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Determination of the Shortest Distribution Routes to Minimize Fuel Consumption and CO_2 Emission Using Sweep and Clarke & Wright Saving Algorithms

Riski Arifian*, Farida Pulansari

Department of Industrial Engineering, Universitas Pembangunan Nasional "Veteran" Jawa Timur, Jl Rungkut Madya No.1, Gunung Anyar, Surabaya 60294, Indonesia

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A B S T R A C T

Nowadays, one of the areas in the field of vehicle routing problems that have received a lot of attention is Green Vehicle Routing Problem (GVRP). GVRP aims to harmonize the financial aspects and environmental concerns while routing vehicles. This research takes a case study at PT. LISA CONCRETE INDONESIA is a company engaged in the concrete industry with various precast concrete products. One of the company's main products is U-Gutter which recorded the highest sales in the company in 2022 with sales of 14,000 tons. According to the high demand for these products, it can be confirmed that the distribution activities to customers are also increased which have a negative impact on the environment. In this research, classical heuristics namely Sweep and Clark & Wright saving algorithm are used. Both of these methods will be implemented using Microsoft Excel software to determine the shortest distribution routes to deliver products to customers in PT. LISA CONCRETE INDONESIA and also to minimize fuel consumption and CO_2 emission. The result shows that Clark & Wright saving algorithm is 11,49% better than the Sweep algorithm and also 43,23% better than the company/existing method to minimize fuel consumption and CO_2 emission.

*Corresponding Author
Riski Arifian
E-mail: riskiarif100@gmail.com

1. INTRODUCTION

The activity of distribution/transportation is one of the most important parts of logistics and supply chain management. There are major challenges in this activity such as limited vehicle capacity, differences in consumer demand, and consumer locations. Optimal distribution routes are needed to minimize distribution costs and meet the company's financial aspects (Riansyah et al., 2022).

Fuel consumption of the vehicle is one of the factors that have a direct impact on distribution costs. besides the financial aspect, fuel consumption also has an impact on environmental aspects. Fuel consumption efficiency must be achieved to minimize distribution costs and reduce the negative impact on the environment. One of the dominant greenhouse gas emissions from the use of fossil fuel in vehicles is carbon dioxide (CO2) which can have a negative impact for thevenvironment. To overcome this, the determination of a environmental-friendly distribution route needs to be considered. The problem of determining an optimal distribution route to meet the financial aspects and environmental considerations are included in the Green Vehicle Routing Problem (GVRP) research stream (Sruthi et al., 2019).

Several studies with the aim to determine the shortest distribution route using Sweep and Clarke & Wright Saving algorithms have been conducted. Chandra and Naro (2020) in their research compared the C &W, KTA, and Sweep algorithm methods in determining the minimum route distance for delivering goods. Based on the results of the study, it was stated that the total route distance generated by the Sweep algorithm was 48.57% shorter than KTA and 33.33% shorter than C&W. In theory, the shorter the mileage, the more efficient of the fuel consumption. Zamah S. H. (2019) Optimizing distribution activities for delivering goods at IKM NUGRAHA using Clarke & Wright Saving method. Based on the results of the study, it is shown that the proposed method using Clarke & Wright savings can minimize the distribution costs compared to the company's existing routes. Hanafi et al. (2020) In their research results, the vehicle routes obtained by the Sweep Algorithm compared to the company's existing daily distribution routes show that the daily costs related to distribution costs can be reduced because there is a significant reduction in total routes distance and the number of vehicles used for the company's daily delivery activities. Pulansari et al. (2021) in their research are using saving algorithm to determine the shortest route of distribution to reduce environmental emissions. Based on the research results, it can be known that saving matrix is better than company’s existing method in order to provide the best solution. The proposed method can give cost minimization by saving IDR 5,788,800 and reducing 19308.11 Kg CO_2/year of CO_2 emissions. Based on any research that has been cited, it can be stated that the Sweep and Clarke & Wright Saving algorithms are effective methods for determining the shortest distribution routes.

This research takes a case study at PT. LISA CONCRETE INDONESIA is a company engaged in the concrete industry with various precast concrete products. One of the company's main products is U-Gutter which recorded the highest sales in the company in 2022 with sales of 14,000 tons. According to the high demand for these products, it can be confirmed that the distribution activities to customers are also increased.

Based on the discussion above, two methods that will be used in this research are Sweep and Clarke & Wright saving algorithms to find the optimal solution. Both of these methods will be implemented to determine the shortest distribution route for U-Gutter products at PT. LISA CONCRETE INDONESIA which can minimize fuel consumption and CO2 emissions.

2. LITERATURE REVIEW

A. VEHICLE ROUTING PROBLEM

According to Wibisono (2018) Vehicle Routing Problem, henceforward referred to as VRP, is a matter of determining the distribution route for certain resources to certain service points, where the resource starts from a depot and then visiting the service points once by taking into account the constraints and operational limitations. VRP aims to determine an optimal solution for distribution routes for vehicles to visit savarel customer locations where each route start and ends at the same depot. (Hanafi et al., 2020).

Based on the basic form of VRP, generally, VRP has made expansions and variations in its application. namely as follows:

1. Capacitated Vehicle Routing Problem (CVRP)
2. Vehicle Routing Problem with Time Window (VRPTW)
3. Split Delivery Vehicle Routing Problem (SDVRP)
4. Dynamic Vehicle Routing Problem (DVRP)
5. Vehicle Routing Problem with Stochastic Demand (VRPSD)
6. Vehicle Routing Problem with Simultaneous Delivery Pickup (VRPSDP)
7. Open Vehicle Routing Problem (OVRP)
8. Green Vehicle Routing Problem (GVRP)

9. Multi Trip Vehicle Routing Problem (MTVRP) (Zhang et al., 2022).

B. GREEN VEHICLE ROUTING PROBLEM

Green Vehicle Routing Problem (GVRP) is included in the domain of green logistics, which refers to the problem of routing vehicles where reducing CO_2 emissions become a consideration. Generally, the GVRP research stream can be divided into two areas, one is considering to minimizing fuel consumption and the other is considering the uses of alternative fuel vehicles and alternative fuels stations (Normasari et al., 2019).

C. CO_2 EMISSION MEASUREMENT

The gas that has a significant role in triggering global warming is carbon dioxide with a contribution of around 9-26% of the total circulating for about 75 years because this gas has a good resistance in the atmosphere (Rahmawati et al., 2012).

Based on the Ministry of Energy and Mineral Resources (2020), the equation for calculating GHG/CO_2 emissions in general is:

$$CO_2\ emission = Activity\ data \times EF \quad (1)$$

Where:
Activity data = fuel consumption and its specification
EF = emission factor

$$Activity\ data = FC \times \rho \times NCV \times 10^{-6} \quad (2)$$

Where:
FC = fuel consumption per year (Kiloliter)
ρ = fuel density (Kg/m^3)
NCV = calorific value (Tj/Kg)

Below in Table 1 is shown density of several types of fuel.

Table 1. The density of fuel

Fuel types	Density (Kg/m^3)
Solar oil (HSD, ADO)	837,5
Diesel oil (IDO)	910,0
Fuel oil (MFO, HFO)	991,0

(Source: General of Electricity Ministry of Energy and Mineral Resources, 2018)

The Net Calorific Value (NCV) of several types of fuel is shown in Table 2.

Table 2. The net calorific value of fuel

Fuel types	NCV (TJ/Gg)
Solar oil (HSD, ADO)	42,66
Diesel oil (IDO)	42,12
Fuel oil (MFO, HFO)	41,31
Natural gas	45,2
LNG	47,1

(Source: General of Electricity Ministry of Energy and Mineral Resources, 2018)

According the Directorate General of Electricity, Ministry of Energy and Mineral Resources (2018), it is explained that emission factors are the amount of greenhouse gas emissions released into the atmosphere per unit of the certain activity. The emission factor data can refer to the IPCC default (2006) as well as specific/national emission factors with consideration the level of accuracy (tier) that want to be achieved. The CO2 gas emission factor for each type of fuel can be seen in Table 3.

Table 3. The emission factor of fuel

Fuel types	Tier 1 (kg CO_2/TJ)	Tier 2/National (kg CO_2/TJ)
Gasoline RON 92	69300	72600
Gasoline RON 88	69300	72967
Avtur	71500	73333
Kerosene	71900	73700
Automotive Diesel Oil (ADO)	74100	74433
Industrial Diesel Oil (IDO)	74100	74067
Residual Fuel Oil (RFO)	77400	75167
Natural gas	56100	57600

(Source: General of Electricity Ministry of Energy and Mineral Resources, 2018)

D. SWEEP ALGORITHM

The Sweep algorithm is a method with two-phases which is consists of the first phase is customer cauterization based on their polar angle, and the second phase is a determination of distribution routes (Saraswati et al., 2017).

1. Cauterization phases
    - Set the depot as the center of the cartesian coordinates, then determine each customers in cartesian coordinates.
    - Convert the customers cartesian coordinates to polar coordinates using the equation below:

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (3)$$

Where:
$r_{ij} = distances\ between\ i\ and\ j$
$(x_i, y_j) = cartesian\ coordinates\ i$
$(x_j, y_j) = cartesian\ coordinates\ j$

$$\theta = arc\ \tan \frac{y}{x} \quad (4)$$

Where:
$\theta = polar\ angle$
$y = coordinat\ y\ or\ latitude$
$x = coordinat\ x\ or\ longitude$

- Clustering the customer starts from customers with the smallest polar angle to the largest with vehicle capacity consideration.

2. Route determination phases

Route distribution is determined by sorting the customers in each cluster using the Nearest Neighbor method.

E. CLARKE & WRIGHT SAVING ALGORITHM

Clarke and Wright savings algorithm calculates the saving from how much route distance, time, or cost can be minimized to determine the best vehicle route based on the highest savings value (Zamah S. H., 2019).

1. Determine the distance matrix for the depot and each customer which in later will be used for calculating the saving matrix.

Table 4. Distance matrix

	v_0	. . .	v_i	. . .	v_j	. . .	v_n
v_0	0						
. . .		0					
v_i	C_{0i}		0				
. . .							
v_j	C_{0j}		C_{ij}		0		
. . .						0	
v_n	C_{0n}		C_{in}		C_{jn}		0

(Source: Zamah S. H., 2019)

2. Determine the saving matrix based on the distance matrix using equation 5 below.

$$s_{ij} = c_{di} + c_{dj} - c_{ij} \quad (5)$$

Where:
$s_{ij} = saving\ between\ i\ and\ j$
$c_{di} = distance\ between\ depot\ and\ i$
$c_{dj} = distance\ between\ depot\ and\ j$

Table 5. Saving matrix

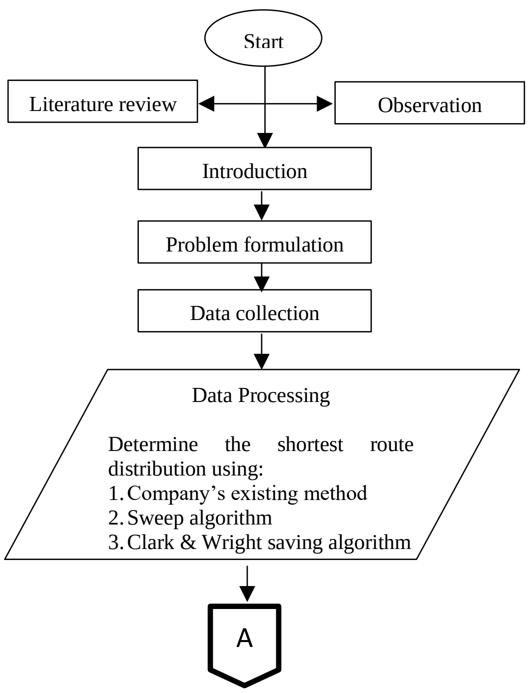
	v_1	. . .	v_i	. . .	v_j	. . .	v_n
v_1	-						
. . .		-					
v_i	S_{1i}		-				
. . .				-			
v_j	S_{1j}		S_{ij}		-		
. . .						-	
v_n	S_{1n}		S_{in}		S_{jn}		-

(Source: Zamah S. H., 2019)

3. Group customers by selecting the highest savings in column and row entries until all customers have been grouped in a route with consideration of vehicle capacity.
4. Determine the route distribution by sorting the customers in each group using the Nearest Neighbor method.

3. RESEARCH METHOD

This research was conducted by taking a case study in PT. LISA CONCRETE INDONESIA. In this study, secondary data were used namely Memo delivery of the company which contains: customer names, customer locations, customer demand and fleets/vehicles used. The research steps for solving the problem can be seen below in Fig. 1.



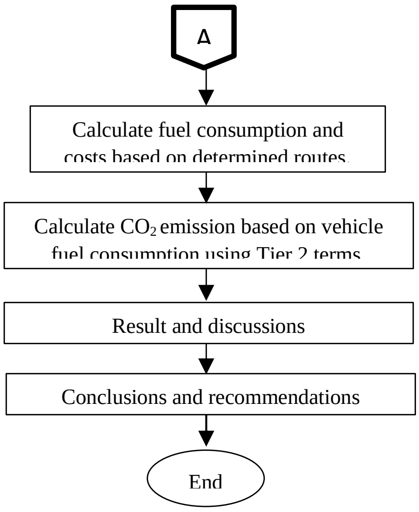


Fig. 1. Research flowchart

4. RESULT AND DISCUSSION

A. CUSTOMER LOCATION

Customers of PT. LISA CONCRETE INDONESIA is shown in Table 7.

Table 6. List of the company's customer

Code	Customers name	Location
Depot	PT. LISA CONCRETE INDONESIA	Mojokerto
C1	PT. ADHI KARYA TBK.	Gresik
C2	PT. WIJAYA KARYA TBK.	Kediri
C3	PT. ANEKA JASA GRHADIKA	Gresik
C4	PT. GRIYO MAPAN SANTOSO	Surabaya
C5	PT. WASKITA KARYA	Probolinggo
C6	PT. LAMONG ENERGI INDONESIA	Surabaya
C7	CV. LINGGA	Malang
C8	PT. SUPARMA TBK.	Surabaya
C9	PT. CITRA MANDIRI CIPTA	Surabaya
C10	PT. MIRANTI ADHI PERSADA	Pasuruan
C11	WIKA-WEGE KSO	Surabaya
C12	PT. KARYA SETIAKAWAN UTAMA	Gresik
C13	CV. KURNIA PERKASA	Malang

(Source: Company's data)

Table 6 above lists customers with an order frequency of at least 2 (two) times per month in the range from December 2022 to. February 2023.

The distances in kilometers (Km) from the depot to the customers location and between customers can be seen below in Table 7.

Table 7. Distance matrix depot and customers location

Jarak	Depot	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	75													
C2	110	132												
C3	60	19	124											
C4	45	50	123	31										
C5	88	148	230	131	114									
C6	51	36	130	18	22	123								
C7	71	110	94	97	101	108	104							
C8	41	48	109	30	16	109	20	78						
C9	52	39	133	20	20	120	6	107	22					
C10	47	107	183	98	80	41	80	75	68	79				
C11	48	35	129	17	18	116	6	104	18	5	77			
C12	66	20	126	2	37	127	22	119	29	22	89	17		
C13	67	127	109	120	100	131	114	99	17	114	67	99	111	

(Source: Processed data)

The distance matrix above, in later will be used for calculating the saving matrix. The results are shown in Table 23.

B. CUSTOMER DEMAND

The quantity of customers demand can be seen in Table 8.

Table 8. Customers demand

Customers code	Cumulative Demand (Ton)	Demand quantity per-order (Ton)
C1	29,15	4,858
C2	26,53	4,422
C3	26,8	4,467
C4	33,3	5,55
C5	24,38	4,063
C6	27,955	4,659
C7	25,38	4,23
C8	33,32	5,553
C9	30,16	5,027
C10	35,25	5,875
C11	39,24	6,54
C12	20,75	3,458
C13	14,896	2,483

(Source: Company's data)

Based on Table 8 above, it can be known the cumulative demand (Ton) in the range from December 2022 to. February 2023. And also the demand quantity per-order (Ton) which in later will be used for determine distribution routes.

C. FLEETS/VEHICLES

The specifications of the vehicle owned by the company used for delivering U-Gutter product to the customers is shown in Table 9.

Table 9. Fleets/Vehicles specification

Vehicle Type	Unit Qty	Capacity	Fuel consumption
HINO RANGER FF 173NA	5	15 Ton	5 Km/Liter

(Source: Franzese (2011) and Company data)

In Table 9 above, it can be known the fuel consumption of its vehicle. In later, it will be used for calculating fuel consumption and costs and also CO_2 emissions.

D. DETERMINE ROUTES USING THE EXISTING COMPANY METHOD

1. Route determination

In general, Product distribution policies established by the company is exclusively deliver products to only one customer taking into account the different types and product specifications requested by each customer. This means that one vehicle will only service delivery for one customer through a distribution route that starts and returns to the depot.

The results of distribution route per-order is shown in Table 10. It is determined using the company method with Microsoft Excel as a tool.

Table 10. Results of route determination by company method

No	Route	Vehicle load	Route distance
1	Depot – C1 - Depot	4,858 Ton	150 Km
2	Depot – C2 – Depot	4,422 Ton	220 Km
3	Depot – C3 – Depot	4,467 Ton	120 Km
4	Depot – C4 – Depot	5,55 Ton	90 Km
5	Depot – C5 – Depot	4,063 Ton	176 Km
6	Depot – C6 – Depot	4,659 Ton	102 Km
7	Depot – C7 – Depot	4,230 Ton	142 Km
8	Depot – C8 - Depot	5,553 Ton	82 Km
9	Depot – C9 – Depot	5,027 Ton	104 Km
10	Depot – C10 – Depot	5,875 Ton	94 Km
11	Depot – C11 – Depot	6,54 Ton	96 Km
12	Depot – C12 – Depot	3,458 Ton	132 Km
13	Depot – C13 – Depot	2,483 Ton	134 Km
	Total		**1642 Km**

(Source: Processed data)

It can be known from Table 10 that the total of route distances obtained by the company method is 1642 Km with 13 routes. Because the number of routes is greater than the number of vehicles, so the delivery must be more than once.

2. Calculate fuel consumption

Based on route distance obtained by route determination, then calculate fuel consumption and also fuel costs per-order with the assumption solar fuel prices Rp 6.800/Liter.

Table 11. Fuel consumption and costs (company method)

Route	Route distance	Fuel consumption	Fuel cost
1	150 Km	30 Liter	Rp204.000
2	220 Km	44 Liter	Rp299.200
3	120 Km	24 Liter	Rp163.200
4	90 Km	18 Liter	Rp122.400
5	176 Km	35,2 Liter	Rp239.360

Table 12. Results of route determination by company method (continued)

Route	Route distance	Fuel consumption	Fuel cost
6	102 Km	20,4 Liter	Rp138.720
7	142 Km	28,4 Liter	Rp193.120
8	82 Km	16,4 Liter	Rp111.520
9	104 Km	20,8 Liter	Rp141.440
10	94 Km	18,8 Liter	Rp127.840
11	96 Km	19,2 Liter	Rp130.560
12	132 Km	26,4 Liter	Rp179.520
13	134 Km	26,8 Liter	Rp182.240
Total	**1642 Km**	**328,4 Liter**	**Rp2.233.120**

(Source: Processed data)

From Table 11 above, it can be known that based on the total of route distances, it is resulting 328,4 Liter fuel consumption. So the fuel costs incurred is Rp2.233.120.

Below in Tables 12 and 13 shown the results of fuel consumption and costs per month and per year with the assumption that 2 (two) deliveries are made to each customer every month.

Table 13. Fuel consumption and costs per-Month (company method)

Route	Route distance per-month	Fuel consumption per-month	Fuel cost per-month
1	300 Km	60 Liter	Rp408.000
2	440 Km	88 Liter	Rp598.400
3	240 Km	48 Liter	Rp326.400
4	180 Km	36 Liter	Rp244.800
5	352 Km	70,4 Liter	Rp478.720
6	204 Km	40,8 Liter	Rp277.440
7	284 Km	56,8 Liter	Rp386.240
8	164 Km	32,8 Liter	Rp223.040
9	208 Km	41,6 Liter	Rp282.880
10	188 Km	37,6 Liter	Rp255.680
11	192 Km	38,4 Liter	Rp261.120
12	264 Km	52,8 Liter	Rp359.040
13	268 Km	53,6 Liter	Rp364.480
Total	**3284 Km**	**656,8 Liter**	**Rp4.466.240**

(Source: Processed data)

It can be known from Table 12 that the total of route distances per-month is 3284 Km. it is resulting 656,8 Liter fuel consumption. So the fuel cost incurred is Rp4.466.240.

Table 14. Fuel consumption and costs per-Year (company method)

Route	Fuel consumption per-year	Fuel cost per-year
1	720 Liter	Rp4.896.000
2	1056 Liter	Rp7.180.800
3	576 Liter	Rp3.916.800
4	432 Liter	Rp2.937.600
5	844,8 Liter	Rp5.744.640
6	489,6 Liter	Rp3.329.280
7	681,6 Liter	Rp4.634.880
8	393,6 Liter	Rp2.676.480
9	499,2 Liter	Rp3.394.560
10	451,2 Liter	Rp3.068.160
11	460,8 Liter	Rp3.133.440
12	633,6 Liter	Rp4.308.480
13	643,2 Liter	Rp4.373.760
Total	**7881,6 Liter**	**Rp53.594.880**

(Source: Processed data)

Based on the results in Table 13, it can be known that total of fuel consumption in a year is 7881,6 Liter. So the fuel costs incurred in a year is Rp53.594.880.

3. Calculate CO_2 emission

Based on fuel consumption per year and vehicle fuel type is Solar oil/ADO, the results of CO_2 emission obtained by Tier 2 measurement are shown below in Table 14.

Table 15. Results of CO_2 emission (company method).

Route	Fuel consumption per-year	CO_2 emission (Kg CO_2/year)
1	720 Liter	1914,713
2	1056 Liter	2808,246
3	576 Liter	1531,770
4	432 Liter	1148,828
5	844,8 Liter	2246,597
6	489,6 Liter	1302,005
7	681,6 Liter	1812,595
8	393,6 Liter	1046,710
9	499,2 Liter	1327,534
10	451,2 Liter	1199,887
11	460,8 Liter	1225,416
12	633,6 Liter	1684,947
13	643,2 Liter	1710,477
Total	**7881,6 Liter**	**20959,725**

(Source: Processed data)

It can be known from Table 14 above that CO_2 emission produced by fuel consumption per-year is 20959,725 Kg CO_2/year.

E. DETERMINE ROUTES USING THE SWEEP ALGORITHM

1. Clusterization phases

Below In Table 15, Cartesian coordinates are shown which are determined using the Google Maps application.

Table 16. Cartesian coordinates of customer location

Code	*Latitude* (X)	*Longitude* (Y)
Depot	0	0
C1	0,4769708	-0,0100710
C2	-0,2032990	-0,6872400
C3	0,4013188	0,0011795
C4	0,2161160	0,1537100
C5	-0,2629392	0,6722605
C6	0,3608467	0,0714031
C7	-0,3242572	-0,1052542
C8	0,2091750	0,0348540
C9	0,3530060	0,1028880
C10	-0,1326390	0,3278020
C11	0,3178240	0,0923530
C12	0,3777718	0,0244433
C13	-0,4101530	-0,0573270

(Source: Processed data)

The results of the cartesian coordinate above is used for calculating the polar angles of each location.

According to the cartesian coordinates of each customer, then convert it to polar coordinates to determine the polar angles. Polar angles for each customer are shown below.

Table 17. Polar angles of customer location

Code	Θ (°)
C1	91,210
C2	253,521
C3	89,832
C4	54,578
C5	338,638
C6	78,807
C7	197,983
C8	80,540
C9	73,751
C10	337,970
C11	73,797
C12	86,298
C13	187,957

(Source: Processed data)

Customer clusterizations are done by sorting customers with polar angle from the smallest to the largest with consideration of the vehicle capacity.

Table 18. Results of customer clusterization (sweep algorithm)

Route	Vehicle load (Ton)	Customers cluster
1	10,577	Depot – C4 – C9 – Depot
2	11,199	Depot – C11 – C6 – Depot
3	13,478	Depot – C8 – C12 – C3
4	11,751	Depot – C1 – C13 – C7
5	14,360	Depot – C2 – C10 – C5

(Source: Processed data)

In Table 17 above, it can be known that there are 5 clusters obtained. Based on these results, in next phase is to sort the customer.

2. Route determination phases

Based on the results of customer clusterization, then sort the customers in each cluster using the Nearest Neighbor method.

Table 19. Results of route determination (sweep algorithm)

Route	Customers cluster	Vehicle load (Ton)	Route distance
1	Depot – C4 – C9 – Depot	10,577 Ton	119 Km
2	Depot – C11 – C6 – Depot	11,199 Ton	105 Km
3	Depot – C8 – C12 – C3 – Depot	13,478 Ton	132 Km
4	Depot – C13 – C7 – C1 – Depot	11,751 Ton	269 Km
5	Depot – C10 – C5 – C2 – Depot	14,360 Ton	428 Km
Total			**1053 Km**

(Source: Processed data)

It can be known from Table 10 that the total of route distances obtained by the sweep algorithm is 1053 Km with 5 routes. Because the number of routes is greater than the number of vehicles, so the delivery can be done by once.

3. Calculate fuel consumption and costs

Based on route distance obtained by route determination, then calculate fuel consumption and also fuel costs with the assumption solar fuel prices Rp6.800/Liter.

Table 20. Fuel consumption and costs (sweep algorithm)

Route	Route distance	Fuel consumption	Fuel cost
1	119 Km	23,8 Liter	Rp161.840
2	105 Km	21 Liter	Rp142.800
3	132 Km	26,4 Liter	Rp179.520
4	269 Km	53,8 Liter	Rp365.840
5	428 Km	85,6 Liter	Rp582.080
Total	**1053 Km**	**210,6 Liter**	**Rp1.432.080**

(Source: Processed data)

From Table 19 above, it can be known that based on the total route distances, it is resulting 210,6 Liter fuel consumption. So the fuel costs incurred is Rp1.432.080.

Below in Table 20 and 21 shown the results of fuel consumption and costs per month and per year with the assumption that 2 (two) deliveries are made to each customer every month.

Table 21. Fuel consumption and costs per-Month (sweep algorithm)

Route	Route distance per-month	Fuel consumption per-month	Fuel cost per-month
1	238 Km	47,6 Liter	Rp323.680
2	210 Km	42 Liter	Rp285.600
3	264 Km	52,8 Liter	Rp359.040
4	538 Km	107,6 Liter	Rp731.680
5	856 Km	171,2 Liter	Rp1.164.160
Total	**2106 Km**	**421,2 Liter**	**Rp2.864.160**

(Source: Processed data)

It can be known from Table 20 that the total route distances per-month is 2106 Km. it is resulting 421,2 Liter fuel consumption. So the fuel costs incurred is Rp2.864.160.

Table 22. Fuel consumption and costs per-Year (sweep algorithm)

Route	Fuel consumption per-year	Fuel cost per-year
1	571,2 Liter	Rp3.884.160
2	504 Liter	Rp3.427.200
3	633,6 Liter	Rp4.308.480
4	1291,2 Liter	Rp8.780.160
5	2054,4 Liter	Rp13.969.920
Total	**5054,4 Liter**	**Rp34.369.920**

(Source: Processed data)

Based on the results in Table 21, it can be known that total of fuel consumption in a year is 5054,4 Liters. So the fuel costs incurred in a year is Rp34.369.920.

4. Calculate CO_2 emission

Based on fuel consumption per year for service delivers to each route and vehicle fuel type is Solar oil/ADO, the results of CO_2 emission are shown below.

Table 23. Results of CO_2 emission (sweep algorithm).

Route	Fuel consumption per-year	CO_2 emission (Kg CO_2/*year*)
1	571,2 Liter	1519,006
2	504 Liter	1340,299
3	633,6 Liter	1684,947
4	1291,2 Liter	3433,719
5	2054,4 Liter	5463,314
Total	**5054,4 Liter**	**13441,285**

(Source: Processed data)

It can be known from Table 14 above that CO_2 emission produced by fuel consumption per-year is 13441,285 Kg CO_2/year.

F. DETERMINE ROUTES USING CLARK & WRIGHT SAVING ALGORITHM

1. Clusterization phases

   Determine the savings matrix based on the distance matrix in Table 7. The savings matrix can be seen below in Table 23.

Table 24. Saving matrix determination

Jarak	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
C1	0												
C2	53	0											
C3	116	46	0										
C4	70	32	74	0									
C5	15	-32	17	19	0								
C6	90	31	93	74	16	0							
C7	36	87	34	15	51	18	0						
C8	68	42	71	70	20	72	34	0					
C9	88	29	92	77	20	97	16	71	0				
C10	15	-26	9	12	94	18	43	20	20	0			
C11	88	29	91	75	20	93	15	71	95	18	0		
C12	121	50	124	74	27	95	18	78	96	24	97	0	
C13	15	68	7	12	24	4	39	91	5	47	16	22	0

(Source: Processed data)

The saving matrix above is used for customer clusterization.

Customer clusterizations are done by sorting the customer combinations from highest to lowest value of saving matrix until all costumers are sorted with consideration of the vehicle capacity.

Table 25. Results of customer clusterization (C&W algorithm)

Route	Vehicle load (Ton)	Customers cluster
1	12,783	Depot – C3 – C12 – C1
2	12,090	Depot – C11 – C4
3	9,686	Depot – C6 – C9
4	14,168	Depot – C5 – C10 – C7
5	12,458	Depot – C8 – C13 – C2

(Source: Processed data)

In Table 24 above, it can be known that there are 5 clusters obtained. Based on these results, in next phase is to sort the customer.

2. Route determination phases

Based on the results of customer clusterization, then sort the customers in each cluster using the Nearest Neighbor method.

Table 26. Results of route determination (C&W algorithm)

Route	Customers cluster	Vehicle load (Ton)	Route distance
1	Depot – C3 – C12 – C1 – Depot	12,783 Ton	157 Km
2	Depot – C4 – C11 – Depot	12,090 Ton	111 Km
3	Depot – C6 – C9 – Depot	9,686 Ton	109 Km
4	Depot – C10 – C5 – C7 – Depot	14,168 Ton	196 Km
5	Depot – C8 – C13 – C2 – Depot	12,458 Ton	359 Km
	Total		**932 Km**

It can be known from Table 25 that the total of route distances obtained by Clark & Wright algorithm is 932 Km with 5 routes. Because the number of routes is greater than the number of vehicles, so the delivery can be done by once.

3. Calculate fuel consumption and costs

Based on route distance obtained by route determination, then calculate fuel consumption and also fuel costs according to the assumption fuel prices Rp6.800/Liter.

Table 27. Fuel consumption and costs (C&W algorithm)

Route	Route distance	Fuel consumption	Fuel cost
1	157 Km	31,4 Liter	Rp213.520
2	111 Km	22,2 Liter	Rp150.960
3	109 Km	21,8 Liter	Rp148.240
4	196 Km	39,2 Liter	Rp266.560
5	359 Km	71,8 Liter	Rp488.240
Total	**932 Km**	**186,4 Liter**	**Rp1.267.520**

(Source: Processed data)

From Table 26 above, it can be known that based on the total route distances, it is resulting 186,4 Liter fuel consumption. So the fuel costs incurred is Rp1.267.520.

Below in Tables 27 and 28 show the results of fuel consumption and costs per month and per year according to the assumption that 2 (two) deliveries are made to each customer every month.

Table 28. Fuel consumption and costs per-Month (C&W algorithm)

Route	Route distance per-month	Fuel consumption per-month	Fuel cost per-month
1	314 Km	62,8 Liter	Rp427.040
2	222 Km	44,4 Liter	Rp301.920
3	218 Km	43,6 Liter	Rp296.480
4	392 Km	78,4 Liter	Rp533.120
5	718 Km	143,6 Liter	Rp976.480
Total	**1864 Km**	**372,8 Liter**	**Rp2.535.040**

(Source: Processed data)

It can be known from Table 27 that the total route distances per-month is 1864 Km. it is resulting 372,8 Liters fuel consumption. So the fuel costs incurred is Rp2.535.040.

Table 29. Fuel consumption and costs per-Year (C&W algorithm)

Route	Fuel consumption per-year	Fuel cost per-year
1	753,6 Liter	Rp5.124.480
2	532,8 Liter	Rp3.623.040
3	523,2 Liter	Rp3.557.760
4	940,8 Liter	Rp6.397.440
5	1723,2 Liter	Rp11.717.760
Total	**4473,6 Liter**	**Rp30.420.480**

(Source: Processed data)

Based on the results in Table 28, it can be known that total of fuel consumption in a year is 4473,6 Liter. So the fuel costs incurred in a year is Rp30.420.480.

4. Calculate CO_2 emission

Based on fuel consumption per year for service delivers to each route and vehicle fuel type is Solar oil/ADO, the results of CO_2 emission is shown below.

Table 30. Results of CO_2 emission (C&W algorithm).

Route	Fuel consumption per-year	CO_2 emission (Kg CO_2/*year*)
1	753,6 Liter	1.995,100
2	532,8 Liter	1.410,549
3	523,2 Liter	1.385,133
4	940,8 Liter	2.490,699
5	1723,2 Liter	4.562,045
Total	**4473,6 Liter**	**11.843,526**

(Source: Processed data)

It can be known from Table 29 above that CO_2 emission produced by fuel consumption per-year is 11843,526 Kg CO_2/year.

G. COMPARISON OF METHODS

1. Comparison of fuel consumption and cost results by each method.

The following Table 30 shows a comparison of each method for fuel consumption and cost per-order results based on route distance.

Table 31. Fuel consumption and cost results by each method

Method	Route distance	Fuel consumption	Fuel cost
Company method	1642 Km	328,4 Liter	Rp2.233.120
Sweep algorithm	1048 Km	209,6 Liter	Rp1.425.280
Clark & wright saving algorithm	932 Km	186,4 Liter	Rp1.267.520

(Source: Processed data)

Below in Tables 31 and 32 show the results of fuel consumption and costs per month and per year provided by each method.

Table 32. Results of fuel consumption and cost per-month by each method

Method	Route distance	Fuel consumption per-month	Fuel cost per-month
Company method	3.284 Km	656,8 Liter	Rp4.466.240
Sweep algorithm	2.096 Km	419,2 Liter	Rp2.850.560
Clark & wright saving algorithm	1.864 Km	372,8 Liter	Rp2.535.040

(Source: Processed data)

Table 33. Results of fuel consumption and cost per-year by each method

Method	Fuel consumption per-year	Fuel cost per-year
Company method	7881,6 Liter	Rp53.594.880
Sweep algorithm	5030,4 Liter	Rp34.206.720
Clark & wright saving algorithm	4473,6 Liter	Rp30.420.480

(Source: Processed data)

Based on the results shown above in Tables 30, 31 and 32, it can be seen that the proposed method can provide a better solution than the company/existing method to determine the shortest distribution route and minimize fuel consumption. It can be concluded that the method that gives the best solution for minimizing route distance, fuel consumption and fuel costs is Clarke & Wright saving algorithm.

2. Comparison of CO_2 emission results by each method.

The following Table 33 shows a comparison of each method for CO_2 emission results based on fuel consumption.

Table 34. Results of CO_2 emission by each method

Method	Fuel consumption per-year	CO_2 Emission (Kg CO_2/*year*)
Company method	7881,6 Liter	20.959,725
Sweep algorithm	5030,4 Liter	13.377,462
Clark & wright saving algorithm	4473,6 Liter	11.896,750

(Source: Processed data)

Based on the results shown in Table 33, it can be concluded that the method that gives the best solution for minimizing CO_2 emission is Clarke & Wright saving algorithm.

5. CONCLUSION

Based on the research results, it can be concluded that the proposed method can provide a better solution than the company/existing method to determine the shortest distribution route and also minimize fuel consumption, fuel costs and CO_2 emission. The proposed method that gives the best solution is Clark & Wright saving algorithm. The results provided with Clark & Wright saving algorithm is 11.49% better than the Sweep algorithm and also 43.23% better than the company/existing method.

For future research, it is expected that in the route determination phases can use other customer sorting methods such as the Nearest insert and farthest insert to find the best solution.

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