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Optimization of LPG Gas Distribution Routes with a Combination of the Saving Matrix Method and Nearest Neighbor

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Abstract

Distribution is an important process in economic activities, which involves the delivery of goods or products from producers to end consumers. Efficiency in the distribution system highly depends on the selection of optimal routes, which can affect costs, time, and the quality of service provided. PT Amartha Anugrah Mandiri, which operates in the distribution of 3 kg LPG, faces significant challenges in terms of inefficient distribution route selection, limited fleet capacity, and unstructured variations in LPG demand. The distribution routes currently used do not consider the aspects of distance, time, and cost efficiency, resulting in the wastage of resources such as fuel and time. This research aims to optimize LPG distribution routes. The methods used in this study are the Saving Matrix and Nearest Neighbor. The Saving Matrix method is used to reduce distribution distance and costs by combining existing delivery routes, while the Nearest Neighbor is applied to determine the order of visits to the nearest bases gradually. Both methods are designed to produce distribution routes that are efficient in terms of time, distance, and cost, as well as to maximize the use of the existing fleet. The data in this study were obtained thru direct observation at PT. Amartha Anugrah Mandiri. The data collected included base locations, LPG demand, vehicle capacity, and operational costs. There are 22 bases served with a total delivery reaching 1120 LPG 3 kg cylinders spread across various sub-districts of Batam City. Deliveries are carried out using trucks with a maximum capacity of 560 cylinders, so in one day, distribution requires more than one trip. Using this data, the distance matrix and savings matrix were calculated to design a more efficient distribution system. The research results show that the application of these two methods successfully reduced the total distance traveled, delivery time, and operational costs significantly, as well as improved the efficiency of LPG distribution. This research is expected to contribute to the company so that the 3 kg LPG delivery process can run optimally.

Keywords: Distribution, LPG, Route Optimization, *Saving Matrix, Nearest Neighbour*

1. Introduction

LPG distribution is an important aspect of the logistics system that affects the efficiency of time, cost, and fleet utilization in delivering products from producers to consumers.[1], [2]. The selection of an optimal distribution route significantly impacts the reduction of operational costs and the improvement of delivery effectiveness. [3], [4]. Especially in the context of distributing goods with varying demand, such as 3 kg LPG, proper route planning becomes a key factor in the success of distribution operations. [5], [6]. The use of inefficient routes can lead to resource wastage, both in terms of time and transportation costs, as well as suboptimal fleet utilization.[7]. Along with the importance of LPG distribution in the logistics system, route efficiency becomes the main key for distribution companies like PT. Amartha Anugrah Mandiri, which faces challenges in route selection. PT. Amartha Anugrah Mandiri is one of the LPG gas agents in Batam City engaged in the distribution of LPG gas from Pertamina to the distribution points. PT. Amartha Anugrah Mandiri faces challenges in the distribution of 3 kg LPG to various distribution points in Batam Kota District, including delivery scheduling that still relies on the allocation of cylinder quotas without considering travel distance and route efficiency. The demand for LPG per base varies between 40 to 120 cylinders per day. The limited capacity of the transport fleet, which can only carry 560 cylinders, forces drivers to return to the agent several times. Moreover, the delivery order is still determined based on the driver's estimate without considering the shortest route.

To address this issue, this research aims to optimize the distribution route of 3 kg LPG by applying the Saving Matrix and Nearest Neighbor methods. These two methods are expected to improve distribution efficiency by minimizing distance, time, and operational costs. The Saving Matrix method is a saving technique designed to minimize distance, time, or costs by considering various constraints.[8], [9]. The Saving Matrix method is capable of providing quick and

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practical solutions in addressing the limitations of vehicle capacity, fleet size, and delivery time. Its use is based on several assumptions, including that all distribution routes are two-way roads with symmetrical distances, and it does not consider traffic factors such as congestion or traffic lights that can affect vehicle speed.[10], [11]. Next, the Nearest Neighbor Method is a simple and fast constructive algorithm used in the TSP by selecting the nearest point sequentially until all points are connected, although the solution produced is approximately optimal.[12], [13], [14]. The Nearest Neighbor method is an effective and realistic heuristic algorithm for route formation, especially for a relatively small number of points. This algorithm works by visiting the nearest location from the current point being visited and has a high computational speed.[15] This concept was first introduced by Solomon in 1987.[16] The implementation of these two methods is expected to reduce the total distance traveled, delivery time, and operational costs, as well as maximize the efficiency of the existing fleet utilization.

Various previous studies have shown the effectiveness of the Saving Matrix and Nearest Neighbor methods in improving the efficiency of distribution systems. Research by [17] proves that the Saving Matrix method can reduce transportation costs by up to 15% and decrease travel distance by 18% in the distribution of chemical goods.[9] applied a similar method to the distribution of 3 kg LPG, resulting in a reduction in travel distance from 200 km to 150 km and a cost efficiency of 12%. [18] combined both methods in the distribution of letters at PT Pos Indonesia, resulting in a 20% reduction in distribution time and a 10% savings in daily operational costs. Research by [19] in the context of the Vehicle Routing Problem (VRP) in motorcycle distribution showed a daily cost savings of 5.8% thru vehicle capacity-based route optimization. [7] also reported a 24% reduction in travel distance and a 6% reduction in distribution costs per month in the distribution of LPG in Bantul. Subsequent research [20] shows that the Saving Matrix method in the distribution of 3 kg LPG in South Bolaang Mongondow Regency can reduce distribution distance by up to 30% and transportation costs by 20%. Research [21] demonstrates that the application of both methods in newspaper distribution successfully improved efficiency, with operational cost savings of Rp134,160 per day. Research [22]. also reported a reduction in travel distance from 43.1 km to 39.3 km and a monthly transportation cost savings of 8.81%. Overall.

Based on previous research, this study aims to design an optimal distribution route by considering vehicle capacity and actual demand at each base, thru the application of the Saving Matrix and Nearest Neighbor methods. Thus, the results of this research are expected to provide an effective solution to existing distribution problems, improve operational efficiency, and minimize transportation costs and delivery times at PT. Amartha Anugrah Mandiri. In addition, this research can contribute to maximizing fleet utilization, which in turn will have a positive impact on resource savings and increased customer satisfaction.

2. Methodology

The method used in this research is a combination of the Saving Matrix and Nearest Neighbor. These two methods were chosen for their ability to minimize travel distance, time, and distribution costs, as well as to optimize the utilization of the existing fleet. The research framework used in this study can be seen in Figure 1 below.

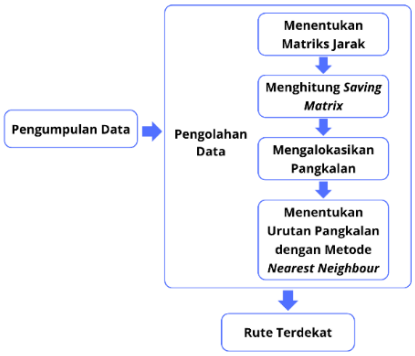

Figure 1. Research Framework

2.1 Data Collection

Data collection, which includes two types of data: primary and secondary. The data obtained are:

1. Base Data
2. Type of vehicle
3. Distribution expenditure costs
4. Distance and cost data

2.2 Data Processing

1 Determining the Distance Matrix
The distance between depots and bases is calculated using geographic coordinates obtained thru surveys or existing data, using Google Maps to generate a distance matrix used in route optimization.

2 Calculating the Saving Matrix
The savings matrix is calculated to determine the efficiency of merging two routes, using the formula:

$$S(x,y) = J(G,x) + J(G,y) - J(x,y) \quad (1)$$

3 Allocating Bases
The base is allocated into the optimal distribution route considering the vehicle capacity.

4 Determining the Base Order with the Nearest Neighbor Method
The order of base visits is determined by selecting the nearest base, starting from the depot, to minimize travel distance and improve distribution efficiency.

2.3 Obtaining the Shortest Path

At this stage, a comparison is made between the distribution routes before and after optimization using the Saving Matrix and Nearest Neighbor methods to minimize travel distance, fuel costs, and distribution costs.

3. Results and Discussion

3.1 Data Collection

The data used in this research includes information about base locations, LPG demand, vehicle capacity, distribution costs, and the distance between depots and bases. This data was obtained thru direct field observations and internal company sources, which were used to design more efficient distribution routes.

1. LPG Gas Base Data

PT. Amartha Anugrah Mandiri is a company engaged in the distribution of LPG, serving the Batam Kota District area. In its distribution activities. The distribution process is expected to be carried out in a timely manner and at an optimal cost. The base data at PT. Amartha Anugrah Mandiri is presented in Table 1 below, with distance determination assisted by Google Maps..

Table 1. LPG Gas Base Data

Code	Base Name	Address	Distance (Km)	Request
P1	Samsurizal	Taman Raya Blk E1 No 17	7.001	50
P2	Musliadi/Nurmayanti	Taman Raya Thp IIA Blk Cu No 24	7.117	50
P3	Nur Alam	Taman Raya Blk DM No 12	7.038	40
P4	M. Imran Salim	Taman Raya Thp III Blk GO No 25	6.668	60
P5	Suyatna	Prenciana Garden Blk G No 6	6.986	60
P6	Sigit Taru Basuki	Taman Raya Thp III Blk HL/37	6.748	50
P7	Ariansyah/J Gultom	Taman Raya Thp III Blk GB No 12	6.664	40
P8	Rahayu	Taman Raya Thp III Blk HC No 28	6.904	50
P9	Amril Taufik	Taman Raya Thp III Blk HK No 15	6.788	60
P10	Sugianto	Taman Raya Thp III Blk HR No 36	6.743	50
P11	Abdul Nasri	Taman Raya Thp IIIBlk HU No 26	6.784	50
P12	Maryuli Septi	Taman Raya Blk CTG No 2	6.965	60
P13	Karim	Taman raya Thp IV Blk NN N0 12	6.59	50
P14	Sinung Basuki/Anwar S.	Graha Permai Blk A6 No 7	6.408	50
P15	Khairul Umam	Taman Raya Thp IV Blk NN No 18	7.134	60
P16	Sahat Lubis	Taman Raya Thp IV Blk NF No 1	6.516	60
P17	M.Syawalluddin	Taman Raya Thp IV Blk NU No 13	6.43	50
P18	Lasmauli Galingging	Taman Raya Thp IV Blk NQ No 11	6.53	50
P19	Nensi Noperiiana S	Buana Regency Blk D No 33A	6.171	40
P20	Nayla	Buana Regency Blk C No 16	6.042	50
P21	Susi	Taman Anugrah Ideal Blk D1 No 17	6.476	40
P22	Yuni Astuti	Grand BSI Cluser Kelinci Blk B No 8	6.541	50

2. Type of Vehicle

LPG distribution is carried out using one type of vehicle, namely a truck with a maximum capacity of 560 3 kg LPG cylinders.

3. Distribution Expense

Product delivery is an activity related to incurring costs. PT. Amartha Anugrah Mandiri has a breakdown of the costs incurred in the LPG delivery process, which can be seen in Table 2.

Table 2. Distribution Expense

Component	Cost
Fuel/Liter	Rp.6.800,-
Driver's Wage	Rp. 110.000,-
Consumption	Rp.30.000

4. Distance and Cost Data

Each distance to be covered has a different route and a different cost, where PT. Amartha Anugrah Mandiri itself has routes and costs for each of its shipments. The following is the distance data for each route currently used by PT. Amartha Anugrah Mandiri, which can be seen in Table 3.

Table 3. Distance and Cost Data

Route	Visit Order	Distance	Fuel Cost 1 L / 10 Km (Rp)	Fixed Cost (Rp)	Total Cost (Rp)
Route 1	Depot - P1 - P2 - P3 - P4 - P5 - P6 - P7 - P8 - P9 - P10 - P11 - Depot	58.4 km	39.440	140.000	217,248
Route 2	Depot - P12 - P13 - P14 - P15 - P16 - P17 - P18 - P19 - P20 - P21 - P22 - Depot	55.2 km	37.400		
	Total	113.6	77.248		

From all routes, a total cost of Rp. 356,840 was obtained for 1 day with the price of diesel per liter at Rp. 6,800 and fixed costs at Rp. 140,000, which include meal costs, retribution, and wages for the driver and conductor, where the transportation costs are determined as follows:

Total Cost = (Distance Traveled x Fuel Cost/ Km) + Fixed Cost Note: 1 liter of diesel covers a distance of 10 Km.

3.2 Data Processing

1. Determining the Distance Matrix

The distance matrix illustrates the distance between distribution points, both from the depot to the base and between bases, calculated based on geographical coordinates (latitude and longitude) using road routes on Google Maps as the initial input in the Saving Matrix method.

The steps to build a distance matrix are as follows:

a. Determining the distribution center point (depot) and all base points.
b. Calculating the distance from the depot to each base.
c. Calculating the distance between all combinations of base pairs (symmetric distance).
d. Arranging the calculation results into a matrix form.

Here is the distance matrix for the routes taken by trucks for LPG distribution, which can be seen in Table 4.

Table 4. Distance Matrix

	P0	P1	P2	P3	P4	P5	P6	P7	P8	P21	P22
P0	0										
P1	7.001	0									
P2	7.117	0.175	0								
P3	7.038	0.037	0.156	0							
P4	6.668	0.402	0.459	0.435	0						
P5	6.986	0.582	0.729	0.582	0.854	0					
P6	6.748	0.424	0.427	0.451	0.136	0.942	0				
P7	6.664	0.38	0.455	0.415	0.005	0.809	0.181	0			
P8	6.904	0.386	0.326	0.401	0.274	0.754	0.159	0.307	0		
P21	6.486	0.326	0.626	0.399	0.774	0.303	0.854	0.678	0.925	0	
P22	6.541	0.675	0.805	0.599	0.912	0.545	0.974	0.763	1.025	0.444	0

2. *Determining the Saving Matrix*

Here are the results of the distance savings calculations from the depot to the base, which can be seen in Table 5.

Table 5. *Saving Matrix*

	P1	P2	P3	P4	P5	P6	P7	P8	P21	P22
P1	0									
P2	13.943	0								
P3	14.002	13.999	0							
P4	13.267	13.326	13.271	0						
P5	13.405	13.374	13.442	12.8	0					
P6	13.325	13.438	13.335	13.28	12.792	0				
P7	13.285	13.326	13.287	13.282	12.841	13.231	0	.		
P8	13.519	13.695	13.541	13.298	12.936	13.493	13.261	0		
P21	12.951	12.932	12.951	12.826	12.732	12.77	12.862	12.97	0	
P22	12.867	12.808	12.848	12.497	13.077	12.449	12.542	12.52	12.573	0

At this stage, the Saving Matrix calculation is carried out to determine the savings that can be obtained by combining two distribution routes in the LPG distribution system.

3. Allocating Bases

Here are the results of the LPG distribution route allocation by maximizing the vehicle capacity to 560 cylinders per route. Each route has been optimized based on the highest Saving Matrix value, taking into account the demand of each base. can be seen in Table 6

Table 6. Allocating Bases

Rute	Pangkalan	Total Permintaan
Rute 1	['P2', 'P15', 'P6', 'P17', 'P19', 'P22', 'P10', 'P20', 'P16', 'P1', 'P18']	560
Rute 2	['P8', 'P12', 'P5', 'P11', 'P13', 'P3', 'P9', 'P4', 'P7', 'P14', 'P21']	560

4. Determining the Base Order with the Nearest Neighbor Method

Here are the visit sequences for each LPG distribution route that have been determined using the Nearest Neighbor method:

Tabel 7. Base Order

Route	Order of Visits	Number of Points	Total Request
Route 1	['Depot', 'P20', 'P19', 'P17', 'P16', 'P6', 'P10', 'P18', 'P2', 'P15', 'P1', 'P22', 'Depot']	11	560
Route 2	['Depot', 'P14', 'P21', 'P13', 'P7', 'P4', 'P9', 'P8', 'P12', 'P11', 'P3', 'P5', 'Depot']	11	560

3.3 Obtaining the Shortest Path

Before optimization, LPG distribution used After the application of the Saving Matrix and Nearest Neighbor methods, distribution route optimization was carried out

to minimize travel distance and reduce operational costs. This optimization results in a more efficient distribution route by considering the distance between the nearest bases. Here are the distribution route results after optimization

Table 8. Calculation after optimization.

Route	Visit Order	Distance	Fuel Cost 1 L / 10 Km (Rp)	Fixed Cost (Rp)	Total Cost (Rp)
Route 1	Depot - P20 - P19 - P17 - P16 - P6 - P10 - P18 - P2 - P15 - P14 - Depot	15.634 km	Rp 10.622		
Route 2	Depot - P14 - P21 - P13 - P7 - P4 - P9 - P8 - P12 - P11 - P1 - Depot	15.299 km	Rp 10.405	140.000	161.027
	Total	30.933 km	Rp 21.027		

Here is a comparison of the total distance traveled, fuel costs, and distribution costs between the routes before and after optimization:

Tabel 9. Before and After Optimization Comparison

Kriteria	Sebelum Pengoptimalan	Setelah Pengoptimalan
Total Mileage	113.6 km	30.933 km
Total Fuel Costs	Rp 77.248	Rp 21.027
Total Distribution Costs	Rp 217.248	Rp 161.027

Based on the comparison results between the routes before and after optimization, it can be concluded that the optimization of the distribution routes using the Saving Matrix and Nearest Neighbor methods has significantly reduced. This optimization provides significant benefits to the company in terms of cost and distribution time efficiency, as well as improving overall operational performance by reducing total travel distance, fuel costs, and distribution costs.

4. Conclusion

This research successfully optimized the distribution route of 3 kg LPG at PT. Amartha Anugrah Mandiri by applying the Saving Matrix and Nearest Neighbor methods, which proved effective in reducing travel distance, fuel costs, and operational costs. The optimization results showed a reduction in travel distance by up to 73%, significantly impacting operational cost savings. This approach allows the company to reduce resource waste, maximize the fleet, and improve customer satisfaction. This research provides significant contributions to the company and can serve as a reference in the implementation of distribution route optimization to enhance operational efficiency.

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