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Optimization of Liquid Petroleum Gas (LPG) Cylinder Distribution Route with the Saving Matrix Method

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Abstract

This research aims to optimize the routes passed so that the transportation costs incurred by the company can be much less. This is done because the company, as an agent for 3 kg LPG gas cylinders in distributing to each base, is still not optimal, with irregular routes, so the costs must incur are quite large and make the company suffer losses. One of the solutions that can be done in solving this distribution problem is to apply the Saving Matrix method. The Saving Matrix method is a method that can be used to determine the distribution route for a product to the area to be marketed by determining which route will be passed by looking at the vehicle capacity and the number of goods to be carried in order to obtain the shortest route and the lowest transportation costs out a little. Based on the research results, a distance of 100.73 km was obtained with an initial total distance of 144.29 km, where the initial route had a total of four routes that had to be passed and changed to three routes that could be passed, and transportation costs that had to be incurred initially Rp. 98,117.1, changed to Rp. 68,496.4. So, this shows that the saving matrix method can minimize the distance and transportation costs.

INTRODUCTION

Liquid Petroleum Gas (LPG) is a fuel commonly used in various fields, such as households, transportation, industry, and others [1]. LPG has become one type of fuel the Indonesian people use since the government made a policy to reduce Fuel Oil (BBM). The low price of LPG and the relatively large gas content in LPG cylinders make LPG a fuel widely used by almost all circles. LPG has several sizes ranging from the largest size of 12 kg, then there is a size of 5 kg, to the smallest, which is 3 kg. LPG cylinders measuring 3 kg are the most popular tubes by everyone because of their economical price so that they can be reached by everyone for personal use and small businesses. To distribute LPG gas to the community, agents need to pay attention to how to distribute it quickly so there is no scarcity in the community.

Distribution is an activity where goods that are fit for consumption are sent to buyers. Good distribution can make consumers more quickly and easily obtain ordered goods [2]. Distribution is one of the essential things in the company because, with distribution, customer satisfaction can be fulfilled very well [3]. There is added value in the distribution process, such as the process of goods delivered to the location where consumers are, the time when consumers

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need a product, the completeness of equipment, and costs that must be optimal [4]. To obtain a smooth running of each process, distribution has several factors, such as distribution systems, distribution route determination, and distribution conveyance. The distribution of LPG cylinders to consumers cannot be separated from transportation problems[5].

Transportation is a way of distributing goods and people from the point of origin to the destination [6]. Transportation connects production areas and markets or can be referred to as a liaison between producers and consumers. This transport issue aims to allocate goods at the source so that all the needs at the destination are met, and the costs incurred can be kept to a minimum [7]. Companies need a good strategy for distributing LPG gas cylinders so that losses do not occur.

The company, an agent of 3 kg LPG gas cylinders in distributing LPG gas to each base, is still not optimal with irregular routes. Hence, the costs incurred by the company are pretty significant. This, if it happens continuously, will make the company experience losses. One way to avoid losses is to optimize the distance traveled in distributing LPG gas cylinders so that transportation costs incurred by the company can be much less. The solution that can be done to solve this distribution problem is to apply the Saving Matrix method.

The Saving Matrix method is one method that can be used to determine the distribution route of a product to the area to be marketed by determining which route to take by looking at the capacity of vehicles and the number of goods carried to get the shortest route and the cost for transportation incurred is small [8]. The advantages of the saving matrix method can be seen from the ease with which it can be changed if delivery time limits, vehicle capacity, number of vehicles, and other restrictions have been obtained. The saving matrix method can be used in the Vehicle routing problem (VRP), which is the problem of determining vehicle routes in transportation problems related to the distribution of goods to consumers [9].

The advantages of this method can also be seen from the research conducted by Fandi Akhmad in 2022. The results of this study indicate that the saving matrix method can minimize mileage so that a distance savings of 7.73 km/day is obtained by minimizing fuel costs of Rp. 136,666 per month, or 4% of the total initial cost [10]. Research related to LPG distribution was also carried out by Rohmad Dwi Kurniawan and Yohanes Anton Nugroho in 2022, using the Clarke and Wright savings algorithms resulting from Rp. 607.155 with a distance of 1190.5 km. Whereas if you use the nearest neighbor algorithm, you get a distance of 1,150.9 km for Rp. 586,908 [11].

Based on the description above, to optimize the cost of distribution of LPG cylinders by optimizing distribution, researchers conducted a study entitled "Optimization of Liquid Petroleum Gas (LPG) Cylinder Distribution Route with the Saving Matrix Method". This research aims to obtain an optimal route, and costs incurred are less than those incurred by Liquid Petroleum Gas (LPG) cylinder companies.

METHOD

This research was conducted at PT. EKG in Medan City in January 2023. This research uses obtained from interviews with PT. EKG as an agent for LPG cylinders. The data obtained are as follows:

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1. The route traversed to distribute LPG cylinders.
2. LPG cylinder request.
3. Transportation costs.
4. The car used is a Colt Diesel, with a capacity of 560 LPG cylinders.
5. The number of bases.

The researcher uses the research flow as a reference to make the research more focused and run well. The following is a research flowchart that can be seen in the image below.

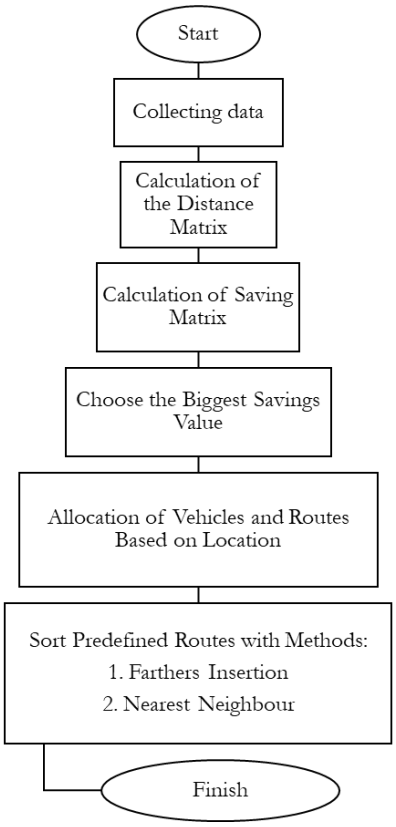

Figure 1. Research Flowchart

For data processing, the method used:

Saving Matrix

The saving matrix method makes various considerations on each obstacle to minimize distance, time, and cost [12]. This method is widely used in determining the distribution route of a product to the area to be marketed by determining which route to take by looking at the volume of vehicles, the number of goods carried to get the shortest route, and the cost of transportation is small. Several elements are used in determining distribution channels, such as consumer distance, existing routes, coordinate points, vehicle capacity, and distribution costs [13].

The saving matrix method has several steps in its completion, such as [14]:

a. Identifying the distance matrix

Knowing the distance between locations is needed in the saving matrix method. Therefore, coordinates are needed at each location. After knowing the coordinates at each location, the distance between locations can be calculated using the following equation [15]:

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

Where:

d_n = Distance

x = Lattitude of the earth

y = Longitude of the earth

However, if the distance at each coordinate is known, there is no need to calculate using the above equation. To find out the total distance can be seen with the application and can also be done manually by looking at the speedometer on the vehicle [16].

b. Define a saving matrix.

After all, distances are known, and the assumption is made in this step that only one vehicle will pass through the location. So, different routes will be passed. To minimize the distance by combining routes in the same direction as other routes.

Determining the saving matrix can be done with the following equation [17]:

$$S(x,y) = J(d,x) + J(d,y) - J(x,y) \quad (2.2)$$

Where:

$S(x,y)$: Saving matrix

$J(d,x)$: Distance from transport to x-destination

$J(d,y)$: Distance from the port to the y-destination

$J(x,y)$: Distance from destination x to destination y

c. Allocation of vehicles and routes based on location

In this step, in determining the transportation route, a route merger is carried out in the previous step. As a result, both locations can use only one route [18].

d. Sort predefined routes

To sort the route to be traversed, several methods can be done, namely [19]:

1. Farthers insertion is used to add customers to a travel route, starting from the one with the most significant or most extended increase in distance [20].
2. The nearest neighbor is used to sort the visit route with steps starting from the warehouse and adding consumers whose distance is closest to the warehouse [21].

RESULTS AND DISCUSSION

The following is a description of the results of data collection and data processing that has been carried out, as follows:

Data Collection

From the results of the interview, the following data were obtained:

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Table 1. 3 Kg LPG Gas Base and Demand Data

Number	Base	Lattitude	Longitude	Demand
0	A	3,51483	98,66262	
1	P1	3,50524	98,68406	110
2	P2	3,50764	98,67093	100
3	P3	3,56055	98,66226	120
4	P4	3,56824	98,66019	100
5	P5	3,4697	98,66379	120
6	P6	3,50698	98,67086	120
7	P7	3,66626	98,64757	140
8	P8	3,42931	98,60863	110
9	P9	3,50767	98,69226	140
10	P10	3,49585	98,58013	130
11	P11	3,60548	98,75713	130
12	P12	3,5226	98,59202	100

Information:
A = Gas Agent (Center)
P (1, 2, ...,12) =Base (1-12)

In Figure 1, the location of the agent and base is done with QGIS software.

Figure 2. Location of Agents and Bases with QGIS Software

The company initially had four routes, of which the routes consisted of:

Table 2. Initial Route

Route	Route Order	Distance
1	0-12-1-6-0	21,09
2	0-9-3-4-0	17
3	0-7-2-10-0	54,41
4	0-8-5-11-0	51,79
	Total	144,29

The graphs of the above routes can be seen in the following figure.

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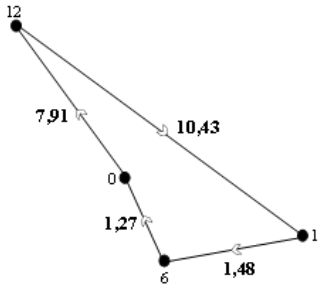

Figure 3. First Route of the Company

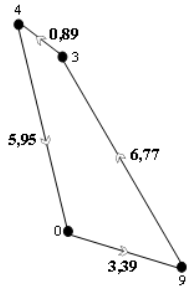

Figure 4. Second Route of the Company

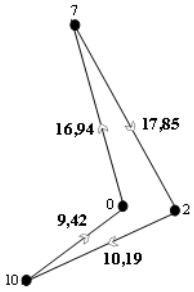

Figure 5. Third Route of the Company

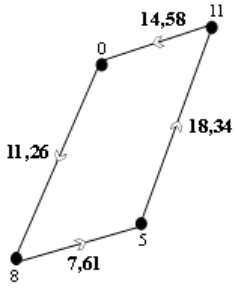

Figure 6. Fourth Route of the Company

The transportation costs incurred by this company are Rp. 98,117.2. Such costs are obtained by the formula [22]:

$\frac{Amount\ of\ distance}{10} \times Rp.6.800$ (the price of 1 liter of diesel)

So, the transportation costs are:

$\frac{144,29}{10} \times Rp.6.800 = 14,429 \times Rp.6.800 = Rp.98.117,2$

Data Processing

1. Distribution Routes

a. Identifying the distance matrix

Table 3. The result of the Distance Matrix, Which Includes the Distance from the Agent as the Center and the 12 Bases

	0	1	2	3	4	5	6	7	8	9	10	11	12
0	0												
1	2,61	0											
2	1,22	1,49	0										
3	5,09	6,62	5,97	0									
4	5,95	7,50	6,85	0,89	0								
5	5,03	4,55	4,30	10,12	10,98	0							
6	1,27	1,48	0,07	6,04	6,92	4,22	0						
7	16,94	18,38	17,85	11,88	11,00	21,96	17,92	0					
8	11,26	11,91	11,14	15,78	16,50	7,61	11,08	26,73	0				
9	3,39	0,95	2,37	6,77	7,63	5,28	2,38	18,34	12,76	0			
10	9,42	11,62	10,19	11,64	12,02	9,76	10,18	20,40	8,06	12,55	0		
11	14,58	13,81	14,52	11,69	11,56	18,34	14,58	13,95	25,65	13,07	23,18	0	
12	7,91	10,43	8,94	8,89	9,13	9,93	8,95	17,15	10,55	11,28	3,26	20,57	0

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To obtain the distance matrix can be done using the formula:

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

For example, to obtain distance can be done in the following way:d_1

$$d_1 = \sqrt{(3{,}51483 - 3{,}50524)^2 + (98{,}66262 - 98{,}68406)^2}$$

$$d_1 = \sqrt{(0{,}00959)^2 + (-0{,}02144)^2}$$

$$d_1 = \sqrt{0{,}00055}$$

$d_1 = 0{,}02349 \times 11{,}322\ km$ (1-degree earth)

$$d_1 = 2{,}61$$

It can be done in the same way to obtain the following distance.

b. Define a saving matrix.

Table 4 is the result of the saving matrix, which includes the distance from the Agent as the center and 12 Bases.

Table 4. Value Saving Matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1	0											
2	2,34	0										
3	1,08	0,34	0									
4	1,06	0,32	10,15	0								
5	3,09	1,95	0,00	0,00	0							
6	2,40	2,42	0,32	0,30	2,08	0						
7	1,17	0,31	10,15	11,89	0,01	0,29	0					
8	1,96	1,34	0,57	0,71	8,68	1,45	1,47	0				
9	5,05	2,24	1,71	1,71	3,14	2,28	1,99	1,89	0			
10	0,41	0,45	2,87	3,35	4,69	0,51	5,96	12,62	0,26	0		
11	3,38	1,28	7,98	8,97	1,27	1,27	17,57	0,19	4,9	0,82	0	
12	0,09	0,19	4,11	4,73	3,01	0,23	7,70	8,62	0,02	14,07	1,92	0

To obtain a saving matrix can be done using the formula:

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

For example, to obtain $S(1,2)$ can be done in the following ways:

$$S(1,2) = J(d,1) + J(d,2) - J(1,2)$$

$$S(1,2) = 2{,}61 + 1{,}22 - 1{,}49$$

$$S(1,2) = 2{,}35$$

It can be done similarly to obtain the following saving matrix.

c. Allocation of vehicles and routes by location

After obtaining the value of the saving matrix, the thing that needs to be done afterward is to allocate vehicles and routes based on location. Assuming the initial is 12 different routes, allocating vehicles can be combined until the vehicle capacity is total. The most significant saving matrix value is used for the initial value in combining routes, aiming to maximize savings. The initial transport routes are in Table 5.

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Table 5. Transport Routes for Allocating Vehicles and Routes

	0	1	2	3	4	5	6	7	8	9	10	11
0	0											
1	2,61	0										
2	1,22	2,34	0									
3	5,09	1,08	0,34	0								
4	5,95	1,07	0,32	10,15	0							
5	5,03	3,09	1,95	0,00	0,00	0						
6	1,27	2,40	2,42	0,32	0,30	2,08	0					
7	16,94	1,17	0,31	10,15	11,89	0,01	0,29	0				
8	11,26	1,96	1,34	0,57	0,71	8,68	1,45	1,47	0			
9	3,39	5,05	2,24	1,71	1,71	3,14	2,28	1,99	1,89	0		
10	9,42	0,41	0,45	2,87	3,36	4,69	0,51	5,96	12,62	0,26	0	
11	14,58	3,38	1,28	7,98	8,97	1,27	1,27	17,57	0,19	4,9	0,82	0
12	7,91	0,09	0,19	4,11	4,73	3,01	0,23	7,70	8,62	0,02	14,07	1,92

From the table above, 3 kg gas cylinders are distributed from the Agent to each Base. To determine the allocation of vehicles starting from the most significant saving matrix value, which is 17.57, the value of the combined base 11 and base 7 with demand respectively 130 and 140, so it can be combined because the demand is still smaller than the vehicle capacity.

Table 6. New Route Sequencing

Number	Route	Result	Request	Capacity	Number	Route	Result	Request	Capacity
1	11,7	17,57	270	560	34	9,8	1,9	250	560
2	12,1	14,07	230	560	35	9,4	1,72	240	560
3	10,8	12,62	240	560	36	9,3	1,72	260	560
4	7,4	11,89	240	560	37	8,7	1,47	250	560
5	4,3	10,16	220	560	38	8,6	1,45	230	560
6	7,3	10,15	260	560	39	8,2	1,34	210	560
7	11,4	8,97	230	560	40	11,2	1,29	230	560
8	8,5	8,67	230	560	41	11,6	1,27	250	560
9	12,8	8,62	210	560	42	11,5	1,26	250	560
10	11,3	7,98	250	560	43	7,1	1,18	250	560
11	12,7	7,7	240	560	44	3,1	1,09	230	560
12	10,7	5,96	270	560	45	4,1	1,07	210	560
13	9,1	5,06	250	560	46	11,1	0,82	260	560
14	11,9	4,91	270	560	47	8,4	0,71	210	560
15	12,4	4,73	200	560	48	8,3	0,57	230	560
16	10,5	4,69	250	560	49	10,6	0,51	250	560
17	12,3	4,11	220	560	50	10,2	0,45	230	560
18	11,1	3,38	240	560	51	10,1	0,42	240	560
19	10,4	3,36	230	560	52	3,2	0,34	220	560
20	9,5	3,14	260	560	53	4,2	0,32	200	560
21	5,1	3,09	230	560	54	6,3	0,32	240	560
22	12,5	3,01	220	560	55	7,2	0,32	250	560
23	10,3	2,87	250	560	56	6,4	0,3	220	560
24	6,2	2,42	220	560	57	7,6	0,29	260	560
25	6,1	2,4	230	560	58	10,9	0,27	270	560
26	2,1	2,35	210	560	59	12,6	0,23	220	560
27	9,6	2,28	260	560	60	12,2	0,19	200	560
28	9,2	2,24	240	560	61	11,8	0,19	240	560
29	6,5	2,07	240	560	62	12,1	0,09	210	560
30	9,7	1,99	280	560	63	12,9	0,02	240	560
31	8,1	1,96	220	560	64	7,5	0,01	260	560
32	5,2	1,95	220	560	65	5,4	0	220	560
33	12,11	1,92	230	560	66	5,3	0	240	560

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d. Sort predefined routes

The bases that must be visited in one route can be sorted from the new routes obtained. The nearest neighbor and farther insertion methods are used to sort the route. The results obtained can be seen in Table 7.

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

Route	Method	Route Order	Distance
1	Nearest Neighbour	0-10-12-7-11-0	58,36
	Fathers Insertion	0-11-7-12-10-0	58,36
2	Nearest Neighbour	0-5-8-3-4-0	35,26
	Fathers Insertion	0-4-3-8-5-0	35,26
3	Nearest Neighbour	0-2-6-1-9-0	7,11
	Fathers Insertion	0-9-1-6-2-0	7,11
	Total		100,73

From the results of the new route with the two methods above, three new routes were obtained where the first route had a route sequence starting from 0-2-6-1-9-0, then the second route had a route sequence starting from 0-5-8-3-4-0, and the third route had a route sequence starting from 0-10-12-7-11-0. Thus, the graphs of the three routes are as follows:

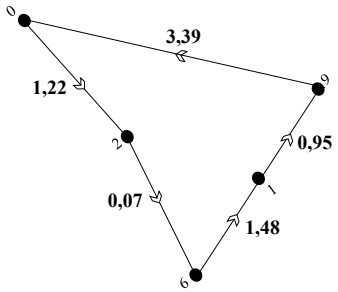

Figure 7. First Route Graph

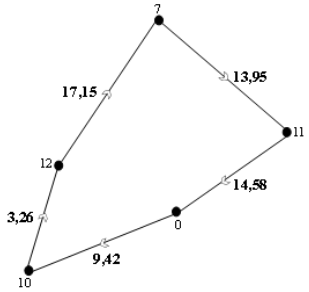

Figure 8. Second Route Graph

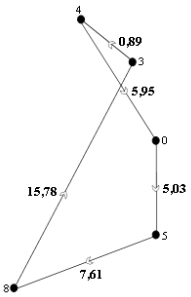

Figure 9. Third Route Graph

2. Transportation Costs

To obtain transportation costs, can use the formula as follows:

$\frac{Amount\ of\ distance}{10} \times Rp.6.800$ (the price of 1 liter of diesel)

So, the transportation costs are:

$\frac{100,73}{10} \times Rp.6.800 = 10,073 \times Rp.6.800 = Rp.68.496,4$

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In the research that has been done, three proposed routes were obtained, namely 0-10-12-7-11-0, 0-5-8-3-4-0, and 0-2-6-2-9-0. This route is obtained by looking at the value of the saving matrix, the number of requests that must be less or equal to the load capacity of the car used to transport 3 kg lpg gas cylinders, and the route results to be obtained can be determined by two methods, namely nearest neighbor and farther insertion.

From the results of observations on the two methods used, the total distance on each route has similarities, and the only difference is the order of each route to be traversed. For example, on the first route, the nearest neighbor method gives the results of the route order, namely 0-10-12-7-11-0, while the farther insertion method gives the results of the route order, namely 0-11-7-12-10-0.

To determine which route order to choose between the order of routes with the nearest neighbor method or the farther insertion method, researchers used references to previous studies conducted by Rizky Ayuning Tyas, Syahriza Dzulqarnain, and Qurrotul Aini using the same two methods [23]. The method used is the nearest neighbor method.

The initial route order used by the company is 0-12-1-6-0, 0-9-3-4-0, 0-7-2-10-0, and 0-8-5-11-0, with a total distance of 144.29 km and transportation costs of Rp. 98117.2. Meanwhile, the total distance from the results of the new route order is 100.73 km, and transportation costs are Rp. 68,496.4. So, this shows that the saving matrix method and continued use of the nearest neighbor and farther insertion method can minimize distance and transportation costs.

CONCLUSION

The proposed route obtained using the saving matrix method is centered from 0-10-12-7-11-0, 0-5-8-3-4-0, 0-2-6-2-9-0, with a total distance of 100.73 km and transportation costs of Rp. 68,496.4 from the initial route, which has a total distance of 144.29 km and transportation costs of Rp. 98,117.2. So, this saving matrix method can be used to minimize distance and transportation costs.

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