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Determining the Shortest Route for LPG Gas Cylinder Distribution Using the Clarke and Wright Savings Algorithm

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ABSTRACT

This research aims to minimize the routes taken, thus reducing the transportation costs incurred by the company. This is necessary because the current routes within the company are suboptimal and may lead to financial losses. The proposed solution to address the issue of determining the shortest distribution routes involves utilizing the Capacitated Vehicle Routing Problem (CVRP) with the Clarke And Wright Savings Algorithm. The Clarke And Wright Savings Algorithm is designed to solve various vehicle routing problems, commonly referred to as the classic vehicle routing problem, based on the concept known as the savings concept. According to the research findings, three routes were identified with a total distance of 43.48 km and transportation cost of Rp. 88,699.2. Through the implemented savings, two new routes were obtained with a total distance of 35.98 km and transportation cost of Rp. 73,399.2. Thus, this study concludes that the Clarke And Wright Savings Algorithm is effective in achieving its goal, optimizing distribution routes, and minimizing distribution costs more efficiently than the current company routes.

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1. INTRODUCTION

Distribution is a crucial process in conveying products from manufacturers to consumers. Ensuring the convenience for consumers to obtain desired products is a top priority for every company aiming to satisfy customers. Efficient distribution and transportation are essential to ensure timely delivery, reaching the intended destinations, and maintaining optimal product conditions [1]. Distribution of goods often poses significant challenges, especially for companies with large-scale production. For instance, the distribution of LPG cylinders faces infrastructure constraints such as adequate transportation fleets and efficient distribution networks. Other factors include delivery regulations, storage safety, and even distribution, all of which impact the smooth flow of large-scale goods distribution.

The demand for LPG continues to rise, and LPG 3kg, as one of the essential needs, is crucial, especially for economically disadvantaged communities receiving subsidies from the government through PT. Pertamina. The government regulates its selling price to the public. Ideally, the public should be able to easily and affordably obtain LPG 3kg. However, in reality, the prices received by the public are often higher than the predetermined prices, and the sales locations are not always easily accessible or predetermined (Theodoridis and Kraemer, n.d.).

LPG SPBE products are distributed through several intermediaries in various regions. Agents distribute LPG to sub-agents/bases, and each sub-agent/base further distributes it to the nearest LPG retailers. While the current sales process has been effective, it has not been fully optimized, resulting in lengthy delivery routes and increased sales costs due to various factors. Therefore, it is expected that each LPG representative can devise a plan to determine the distribution routes so that the LPG distribution process can run optimally and at the lowest possible cost [2]

The problem of determining these routes is known as the Vehicle Routing Problem (VRP). The VRP solution consists of a series of distribution routes where vehicles leave the depot, travel to customers, and return to the depot. This VRP study is conducted using the Clarke & Wright Savings algorithm. The Clarke & Wright Savings algorithm works by determining which customers to serve based on the highest distance savings value. The Clarke & Wright savings algorithm is suitable for handling relatively large problems, such as a large number of routes. Research using the Clarke & Wright Savings algorithm has been conducted extensively, including studies by [3]–[7], he aim of this research is to determine the solution to the problem of LPG gas cylinder distribution routes using the Clarke & Wright Savings algorithm and to assess the effectiveness of this solution in optimizing LPG gas cylinder distribution routes."

2. RESEARCH METHODE

a. The research method was conducted through direct observation of the research object, using the Clarke & Wright Savings algorithm. The data analysis techniques used in this study are as follows: Determine customer data, demand quantity, and vehicle capacity as required input.
b. Create a distance matrix between the depot and customers, as well as between customers.
c. Calculate the saving value using the equation $sij = ci0 + c0j - cij$ for each customer to determine the saving value.
d. Sort customer pairs based on the saving value matrix from the largest saving value to the smallest.
e. Formation of the first route (t = 1).
f. Determine the first customer assigned to the route by selecting a combination of customers with the highest saving value.
g. Calculate the total demand from the selected customers. If the demand quantity still fits the vehicle capacity, proceed to step 8. If the demand quantity exceeds the vehicle capacity, proceed to step 9.
h. Choose the next customer to be assigned based on the last selected customer combination with the highest saving value. Go back to step 7.
i. Remove the last selected customer. Proceed to step 10.
j. Insert the previously selected customers to be assigned to the route, and the route (t) is formed. If there are still unassigned customers, proceed to step 11. If all customers have been assigned, the Clarke & Wright Savings algorithm process is complete
k. Formation of a new route $(t = t + 1)$.
l. If all shipped product demands to customers have been fulfilled, stop this procedure.

2.1 Vehicle Routing Problem (VRP)

The Vehicle Routing Problem (VRP) was first introduced in 1959 by Dantzig and Ramser in their study titled "The Truck Dispatching Problem." VRP plays a crucial role in distribution management and is one of the most extensively studied combinatorial optimization problems [1].

2.2 Capacitated Vehicle Routing Problem (CVRP)

The Capacitated Vehicle Routing Problem (CVRP) is the simplest form of VRP. It is an optimization problem to find the most cost-effective routes for multiple vehicles with a homogeneous fleet serving the demands of many customers, where the demand quantities are known before the delivery process. The definition of CVRP as a directed graph G = (V, A) with V = $\{v_0, v_1, v_2, ..., vn\ \ , v_n+1\}$ is a set of points, where v_0 represents the depot and vn+1 is the pseudo-depot from v0, indicating the place where vehicles start and end their travel routes. Meanwhile, A = $\{(vi_i,\ v_j)$: $v_i,\ v_i, \epsilon$ V, i ≠ j} is a set of edges connecting points. Each point vi in V has a demand denoted as di. The set K = {k₁, k₂, ..., kₘ} represents a set of homogeneous vehicles with identical capacities, denoted as Q, so the length of each route is limited by the vehicle's capacity. Each edge (v_i,v_j) has a travel distance cij, representing the distance from point vi to point vj. This travel distance is assumed to be symmetric, meaning $c_{ij} = c_{ji}$ dan $c_{ii} = 0$

2.3 Clarke & Wright Savings Algorithm

In 1964, Clarke and Wright published an algorithm to solve various vehicle routing problems, often referred to as the classic vehicle routing problem. This algorithm is based on a concept called the savings concept. The Clarke & Wright Savings Algorithm is a heuristic algorithm, and therefore, it does not provide an optimal solution. However, it often produces good solutions, which are slightly different from the optimal solution. The basis of this savings concept is to achieve cost savings by combining two routes into one route, as illustrated in Figure 1, where point 0 represents the depot.

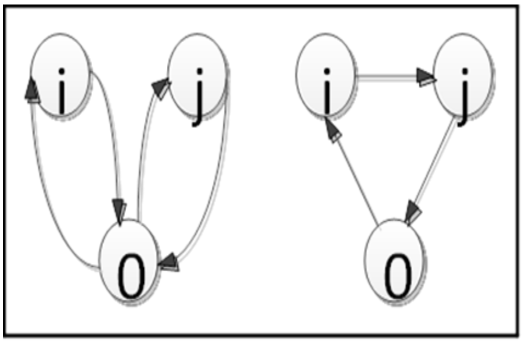

Figure 1. Illustration of Clarke & Wright Savings Concept

2.3.1 Form of Clarke & Wright Savings Algorithm

There are steps in solving the Capacitated Vehicle Routing Problem (CVRP) using the Clarke And Wright Savings Algorithm through several steps. The steps are as follows:

1. Create a distance matrix between the depot and customers, and among customers. To find the distance matrix values, you can use the formula:

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

   Explanation:
   d_n= Distance
   x = Latitude or Earth's latitude
   y = Longitude or Earth's longitude

2. Calculate the saving matrix values using the equation

   $$S_{(i,j)} = C_{(i0,x)} + C_{(0j,y)} - C_{(i,j)}$$

   Explanation:
   C_{oi}= distance from the depot to node i
   C_{ij} = distance from node i to node j
   S_{ij} = saving value of the distance from node i to node j
3. Sort customer pairs based on the saving matrix values from the largest saving to the smallest.
4. Formation of the first route

2.4 Transportation Cost

To obtain the transportation cost, you can use the formula

$$\frac{Total\ distance}{10} \times \text{Rp.6,800 (price of 1 liter of diesel)}$$

3. RESULT AND ANALYSIS

The distribution routes of 3 kg LPG gas cylinders from the center to the depots before the research were analyzed for three routes obtained using QGIS software. The company utilized specialized Colt Diesel vehicles with a cargo capacity of 560 LPG gas cylinders. The initial routes used by the company are as follows: [provide details or descriptions of the initial routes].

Table 1. Initial route of the company

Route	Initial Sequence	Distance (Km)
1	0-2-1-4-3-0	18,40
2	0-10-5-9-0	10, 96
3	0-8-6-7-0	14,12
	Total	43,48

Table 2. Latitude and Longitude Values

Symbol	*Lattitude*	*Longitude*
0	3,576366	98,732599
1	3,599556	98,702422
2	3,606586	98,682420
3	3,607755	98,683392
4	3,611199	98,697435
5	3,572170	98,695909
6	3,559345	98,708461
7	3,568324	98,686530
8	3,550826	98,698087
9	3,573756	98,694796
10	3,558151	98,692376

Below are the distance matrix values for 10 depots, which can be viewed more clearly in the following table:

Table 3. Distance Matrix

	0	1	2	3	4	5	6	7	8	9	10
0	0										
1	4.24	0.00									
2	6.52	2.36	0.00								
3	6.50	2.31	0.17	0.00							
4	5.51	1.41	1.75	1.61	0.00						
5	4.11	3.13	4.12	4.20	4.35	0.00					
6	3.29	4.53	6.01	6.07	5.90	2.00	0.00				
7	5.21	3.90	4.28	4.40	4.92	1.13	2.64	0.00			
8	4.78	5.45	6.45	6.55	6.72	2.39	1.49	2.33	0.00		
9	4.22	2.99	3.91	3.99	4.18	0.22	2.21	1.10	2.58	0.00	
10	4.92	4.74	5.50	5.61	5.93	1.61	1.80	1.31	1.03	1.76	0.00

With the distance values as seen in the distance matrix table, here are the saving matrix values for the 10 depots:

Table 4. Savings Matrix

	1	2	3	4	5	6	7	8	9	10
1	0									
2	8.40	0.00								
3	8.43	12.85	0.00							
4	8.34	10.28	10.40	0.00						

5	5.21	6.52	6.41	5.27	0.00					
6	3.00	3.80	3.72	2.90	5.40	0.00				
7	5.54	7.44	7.30	5.79	8.19	5.86	0.00			
8	3.57	4.85	4.73	3.57	6.50	6.57	7.65	0.00		
9	5.46	6.83	6.72	5.55	8.11	5.30	8.32	6.42	0.00	
10	4.41	5.93	5.80	4.49	7.42	6.41	8.82	8.66	7.38	0.00

Sort customer pairs based on the saving matrix values from the largest saving to the smallest:

Table 5. Sorting of Saving Matrix Values

Route	Result	Demand
3.2	12.85	240
4.3	10.40	210
4.2	10.28	210
10.7	8.82	220
10.8	8.66	200
3.1	8.43	210
2.1	8.40	210
4.1	8.34	180
9.7	8.32	210
7.5	8.19	210
9.5	8.11	200
8.7	7.65	200
7.2	7.44	230
10.5	7.42	210
10.9	7.38	210
7.3	7.30	230
9.2	6.83	220
9.3	6.72	220
8.6	6.57	180
5.2	6.52	220
8.5	6.50	180
9.8	6.42	190
5.3	6.41	220
10.6	6.41	200
10.2	5.93	230
7.6	5.86	200
10.3	5.80	230
7.4	5.79	200
9.4	5.55	190
7.1	5.54	200
9.1	5.46	190
5.6	5.40	190
9.6	5.30	190
5.4	5.27	190

5.1	5.21	190
8.2	4.85	210
8.3	4.73	210
10.4	4.49	200
10.1	4.41	200
6.2	3.80	210
6.3	3.72	210
8.1	3.57	180
8.4	3.57	180
6.1	3.00	180
6.4	2.90	180

To determine the vehicle allocation, it starts with the largest saving matrix value, which is 12.85, representing the combination of depot 3 and depot 2 with demand values of 120 each. They can be combined because the total demand is still less than the vehicle's capacity. From the calculation results, the new route sequence can be seen in the table.

Table 6. New Route Sequence

Route	New Sequence	Distance (Km)
1	0-3-2-10-7-0	18,68
2	0-4-1-9-5-8-6-0	17,30
	Total	35,98

Thus, the transportation cost is obtained:"

$$\frac{Total\ distance}{10} \times Rp.6.800 = \frac{35,98}{10} \times Rp.6.800$$

$$= 3,598 \times Rp.6.800$$

$$= Rp.\ 24.466,4 \times 3$$

$$= 73.399,2$$

4. CONCLUSION

In conclusion, the implementation of the Capacitated Vehicle Routing Problem (CVRP) with the Clarke And Wright Savings Algorithm can reduce transportation costs and the distance traveled in solving the problem of determining the shortest route. Initially, the company used three routes with the sequences 0-2-1-4-3-0, 0-10-5-9-0, and 0-8-6-7-0, totaling 43.48 km with transportation costs of Rp. 88,699.2. After optimization, two new routes were created: 0-3-2-10-7-0 and 0-4-1-9-5-8-6-0 with a total distance of 35.98 km and transportation costs of Rp. 73,399.2. The research results indicate that the Clarke And Wright Savings Algorithm successfully optimized distribution routes by reducing distribution costs and achieving more efficient distances compared to the routes initially used by the company

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