.29 km. The company initially paid IDR 98,117 for transportation costs. The research resulted in transportation costs of Rp. 68,496.4 (Armanda, Sari, & Garba, 2023).

Research conducted by Winny Andalia, Devie Oktarini, and Siti Humairoh in 2021 used the saving matrix method to minimize mileage. The results of this study show that the Saving Matrix method can minimize the mileage for cosmetics distribution from 129 km to 73.6 km (Andalia, Oktarini, & Humairoh, 2021).

This study was conducted with the aim of determining the optimal waste transportation route in Binjai City by comparing the saving matrix and Floyd-Warshall methods..

METHOD

Saving Matrix Method

The saving matrix shows the savings achieved by combining two TPSs and allowing them to be transported by one vehicle. In this way, transportation distance, time, and cost can be minimized.

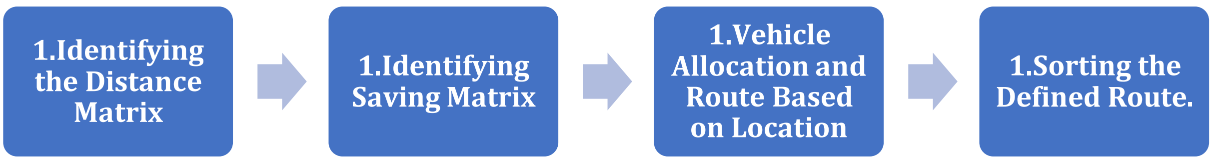

Figure 1. Research Procedure using Saving Matrix

Based on Figure 1, the stages of using the method are:

1. **Identifying the Distance Matrix**

Using the following formula, one can determine the distance between two locations after knowing their coordinates:

$$f = \sqrt{(x - x_n)(n)^2 + (y - y_n)^2} \quad (2.1)$$

However, if the distance between the two coordinates is known, then the calculation using the formula is not used and uses the existing distance (Turseno & Hernika, 2022).

2. **Identifying Saving Matrix**

In this stage, it is expected that each point will be passed by one truck after all distances are known, namely the distance between Binjai City Environmental Service and TPS and TPS with other TPS.

$S(x, y) = J(G, x) + J(G, y) - J(x, y)$ (2.2)
Description:
S : Distance Saving
J : Distance
G : Center Point
x : Place of Transportation x
x, y : Place of Transportation y
$S(x, y)$ is the distance saved when paths x and y merge.

3. Vehicle Allocation and Route Based on Location

Once the matrix is created, the next step is to determine the route or location of the vehicle. That is, the combined routes from the previous two phases will be used to establish new delivery routes in this step. Combine to optimize savings, starting with the largest savings.

4. Sorting the Defined Route.

After establishing the sequence of visits, the next route is chosen, and the destination has been set. The nearest neighbor and farthest insert methods are used to determine the sequence.

a. The farthest insert includes retailers that offer the furthest travel distance. If a retailer is already included in a route, assess how much distance needs to be increased for it to be included, and then insert the retailer with the largest required (Ikfan & Masudin, 2013).
b. Nearest neighbor retailers closest to the previously visited retailer are included in doing this.

Floyd Warshall Algorithm

Dynamic programming that solves problems by considering the final answer as a connected choice is often the strategy used in the Floyd-Warshall algorithm (Triana & Syahputri, 2018). The Floyd Warshall method is a basic algorithm that determines the shortest route between every pair of vertices in a directed graph (Singh & Kumar Mishra, 2014). To identify the shortest route, the Floyd Warshall algorithm must traverse each path and distinguish intermediate paths. The notion of intermediate nodes serves as the basis for this method. This type of all-pairs calculation, which determines the shortest path by identifying all pairs of nodes, can be determined quickly if applied in the system, the performance is stable, and the decision will be taken accordingly, is the advantage of applying the Floyd Warshall algorithm to obtain the shortest path using the recursive method. The following is Floyd Warshall's method of determining the shortest path:

1. Equation $W[i, j] > W[i, k] + W[k, j]$ is used to check each cell of the matrix in the first iteration.
2. If the answer is yes, the distance between the two starting positions $(W[i, j])$ is adjusted to the total distance $(W[i, k] + W[k, j])$ from the starting point to the destination point at the nth iteration.
3. The distance used is the distance between the two starting points $(W[i, j])$ if the result is not.
4. The iteration procedure continues until the last iteration (the number of iterations is equal to the total number of points).

Description:
W: Matrix
I : Column
J : Row
n : Number of Points/Vertex
k : Nth loop

RESULTS AND DISCUSSION

Data Description

In this study, using the East Binjai garbage collection route with a dump truck fleet with a load of 6–8 m^3 or 3-5 tons, this study used the following data:

Table 1. Data Point (Vertex) of Waste Transportation in East Binjai

No.	Symbol	Lattitude	Longitude	Weight (kg)
1	v1	3.5931079	98.4878944	-
2	v2	3.5911852	98.5181966	600
3	v3	3.6031095	98.5180833	550
4	v4	3.6080370	98.5170295	400
5	v5	3.6035944	98.5132503	450
6	v6	3.6131529	98.5182047	400
7	v7	3.6172431	98.5183103	600
8	v8	3.6278612	98.5192628	350
9	v9	3.6173495	98.5345004	450
10	v10	3.6133292	98.5343271	350
11	v11	3.6131024	98.5102009	550
12	v12	3.576794	98.500022	-

Here are the locations of TPS and TPA when viewed from the Map Marker software.

Figure 2. TPS and Landfill Locations

There were two routes for transporting waste from the Binjai City Environmental Service to the landfill before the research was conducted. The following are the routes:

Table 2: Initial Waste Collection Route

Route	Starting Sequence	Distance (Km)	Weight (Kg)
1	v1-v2-v3-v4-v5-v11-v12-v1	13.46	2550
2	v1-v6-v7-v8-v9-v10-v12-v1	16	2150
	Total	29.46	4700

Based on Table 2, the above garbage collection route graph can be seen in Figure 3 and 4.

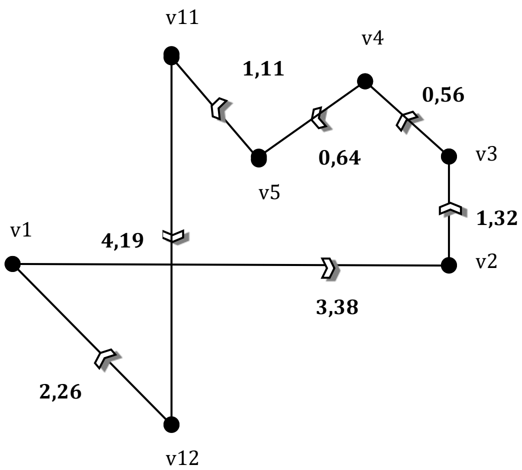

Figure 3. First Route Graph of Garbage Collection

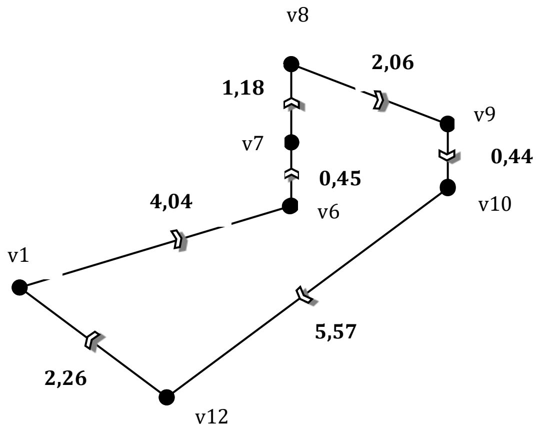

Figure 4. Second Garbage Collection Route Graph

The transportation costs incurred by the Binjai City Environmental Service with one dump truck vehicle in a day are IDR 20,032.8 and IDR 600,984.

The cost is obtained by the formula:

$\frac{Total\ Distance}{10}\ x\ Rp.6{,}800$ (price of 1 liter of diesel)

So, the transportation cost is:

$\frac{29.46}{10}$ x Rp. 6,800 = Rp 20,032.8

Form of Saving Matrix Method

There are four steps in solving the saving matrix method, namely:

1. Identifying the distance matrix

Table 3 . Distance Matrix Results of 12 Points (Vertex).

	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12
v1	0											
v2	3.38	0										
v3	3.54	1.32	0									
v4	3.64	2.43	0.56	0								
v5	3.05	1.48	0.54	0.64	0							
v6	4.04	2.44	1.11	0.58	1.19	0						
v7	4.32	2.90	1.57	1.03	1.62	0.45	0					
v8	5.21	4.08	2.75	2.22	2.78	1.64	1.18	0				
v9	5.84	3.43	2.41	2.20	2.81	1.87	1.80	2.06	0			
v10	5.63	3.04	2.13	2.01	2.58	1.79	1.83	2.33	0.44	0		
v11	3.33	2.59	1.41	0.94	1.11	0.89	1.01	1.92	2.74	2.68	0	
v12	2.26	2.58	3.55	3.95	3.32	4.52	4.94	6.07	5.92	5.57	4.19	0

Based on Table 3, to determine the value of the distance matrix, it can be obtained using the formula:

$f = \sqrt{(x - x_n)(n)^2 + (y - y_n)^2}$

For example, obtaining the distance f (1,2) can be done in the following way:

$f(1,2)$

$= \sqrt{(3.59.. -3.59\ ...)^2 + (98.48\ ... - 98.51\ ...)^2}$

$f(1,2) = 0.030363\ x\ 111.32\ (1\ derajat\ bumi)$

$f(1,2) = 3.38\ km$

This can be done in a similar way to get to the next distance.

2. Identifying Saving Matrix

Table 4. Saving Matrix Result of 12 Vertices

	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12
v2	0										
v3	5.60	0									
v4	4.59	6.62	0								
v5	4.95	6.05	6.05	0							
v6	4.98	6.47	7.1	5.9	0						
v7	4.80	6.29	6.93	5.75	7.91	0					
v8	4.51	6	6.63	5.48	7.61	8.35	0				
v9	5.79	6.97	7.28	6.08	8.01	8.36	8.99	0			
v10	5.97	7.04	7.26	6.1	7.88	8.12	8.51	11.03	0		
v11	4.12	5.46	6.03	5.27	6.48	6.64	6.62	6.43	6.28	0	
v12	3.06	2.25	1.95	1.99	1.78	1.64	1.4	2.18	2.32	1.4	0

Based on Table 4, to determine the value of the saving matrix, it can be obtained using the formula:

$S(x,y) = J(G,x) + J(G,y) - J(x,y)$

For example, obtaining S (2,3) can be done in the following way:

$S(2{,}3) = J(G,2) + J(G,3) - J(2{,}3)$

$S(2{,}3) = 3.38 + 3.54 - 1.32$

$S(2{,}3) = 5.60$

This can be done in the same way to get the next saving matrix value.

3. Vehicle Allocation and Route Based on Location

After obtaining the saving matrix value, the next thing that needs to be done is to allocate vehicles and routes based on location. The initial assumption is 12 different points, but the allocation of vehicles can be combined until the vehicle capacity is full. The largest saving matrix value is used in the initial value for combining routes, which has the aim of optimizing savings. Table 5 shows the first route for transportation.

Table 5. Initial Route

	v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12
v1	0											
v2	3.38	0										
v3	3.54	5.60	0									
v4	3.40	4.59	6.62	0								
v5	3.05	4.95	6.05	6.05	0							
v6	4.04	4.98	6.47	7.1	5.9	0						y
v7	4.32	4.80	6.29	6.93	5.75	7.91	0					
v8	5.21	4.51	6	6.63	5.48	7.61	8.35	0				
v9	5.84	5.79	6.97	7.28	6.08	8.01	8.36	8.99	0			
v10	5.63	5.97	7.04	7.26	6.1	7.88	8.12	8.51	11.03	0		
v11	3.33	4.12	5.46	6.03	5.27	6.48	6.64	6.62	6.43	6.28	0	
v12	2.26	3.06	2.25	1.95	1.99	1.78	1.64	1.4	2.18	2.32	1.4	0

Based on Table 5, waste transportation is carried out from the Environmental Agency to each TPS. To determine the allocation of vehicles starting from the largest saving matrix value, which is 11.03, which is the value of the combined base 10 and base 9, they can be combined because the demand is still smaller than the vehicle capacity. From the calculation results, the new route sorting can be seen in Table 6.

4. Sorting the defined routes with Father's Insertion and Nearest Neighbor methods

Using the newly obtained route, the sorting of TPS that must be visited on one route is carried out by sorting the routes using the Father's Insertion and Nearest Neighbor methods. Table 7 presents the results of the route obtained.

Table 6. New Route

No.	Route	Results	Weight (kg)	Payload (kg)
1	10.9	11.03	800	5000
2	9.8	8.99	800	5000
3	10.8	8.51	700	5000
4	9.7	8.36	1050	5000
5	8.7	8.35	950	5000
6	10.7	8.12	950	5000
7	9.6	8.01	850	5000
8	7.6	7.91	1000	5000
9	10.6	7.88	750	5000
10	8.6	7.61	750	5000
11	9.4	7.28	850	5000
12	10.4	7.26	750	5000
13	6.4	7.1	800	5000
14	10.3	7.04	900	5000
15	9.3	6.97	1000	5000
16	7.4	6.93	1000	5000
17	11.7	6.64	1150	5000
18	8.4	6.63	750	5000
19	11.8	6.62	900	5000
20	4.3	6.62	950	5000
21	11.6	6.48	950	5000
22	6.3	6.47	950	5000
23	11.9	6.43	1000	5000
24	7.3	6.29	1150	5000
25	11.10	6.28	900	5000
26	10.5	6.1	800	5000
27	9.5	6.08	900	5000
28	5.3	6.05	1000	5000
29	5.4	6.05	950	5000
30	11.4	6.03	950	5000
31	8.3	6	900	5000
32	10.2	5.97	950	5000
33	6.5	5.9	950	5000
34	9.2	5.79	1050	5000
35	7.5	5.75	1050	5000
36	3.2	5.60	1150	5000
37	8.5	5.48	800	5000
38	11.3	5.46	1100	5000
39	11.5	5.27	1000	5000
40	6.2	4.98	1000	5000
41	5.2	4.95	1050	5000
42	7.2	4.80	1200	5000
43	4.2	4.59	1000	5000
44	8.2	4.51	950	5000
45	11.2	4.12	1150	5000

Table 7. Comparison of the New Sequences of the Two Methods

Route	Methods	Order	Distance	Weight (kg)
1	Fathers Insertion	v1-v10-v9-v8-v7-v6-v4-v5-v3-v11-v2-v12-v1	20.36	4700
	Nearest Neighbor	v1-v2-v11-v3-v5-v4-v6-v7-v8-v9-v10-v12-v1	21.1	4700

Based on Table 7, the results of the new route using the two methods above, namely $v1 - v10 - v9 - v8 - v7 - v6 - v4 - v5 - v3 - v11 - v2 - v12 - v1$.

5. Transportation Costs with the Saving Matrix Method

The following formula can be used to obtain transportation costs:

$\frac{Total\ Distance}{10}\ x\ Rp.6{,}800$ (price of 1 liter of diesel)

So, the transportation cost is:

$$\frac{20.63}{10} \text{ x Rp. } 6{,}800 = \text{Rp } 14{,}028.4.$$

After the research was carried out, the proposed route was obtained, namely v1-v10-v9-v8-v7-v6-v4-v5-v3-v11-v2-v12-v1. This route is obtained by looking at the value of the saving matrix, the number of loads that must be a minimum of or equal to the load capacity of the dump truck fleet used for waste transportation, and the route results obtained using two methods, namely farther insertion and nearest neighbor. Observation of the two methods used shows that the total distance using the father's insertion method is minimal compared to the total distance using the nearest neighbor method. Therefore, researchers chose the father's insertion method. The initial route sequence used by the Binjai City Environmental Service is $v1 - v2 - v3 - v4 - v5 - v11 - v12 - v1$ and $v1 - v6 - v7 - v8 - v9 - v10 - v12 - v1$, with a total distance of 29.46 km and transportation costs of Rp 20,032.8/day or Rp 600,984/month. Meanwhile, the new route sequence is $v1 - v10 - v9 - v8 - v7 - v6 - v4 - v5 - v3 - v11 - v2 - v12 - v1$ with a total distance of 20.63 km and transportation costs of Rp. 14,028.4/day or Rp. 420,852/month. So, this shows that the saving matrix method and continued use of the nearest neighbor and farther insertion method can be used to minimize distance and transportation costs.

Form of the Floyd Warshall Algorithm

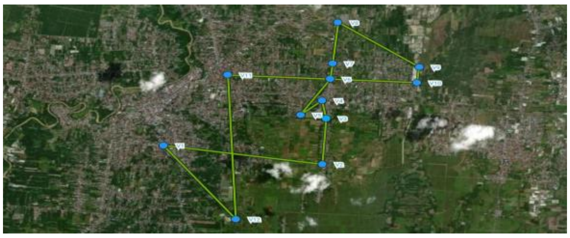

Figure 5. Map of TPS and Landfill Locations

Based on Figure 5, Creating vertices on the map is the first step in the shortest route-finding procedure.

Table 8. Related Vertex

No.	Related Vertex	Distance (km)
1	v1-v2	3.38
2	v2-v3	1.32
3	v3-v4	0.56
4	v4-v5	0.64
5	v5-v6	1.19
6	v6-v7	0.45
7	v6-v10	1.79
8	v6-v11	0.89
9	v7-v8	1.18
10	v8-v9	2.06
11	v9-v10	0.44
12	v10-v11	2.68
13	v11-v1	3.33
14	v11-v12	4.19
15	v12-v1	2.26

Table 9. W_0 Matrix

v1	v2	v3	v4	v5	v6	v7	v8	v9	v10	v11	v12
0	3.38	∞	∞	∞	∞	∞		∞	∞	3.33	2.26
3.38	0	1.32	∞	∞	∞	∞	∞	∞	∞	2.59	2.58
∞	1.32	0	0.56	∞	∞	∞	∞	∞	∞	∞	∞
∞	∞	0.56	0	0.64	∞	∞	∞	∞	∞	∞	∞
∞	∞	∞	0.64	0	1.19	∞	∞	∞	∞	∞	∞
∞	∞	∞	∞	1.19	0	0.45	∞	∞	1,79	0,89	∞
∞	∞	∞	∞	∞	0.45	0	1.18	∞	∞	∞	∞
∞	∞	∞	∞	∞	∞	1.18	0	2.06	∞	∞	∞
∞	∞	∞	∞	∞	∞	∞	2.06	0	0.44	∞	∞
∞	∞	∞	∞	∞	1.79	∞	∞	0.44	0	∞	∞
3.33	2.59	∞	∞	∞	0.89	∞	∞	∞	∞	0	4.19
2.26	2.58	∞	∞	∞	∞	∞	∞	∞	∞	4.19	0

Based on Table 9, if a directed graph has no direct connection between its nodes, then the value of its connection matrix is ∞; when there is a direct connection, then the value is there. Next, the Floyd Warshall method is used for the first matrix calculation procedure (W_0) in Table 9 to determine the shortest path between each node. The calculation process of the Floyd Warshall technique is as follows:

Each cell of the W_0 matrix is checked $W[i,j] > W[i,k] + W[k,j]$. If the result is yes, then the value $W[i,j]$ is replaced by the value $W[i,k] + W[k,j]$. The distance used is the distance between the two starting points ($W[i,j]$) if the result is not.

Description:
W: Matrix
I : Column
J : Baris
n : Number of Points/Vertex
k : Nth loop

Example to obtain $w[2,3]$ and $w[2,4]$ Iteration at k = 1
$w[2,3] = 1.32$ and on $w[2,1] + w[1,3] = 3.38 + \infty = \infty$.
Because $w[2,3] < w[2,1] + w[1,3]$ the va
$w[2,4] = \infty$ and on $w[2,1] + w[1,4] = 3.38 + \infty = \infty$.
Because $w[2,4] < w[2,1] + w[1,4]$ the value of $w[2,4]$ is not replaced.

The final matrix of the results of the calculation stage of the Floyd Warshall algorithm, which shows the shortest route between each point, is obtained after the calculation is carried out until the last iteration, namely when k = 12. A web-based system in the figure below is used to conduct a waste transportation route from the Binjai City Environmental Service to the TPA based on calculations made using the Floyd Warshall algorithm.

Figure 6. Floyd Warshall Algorithm Calculation Results

Based on Figure 6, the shortest path for each TPS waste transportation route in East Binjai District to Sei Lepan Landfill can be determined based on the results of the matrix calculations that have been carried out. The Floyd Warshall algorithm can be used to calculate the shortest path for each given path. The shortest route from the Binjai City Environmental Service to the Sei Lepan Landfill and back to the Binjai City Environmental Service using the Floyd Warshall algorithm is The Binjai City Environmental Service → TPS 10 → TPS 7 → TPS 6 → TPS 8 → TPS 9 → TPS 5 → TPS 3 → TPS 4 → TPS 2 → TPS 1 → TPA → Binjai City Environmental Service (v1 – v11 – v8 – v7 – v9 – v10 – v6 – v4 – v5 – v3 – v2 – v12 – v1) with a distance of 23.55 km and transportation costs of Rp 16.014/day or IDR 480,420/month. The initial route sequence used by the Binjai City Environmental Agency is v1 – v2 – v3 – v4 – v5 – v11 – v12 – v1 and v1 – v6 – v7 – v8 – v9 – v10 – v12 – v1, with a total distance of 29.46 km and transportation costs of IDR 20,032.8/day or IDR 600,984/month. So, this shows that the Floyd Warshall method can be used to minimize distance and transportation costs.

CONCLUSIONS AND SUGGESTIONS

Based on the analysis process by comparing the Saving Matrix method and the Floyd Warshall algorithm, the initial total distance used by the Binjai City Environmental Service was 29.46 km through two routes, with transportation costs of Rp. 20,032.8/day or Rp. 600,984/month. The total distance using

Saving Matrix is 20.63 km with transportation costs of Rp. 14,028.4/day or Rp. 420,852/month, and the total distance using Floyd Warshall is 23.55 km with transportation costs of Rp. 16,014/day or Rp. 480,420/month. This shows that the Saving Matrix method is more optimal for minimizing distance and transportation costs.

Based on the conclusions above, the researchers provide suggestions: The Binjai City Environmental Office is expected to consider the application of the saving matrix method in optimizing waste transportation routes.

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