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Completion of CVRP with a Combination of Sweep and Local Search Algorithms (Case Study: PT. AJW)

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Abstract

PT. AJW is a consumer goods distribution company for Indofood products and non-Indofood products. PT. AJW moves throughout the Karo district. The number of tourist attractions in Karo increases the demand for goods such as Pop noodles, Indomie, chitato and others. Thus, having an impact on the distribution of goods. Based on the author's observations at PT. AJW Kabanjahe has no standard provisions in determining the route. The delivery of goods is still carried out based on consumer requests, so it ignores the distance travelled and time. A way that can solve this distribution problem is the Capacitated Vehicle Routing Problem (CVRP). CVRP is a problem in determining the optimal route by looking at the problem that each vehicle has a capacity limit. To solve CVRP problems, an excellent heuristic algorithm is used: sweep algorithm and local search route improvement. This study uses the sweep algorithm to solve the CVRP problem, and the routes obtained by the sweep algorithm will be improved with local search. The sweep algorithm is a simple calculation method, even for calculating large problems. The sweep algorithm will be combined with local search. Local search is an algorithm used to get shorter routes. The combination of the two algorithms is perfect for solving CVRP problems. After research, a distance of 39.96 km was obtained compared to the company's route of 103.5 km. So the percentage of mileage savings is 61.39%. This shows that sweep algorithms can minimize distance while saving company expenses.

INTRODUCTION

Distribution is distributing goods and services from sellers to end consumers through distribution flows. This process brings out the added value of shipping goods to the consumer's position, of wool utilization and cost efficiency. when the consumer needs it. According to Sesa [1], forming the optimal route is one way to minimize the total cost distribution. A good distribution process is needed for products to be delivered to consumers on time, and according to a predetermined location and products in good condition [2]. An effective and efficient distribution process is a factor in achieving consumer satisfaction. An essential component of distribution problems is determining vehicle routes in making scheduling to satisfy customers [3]. This route selection problem is often referred to as the Vehicle Routing Problem [4] by functioning to reduce distribution mileage by paying attention to vehicle capacity limits, the number of customer requests, and others.

Problems related to VRP are still an obstacle for business people. The mistake of choosing a delivery route will make the distance farther, so that time and costs will increase. VRP is defined as designing. The phenomenon of distribution route determination problems is also experienced by the object in this study, namely PT. AJW. PT. AJW is a consumer goods distribution company for Indofood products and non-Indofood products. PT. AJW moves throughout the Karo district. The number of tourist attractions in Karo increases the demand for goods such as Pop noodles, Indomie, chitato and others. Thus having an impact on the distribution of goods. Based on the author's observations at PT. AJW has no standard provisions in determining the route. The delivery of goods is still carried out based on consumer requests, so it ignores the distance travelled and time. The method that can solve this distribution problem is the Capacitated Vehicle Routing Problem (CVRP). According to Cahyaningsih [6], CVRP is the basis of the design arrangement to calculate route determination, almost like the Vehicle Routing Problem. CVRP is an optimization problem in finding the shortest route by minimizing costs and known vehicle capacity limits before the distribution occurs.

CVRP is a matter of determining the optimal route with the limitation that each vehicle has an apparent capacity. Each vehicle distributes one shipment from the depot to each customer/agent area and then back to the depot, making the distribution route service system more efficient and effective to improve the company's ability to respond to product needs more quickly so that consumer confidence increases [7]. The advantage of CVRP is that the vehicle capacity used in CVRP must be homogeneous (similar), and each vehicle distributes as much as one shipment, namely from the depot/delivery centre to each service area and then back to the depot, so that a service system in determining distribution routes becomes more effective and efficient. VRP can be solved using heuristic algorithms and metaheuristic algorithms. According to Respati [8] heuristic algorithm is designed to solve a problem in the search for a solution and used to find a solution that can be verified. The heuristic algorithm is problem dependent, meaning that this algorithm can only be applied to specific problems [9]. Heuristic algorithms that can be used to solve CVRP problems are sweep algorithms and local search route correction [10].

This study uses the sweep algorithm to solve the CVRP problem, and the routes obtained by the sweep algorithm will be improved with local search. The sweep algorithm is a simple method, even for calculating significant problems. According to Ballou, the accuracy of this method is 10% on average, and the accuracy of this method is on the creation of the route path. The sweep algorithm will be combined with local search. Local search is a route improvement algorithm to find shorter distances. Combining the two algorithms is excellent for solving CVRP problems [11].

In a previous study in his journal entitled "Solving Capacitated Vehicle Routing Problems Using Sweep Algorithms for Determining Newspaper Distribution Routes: A Case Study", In his research, agents were grouped first based on polar angles and then determined each cluster's route using the Nearest Neighbor method. The results showed a total mileage of 144.0 Km [12]. Ibrahim et al. [13] conducted research that solved the capacitated vehicle routing problem with

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several settlement methods. The research found that settlement with Reinforcement Learning can produce the most valuable solutions, even if it takes longer.

Based on this, the author is interested in conducting research entitled CVRP Completion with a Combination of Sweep and Local Search Algorithms (Case Study: PT. AJW).

METHOD

This study will obtain data from interviews and directly following distribution activities at PT. AJW. This research is carried out in 3 stages, namely data collection, data processing, and making conclusions.

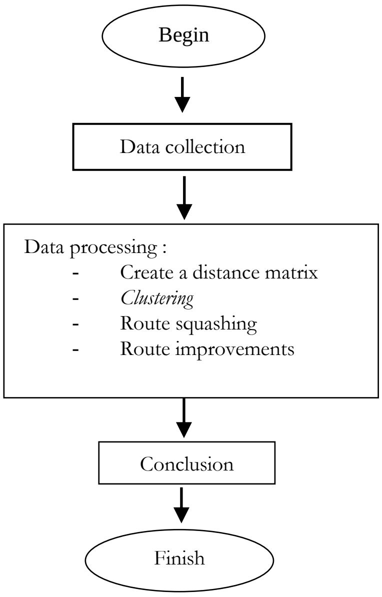

Figure 1. Research Flow Design

Data collection

The type of data used is quantitative data. The data obtained from the company is as follows:

1. Customer delivery data, including:
   a. Delivery time according to order
   b. Customer store as many as 16 customers,
   c. Item weight (kilograms)
2. Delivery of goods using a 6-wheeled Cold Diesel Car as much as one vehicle with a vehicle capacity of 6500 kilograms/vehicle.
3. Data on the route of delivery of goods by the company.

Data Processing

Data processing using CVRP by Combining Sweep and Local Search Algorithms is as follows.

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Sweep Algorithm

The sweep algorithm uses a two-stage method with the first stage being grouping customers (clustering) based on the position of consumers and existing vehicles, and the second phase forming routes [14].

Solving the problem of routing using the sweep algorithm is as follows.

1. First Stage: Clustering

   The steps of the grouping stages are:

   a. Enter the map into cartesian coordinates where the deport is the coordinate centre.

   b. Measure distances and find the polar angles of each agent with the depot. So that it can determine the coordinates of the agent

   $$r = \sqrt{x^2 + y^2} \quad (1)$$

   $$\theta = \tan^{-1} \frac{yi - y0}{xi - x0} \quad (2)$$

   c. Perform clustering by choosing the smallest to most significant polar angle paying attention to vehicle capacity.

   d. All agents are "swept up" in a group.

   e. Grouping is stopped if one cluster reaches the vehicle capacity limit.

   f. When that happens, please create a new cluster by following steps *b-d*

2. Second Stage: Route Establishment

The route formation stage will be carried out using the Nearest Neighbor method.

Local Search

Local Search is a heuristic method that uses a combination of optimization techniques. The route improvement process is implemented by moving one agent to another agent in the same route [15]. Local Search is a pretty good method for calculating quality solutions to solve the Vehicle Routing Problem relatively quickly [16].

Route Improvement Steps with Local Search Algorithm (intra-Route Insertion (1-0)):

a. Input the results of the Sweep Algorithm, vehicle capacity, demand for each customer, distance matrix

b. Starting from the 1st iteration, $i = 1$,

c. Carry out the intra-route insertion process, change the order of service for each agent in one route for each vehicle route, continue to *d* if all routes are searched for iteration marks and continue to *f*.

d. If the total distance on the new route is smaller than before, then go to step *e*; otherwise, return to *c*.

e. Choose a new route to replace the previous one, and return to *c*.

f. If all iterations have been searched, go to *h*; otherwise, go to *g*.

g. Calculate $i = i + 1$—return *c*.

h. The procedure is complete [17].

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RESULTS AND DISCUSSION

Distance Matrix

The calculation of Euclidean distances can do the calculation of distances. Euclidean distance is the calculation of the distance between two agents in Euclidean space, which explores the relationship between angle and distance. Here is the Euclidean distance equation [18]:

$$d = \sqrt{(lat_1 - lat_2) + (long_1 - long_2)^2} \qquad (3)$$

Information:

d : Range
Lat : Lattitude or latitude longitude
Long : Longitude or longitude of the earth

$$d(i,j) \quad = \sqrt{(lat_1 - lat_2) + (long_1 - long_2)^2}$$

$$d(0,1)$$
$$= \sqrt{(3{,}0969229 - 3{,}191106)^2 + (98{,}481256 - 98{,}508459)^2}$$
$$= \sqrt{(-0{,}094742)^2 + (-0{,}02720)^2}$$
$$= \sqrt{0{,}008976 + 0{,}00074}$$
$$= \sqrt{0{,}00972} = 0{,}09857 \times 111{,}322 \text{ km (1 derajat bumi)}$$
= 10,97 km

Thus, the distance from the depot to the first agent using the Euclidean distance equation is 10.97. However, because the pick-up system is by road trip, the calculation must consider whether company vehicles can pass roads. For this reason, the calculation of the distance from the depot to each agent and agent to other agents is searched with the help of Google Maps. It is assumed that the distance matrix has the same mileage between depot and agent, or the distance between agent and agent, i.e., the J$C_{ij} = C_{ji} C_{ij} = 0$ Distance matrix is shown in Table 1.

Table 1. Distance Matrix

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
0	-	10,97	10,97	10,94	10,78	9,22	0,21	0,84	0,62	8,99	8,59	14,40	14,48	17,41	10,81	10,80	9,83
1	10,97	-	0,21	0,05	0,22	1,86	11,11	10,30	10,52	6,63	2,49	3,48	3,52	6,53	0,25	0,42	1,29
2	10,97	0,21	-	0,17	0,22	1,80	11,11	10,29	10,51	6,80	2,44	3,53	3,56	6,49	0,16	0,25	1,21
3	10,94	0,05	0,17	-	0,18	1,82	11,08	10,27	10,49	6,64	2,45	3,52	3,56	6,55	0,20	0,38	1,25
4	10,78	0,22	0,22	0,18	-	1,64	10,92	10,10	10,32	6,61	2,27	3,70	3,73	6,70	0,09	0,28	1,07
5	9,22	1,86	1,80	1,82	1,64	-	9,37	8,52	8,74	6,33	0,64	5,33	5,36	8,19	1,65	1,60	0,61
6	0,21	11,11	11,11	11,08	10,92	9,37	-	1,05	0,83	9,01	8,74	14,53	14,61	17,56	10,95	10,95	9,98
7	0,84	10,30	10,29	10,27	10,10	8,52	1,05	-	0,24	8,78	7,89	13,75	13,82	16,69	10,13	10,11	9,14
8	0,62	10,52	10,51	10,49	10,32	8,74	0,83	0,24	-	8,90	8,11	13,97	14,04	16,92	10,35	10,34	9,36
9	8,99	6,63	6,80	6,64	6,61	6,33	9,01	8,78	8,90	-	6,23	8,62	8,87	12,26	6,70	6,85	6,57
10	8,59	2,49	2,44	2,45	2,27	0,64	8,74	7,89	8,11	6,23	-	5,97	5,99	8,81	2,28	2,24	1,25
11	14,40	3,48	3,53	3,52	3,70	5,33	14,53	13,75	13,97	8,62	5,97	-	0,33	3,65	3,69	3,75	4,74
12	14,48	3,52	3,56	3,56	3,73	5,36	14,61	13,82	14,04	8,87	5,99	0,33	-	3,39	3,71	3,76	4,76
13	17,41	6,53	6,49	6,55	6,70	8,19	17,56	16,69	16,92	12,26	8,81	3,65	3,39	-	6,65	6,63	7,58
14	10,81	0,25	0,16	0,20	0,09	1,65	10,95	10,13	10,35	6,70	2,28	3,69	3,71	6,65	-	0,19	1,06
15	10,80	0,42	0,25	0,38	0,28	1,60	10,95	10,11	10,34	6,85	2,24	3,75	3,76	6,63	0,19	-	1,00
16	9,83	1,29	1,21	1,25	1,07	0,61	9,98	9,14	9,36	6,57	1,25	4,74	4,76	7,58	1,06	1,00	-

Route Grouping

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The first rare *h* performed in route grouping is the depot to draw a cartesian diagram with the coordinate centre. PT. AJW as a warehouse is placed at coordinates (0, 0). The locations of agents and depots after depicting in the cartesian diagram can be seen in Figure 2.

Figure 2. Map

Furthermore, the search for polar angles can be done using the help of Qgis software. To calculate the angle, a line is drawn from the depot to the coordinates of the agent and a straight line of the *x*-axis.

Table 2. Polar Angles

Agent	Distance	*Lattitude*	*Longitude*	θ (°)
PT AJW	0,00	3,10	98,48	0,00
1	10,97	3,19	98,51	73,97
2	10,97	3,19	98,51	72,88
3	10,94	3,19	98,51	73,78
4	10,78	3,19	98,51	73,43
5	9,22	3,17	98,51	70,48
6	0,21	3,10	98,48	245,70
7	0,84	3,10	98,49	38,07
8	0,62	3,10	98,49	31,91
9	8,99	3,17	98,45	111,14
10	8,59	3,17	98,51	69,74
11	14,40	3,22	98,51	76,83
12	14,48	3,22	98,51	75,57
13	17,41	3,24	98,54	69,37
14	10,81	3,19	98,51	72,96
15	10,80	3,19	98,51	71,94
16	9,83	3,18	98,51	70,61

Based on the polar angle order, agents are grouped into routes by considering demand and vehicle capacity, grouping routes according to vehicle demand and capacity. Grouping all agents starting from the agent that has the smallest to the most significant polar angle. Grouping is applied counterclockwise. If the request is close to reaching the capacity limit, Grouping is stopped. The grouping of each agent is done based on polar angle ratings until capacity is met.

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The agent will be grouped to the following route if the vehicle capacity is maximised and done continuously so that all agents are served. The formed route groups are shown in Table 3 [19].

Table 3. Route Group

Vehicle Routes	Agent	θ (°)	Demand (kg)	Number of Requests (kg)
1	8	31,91	250	4910
	7	38,07	375	
	13	69,37	350	
	10	69,74	245	
	5	70,48	365	
	16	70,61	395	
	15	71,94	215	
	2	72,88	215	
	14	72,96	200	
	4	73,43	245	
	3	73,78	350	
	1	73,97	230	
	11	76,83	375	
	12	75,573	250	
	9	111,14	325	
	6	245,7	525	

Based on the table above, it can be a group of shipping routes. This is because there is still free space in the vehicle's capacity to carry requests from each agent. The total number of requests channelled to all agents amounted to 4910 kg.

Route Formation

After grouping the routes, the stages of route formation will be carried out using the Nearest Neighbor method. The first stage is to look at the distance matrix in Table 1, choose the agent closest to the depot, and then set the destination to be visited next by considering the nearest agent, carried out continuously until it is swept away in the route group. After all the agents have been visited, the vehicle will return to the depot.

The routes formed using Nearest Neighbour are:

a. The route starts from the depot (point 0). The nearest agent from point 0 is agent 6, so the temporary route formed is 0 – 6 with a distance of 0.21 km.
b. The nearest agent of agent 6 is agent 8, so the temporary route is 0 – 6 – 8 with a distance of 0.83 km.
c. The nearest agent of agent 8 is agent 7, so the temporary route is 0 – 6 – 8 – 7 with a distance of 0.24 km.
d. The nearest agent of Agent 7 is Agent 10, so the temporary route is 0 –6 – 8 – 7 – 10, with a distance of 7.89 km.
e. The nearest agent of Agent 10 is Agent 5, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 with a distance of 0.64 km.
f. The nearest agent of agent 5 is agent 16, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 with a distance of 0.61 km.
g. The nearest agent of Agent 16 is Agent 15, so the temporary route is 0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 with a distance of 1 km.

h. The nearest agent of Agent 15 is Agent 14, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 with a distance of 0.19 km.
i. The nearest agent of agent 14 is agent 4, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 with a distance of 0.09 km.
j. The nearest agent of Agent 4 is Agent 3, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 with a distance of 0.18 km.
k. The nearest agent of Agent 3 is Agent 1, so the temporary route is 0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 with a distance of 0.05 km.
l. The nearest agent of Agent 1 is Agent 2, so the temporary route is 0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 with a distance of 0.21 km.
m. The nearest agent of agent 2 is agent 11, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 with a distance of 3.53 km.
n. The nearest agent of agent 11 is agent 12, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 – 12 with a distance of 0.33 km.
o. The nearest agent of agent 12 is agent 13, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 – 12 – 13 with a distance of 3.39 km.
p. The nearest agent of agent 13 is agent 9, so the temporary route is 0 –6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 – 12- 13 – 9 mileage 12.46 km.
q. In distributing trips starting at the depot and stopping at the depot, the sequence of route one is obtained 0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 – 12- 13 – 9 – 0 with a distance of 8.99 km.

Then the route of the results using the sweep algorithm in Table 4.

Table 4. Delivery Routes Using the Sweep Algorithm

No	Route	Weight (kg)	Mileage (km)
1	0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 – 12- 13 – 9 – 0	4910	40,64

Route Improvement

Based on the results of the sweep algorithm, there is one route with a total distance of 40.64 km. The route obtained from the sweep algorithm will be corrected with a local search. The results of the sweep algorithm can be seen in Table 4, and The next step is to perform a Local search, which is the process of moving agents with other agents sequentially in the same route to minimize distribution time and distance. The results of Intra Route Insertion are in Table 5 [20].

Table 5. Local search

	Route	Mileage (km)
Sweep Algorithm	0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 3 – 1 – 2 – 11 – 12- 13 – 9 – 0	40,21
Local search	0 – 6 – 8 – 7 – 10 – 5 – 16 – 15 – 14 – 4 – 1 – 3 – 2 – 13 – 12- 11 – 9 – 0	39,96

There were two route improvements, first moving positions on agent 13 with agent 11, and second moving positions on agent 3 with agent 1 to minimize route distance. Route Comparison Using Sweep and Local Search Algorithms with Company Routes Routes obtained from PT. AJW A total of 3 freight delivery routes with 1 vehicle.

Table 6. Corporate Routes

No.	**Route**	**Weight (kg)**	**Mileage (km)**
1	0 – 11 – 12 – 1 – 3 – 7 – 0	1580	29,37
2	0 – 16 – 13 – 14 – 9 – 4 – 0	1515	48,13
3	0 – 15 – 5 – 2 – 10 – 6 – 8 – 0	1815	26
	Sum	4910	103,5

From the table above, a comparison of company routes and routes using sweep and local search algorithms is obtained as follows.

Table 7. Comparison of Company Route Mileage and AS and LS Routes

Route	**Company Route Mileage (km)**	**Mileage Route Combination Algorithm Sweep and local search (km)**
1	29,37	39,96
2	48,13	
3	26	
Total Mileage (km)	103,5	39,96

Based on the route using the sweep algorithm and improvement of local search routes and routes from the company, the percentage of total mileage savings is obtained below.

$$= \frac{\text{Total JRP } - \text{Kombinasi AL dan Ls}}{\text{Total jarak rute perusahaan}} \times 100\ \% \quad (4)$$

$$= \frac{103{,}5\ - 39{,}96}{103{,}5} \times 100\%$$

$$= 61{,}39\ \%$$

CONCLUSION

CVRP determines a collection of routes; each route will be served by a vehicle that starts the journey at the starting point and ends at the starting point, meeting customer demand with limitations on vehicle capacity. This study uses the sweep algorithm to solve the CVRP problem. The routes obtained by the sweep algorithm will be improved with local Search. The sweep algorithm is a simple method, even for calculating significant problems. The sweep algorithm will be combined with local search. Local search is a route improvement algorithm to find shorter distances. The combination of the two algorithms is excellent for solving CVRP problems. A case study in this research at PT. AJW. This company has problems that can be solved by this method. After research, a distance of 39.96 km was obtained compared to the company's route of 103.5 km. So the percentage of mileage savings is 61.39%. This shows that sweep algorithms can minimize distance while saving company expenses.

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