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Determination of Optimal Cylinder Gas Packaging Distribution Routes Through the Solution of the Capacitated Vehicle Routing Problem at PT Samator Gas Industri Balikpapan

Vincent Surianto*, Wahyuda, Farida Djumiati Sitania
Faculty of Engineering, Mulawarman University, Jl. Sambaliung No. 9 Kampus Gn. Kelua Samarinda, Kalimantan Timur 75119 Indonesia

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A B S T R A C T

The distribution of industrial and medical gases in Indonesia faces significant supply chain challenges. In general, the distribution is not yet fully adequate to meet the continuously growing demand. Based on this industrial issues, the researcher conducted an observation of PT Samator Gas Industri Balikpapan distribution activities. The company has not maximized the truck load by only loading 60 to 80 cylinders per truck. The issue has resulted in fuel costs not being optimal. Another issue arises because the distribution routes is done subjectively without considering the best route to deliver products. In this research, the issue was addressed by solving the Capacitated Vehicle Routing Problem (CVRP) using the Clarke-Wright Saving Heuristic Algorithm and the Sweep Algoritm (cluster first, route second), combined with the Nearest Neighbor route sorting method. Based on the research results, the Clarke-Wright Saving Heuristic Algorithm successfully reduced the travel distance to 167.1 km and resulted in fuel cost savings of IDR402,051.67 (49.21%). Meanwhile, the route generated by the Sweep Algorithm also showed better results compared to the initial route. The Sweep Algorithm produced savings of IDR340,465.00 (41.67%). Although the results obtained were not better than those of the Clarke-Wright Saving Heuristic Algorithm, the Sweep Algorithm has the advantage of simplifying the grouping process of delivery points based on their geographical proximity, making the route more efficient even without complex calculation steps.

*Corresponding Author
Vincent Surianto
E-mail: Vincent.suryanto04.vs@gmail.com

1. INTRODUCTION

The distribution of goods from producers to customers is a major issue in daily industrial activities (Lestari et al., 2022). Distribution is responsible for the entire process, which includes planning, executing, and controlling the flow of goods (Bastuti & Teddy, 2017). The business must also use distribution strategies that support meeting consumer needs in order to draw in customers and encourage them to buy the products being offered (Margie et al., 2020). Distribution is related to the delivery of goods from the company to a number of customers whose locations vary, with the aim of minimizing distance and distribution costs. Reducing distribution costs is an important challenge for companies (Duque et al., 2016). Businesses must choose distribution routes while delivering their goods in order to maximize the process's distance and reduce losses (Nezarulloh & Sumiati, 2024). The issue of product distribution requires serious handling (Bastuti et al., 2019). In general, the distribution of industrial and medical gases is not yet fully adequate to meet the continuously growing demand. The existing distribution systems are often not well integrated and are not yet optimal in terms of cost efficiency. Transportation costs affect profit margins (Chopra & Meindl, 2016). One of the elements that directly affects distribution costs is the vehicle's fuel usage (Arifian & Pulansari, 2023). A large amount of money is spent every day on fuel (Ibrahim, 2019). A lot of fuel is wasted unnecessarily (Tamin, 2000). This results in resource wastage and increased distribution costs, which can ultimately affect the competitiveness of the national industry.

Based on the issues in the industrial world, the researcher conducted observations on the distribution activities of PT Samator Gas Industri Balikpapan. As a company engaged in the field of industrial and medical gases, this company relies on the processes of production and distribution. This company has a filling depot known as a filling station. Gas distribution activities are carried out in the area of Balikpapan City. The gas produced by the filling station includes oxygen, nitrogen, argon, carbon dioxide, and mixed gas. These products are packaged in 6 m^3 cylinder containers and distributed to customers using trucks.

PT Samator Gas Industri Balikpapan uses 4 trucks for gas cylinder distribution activities. Each truck has a maximum carrying capacity of 120 cylinders with a size of 6 m^3. Distribution activities are carried out every working day without time restrictions on delivery. The distribution activity begins with a single loading process of filled cylinders in the morning, and the truck will return to the depot once all the cylinders have been delivered. Through initial observation, the researcher found issues in the distribution activities of PT Samator Gas Industri Balikpapan. There are indications that the company has not maximized the daily transport capacity of the trucks, loading only 60 to 80 cylinders per truck. The issue results in suboptimal distribution costs and truck fuel usage. Furthermore, another problem arises because the determination of distribution routes is done subjectively without considering the best distribution routes to deliver products to customers.

The best route that can be chosen in the context of distribution is the route with the shortest distance. The determination of this route is a crucial factor because it has a direct implication on the distribution costs that must be incurred. In other words, the shorter the distance traveled by the vehicle, the lower the distribution costs that will be incurred (Sarjono, 2014). The company can minimize distribution costs by determining the load capacity and the best distribution routes from the company to customers located in various locations. This issue can be addressed by solving the Capacitated Vehicle Routing Problem (CVRP), which considers the number and capacity of vehicles, the demand of each customer, and the distance from the depot to the customers in order to minimize the total distribution cost (Purnomo et al., 2023). The solution to the CVRP focuses on designing several routes with minimal distance and cost (Toth & Vigo, 2002).

Several previous studies have shown that solving the CVRP consistently focuses on optimizing distribution routes, both in terms of distance, cost, and vehicle capacity. The methods used, such as Clarke-Wright Saving Heuristic, Sweep, and Nearest Neighbor, are commonly employed in the CVRP literature and have proven their effectiveness. Therefore, this research will use the Clarke-Wright Saving Heuristic Algorithm and the Sweep method of cluster first, route second, combined with the Nearest Neighbor route sorting method. The methods selected because can provide an overview of the optimal route through a comparison of routes resulting from the Clarke-

Wright Saving Heuristic Algorithm, Sweep, and the initial route.

2. LITERATURE REVIEW

A. Optimal Route

A route can be considered the best route if it has the shortest distance. The selection of the best route will certainly impact transportation costs. In other words, the shorter the distance traveled, the lower the transportation costs that need to be incurred (Sarjono, 2014).

B. Vehicle Routing Problem

Vehicle Routing Problem (VRP) is a challenge in planning routes for multiple vehicles aimed at visiting service points. Each vehicle departs from the same central point (depot). The vehicle visits several service points on a single route only once before finally returning to the central point (depot). The route is designed with consideration of certain operational constraints (Wibisono, 2018). VRP focuses on designing several transportation routes with minimal distance and cost. Each vehicle moves from and returns to the depot, and each customer can only be visited once. The amount of customer demand transported by the vehicle must not exceed the available vehicle capacity. So, the VRP solution is to determine routes with multiple vehicles, so that customer demand can be met with minimal total distance and cost (Toth & Vigo, 2002).

C. Clarke-Wright Saving Heuristic Algorithm

The principle of savings serves as the basis for this algorithm to determine the distribution route. Savings are measured by the number of distance deficits from several existing nodes and combining them into a route based on the largest distance savings. The savings are made to minimize distribution costs in a one-day delivery (Kusuma & Sumiati, 2020). The Clarke-Wright Saving Heuristic algorithm can be used to determine the number of fleets and distribution routes for a company. This algorithm is quite effective because it can be applied without violating the vehicle's load capacity limits. Through this algorithm, the utility of the vehicle, travel time, distance traveled, and fuel cost can be determined (Sukendar et al., 2020).

According to Kusuma & Sumiati (2020), the Clarke-Wright Saving Heuristic Algorithm is applied through the following steps, (1) Creating a Distance Matrix: Identification of the distance between the depot and customers, as well as the travel distance between customers, was carried out. The results of the identification are then loaded into a matrix table. The table is used as a reference in subsequent calculations. (2) Creating a Saving Matrix: The saving matrix reflects the savings value if a vehicle visits multiple locations simultaneously compared to visiting each location one by one. The saving matrix S(x,y) represents the combination of the route from the depot to customer x, then continuing the journey to customer y, and finally returning to the depot (the starting point). To calculate the value of the saving matrix, Equation 1 below can be used.

$$S(x,y) = D(DC,x) + D(DC,y) - D(x,y) \quad (1)$$

Where:

S(x,y)= saving value from customer x to y
D(DC,x)= distance from depot to customer x
D(DC,y)= distance from depot to customer y
D(x,y)= distance from customer x to customer y

(3) Dividing Customers on Vehicle Routes Based on Load Capacity: Based on the saving matrix table, customers with the highest saving values are selected as the first destination. The route will be considered feasible if the total demand from customers does not exceed the vehicle's capacity. (4) Determining the Order of Customers in the Established Route: After the customers have been divided based on transport capacity, the next step is to determine the delivery route based on customer pairs with the highest saving value.

D. Sweep Algorithm

The Sweep Algorithm is a two-stage constructive method. Sweep Algorithm determine clusters followed by the Nearest Neighbor route sorting method (Solihin et al., 2023). The Sweep Algorithm is the simplest clustering method for solving the CVRP problem, but this method can also produce optimal route than any method else (Simanungkalit et al., 2022). The Sweep Algorithm in solving routing problems requires geographic position data and delivery coordinate points (Wibisono, 2018).

According to Rahmadini et al. (2023), the following is the method for clustering delivery points using the Sweep Algorithm: (1) Drawing delivery points in Cartesian coordinates with the depot as the origin point, (2) Determining the polar coordinates of each Cartesian coordinate point of each location with Formula 2,

$$\theta = Arc \tan \frac{y}{x} \quad (2)$$

Where:
θ= polar coordinate,
x= cartesian coordinate in x axis,
y= Cartesian coordinate in y axis

(3) The clustering process begins from the point with the smallest polar angle and continues sequentially until it reaches the point with the largest polar angle, while considering the vehicle's capacity. Clustering is stopped if adding a point to one cluster would exceed the vehicle's carrying capacity, (4) Form a new cluster with the same steps as step 3, starting from the point with the smallest polar angle that has not yet been included in the previous cluster, (5) Repeat steps 3 and 4 until all delivery points have a cluster, (6) After the cluster is formed, the next step will be to perform route sorting using the Nearest Neighbor method.

E. Nearest Neighbor Method

the next step will be to determine the delivery sequence using the Nearest Neighbor method (Azhar et al., 2023). the route is built by adding the nearest point from the last point visited by the vehicle, until all distribution points have been visited (Basriati et al., 2012 in Wati & Wustqa, 2023). According to Fitriani et al. (2021), steps for using the Nearest Neighbor method: (1) The calculation starts from the depot, then finding customers who are closest to the depot, (2) Next, another customer is selected who is closest to the first customer, (3) If all customers have been visited exactly once, then the algorithm has ended.

3. RESEARCH METHOD

The stages carried out to complete this research can be explicitly seen through the flowchart in Figure 1. The primary data collected includes the coordinates of the depot and delivery locations, the travel distance between each locations, and the mass of the gas cylinders. The secondary data collected includes company profiles, the number and types of vehicles, the maximum load capacity of the vehicles, the names of the relationships (customers), the number of shipments, the distance of the initial route, the fuel ratio and price, and the fuel cost of the initial route.

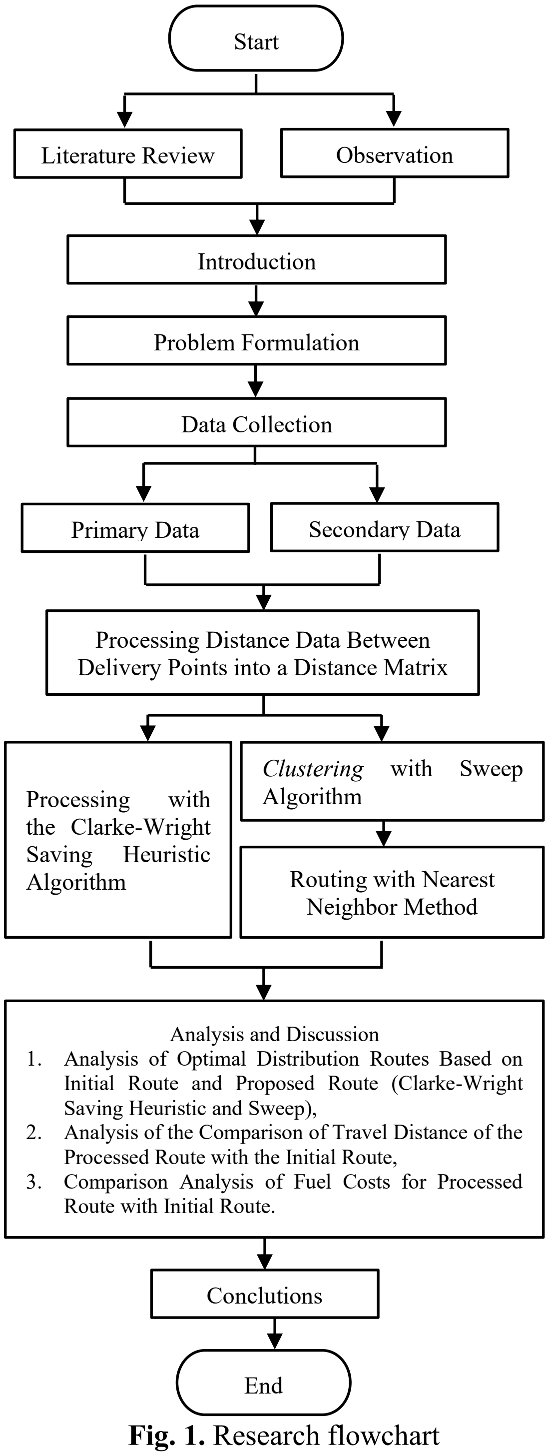

Fig. 1. Research flowchart

4. RESULT AND DISCUSSION

A. Gas Cylinder Mass Data

The measurement results show that the mass of the weighed gas cylinder is 56.8 kg. In the capacity calculation, the mass of the cylinder is rounded up to 60 kg as a safety limit.

B. Vehicles Data

The data collected includes the type of vehicle, license plate number, type of fuel, and the allowed weight based on the vehicle inspection document (KIR) and Surat Tanda Nomor Kendaraan (STNK). This data will serve as the basis for calculating optimal load capacity and planning effective distribution routes. The data on the transport vehicles owned by PT Samator Gas Industri Balikpapan can be seen in Table 1.

Tabel 1. Vehicles data

Vehicle Type	License Plate	Capacity
Colt Diesel	KT 8995 CG	7.323 kg≈ 122 cyl
FE74 S	KT 8956 CG	7.323 kg ≈ 122 cyl
Colt Diesel	KT 8258 YV	8.323 kg ≈ 139 cyl
FE SHD	KT 8257 YV	7.323 kg ≈ 122 cyl

C. Consumers Data

To gain a deeper understanding of the gas cylinder distribution patterns in the Balikpapan area and to optimize delivery routes, this research conducted data collection on consumers of PT Samator Gas Industri Balikpapan. The secondary data collected includes the consumer's name, the consumer's address, and the number of gas cylinder deliveries per consumer. In addition, primary data in the form of delivery location coordinates obtained through interviews with distribution staff were also collected. Based on the consumer data collected in Table 2, there are 26 delivery location points and 1 depot location point.

Table 2. Consumer data, coordinate points, and shipment quantity

No	Consumer Name	Coordinate	Code	Quantity (cyl)
1	PT Samator Gas Industri Balikpapan (Depot)	1°14'15.3"S 116°56'59.8"E	G	
2	RS Restu Ibu	1°16'20.9"S 116°50'14.5"E	X1	15
3	RS Sayang Ibu	1°14'02.9"S 116°49'17.1"E	X2	11
4	RS Balikpapan Baru	1°14'18.7"S 116°52'21.9"E	X3	10
5	RSUD dr. Kanudjoso Djatiwibowo	1°13'26.4"S 116°52'10.5"E	X4	6
6	RSUD Beriman Balikpapan	1°15'49.7"S 116°50'51.1"E	X5	20
7	RS dr. R. Hardjanto	1°16'24.4"S 116°49'43.9"E	X6	9
8	PT Mandiri Herindo Adiperkasa Tbk	1°14'51.8"S 116°56'13.9"E	X7	8
9	PT Hexindo Adiperkasa Tbk	1°14'27.9"S 116°56'39.0"E	X8	5
10	CV Multi Prima Teknik	1°14'41.5"S 116°56'28.1"E	X9	5
11	PT Duma Nusatama (Plant 2)	1°13'51.8"S 116°57'16.6"E	X10	13
12	PT Grace Tehnic	1°14'05.2"S 116°57'08.2"E	X11	12
13	PT Halmahera Indoserv	1°13'08.3"S 116°57'19.1"E	X12	8
14	PT Wellbore Integrity Solutions Indonesia	1°13'25.2"S 116°57'20.0"E	X13	5
15	PT Garuda Maintenance Facility	1°15'44.7"S 116°53'50.9"E	X14	3
16	PT Geoservice	1°15'32.5"S 116°51'59.5"E	X15	15
17	PT Nuga Sigma Potenzia	1°14'53.0"S 116°49'43.6"E	X16	10
18	CV Sumber Alam Semesta	1°09'24.0"S 116°51'18.8"E	X17	26
19	PT Diva Cahaya Sejahtera	1°12'18.1"S 116°52'54.0"E	X18	10
20	PT Kutai Refinery Nusantara	1°10'47.1"S 116°47'29.8"E	X19	27
21	PT Rhodes	1°11'03.1"S 116°51'09.1"E	X20	9
22	PT Inbang-Duta Firza JO	1°09'17.8"S 116°49'40.9"E	X21	10
23	PT United Tractors Pandu Engineering	1°09'48.1"S 116°52'24.0"E	X22	13
24	PT Sarana Sukses Sejahtera	1°11'34.2"S 116°51'26.9"E	X23	7
25	Lia Erlytha	1°12'54.4"S 116°51'03.4"E	X24	43
26	PT Daha Surya Persada	1°11'36.4"S 116°51'29.5"E	X25	7
27	Marlin Siagian	1°13'31.4"S 116°50'40.1"E	X26	5

D. Initial Route And Fuel Costs

Secondary data in the form of daily distribution reports from PT Samator Gas Industri Balikpapan. This data includes route details, distance traveled, fuel consumption, and fuel costs. The data can be seen in Table 3.

Table 3. Existing route and fuel costs data

License Plate	Distribution Points	Initial Odometer (km)	Final Odometer (km)	Distance Traveled (km)	Ratio	Fuel Consumption (L)	Fuel Price	Fuel Costs
KT 8257 YV	X14 X1 X2 X15 X16 X17	49.556	49.628	72	0,167	12,000	IDR 14.900	IDR 178.800
KT 8258 YV	X18 X19 X20 X21 X22	48.238	48.323	85	0,167	14,167	IDR 14.900	IDR 211.083
KT 8995 CG	X23 X24 X25 X26 X4 X5 X6 X3	476.368	476.493	125	0,167	20,833	IDR 14.900	IDR 310.417
KT 8956 CG	X7 X8 X9 X10 X11 X12 X13	464.432	464.479	47	0,167	7,833	IDR 14.900	IDR 116.717

E. The Distance Matrix

The distance matrix table is an important component in the routing algorithm. This table contains complete information about the distance between each distribution point, which will be used as input by the algorithm to calculate the optimal delivery route. In the processing of the distance matrix table, data on the shipping distances between distribution points is required. The shipping distance is obtained through Google Maps. After the distance between distribution points is known, this data will be entered into a matrix table as shown in Table 4.

Table 4. The distance matrix

	G	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26
G	0	15,4	18,2	10,8	13,3	14,5	17,1	1,8	0,8	1,3	1,1	0,5	2,8	2,2	7	11,6	18,6	22,4	18,6	31	18,8	25,6	23,4	17,6	15,6	17,6	16,7
X1	15,4	0	5,9	7,3	9,1	2,6	1,4	14,4	15,5	14,9	17,3	16,7	19	18,4	10,6	5,5	5,4	16,4	12,6	25	12,8	19,7	17,4	11,6	7,9	11,6	6,4
X2	18,2	5,9	0	7,8	7,5	5,7	6,5	16,4	17,5	16,9	19,3	18,7	20,9	20,4	13	7,7	2,2	13,3	9,5	22	9,7	16,6	14,3	8,6	4,8	8,5	3,4
X3	10,8	7,3	7,8	0	2,5	5,9	7,7	9	10,1	9,5	11,9	11,3	13,5	13	5,9	3,1	7,5	11,6	6,5	20,3	8	14,9	11,3	6,9	4,8	6,8	5,9
X4	13,3	9,1	7,5	2,5	0	8,2	10	11,4	12,5	11,8	14,3	13,6	15,9	15,3	8	5,2	9,2	10,6	5,8	19,3	7	13,9	10,5	6,3	3,8	6,2	4,9
X5	14,5	2,6	5,7	5,9	8,2	0	3,1	13,2	14,3	13,7	16,1	15,5	17,8	16,8	9,4	3,4	4,3	16,2	12,2	24,9	12,6	19,5	16,9	11,5	7,7	11,4	6,3
X6	17,1	1,4	6,5	7,7	10	3,1	0	14,6	15,7	15,1	17,5	16,9	19,1	18,6	10,7	5,7	8,5	17	13,3	25,7	13,4	20,3	18	12,3	8,5	12,2	7,1
X7	1,8	14,4	16,4	9	11,4	13,2	14,6	0	1,2	0,6	3	2,3	4,6	4	5,2	10,2	16,8	20,6	16,9	29,3	17	23,9	20,3	15,9	13,8	15,8	14,9
X8	0,8	15,5	17,5	10,1	12,5	14,3	15,7	1,2	0	0,6	2	1,4	3,6	3,1	6,3	11,3	17,9	21,7	18	30,4	18,1	25	21,4	17	14,9	16,9	16
X9	1,3	14,9	16,9	9,5	11,8	13,7	15,1	0,6	0,6	0	2,4	1,8	4	3,5	5,7	10,7	17,3	21,1	17,4	29,8	17,5	24,4	22,1	16,4	14,3	16,3	15,4
X10	1,1	17,3	19,3	11,9	14,3	16,1	17,5	3	2	2,4	0	0,9	2,2	1,6	8,1	13,1	19,7	23,5	19,7	32,2	19,9	26,8	24,5	18,8	16,7	18,7	17,8
X11	0,5	16,7	18,7	11,3	13,6	15,5	16,9	2,3	1,4	1,8	0,9	0	2,6	2	7,5	12,5	19,1	22,9	19,1	31,5	19,2	26,1	23,9	18,1	16	18,1	17,2
X12	2,8	19	20,9	13,5	15,9	17,8	19,1	4,6	3,6	4	2,2	2,6	0	0,5	10,1	15,1	21,7	25,5	21,7	34,2	21,9	28,8	26,5	20,7	18,7	20,7	19,8
X13	2,2	18,4	20,4	13	15,3	16,8	18,6	4	3,1	3,5	1,6	2	0,5	0	9,1	14,1	20,7	24,9	21,1	33,6	20,9	28,2	25,9	19,8	17,7	19,7	18,8
X14	7	10,6	13	5,9	8	9,4	10,7	5,2	6,3	5,7	8,1	7,5	10,1	9,1	0	7,1	12,9	18,4	14,7	27,1	14,8	21,7	19,4	13,7	11,6	13,6	12,7
X15	11,6	5,5	7,7	3,1	5,2	3,4	5,7	10,2	11,3	10,7	13,1	12,5	15,1	14,1	7,1	0	7,4	14,2	10,5	22,9	10,6	17,5	15,2	9,5	7,4	9,4	7,9
X16	18,6	5,4	2,2	7,5	9,2	4,3	8,5	16,8	17,9	17,3	19,7	19,1	21,7	20,7	12,9	7,4	0	15,7	12	23,4	11,1	18	16,7	10	6,5	10	4,2
X17	22,4	16,4	13,3	11,6	10,6	16,2	17	20,6	21,7	21,1	23,5	22,9	25,5	24,9	18,4	14,2	15,7	0	9,8	9,8	3,7	4,4	2,8	5,4	8,9	5,3	10
X18	18,6	12,6	9,5	6,5	5,8	12,2	13,3	16,9	18	17,4	19,7	19,1	21,7	21,1	14,7	10,5	12	9,8	0	18,6	6,4	13,2	6,6	5,3	4,1	5,2	5,2
X19	31	25	22	20,3	19,3	24,9	25,7	29,3	30,4	29,8	32,2	31,5	34,2	33,6	27,1	22,9	23,4	9,8	18,6	0	12,4	7,4	12,2	14	17,5	14	18,7
X20	18,8	12,8	9,7	8	7	12,6	13,4	17	18,1	17,5	19,9	19,2	21,9	20,9	14,8	10,6	11,1	3,7	6,4	12,4	0	6,5	6,1	1,7	5,2	1,6	6,3
X21	25,6	19,7	16,6	14,9	13,9	19,5	20,3	23,9	25	24,4	26,8	26,1	28,8	28,2	21,7	17,5	18	4,4	13,2	7,4	6,5	0	6,7	8,5	12	8,5	13,1
X22	23,4	17,4	14,3	11,3	10,5	16,9	18	20,3	21,4	22,1	24,5	23,9	26,5	25,9	19,4	15,2	16,7	2,8	6,6	12,2	6,1	6,7	0	7,6	11,1	7,5	12,2
X23	17,6	11,6	8,6	6,9	6,3	11,5	12,3	15,9	17	16,4	18,8	18,1	20,7	19,8	13,7	9,5	10	5,4	5,3	14	1,7	8,5	7,6	0	4,1	0,1	5,2
X24	15,6	7,9	4,8	4,8	3,8	7,7	8,5	13,8	14,9	14,3	16,7	16	18,7	17,7	11,6	7,4	6,5	8,9	4,1	17,5	5,2	12	11,1	4,1	0	4	1,5
X25	17,6	11,6	8,5	6,8	6,2	11,4	12,2	15,8	16,9	16,3	18,7	18,1	20,7	19,7	13,6	9,4	10	5,3	5,2	14	1,6	8,5	7,5	0,1	4	0	5,1
X26	16,7	6,4	3,4	5,9	4,9	6,3	7,1	14,9	16	15,4	17,8	17,2	19,8	18,8	12,7	7,9	4,2	10	5,2	18,7	6,3	13,1	12,2	5,2	1,5	5,1	0

F. Clarke-Wright Saving Heuristic Algorithm

After obtaining the distance matrix table, the next step is to create the saving matrix with Formula 1. This matrix will be used in the Clarke-Wright Saving Heuristic Algorithm to determine the most advantageous pairs of delivery points to be combined into a single

route. For example, to determine the saving value between the delivery points RS Restu Ibu (X1) and RS Sayang Ibu (X2), it is necessary to first know the travel distance data from Depot (G) → RS Restu Ibu (X1), Depot (G) → RS Sayang Ibu (X2), and RS Restu Ibu (X1) → RS Sayang Ibu (X2).
D(G, X1) = 15.4 km
D(G, X2) = 18.2 km
D(X1, X2) = 5.9 km.
After the distance data between all delivery points is obtained, the next step is to perform mathematical calculations using Equation 1. The puIDRose of this calculation is to determine the amount of savings that can be achieved if points X1 and X2 are paired on a single route. In other words, it will be determined how optimal the new route formed between the pair X1 and X2 is when compared to the delivery to X1 and X2 separately.
S(X1, X2) = D(G, X1) + D(G, X2) – D(X1, X2)
S(X1, X2) = 15.4 km + 18.2 km – 5.9 km
S(X1, X2) = 27.7 km

Table 5. The saving matrix

	G	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11	X12	X13	X14	X15	X16	X17	X18	X19	X20	X21	X22	X23	X24	X25	X26
G	0	15,4	18,2	10,8	13,3	14,5	17,1	1,8	0,8	1,3	1,1	0,5	2,8	2,2	7	11,6	18,6	22,4	18,6	31	18,8	25,6	23,4	17,6	15,6	17,6	16,7
X1	15,4	0	27,7	18,9	19,6	27,3	31,1	2,8	0,7	1,8	-0,8	-0,8	-0,8	-0,8	11,8	21,5	28,6	21,4	21,4	21,4	21,4	21,3	21,4	21,4	23,1	21,4	25,7
X2	18,2	27,7	0	21,2	24	27	28,8	3,6	1,5	2,6	0	0	0,1	0	12,2	22,1	34,6	27,3	27,3	27,2	27,3	27,2	27,3	27,2	29	27,3	31,5
X3	10,8	18,9	21,2	0	21,6	19,4	20,2	3,6	1,5	2,6	0	0	0,1	0	11,9	19,3	21,9	21,6	22,9	21,5	21,6	21,5	22,9	21,5	21,6	21,6	21,6
X4	13,3	19,6	24	21,6	0	19,6	20,4	3,7	1,6	2,8	0,1	0,2	0,2	0,2	12,3	19,7	22,7	25,1	26,1	25	25,1	25	26,2	24,6	25,1	24,7	25,1
X5	14,5	27,3	27	19,4	19,6	0	28,5	3,1	1	2,1	-0,5	-0,5	-0,5	-0,1	12,1	22,7	28,8	20,7	20,9	20,6	20,7	20,6	21	20,6	22,4	20,7	24,9
X6	17,1	31,1	28,8	20,2	20,4	28,5	0	4,3	2,2	3,3	0,7	0,7	0,8	0,7	13,4	23	27,2	22,5	22,4	22,4	22,5	22,4	22,5	22,4	24,2	22,5	26,7
X7	1,8	2,8	3,6	3,6	3,7	3,1	4,3	0	1,4	2,5	-0,1	0	0	0	3,6	3,2	3,6	3,6	3,5	3,5	3,6	3,5	4,9	3,5	3,6	3,6	3,6
X8	0,8	0,7	1,5	1,5	1,6	1	2,2	1,4	0	1,5	-0,1	-0,1	0	-0,1	1,5	1,1	1,5	1,5	1,4	1,4	1,5	1,4	2,8	1,4	1,5	1,5	1,5
X9	1,3	1,8	2,6	2,6	2,8	2,1	3,3	2,5	1,5	0	0	0	0,1	0	2,6	2,2	2,6	2,6	2,5	2,5	2,6	2,5	2,6	2,5	2,6	2,6	2,6
X10	1,1	-0,8	0	0	0,1	-0,5	0,7	-0,1	-0,1	0	0	0,7	1,7	1,7	0	-0,4	0	0	0	-0,1	0	-0,1	0	-0,1	0	0	0
X11	0,5	-0,8	0	0	0,2	-0,5	0,7	0	-0,1	0	0,7	0	0,7	0,7	0	-0,4	0	0	0	0	0,1	0	0	0	0,1	0	0
X12	2,8	-0,8	0,1	0,1	0,2	-0,5	0,8	0	0	0,1	1,7	0,7	0	4,5	-0,3	-0,7	-0,3	-0,3	-0,3	-0,4	-0,3	-0,4	-0,3	-0,3	-0,3	-0,3	-0,3
X13	2,2	-0,8	0	0	0,2	-0,1	0,7	0	-0,1	0	1,7	0,7	4,5	0	0,1	-0,3	0,1	-0,3	-0,3	-0,4	0,1	-0,4	-0,3	0	0,1	0,1	0,1
X14	7	11,8	12,2	11,9	12,3	12,1	13,4	3,6	1,5	2,6	0	0	-0,3	0,1	0	11,5	12,7	11	10,9	10,9	11	10,9	11	10,9	11	11	11
X15	11,6	21,5	22,1	19,3	19,7	22,7	23	3,2	1,1	2,2	-0,4	-0,4	-0,7	-0,3	11,5	0	22,8	19,8	19,7	19,7	19,8	19,7	19,8	19,7	19,8	19,8	20,4
X16	18,6	28,6	34,6	21,9	22,7	28,8	27,2	3,6	1,5	2,6	0	0	-0,3	0,1	12,7	22,8	0	25,3	25,2	26,2	26,3	26,2	25,3	26,2	27,7	26,2	31,1
X17	22,4	21,4	27,3	21,6	25,1	20,7	22,5	3,6	1,5	2,6	0	0	-0,3	-0,3	11	19,8	25,3	0	31,2	43,6	37,5	43,6	43	34,6	29,1	34,7	29,1
X18	18,6	21,4	27,3	22,9	26,1	20,9	22,4	3,5	1,4	2,5	0	0	-0,3	-0,3	10,9	19,7	25,2	31,2	0	31	31	31	35,4	30,9	30,1	31	30,1
X19	31	21,4	27,2	21,5	25	20,6	22,4	3,5	1,4	2,5	-0,1	0	-0,4	-0,4	10,9	19,7	26,2	43,6	31	0	37,4	49,2	42,2	34,6	29,1	34,6	29
X20	18,8	21,4	27,3	21,6	25,1	20,7	22,5	3,6	1,5	2,6	0	0,1	-0,3	0,1	11	19,8	26,3	37,5	31	37,4	0	37,9	36,1	34,7	29,2	34,8	29,2
X21	25,6	21,3	27,2	21,5	25	20,6	22,4	3,5	1,4	2,5	-0,1	0	-0,4	-0,4	10,9	19,7	26,2	43,6	31	49,2	37,9	0	42,3	34,7	29,2	34,7	29,2
X22	23,4	21,4	27,3	22,9	26,2	21	22,5	4,9	2,8	2,6	0	0	-0,3	-0,3	11	19,8	25,3	43	35,4	42,2	36,1	42,3	0	33,4	27,9	33,5	27,9
X23	17,6	21,4	27,2	21,5	24,6	20,6	22,4	3,5	1,4	2,5	-0,1	0	-0,3	0	10,9	19,7	26,2	34,6	30,9	34,6	34,7	34,7	33,4	0	29,1	35,1	29,1
X24	15,6	23,1	29	21,6	25,1	22,4	24,2	3,6	1,5	2,6	0	0,1	-0,3	0,1	11	19,8	27,7	29,1	30,1	29,1	29,2	29,2	27,9	29,1	0	29,2	30,8
X25	17,6	21,4	27,3	21,6	24,7	20,7	22,5	3,6	1,5	2,6	0	0	-0,3	0,1	11	19,8	26,2	34,7	31	34,6	34,8	34,7	33,5	35,1	29,2	0	29,2
X26	16,7	25,7	31,5	21,6	25,1	24,9	26,7	3,6	1,5	2,6	0	0	-0,3	0,1	11	20,4	31,1	29,1	30,1	29	29,2	29,2	27,9	29,1	30,8	29,2	0

The next step is to identify branch pairs that have the highest saving values and meet the truck load capacity constraints, which is a maximum of 122 cylinders. With a focus on pairs that provide optimal savings, the selection of these branches will also consider the transportation capacity limits to ensure that the resulting routes remain efficient and within the available vehicle capacity. Based on the calculations using the Clarke-Wright Saving Heuristic Algorithm presented in Table 6, it was found that the delivery routes consist of 3 separate routes. The total distance that must be covered by the vehicle to serve all customers is 167.1 km. This figure represents the shortest distance that can be achieved based on the optimization model used. The travel distance results obviously imply savings in fuel costs, thereby contributing positively to the company's operational efficiency.

Table 6. Route resulting from the Clarke-Wright saving heuristic algorithm

Route	Shipment Allocation	Total Load (Cyl)	Distance Traveled (km)
1	G-X19-X21-X17-X22-X20-X25-X23-X18-X26-X4-G	120	82,1
2	G-X2-X16-X5-X6-X1-X24-X3-X14-G	121	54,8
3	G-X12-X13-X10-X11-X8-X9-X7-X15-G	71	30,2
	TOTAL	**312**	**167,1**

G. Sweep Algorithm

In this study, the "cluster first, route second" approach is used in the Sweep Algorithm, where the formation of groups or clusters is done before determining the route for each cluster. The process of cluster formation in this algorithm is based on polar coordinate references. Polar coordinates are obtained through the conversion of geographic position data, namely longitude and latitude, which were previously in Cartesian coordinates, into polar coordinate format. To support the processing of coordinate data, this research utilizes the Geogebra software. The result of sorting the polar coordinates from the smallest to the largest angle can be seen in Table 7 below.

Table 7. Sorting the smallest polar coordinates

Code	Latitude	Longitude	x	y	r	θ (^{0})
G	-1,237583	116,949944	0	0	0	0
X12	-1,218972	116,955306	0,018611	0,005362	0,02	16,07
X13	-1,223667	116,955556	0,013916	0,005612	0,02	21,96
X10	-1,231056	116,954611	0,006527	0,004667	0,01	35,57
X11	-1,234778	116,952278	0,002805	0,002334	0	39,76
X9	-1,244861	116,941139	-0,007278	-0,008805	0,01	230,42
X7	-1,247722	116,937194	-0,010139	-0,01275	0,02	231,51
X8	-1,241083	116,944167	-0,0035	-0,005777	0,01	238,79
X14	-1,262417	116,897472	-0,024834	-0,052472	0,06	244,67
X1	-1,272472	116,837361	-0,034889	-0,112583	0,12	252,78
X6	-1,273444	116,828861	-0,035861	-0,121083	0,13	253,5
X15	-1,259028	116,866528	-0,021445	-0,083416	0,09	255,58
X5	-1,263806	116,847528	-0,026223	-0,102416	0,11	255,64
X16	-1,248056	116,828778	-0,010473	-0,121166	0,12	265,06
X3	-1,238528	116,872750	-0,000945	-0,077194	0,08	269,3
X2	-1,234139	116,821417	0,003444	-0,128527	0,13	271,53
X26	-1,225389	116,844472	0,012194	-0,105472	0,11	276,59
X4	-1,224000	116,869583	0,013583	-0,080361	0,08	279,59
X24	-1,215111	116,850944	0,022472	-0,099	0,1	282,79
X19	-1,179750	116,791611	0,057833	-0,158333	0,17	290,07
X18	-1,205028	116,881667	0,032555	-0,068277	0,08	295,49
X25	-1,193444	116,858194	0,044139	-0,09175	0,1	295,69
X23	-1,192833	116,857472	0,04475	-0,092472	0,1	295,82
X20	-1,184194	116,852528	0,053389	-0,097416	0,11	298,73
X21	-1,154944	116,828028	0,082639	-0,121916	0,15	304,13
X17	-1,156667	116,855222	0,080916	-0,094722	0,12	310,51
X22	-1,163361	116,873333	0,074222	-0,076611	0,11	314,09

After the data is sorted, the clustering process continues by considering the available vehicle load capacity. In this study, the vehicle load capacity is set at 122 cylinders, which means that each formed cluster must not exceed this load capacity limit. The results of this clustering process can be seen in Table 8 below.

Table 8. Cluster results of Sweep Algorithm

Cluster	Shipment Point	Total Load (Cyl)
1	X12, X13, X10, X11, X9, X7, X8, X14, X1, X6, X15, X5	118
2	X16, X3, X2, X26, X4, X24, X19, X18	122
3	X25, X23, X20, X21, X17, X22	72
	TOTAL	**312**

After the clusters are formed, the next step is to sort the customer points within each cluster using the Nearest Neighbor Algorithm. This algorithm is used to determine the most efficient route by sequentially selecting the nearest customers. Based on the calculations using the Sweep Algorithm with the cluster first, route second type and the Nearest Neighbor routing method, it was found that the delivery route consists of 3 separate routes. The total distance that the vehicle must travel to serve all customers is 191.1 km. The route results can be seen in Table 9.

Table 9. Route resulting from the sweep algorithm

Route	Shipment Allocation	Total Load (Cyl)	Distance Traveled (km)
1	G-X11-X10-X13-X12-X8-X9-X7-X14-X15-X5-X1-X6-G	118	45,1
2	G-X3-X4-X24-X26-X2-X16-X18-X19-G	122	85,8
3	G-X20-X25-X23-X17-X22-X21-G	72	61
	TOTAL	**312**	**191,9**

The initial route is used as a reference point for comparison with other algorithms. This route has the longest total distance compared to the algorithm from the research, which is 329 km. Due to the long distance, the initial route also results in higher fuel costs. The use of four vehicles on this route may indicate that there is still suboptimal efficiency in route allocation, making this initial route an ideal basis for evaluating how well other methods can reduce travel distance, the number of vehicles used, and fuel costs incurred.

The route generated by the Clarke-Wright Saving Heuristic Algorithm shows a significant increase in efficiency compared to the initial route. By using only 3 vehicles, this algorithm successfully reduced the travel distance to 167.1 km, which is almost half of the total distance on the initial route. The reduction in travel distance also directly impacts a significant decrease in fuel costs, indicating that this algorithm is capable of optimizing routes effectively. The fuel cost savings generated by this method are also quite significant, amounting to IDR 402,051.67 (49.21%), reflecting the potential for operational cost reduction if this algorithm is consistently applied.

The routes produced by the Sweep Algorithm also show a significant improvement compared to the initial routes. The Sweep Algorithm still managed to achieve good efficiency in reducing the total travel distance. Fuel costs also experienced a significant reduction, resulting in savings of IDR 340,465.00 (41.67%).

The comparison of the initial route results, the Clarke-Wright Saving Heuristic Algorithm, and the Sweep Algorithm can be seen explicitly in the following Table 10.

Table 10. Comparison of results

No	Method	Route Qty	Distance Traveled (km)	Fuel Costs (IDR)	Cost Savings
1	Initial Route	4	329	IDR 817.016,67	-
2	Clarke-Wright Saving Heuristic	3	167,1	IDR 414.965,00	IDR 402.051,67
3	Sweep (cluster first, route second)	3	191,9	IDR 476.551,67	IDR 340.465,00

Based on the results of solving the Capacitated Vehicle Routing Problem (CVRP), the Clarke-Wright Saving Heuristic Algorithm has proven to be the most effective method for optimizing routes in this study. This algorithm is capable of significantly reducing the number of vehicles used, travel distance, and total fuel costs compared to the initial route. In this study, the Clarke-Wright Saving Heuristic Algorithm produced better routes compared to the Sweep Algorithm. This can occur because the approach used by the Clarke-Wright Saving Heuristic Algorithm considers the direct relationship between delivery points and the distance to the depot. This algorithm also places more emphasis on the total distance savings in determining the delivery sequence and route structure. In general, this algorithm focuses on distance savings by iteratively combining routes based on the potential reduction in travel distance (saving value) between points. Additionally, in the results of this study, the last delivery point on the Clarke-Wright Saving Heuristic route tends to be closer to the depot, thereby contributing to the reduction of total travel distance and improving route efficiency.

5. CONCLUSION

Based on the result, the Clarke-Wright Saving Heuristic Algorithm is the most effective algorithm in optimizing routes in this study. Here are the routing results of the Clarke-Wright Saving Heuristic algorithm. Route 1: G-X19-X21-X17-X22-X20-X25-X23-X18-X26-X4-G. Route 2: G-X2-X16-X5-X6-X1-X24-X3-X14-G. Route 3: G-X12-X13-X10-X11-X8-X9-X7-X15-G.

The Clarke-Wright Saving Heuristic Algorithm successfully reduced the travel distance to 167.1 km, and Sweep Algorithm produced a route with total travel distance of 191.9 km. The Clarke-Wright Saving Heuristic Algorithm Successfully reduced fuel costs to IDR 414,965.00, and Sweep Algorithm produced a route with fuel costs of IDR 476,551.67. Suggestions for further research could include a more in-depth analysis of road conditions and traffic levels.

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