Jurnal Riset Rumpun Matematika dan Ilmu Pengetahuan Alam (JURRIMIPA)
Vol.2, No.1 April 2023
e-ISSN: 2828-9390; p-ISSN: 2828-9382, Hal 87-101

Penyelesaian Vehicle Routing Problem Dengan Algoritma Clarke And Wright Savings Di Perumahan Umum Bulog Medan Amplas

Solution of The Vehicle Routing Problem with The Algorithm Clarke and Wright Savings in Bulog General Company Medan Amplas

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***Abstract**. Distribution routes are generally a problem for every company, including in the public company BULOG Medan Amplas. Distribution to the Medan Amplas BULOG public company, namely having to serve every stall that is far from the warehouse with scattered locations, and limited vehicle capacity. So far, driver considerations in distributing products have only been based on random intuitions of driver and does not consider the efficiency of the route taken. Therefore, this research uses Clarke and Wright Savings algorithm to obtain optimal mileage by taking into account every consumer demand and vehicle capacity. Calculation results using the Clarke and Wright Savings Algorithm obtained the vehicle mileage of 695.08 km with a savings of 11 km or 1.56%.*

***Keyword:** Clarke and Wright Savings Algorithm, Capacitated Vehicle Routing Problem, Distribution.*

Abstrak. Rute distribusi umumnya menjadi masalah bagi setiap perusahaan, termasuk di perusahaan umum BULOG Medan Amplas. pendistribusian pada perum BULOG Medan Amplas yaitu harus melayani setiap warung yang jauh dari gudang dengan lokasi yang tersebar, dan kapasitas kendaraan yang terbatas. Selama ini pertimbangan pengemudi dalam mendistribusikan produk hanya berdasarkan intuisi acak pengemudi dan dan tidak mempertimbangkan keefisienan rute yang ditempuh.Oleh karena itu, penelitian ini menggunakan algoritma Clarke and Wright Savings untuk memperoleh jarak tempuh yang optimal dengan memperhatikan setiap permintaan konsumen dan kapasitas kendaraan. Hasil dari perhitungan dengan menggunakan Algoritma Clarke and Wright Savings diperoleh jarak tempuh kendaraan 695,08 km dengan penghematan 11 km atau 1,56%.

Received Febuari 01, 2023; Revised Maret 02, 2023; April 01, 2023
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Kata Kunci: Algoritma Clarke and Wright Savings, Capacitated Vehicle Routing Problem, Distribusi.

INTRODUCTION

Distribution is an activity to distribute goods or services from producers to consumers. Distribution activities can help producers and companies to spread their products to each region.So, the more distributors spread across various regions, the more consumers will get their products. Therefore, the distribution and transportation system must be designed optimally so asto obtain minimum costs and distances. Perum BULOG is one of the institutions assigned by thegovernment to distribute rice in every e-warong that has been provided by the government.

The problem of distribution at Perum BULOG Medan Amplas is that it has to serve every stall far from the warehouse with scattered locations, and limited vehicle capacity. Therefore, it is necessary to determine an efficient distribution route for distributing rice at each e-warong so that the company can obtain optimal mileage by taking into account every consumer demand and vehicle capacity. This vehicle route problem is included in the VRP (Vehicle Routing Problem).

The Clarke and Wright Savings Algorithm is a method invented by Clarke and Wright in 1964. This method is published as an algorithm that is used as a solution to the vehicle route problem where a set of routes at each step is exchanged to get a better set of routes, and this method is used to overcome problems that are quite large and the number of routes is large.

LITERATURE REVIEW

Graph

The use of graphs in everyday life to describe various kinds of existing structures. The goal is tovisualize objects to make them easier to understand. A graph is a pair of sets (V, E) and is written with the notation $G = (V, E)$, V is a non-empty set of vertices (vertices or nodes) $\{v_1, v_2, \dots, v_n\}$ and E is a set of edges (edge or arcs) $\{e_1, e_2, \dots, e_n\}$ connecting a pair of vertices (Munir & Rinaldi,2016).

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Vehicle Routing Problem

The Vehicle Routing Problem (VRP) is one of the complex problems of combinatorial optimization, which can be seen as a combination of two problems, namely the Traveling Salesperson Problem (TSP) and the Bin Packing Problem (BPP). If given a fleet of vehicleswith uniform capacity, general depots, and several customer requests, it will obtain a set of routes with a minimum overall route cost that satisfies all requests (Machado et all, 2002)

Capacitated Vehicle Routing Problem

The Capacitated Vehicle Routing Problem (CVRP) is the most basic form of VRP. CPRV is an optimization problem to determine a route with a minimum cost for a number of vehicles with a certain homogeneous capacity (homogeneous fleet), which serves a number of customer requests whose demand quantity is known before the delivery process takes place. CVRP as a directed graph $G = (V, E)$ where $V = \{v_0, v_1, v_2, \dots, v_n, v_{n+1}\}$ is a set of nodes (vertices), v_0 represents the depot and v_{n+1} is the pseudo depot of $v_0$which is where the vehicle starts and ends the route. Meanwhile, $A = \{v_i, v_j \in V, i \neq j\}$ is a set of directed edges which isa set of edges that connect between nodes. Each node V has a demand of q_i.

The set $K = \{k_1, k_2, \dots, k_n\}$ is a vehicle with a limited capacity, namely Q, so the length of each route is limited by the capacity of the vehicle. Each node (v_i, v_j) has a distance of C_{ij}, which is the distance from node i to node j. The travel distance is assumed to be symmetric, namely $C_{ij} = C_{ji}$ and $C_{ii} = 0$ (Caric & Gold,2008).

Clarke and Wright Savings Algorithm

Clarke and Wright Savings Algorithm is one of the algorithms developed for CVRP problems and is often used. The purpose of the savings method is to minimize the total distance traveled by all vehicles and indirectly to reduce the number of vehicles needed to serve all stops (Clarke & Wright, 1964). The basis of this saving concept is to combine two routes into one route as shown in Figure 1.

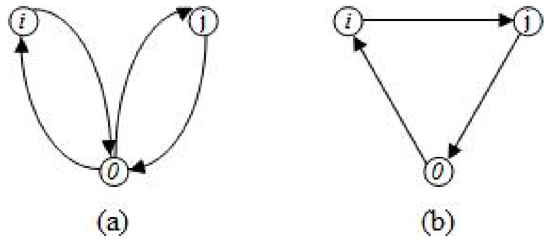

Figure 1. Illustration Of The Concept Of Saving

Based on Figure 1(a). Customers *i* and *j* are visited by separate routes. To get savings, customers *i* and *j* will be visited by the same route, an example is shown in Figure 1(b). The route of the vehicle is shown between nodes *i* and *j* by C_{ij}, the route of the vehicle by D_a in Figure 1(a).

$$D_a = C_{0i} + C_{i0} + C_{0j} + C_{j0} \quad (1)$$

The equivalent of the vehicle route D_b in Figure 1(b) is

$$D_b = C_{0i} + C_{ij} + C_{j0} \quad (2)$$

By combining the two routes we get the S_{ij} savings:

$$S_{ij} = C_{0i} + C_{i0} + C_{0j} + C_{j0} - (C_{0i} + C_{ij} + C_{j0}) \quad (3)$$

$$S_{ij} = C_{i0} + C_{0j} - C_{ij} \quad (4)$$

Where:
C_{i0} = distance from node *i* to depot
C_{0j} = distance from depot to node *j*
C_{ij} = distance from node *i* to node *j*
S_{ij} = distance saving value from node *i* to node *j*
The value of savings (S_{ij}) is the distance that can be saved if route $0 - i - 0$ is combined with
$0 - j - 0$ to become route $0 - i - j - 0$ served by the same vehicle (Octora,2014).

The steps for establishing a distribution route using the Clarke and Wright Savings Algorithmare as follows:

Step 1

Create a distance matrix between depots to customers or between customers to customers.

Step 2

Calculate the savings value using the equation $S_{ij} = C_{i0} + C_{0j} - C_{ij}$ for each customer and then create a savings matrix.

Step 3

Sort customer pairs based on the value of the largest savings to the smallest. This step is an iteration of the savings matrix, where if the largest saving value is at points *i* and *j* then row *i* and column *j* are crossed out, then *i* and *j* are combined in one route, and so on until the last iteration. The iteration will stop when all entries in the rows and columns are selected.

Step 4

Establishment of the first route (t = 1)

Step 5

Determine the first customer assigned to the route by selecting the customer combination with the largest savings value.

Step 6

Count the number of requests from consumers who have been selected. If the number of requests still meets the vehicle capacity, then proceed to step 7. If the number of requests exceeds the vehicle capacity, then proceed to step 8.

Step 7

Select the next customer to be assigned based on the last selected customer combination withthe largest savings value, go back to step 8.

Step 8

Delete the last selected customer, go to step 9.

Step 9

Insert the pre-selected customer to be assigned to the route t formed. If there are still customers who have not been selected, then proceed to step 10. If all customers have been assigned, the Clarke and Wright Savings algorithm work process has been completed.

Step 10

Formation of a new route (t=t+1).

RESEARCH METHODS

This research uses data collection techniques with field research and library research to obtain information. This research was conducted at Perum BULOG Medan Amplas which is located at Jalan Sisingamangaraja km 10.2. This research was conducted from March to December 2020.

The research methodology was carried out with the following steps:

1. Data Collection The data obtained from the company are as follows: a. The location of depots and customers as well as the amount of rice demanded by each customer. b. The number and capacity of the transportation equipment used by the company. c. The distribution routes carried out by the company.
2. Data Processing Finding the optimal route using the Clarke and Wright Savings algorithm: a. Modeling the Capacitated Vehicle Routing Problem on rice distribution. b. Solving the Capacitated Vehicle Routing Problem Using the Clarke and Wright Savings Algorithm.
   a. Create a distance matrix from the depot to the customer and between customers.
   b. Create a saving matrix.
   c. Sort the saving value from largest to smallest.
   d. Clustering routes.
   e. Sorting routes using the Nearest Neighbor algorithm.
3. Analysis and interpretation of results Comparison of Clarke and Wright Savings algorithm routes with company routes.
4. Conclusions and Suggestions Draw conclusions and suggestions based on the route results obtained using the Clarke and Wright Savings algorithm.

RESULT AND DISCUSSION

3.1 Data collection

The data obtained are the location of each e-warong, the demand for each e-warong, thecapacity of the vehicle and the number of vehicles. There are 38 e-warongs in the Medan city area with different requests for each e-warong, where each vehicle is capable of carrying 9.000 kg of rice.

Table 1. E-Warong Location Data and Number of Rice Requests (Kilograms)

No	Name E-Warong	Address	Kg
1	E-Warong Doa Bersama	Jl. Merpati No. 63 D	2000
2	E-Warong Serba Setia	Jl. Sunggal No. 242	4000
3	E-Warong Pelita Harapan	Jl. Flamboyan Gg. Inpres Lk II No. 50	2200
4	E-Warong Bagelen Jaya Abadi	Jl. Abdul Hamid Lk IV	9000
5	E-Warong Tambangan Jaya Bersama	Jl. Aluminium Lk. I	9000
6	E-Warong Platina Raya	Jl. Platina Raya Gg. Masjid Lk. 21	2500
7	E-Warong Manggis Bersama	Jl. Marelan Raya Gg. Manggis D	3500
8	E-Warong Asoka Bersama	Jl. Marelan IX. Gg. Hasan	3000
9	E-Warong Marelan Rengganis	Jl. Marelan V Gg. Abadi Lk. II	3500
10	E-Warong Marelan Sukses	Jl. Baru Gg. Klinik Evi Lk. 15	3500
11	E-Warong Pringgan Bersinar	Jl. Marelan Gg Pringgan Lk. VIII	3500
12	E-Warong Berkah Bersama	Jl. Titi Pahlawan Gg. Abu Bakar Lk 5	2000
13	E-Warong Deli Sejahtera	Jl. Young Panah Gg. Kenanga II Pekan Labuhan	3300
14	E-Warong Handayani	Jl. Pasar IV Timur Marelan	3500
15	E-Warong Hidup Baru	Jl. Raya Menteng Gg. Rahayu No. 72A	1000
16	E-Warong Menteng Indah	Jl. Menteng VII Gg. Buntu	1500
17	E-Warong Berkah Abadi	Jl. Tangguk Bongkar X	3000
18	E-Warong Jaya Bersama	Jl.Denai Gg. Krio	1000
19	E-Warong Labuhan Satu	Jl. Pasar Lama Gg. Pesantren Lk.29	2000
20	E-Warong Labuhan Dua	Jl. Tangguk Damai II No. 125 Lk. 13 Griya Martubung	1000
21	E-Warong Labuhan Tiga	Jl. Sei Mati Lk.6	1500
22	E-Warong Labuhan Empat	Jl. Chaidir Lk.8	2000
23	E-Warong Labuhan Lima	Jl. Syahbuddin Yatim Lk. 9	1000
24	E-Warong Mawar Labuhan	Jl. Lorong I Masjid As'Saadah	2000
25	E-Warong Berkah Labuhan	Jl. Rawe V No. 151 Lk. 7	1500
26	E-Warong Harapan Bersama	Jl. Perwira II No. 140	3000
27	E-Warong Sumber Rezeki	Jl. Bilal Ujung No. 251	3500

No	Name E-Warong	Address	Kg
28	E-Warong Maju Bersama	Jl. Jawa Belawan	3500
29	E-Warong Sehati Belawan I	Jl.TM Pahlawan No.18 Lk. XIII	2000
30	E-Warong Samudra	Jl. Pulau Seram Lk. VI	2000
31	E-Warong Rukun Selalu	Jl. Selar Lk. XIV	2000
32	E-Warong Bahagia Selalu	Jl. Sembilang Lk. XIV	3000
33	E-Warong Sicanang	Blok XXI Lk. VII	1500
34	E-Warong Sapriyan	Jl. Hiu No.1 P1 Lk II, Belawan	2000
35	E-Warong Indra Kasih	Jl. Karya Bakti No. 50	1000
36	E-Warong Sidorejo	Jl. Sring Gg. Medung No. 6	500
37	E-Warong Tembung	Jl. Benteng Hulu No. 32A	1000
38	E-Warong Bantan	Jl. Pertiwi Gg. Kesuma No. 9A	1000

3.2. Data processing

Capacitated Vehicle Routing Problem Model on Rice Distribution The CVRP problem on rice distribution is modeled as a graph *G = (V, E).* The set *V* is a node set consisting of a combination of customer sets *C* and depots, V= {v_0, v_1, v_2, v_3, … , v_{38}} where depot is v_0 and C = {v_1, v_2, v_3, … , v_{38}} is e-warong 1 to 38. The road traversed by the vehicle is expressed as a set of directed edges *E*, namely the link between customers, $E = \{(i, j)|i, j \in V, i \neq j\}$. K is the set of vehicles used which are homogeneous with a capacity of *q*. Unit q_i starts from depot 0. Every customer *i* for every *i* ∈ *C* has a request d_i, so that the length of the route is limited by the capacity of the vehicle. Every {i, j} ε E has a distance of c_{ij} and $c_{ij} = c_j$. A route is defined as the cycle cost of the graph G passing through depot 0 so that the total demand from the visited vertices does not exceed the vehicle capacity, where *i* is the initial customer, *j* is the destination customer and *k* is the vehicle.

The decision variables for each k vehicle are defined as follows:

$$X_{ijk} \begin{cases} 1, \text{if there is a trip from } i \text{ to } j \text{ by vehicle } k \\ 0, \text{if there is no trip from } i \text{ to } j \text{ by vehicle } k \end{cases}$$

The purpose function of CVRP for rice distribution in BULOG Medan Amplas is as follows:

$$\text{Min } Z = \sum_{i=0}^{38} \sum_{j=1}^{39} \sum_{k=1}^{4} c_{ij}^{k} x_{ij}^{k} \qquad (5)$$

Obstacles, among others:

1. Each customer can only be visited exactly once by one vehicle.

$$\sum_{j=1}^{39}\sum_{k=1}^{4} X_{ij}^{k} = 1; \qquad \forall_{i \in V} \qquad (6)$$

2. Each route starts from the depot.

$$\sum_{j=1}^{39} X_{0j}^{k} = 1 \qquad \forall_{k \in K} \qquad (7)$$

3. Route continuity means that every vehicle that has finished serving one node will leave thatnode.

$$\sum_{i=0}^{38} X_{ij}^{k} - \sum_{j=1}^{39} X_{ji}^{k} = 0 \qquad \forall_{k \in K} \qquad (8)$$

4. Each vehicle carrying goods does not exceed the capacity of the vehicle.

$$\sum_{i=0}^{38} q_i \sum_{j=1}^{39} X_{ij}^{k} \leq 900; \qquad \forall_{k \in K} \qquad (9)$$

5. Each route ends at the depot.

$$\sum_{i=0}^{38} X_{i0}^{k} = 1; \qquad \forall_{k \in K} \qquad (10)$$

6. The decision variable is a binary variable.

$$X_{ij}^{k} \in \{0, 1\}; \qquad \forall_{i,j} \in V, \forall_{k} \in K \qquad (11)$$

Where:

V	: Customer set
i	: Initial node index
j	: Destination node index
k	: Vehicle index
C_{ij}^{k}	: The distance from the starting node i to the destination node j which is done by vehicle k.
X_{ij}^{k}	: The decision variable (decision variable is a binary variable which identifies node i, node j is performed by vehicle k)
q_i	: Vehicle capacity at the starting node
$X_{ij}^{k} \in \{0, 1\}$	: Binary constraints for the decision variables

Distance Matrix

In this stage the identification process of the distance matrix is carried out, the distance matrix isthe distance between the depot and the customer and between the customer and the customer using kilometers (km) with the help of Google Maps.

Table 2. Distance Matrix

Cij	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	...	38
0	0																	
1	20	0																
2	18	1,6	0															
3	17	7,9	6,8	0														
4	16	7,5	4,5	11	0													
5	21	4,1	2,2	18	7,5	0												
6	25	15	16	22	13	7,8	0											
7	26	15	14	21	13	9	1,4	0										
8	26	14	15	22	14	9,9	2,2	2	0									
9	28	16	17	24	17	11	3,5	3,8	2,4	0								
10	31	18	20	27	22	16	6,2	6,5	4,9	3,5	0							
11	29	20	22	27	18	12	5,8	7,2	6,6	6,3	6,2	0						
12	30	21	18	25	19	13	4	4,3	5	4,7	4,7	1,8	0					
13	36	18	23	27	19	14	5,8	8,6	6,6	8	8	2	3,6	0				
14	28	17	17	24	17	11	3	3,3	4,1	2,3	3,4	4,1	2,5	5,9	0			
15	8,6	11	11	16	9,7	12	21	18	23	21	26	23	27	33	22	0		
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	0	
38	12	14	14	23	11	12	16	18	18	20	24	21	22	28	20	5,9	...	0

3.3 Saving Matrix

Saving matrix is obtained by combining two customers in one route. The following is an example of calculating the saving value for e-warong 1 and 2.

$$S_{i,} = C_{i,0} + C_{0,j} - C_{i,j}$$

$$S_{1,2} = C_{1,0} + C_{0,2} - C_{1,2}$$

$$S_{1,2} = 20 + 18 - 1{,}6$$

$$S_{1,2} = 36{,}4$$

3.4 Saving Value Ordering

The saving values that have been obtained are sorted from the largest to the smallest based on the saving matrix. The largest saving value is selected then the next iteration crosses out the rows and columns where there is the largest saving value. The iteration stops when all row and column entries have been selected so that a table of saving values is obtained.

Table 3. Order of Saving Values

Iteration	Saving Value	(i,j)
1	71,8	(22,13)
2	67,9	(30,22)
3	67,1	(33,30)
4	66,87	(32,31)
5	66,6	(34,32)
6	65,9	(29,28)
7	65,1	(31,19)
8	63	(13,11)
9	59,9	(21,12)
10	59,1	(23,21)
11	58,5	(28,23)
12	56,3	(12,10)
13	55,5	(10,9)
14	54,5	(19,14)
15	51,6	(9,8)
16	50,7	(14,7)
17	49,6	(7,6)
18	48,8	(24,20)
19	45,8	(25,24)
20	40,7	(26,5)
21	37,2	(27,26)
22	36,9	(5,1)
23	30,7	(36,27)
24	29,5	(4,2)
25	28	(6,4)
26	24,2	(38,37)
27	22,5	(18,17)
28	21,3	(35,25)
29	21	(8,3)
30	21	(37,29)
31	17,7	(17,15)
32	17	(20,18)
33	0	(16,16)

3.3 Route Grouping

Based on the order of saving values, customers with the largest to the smallest saving values are grouped into routes by paying attention to demand and vehicle capacity so that a route grouping table is obtained based on the saving matrix.

Table 4. Route Grouping

Vehicle Route	E-warong	Request (kg)	Number Of Requests (kg)
1	22	2000	8800
	13	3300	
	30	2000	
	33	1500	
2	32	3000	9000
	31	2000	
	34	2000	
	29	2000	
3	28	3500	9000
	19	2000	
	11	3500	
4	21	1500	8000
	12	2000	
	23	1000	
	10	3500	
5	9	3500	7000
	14	3500	
6	8	3000	9000
	7	3500	
	6	2500	
7	24	2000	7500
	20	1000	
	25	1500	
	26	3000	
8	5	9000	9000
9	27	3500	6000
	1	2000	
	36	500	
10	4	9000	9000
	2	4000	

e-ISSN: 2828-9390; p-ISSN: 2828-9382, Hal 87-101

11	38	1000	7000
	37	1000	
	18	1000	
12	17	3000	8700
	35	1000	
	3	2200	
	15	1000	
	16	1500	

3.7 Route Sequencing Using Nearest Neighbor Algorithm

The routes that have been grouped based on the saving matrix are then sorted using the Nearest Neighbor algorithm. Thus, the calculation table for the Clarke and Wright Savings algorithm is obtained.

Table 5. Clarke and Wright Savings Algorithm Route

Route to-	Travel Order	Number of Requests (kg)	Mileage (km)
1	0 – 30 – 13 – 22 – 33 – 0	8800	83,5
2	0 – 29 – 31 – 32 – 34 – 0	9000	67,93
3	0 – 11 – 19 – 28 – 0	9000	71,3
4	0 – 23 – 12 – 21 – 10 – 0	8000	75,1
5	0 – 9 – 14 – 0	7000	58,3
6	0 – 6 – 7 – 8 – 0	9000	54,4
7	0 – 26 – 25 – 20 – 24 – 0	7500	61
8	0 – 5 – 0	9000	42
9	0 – 36 – 27 – 1 – 0	6000	47,3
10	0 – 4 – 0	9000	32
11	0 – 18 – 37 – 38 – 2 – 0	7000	47,95
12	0 – 16 – 15 – 17 – 35 – 3 – 0	8700	54,3
Total		9.8000	695,08

CONSLUSION

Based on the previous description and discussion, several conclusions were obtained, namely:

1. The results in this study obtained a comparison of rice delivery routes at Perum BULOG Medan Amplas, which was 706.08 km with a total demand of 9,800 kg and 12 routes, while using the Clarke and Wright Savings algorithm the distance was 695.08 km with a total demand of 9,800 kg and 12 routes.
2. This algorithm is able to provide mileage savings of 11 km or 1.56%. This shows that the Clarke and Wright savings algorithm can reduce the distance traveled and at the same time the cost of distributing rice.

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