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Optimization of 3 Kg LPG Gas Distribution Route at PT Arafizza Sikumbang Using the VRP Model and Clarke and Wright Savings Algorithm

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Abstract
This study aims to optimize the distribution of 3 kg LPG cylinders at PT Arafizza Sikumbang, Medan Selayang District, Medan City. Efficient distribution is important to prevent shortages and reduce operational costs. The company serves 12 bases using Colt Diesel vehicles. The Vehicle Routing Problem (VRP) model with the Clarke and Wright Savings Algorithm was applied to improve delivery route efficiency. The data used was secondary data from December 2024, including distribution center locations, demand, vehicle capacity, and transportation costs, processed using Google Maps API and Microsoft Excel to create distance matrices and savings matrices. The initial route of 110.1 km with a cost of Rp 74,868 was successfully optimized to 90.9 km and Rp 61,812, achieving savings of 17.44% in distance and 17.4% in cost. These results demonstrate the effectiveness of the algorithm in improving LPG distribution efficiency and are relevant for application in similar logistics cases.

Keywords: LPG Distribution, Route Optimization, Vehicle Routing Problem, Clarke and Wright Savings.

Abstrak
Penelitian ini bertujuan untuk mengoptimalkan distribusi tabung gas LPG 3 kg di PT Arafizza Sikumbang, Kecamatan Medan Selayang, Kota Medan. Distribusi yang efisien penting untuk mencegah kelangkaan dan menekan biaya operasional. Perusahaan melayani 12 pangkalan menggunakan kendaraan Colt Diesel. Model Vehicle Routing Problem (VRP) dengan Algoritma Clarke and Wright Savings diterapkan untuk meningkatkan efisiensi rute pengiriman. Data yang digunakan merupakan data sekunder Desember 2024, berupa lokasi pangkalan, permintaan, kapasitas kendaraan, dan biaya transportasi, yang diolah menggunakan Google Maps API dan Microsoft Excel untuk membentuk matriks jarak dan matriks penghematan. Rute awal sejauh 110,1 km dengan biaya Rp 74.868 berhasil dioptimalkan menjadi 90,9 km dan Rp 61.812, dengan penghematan 17,44% jarak dan 17,4% biaya. Hasil ini membuktikan efektivitas algoritma dalam meningkatkan efisiensi distribusi LPG dan relevan diterapkan pada kasus logistik yang sama.

Kata Kunci: Distribusi LPG, Optimasi Rute, Vehicle Routing Problem, Clarke and Wright Savings.

1. INTRODUCTION

The development of the times has led to significant changes in the use of energy sources by humans. In the early days of civilization, humans used firewood as their main source of energy for cooking and lighting. Over time, the coal and petroleum industries began to replace firewood as the primary energy source due to their greater availability and higher efficiency. Liquefied Petroleum Gas (LPG) is a widely used fuel across various sectors, including households, transportation, industry, and others. LPG comes in various cylinder sizes, ranging from 12 kg, 5 kg, to the smallest, 3 kg. The 3 kg LPG cylinder is the most popular due to its economical price, making it accessible to everyone for personal use and small businesses. To distribute LPG gas to the public, agents must ensure it is distributed quickly to prevent shortages in the community (Fitri Armanda et al., 2023).

Distribution is one of the important activities for companies, because the profit of a company depends on the distribution process which is valued from customer satisfaction which must be fulfilled properly (Asniwaty et al., 2023). Transportation problems often arise in the distribution of goods, especially in determining routes that can optimize mileage or travel time. Transportation costs are influenced by two main factors, namely the amount of goods shipped and the delivery time per unit. Therefore, the main challenge in transportation is how to distribute goods from source to destination by meeting the entire demand in an optimal time (James & Nugroho, 2024).

The distribution of LPG gas cylinders, PT Arafizza Sikumbang needs to implement an effective strategy in order to avoid losses. By determining the shortest route, the company can minimize operational costs, thus not only avoiding losses but also potentially increasing profits. The route determination problem will be solved with the Vehicle Routing Problem (VRP) model using the Clarke & wright savings algorithm.

Vehicle Routing Problem (VRP) is the problem of determining the optimal vehicle in the distribution of goods from one or more origin locations to a number of consumer locations in different places and also the amount of demand that is previously known and meets a number of constraints. In solving VRP problems, exact methods are often unable to provide optimal solutions in a reasonable time, especially for large- scale problems. Therefore, heuristic methods are used as an alternative approach. Some heuristic methods commonly used in solving optimization problems include Nearest Neighbor (NN), Sweep Algorithm, Greedy Algorithm, Genetic Algorithm (GA), Simulated Anneling (SA), Clarke & Wright Savings and others.

Clarke & Wright Savings Algorithm is a heuristic method commonly used in routing problems with a considerable saving matrix calculation and reduces delivery time by connecting points and making it a route based on the largest saving value (Pratiwi & Lubis, 2023). This directly contributes to operational cost savings, including efficiency in

the use of fuel and labor. By combining routes based on the greatest potential savings, this algorithm allows vehicles to reach more customers in one trip without having to go through less efficient routes. The advantages of this method can also be seen from the many studies that have been conducted by several researchers which show that the Clarke and Wright savings algorithm can solve vrp problems efficiently.

Previous research by Lyoni Elisabet Marpaung (2022) showed that the use of the Clarke & Wright Savings Algorithm was able to reduce the number of distribution routes from five to two, with a distribution distance saving of 64.79% and a reduction in fuel costs from Rp 296,894 to Rp 104,519. Another study by Turid Hijri Hartien (2021) compared the Clarke & Wright Heuristic method with the Generalized Assignment method in LPG gas distribution, resulting in a total of 12 routes. The total distance traveled using the heuristic method reached 489.93 km, while the Generalized Assignment method reached 403.34 km. As a result, daily distribution costs decreased from Rp 1,474,123 to Rp 1,353,346, with savings of Rp 120,777 or approximately 8% of the total cost. Although both studies demonstrate the effectiveness of the algorithm in reducing distribution distance and costs, most still rely on simulation-based approaches and have not integrated real operational data from the company.

The distribution of subsidized 3 kg LPG in densely populated urban areas with varying customer demand has not been thoroughly researched. One such area is Medan Selayang District in Medan City, which has numerous distribution points, heavy traffic, and diverse customer needs. Therefore, this study aims to optimize the distribution route for 3 kg LPG gas at PT Arafizza Sikumbang by applying the Vehicle Routing Problem (VRP) model using the Clarke and Wright Savings Algorithm, based on real operational data, to obtain a more efficient, accurate, and directly implementable distribution solution in the field.

2. RESEARCH METHOD

This research uses a descriptive quantitative method to optimize the 3 kg LPG gas distribution route at PT. Arafizza Sikumbang, which is located at Jalan Bunga Raya Asam Kumbang No. 132, Medan Selayang District, Medan City, North Sumatra 20133. The research data consists of primary data and secondary data. Secondary data obtained in the form of travel route data during the distribution of LPG gas, such as the name of the base, base location, LPG gas demand for each base, vehicle capacity, and transportation costs. The calculation is done with the help of Microsoft Excel software and Google Maps API for distance calculation. The criteria in optimization are focused on the minimum distance traveled, fulfilling demand, and according to vehicle capacity.

2.1 Vehicle Routing Problem

Vehicle Routing Problem (VRP) is a problem in distributing goods from depots to customers with the aim of finding the best route. Distribution is carried out by vehicles

departing from the depot, delivering goods to all customers, and returning to the depot after the goods run out or all customers have been served (Sulistyono, 2022). In VRP there are several restrictions that must be met such as vehicles that cannot exceed capacity, vehicles can only pass through predetermined routes, and services to customers must be carried out within a predetermined time frame (Arif et al., 2023). Here is the basic formula for VRP :

Minimize:

$$Z = \sum_{l \in V} \sum_{j \in V, l \neq j} c_{lj} X_{l,j}$$

Description :

i, j = Customer Node

$C_{i,j}$ = Distance between node v_i and node v_j

2.2 Clarke and Wright Savings

The Clarke and Wright Savings algorithm is a method discovered by Clarke and Wright in 1964. This method was published as an algorithm used as a solution to solve the determination of distribution routes in VRP. In addition, the Clarke and Wright Savings algorithm only considers capacity constraints, while in its application it is also necessary to consider operational time constraints (Muhammad Yusuf & Sukoyo, 2023).

The steps in solving using the Clarke and Wright Savings Algorithm are:

a) Step 1: Create a distance matrix between depots to customers and between customers to customers. The general form of this distance matrix is as follows:

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

Description:

d_n : Distance

x : *Latitude* or latitude of the earth

y : *Longitude* or longitude of the earth

b) Step 2: Calculate the saving value for each customer to determine the value of savings.

c) Step 3: Customer pairs are sorted based on the saving value in the savings matrix, starting from the largest value to the smallest.

d) Step 4: Formation of the first route (t= 1).

2.3 Research Design

The steps taken to resolve this issue include:

1. Prepare customer data, total demand and vehicle capacity as required input data.
2. Develop a distance matrix between depots to consumers, as well as between consumers to consumers.

3. Using the equation $S_{ij} = C_{i0} + C_{0j} - C_{ij}$ to calculate the saving value in order to know the value of savings for each consumer
4. Arrange customer pairs in order based on the savings matrix, starting from the highest savings value to the lowest
5. Form the main route (t= 1)
6. Determine the initial customers assigned to the route by selecting the combination of customers with the highest savings value
7. Calculate the total demand from the selected consumers. If the total demand is still within the vehicle's capacity, proceed to step 8. However, if the demand exceeds the capacity, the process continues to step 9.
8. Determine the next customer to be allocated by considering the last selected customer combination with the highest savings value, then return to step 7.
9. Remove the last selected customer and proceed to step 10.
10. Add the selected customers to the route, forming route - t. If there are still unselected customers, the process continues to the next step. If all customers have been added, the Clarke & Wright Saving algorithm is complete.
11. Form a new route.
12. If all customer demand for goods has been met, the procedure is complete.

3. RESULT AND DISCUSSION

3.1 Data Collection

The following is the delivery route of PT Arafizza Sikumbang's 3 Kg LPG gas cylinders to 12 bases with Colt Diesel vehicles and a maximum vehicle capacity of 560 cylinders. And written down by having the base address, LPG demand for each base, base lattidude point and base longitude:

Table 1. Initial Data and Demand for LPG Gas

No	Name of the base	Address	Latitude	Longitude	Demand
0	PT.Arafizza Sikumbang	Jl. Bunga Raya No.132, Asam Kumbang, Kec. Medan Selayang	3,55205	98,61102	-
1	Lambok Siahaan	Jl. SMA N 15 NO 366, Kec Medan Sunggal	3,56871	98,62085	100
2	Pelita Gas	JL. Cempaka Raya Baru NO.7 Kec. Medan Selayang	3,53904	98,62385	100
3	Azril Gas	Jl. Seroja No.68, Kec Medan Sunggal	3,58199	98,62235	130
4	Dhannie	Jl. Titipapan No.38, Medan	3,58801	98,64775	110

		Petisah			
5	AG 21 Gas	Jl. PWS No 59, Medan Petisah	3,59469	98,66009	140
6	Rezeky Baru	Jl. Ngumban Surbakti No.11-41, Kec. Medan Selayang	3,54058	98,64333	100
7	J.J Gas	Jl. Pembangunan No.20, Medan Helvetia	3,60994	98,64742	110
8	Harafah	Jl. Karya Selamat gg Syukur V, Medan Johor	3,52862	98,67873	120
9	Elviana Sitompul	Jl. Karya Darma No.20, Medan Johor	3,53035	98,67383	120
10	Doni Gas	Jl. Klambir V No.20, Medan Helvetia	3,61159	98,60741	130
11	Anshari gas	Jl. Gaharu BLOK-G No.2, Medan Timur	3,59848	98,67815	140
12	Azka Gas	Jl. Bunga Kenanga No.20 A, Medan Selayang	3,54529	98,64947	100

The distribution route of 3kg lpg gas cylinders from the center to the base before the research was carried out there were 3 routes, while the routes consisted of :

Table 2. Initial Route of the Company

Route	Initial Sequence	Distance (Km)
1	0-3-7-2-0	24
2	0-11-5-1-0	29,7
3	0-4-8-9-0	29,3
4	0-10-12-6-0	27,1
	Total	110,1

The graph of the above routes can be seen in the following figure :

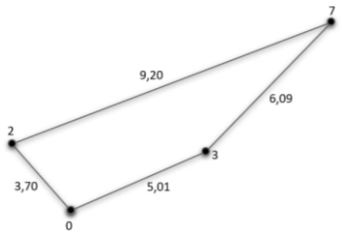

Figure 1. First Route Graph of the Company

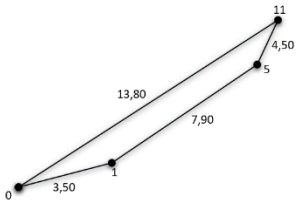

Figure 2. Second Route Graph of the Company

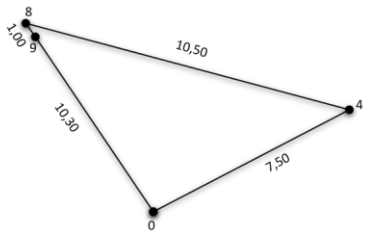

Figure 3. Third Route Graph of the Company

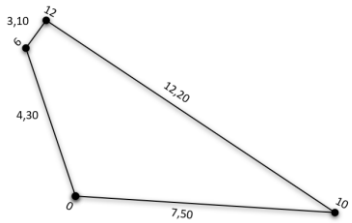

Figure 4. Fourth Route Graph of the Company

With transportation costs incurred by the company amounting to : Rp 74,868, the cost is obtained by the formula:

$$\frac{\text{Total distance}}{10} \times \text{Rp } 6.800 \text{ (price of 1 liter of diesel)}$$

So that tranportation costs

$$= \frac{110,1}{10} \times \text{Rp } 6.800 \text{ =Rp } 74,868.$$

3.2 Calculation of Distance Matrix

Distance matrix or distance calculation is a calculation of the relationship between angle and distance that studies the distance of two points called Euclidean space is as follows :

$$d = \sqrt{(lat_1 - lat_2)^2 + (long_1 - long_2)^2} \times 111,322 \text{ (1 deegree of earth)} \qquad (1)$$

Description :
d : Distance
Lat : *Latitude*
Long : *Longitude*

For example, the calculation of the distance from the depot to base 1 is seen below. The latitude and longitude values of each agent are shown below:

$$d_{0,1} = \sqrt{(3,55205 - 3,56871)^2 + (98,61102 - 98,62085)^2}$$
$$d_{0,1} = \sqrt{(-0,01666)^2 + (-0,00983)^2}$$
$$d_{0,1} = \sqrt{0,001237}$$
$$d_{0,1} = 0,035171 \times 111,322 \text{ (1 degree of earth)}$$
$$d_{0,1} = 3,91 \text{ Km}$$

Table 3. Distance Matrix

	0	1	2	3	4	5	6	7	8	9	10	11	12
1	3,91	0											
2	2,03	3,31	0										
3	3,08	1,50	4,78	0									
4	5,70	3,68	6,06	2,90	0								
5	7,25	5,23	7,20	4,43	1,56	0							
6	3,81	4,00	2,17	5,16	5,30	6,30	0						
7	7,61	5,46	8,30	4,17	2,44	2,27	7,73	0					
8	9,97	7,83	6,21	8,64	7,45	7,64	4,15	9,70	0				
9	7,39	7,28	5,64	8,11	7,04	7,35	3,58	9,33	0,57	0			
10	6,62	5,00	8,28	3,69	5,20	6,94	8,85	4,45	12,17	12,00	0		
11	9,08	7,18	8,96	6,47	3,57	2,05	7,52	3,65	7,77	7,58	8,00	0	
12	3,34	4,11	2,93	5,07	4,75	5,62	0,85	7,20	3,74	3,18	8,74	6,72	0

3.3 Saving Matrix

Calculating the saving matrix value using the equation *s(i,j) = c(i0,x) + c(0j,y)–c(i, j).* Calculated the value of savings Sij in the form of distance traveled from four routes to three routes serving nodes i and j.

With the distance value can be seen in the distance matrix table. The following is the value of the saving matrix:

$$S(1,2) = C(i0,1) + C(0j,2) - C(1,2)$$
$$S(1,2) = 3,91 + 2,03 - 3,31$$
$$S(1,2) = 2,63$$

The following saving matrix values from 12 bases can be seen in the following table :

Tabel 4. Savings Matrix

	1	2	3	4	5	6	7	8	9	10	11	12
1	0											
2	2,63	0										
3	5,49	0,33	0									
4	5,93	1,67	5,88	0								

5	5,93	2,08	5,90	11,39	0							
6	3,72	3,67	1,73	4,21	4,76	0						
7	6,06	1,34	6,52	10,87	12,59	3,69	0					
8	6,05	5,79	4,41	8,22	9,58	9,63	7,88	0				
9	4,02	3,78	2,36	6,05	7,29	7,62	5,67	16,79	0			
10	5,53	0,37	6,01	7,12	6,93	1,58	9,78	4,42	2,01	0		
11	5,81	2,15	5,69	11,21	14,28	5,37	13,04	11,28	8,89	7,70	0	
12	3,14	2,44	1,35	4,29	4,97	6,30	3,75	9,57	9,07	1,22	5,70	0

Table 5. Largest Saving Matrix by Sorting Routes

Route	Result	Demand
9,8	16,79	240
11,5	14,28	280
11,7	13,04	250
7,5	12,59	250
5,4	11,39	250
11,8	11,28	260
11,4	11,21	250
7,4	10,87	220
10,7	9,78	240
8,6	9,63	220
8,5	9,58	260
12,8	9,57	220
11,9	8,89	260
8,4	8,22	230
8,7	7,88	230
11,10	7,70	270
9,6	7,62	220
12,9	7,55	220
9,5	7,29	260
10,4	7,12	240
10,5	6,93	270
7,3	6,52	240
12,6	6,30	200
7,1	6,06	210
8,1	6,05	220
9,4	6,05	230
10,3	6,01	260
4,1	5,93	210
5,1	5,93	240
5,3	5,90	270

4,3	5,88	240
11,1	5,81	240
8,2	5,79	220
12,11	5,70	240
11,3	5,69	270
9,7	5,67	230
10,1	5,53	230
3,1	5,49	230
11,6	5,37	240
12,5	4,97	240
6,5	4,76	240
10,8	4,42	250
8,3	4,41	250
12,4	4,29	210
6,4	4,21	210
9,1	4,02	220
9,2	3,78	220
12,7	3,75	210
6,1	3,72	200
7,6	3,69	210
6,2	3,67	200
12,1	3,14	200
2,1	2,63	200
12,2	2,44	200
9,3	2,36	250
11,2	2,15	240
5,2	2,08	240
10,9	2,01	250
6,3	1,73	230
4,2	1,67	210
10,6	1,58	230
12,3	1,35	230
7,2	1,34	220
12,10	1,22	230
10,2	0,37	230
3,2	0,33	230

After sorting the route with the largest savings matrix value, the new optimal route sequence is obtained. The new route is fulfilled (from the largest order and cannot return to the same point). By using the Clarke and Wright algorithm, savings become

more efficient and only have 3 routes. From the calculation results, the new route sequencing can be seen in the table:

Table 6. New Route Sorting

Route	New Sequence	Distance (Km)
1	0-9-8-11-5-0	36,0
2	0-7-4-12-6-0	28,6
3	0-10-3-2-1-0	26,3
Total		90,9

The transportation cost that needs to be incurred after the new route is :

$$= \frac{90,9}{10} \times \text{Rp } 6.800$$
$$= 9,09 \times \text{Rp } 6.800$$
$$= \text{Rp } 61.812$$

Based on the route with the use of the Clarke and Wright Savings algorithm and also the improvement of the path from the company, the percentage value of the total mileage savings is obtained below:

$$\frac{\text{Total company route distance} - \text{Total Clarke Route distance}}{\text{Total company route distance}} \times 100\%$$
$$= \frac{110,1 - 90,9}{101,1} \times 100\%$$
$$= 17,44\%$$

The savings value of the total route mileage of 17.44%, has direct implications for the efficiency of the company's operational costs up to IDR 13,056 per month.

4. CONCLUSIONS

To solve the problem of determining the distribution route of 3 kg LPG gas cylinders at PT Arafizza Sikumbang, Medan Selayang District, Medan City, the Vehicle Routing Problem (VRP) can be applied using the Clarke and Wright Savings Algorithm. The results of the company's initial route with a total distance of 110.1 km and a cost of Rp 74,868 were successfully optimized to a total distance of 90.1 km at a cost of Rp 61,812. Mileage savings reached 17.44% and a decrease in transportation costs by 7.4%, so the new distribution route is more optimal than the initial distribution route. This research demonstrates the effectiveness of the heuristic method in the context of medium-scale logistics distribution, and can be used as a reference for the distribution of similar commodities.

5. RECOMMENDATIONS

This research improves the development of VRP by using the Clarke and Wright savings algorithm with more optimal and relevant results for the context of distribution routes in LPG gas companies. Future research is expected to choose different research sites to ensure this method can be applied in various regional conditions and route characteristics. In addition, future research can consider the use of alternative heuristic algorithms or integrate other approaches, such as VRP using the Tabu Search method or with Genetic Algorithm (GA), so that the resulting optimization solution can be comparable and suitable for more complex distribution problems.

6. REFERENCES

Adri, M. A., Panjaitan, D. J., & Cipta, H. (2022). Vehicle Routing Problem (VRP) dalam Penentuan Rute Terpendek Pendistribusian Tabung Gas LPG Dengan Mempertimbangkan Jumlah Permintaan. *Jurnal Ilmiah Matematika Dan Terapan*, *19*(1), 49–57. https://doi.org/10.22487/2540766x.2022.v19.i1.15885

Akuntansi, P. S. (2022). *Optimasi Distribusi Alat Kesehatan Steril Dan Non Steril menggunakan Metode Saving Matriks And Algoritma Clarke Studi Kasus : PT Multitama Sarana Indonesia (MSI)*. *20*(1), 105–123.

Arif, M., Suhaimi, M., Fitra, F., & Nurlaila, Q. (2023). Optimasi Vehicle Routing Problem Untuk Mengoptimalkan Distribusi Truk Tangki Cpo Di Kota Dumai. *PROFISIENSI: Jurnal Program Studi Teknik Industri*, *11*(2), 107–114. https://doi.org/10.33373/profis.v11i2.5671

Asniwaty, Yani, N., & Rahmiyana. (2023). Distribusi Pemasaran Barang Campur Pada Usaha Dagang Sumber Alam" Di Distrik Bade Kecematan Edera Kabupaten Mappi. *Jurnal Ekonomi Dan Bisnis*, *15*(1), 41–44. https://doi.org/10.55049/jeb.v15i1.183

Cipta, H., & Fitriana Hasibuan, M. (2023). Optimal Vehicle Routing Problem (VRP) For The Distribution Of Medical Devices By Applying The Clarke-Wright Algorithm. *International Journal of Science and Environment (IJSE)*, *3*(1), 7–12. https://doi.org/10.51601/ijse.v3i1.56

Daulay, M. S., & Cipta, H. (2023). *Zero : Journal of Science , Mathematics , and Applied Optimization of Garbage Collection Routes Using The Clarke-Wright Saving Heuristic Method in Medan*. *7*(1), 23–32.

Fitri Armanda, Filia Sari, R., & Garba, M. D. (2023). Optimization of Liquid Petroleum Gas (LPG) Gas Cylinder Distribution Route with Saving Matrix Method. *Numerical: Jurnal Matematika Dan Pendidikan Matematika*, *7*(1), 99–110. https://doi.org/10.25217/numerical.v7i1.3452

Issue, V., Sanggala, E., & Bisma, M. A. (2025). *JUTIN : Jurnal Teknik Industri Terintegrasi Penyelesaian Capacitated Vehicle Routing Problem (CVRP) dengan Nearest Neighbour (Studi Kasus : Russian CVRP Instances)*. *8*(3).

James, J. J., & Nugroho, A. J. (2024). Penyelesaian Vehicles Routing Problem dalam Meminimumkan Waktu Transportasi PT Petrogas Prima Services. *Sci-Tech Journal*, *3*, 60–73.

Marpaung, L. E., Arifin, J., & Winarno, W. (2022). Optimalisasi Rute Distribusi Menggunakan Algoritma Clarke and Wright Savings. *Jurnal Media Teknik Dan Sistem Industri*, *6*(2), 76. https://doi.org/10.35194/jmtsi.v6i2.1784

Misbahul Munir,Muchamad Kurniawan, Moch. Kalam M, I. S. (2023). Implementasi Metode Clarke And Wright Savings Dalam Penyelesaian Vehicle Routing Problem Di PT. Adiguna Gasindo. *Jurnal Teknologi Terpadu*, *9* no *2*, 116–122. https://journal.nurulfikri.ac.id/index.php/jtt

Moudya, F., Rarasati, N., & Syafmen, W. (2023). Optimisasi Rute Pada Cvrp Dalam Pendistribusian Gas Oksigen Menggunakan Algoritma Clarke and Wright Savings. *FIBONACCI: Jurnal Pendidikan Matematika Dan Matematika*, *9*(1), 105. https://doi.org/10.24853/fbc.9.1.105-118

Muhammad Yusuf, N., & Sukoyo. (2023). *Penyelesaian Capacitated Vehicle Routing Problem MenggunakanPengembangan Algoritma Clarke and Wright Savings*. 628–638.

Nurjanna, & Rakhmawati, F. (2023). Optimization Of Sipirok Woven Fabric Production Using Fuzzy-Multi Objective Linear Program. *MATHLINE Jurnal Matematika Dan Pendidikan Matematika*, *8*(3), 1227–1238. http://doi.org/10.31943/mathline.v8i3.504

Nurul Aina, & James Piter Marbun. (2023). Penyelesaian Vehicle Routing Problem Dengan Algoritma Clarke And Wright Savings Di Perumahan Umum Bulog Medan Amplas. *Jurnal Riset Rumpun Matematika Dan Ilmu Pengetahuan Alam*, *2*(1), 87–101. https://doi.org/10.55606/jurrimipa.v2i1.723

Pratiwi, M., & Lubis, R. S. (2023). Distribution Route Optimization Using Nearest Neighbor Algorithm and Clarke and Wright Savings. *Sinkron*, *8*(3), 1638–1652. https://doi.org/10.33395/sinkron.v8i3.12622

Roban, Ade Suhara, Asep Hermawan, & M. Ali Akbar. (2023). Penentuan Rute Dan Penjadwalan Distribusi Gas Lpg 3 Kg Pada Pt. Mita Sani Jaya. *Jurnal Teknologika*, *13*(1), 95–102. https://doi.org/10.51132/teknologika.v13i1.264

Sari, G., Heryanto, R., & Santoso, S. (2020). Penentuan Rute Distribusi Menggunakan Model Integer Linear Programming dengan Metode Branch and Bound. *Go-Integratif : Jurnal Teknik Sistem Dan Industri*, *1*(01), 69–79. https://doi.org/10.35261/gijtsi.v1i01.4265

Simamora, H. U. U., & Rakhmawati, F. (2023). Optimization of Salak Fruit Distribution Routes With Vehicle Routing Problem (VRP) Using Clarke And Wright Saving's. *Mathline: Jurnal Matematika Dan Pendidikan Matematika*, *8*(2), 691–704. https://scholar.google.com/citations?view_op=view_citation&hl=en&user=R_FgqtgAAAAJ&pagesize=100&citation_for_view=R_FgqtgAAAAJ:ZHo1McVdvXMC

Siraj, M. M., & Astuti, Y. P. (2020). Penentuan Biaya Transportasi Minimum Pada Pemilihan Rute Pengiriman Menggunakan Metode Clark and Wright Saving Heuristic. *MATHunesa: Jurnal Ilmiah Matematika*, *8*(1), 7–16. https://doi.org/10.26740/mathunesa.v8n1.p7-16

Sulistyono, E. S. (2022). Model Rute Perjalanan Minimal Dengan Menggunakan Vehicle Routing Problem Pada PT X. *Jurnal Teknologi Dan Sistem Informasi Bisnis*, *4*(2), 293–299. https://doi.org/10.47233/jteksis.v4i2.497

Zalfaa, A., Fitriani, R., Handayani, M., Prasetiowati, A. S., Ghani, Z. A., Tsani, R. R., & Rahmawati, A. Y. (2024). Analisis Faktor Keterlambatan Pasokan LPG pada PT Pertamina Energy Terminal LPG Tanjung Sekong. *Go-Integratif : Jurnal Teknik Sistem Dan Industri*, *5*(01), 22–35. https://doi.org/10.35261/gijtsi.v5i01.11298