Determining Newspaper Distribution Routes Using Sweep Algorithm and Local Search to Solve the Capacitated Vehicle Routing Problem and Minimizing Cost

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Abstract

XYZ Ltd. is a daily newspaper company, one of which is located in Kartasura, Sukoharjo. Newspapers were distributed to 11 locations around Kartasura and Klaten. In the delivery process, there are limitations such as the number of vehicles and vehicle capacity. The company wants to find a better or shorter route in distributing its products to agents to minimize transportation costs. This issue can be considered a Capacity Vehicle Routing Problem. In this study, the sweep algorithm was first used to find the initial solution. The local search procedure is used for the solution obtained by the sweep and nearest neighbor algorithm. The new first route is Depot-A2-A4-A5-A6-A10-A1-Depot, while the second route is Depot-A7-A3-A8-A9-A11-Depot. Those routes are found using local search combination of 1-insertion intra route, and swap intra route. After that, the minimum cost is calculated. The results are a decrease in the distance, time, and fuel costs from the previous route. The improvements are saving IDR 1,119,323 per year, 8 minutes faster, and 4.3 km shorter than the previous route for route 1 and IDR 728,862 per year, 6 minutes faster and 2.8 km shorter than the previous route for route 2.

Keywords
Capacitated Vehicle Routing Problem, Sweep Algorithm, Local Search, Minimizing Cost.

1. Introduction
Supply chain management is a series of activities that include coordination, scheduling and control of procurement, production, inventory and delivery of products or services to customers which includes daily administration, operations, logistics and information processing from customers to suppliers. In these activities a company needs to

cooperate with related parties, namely suppliers, distributors, third service providers, and consumers. A company in managing the supply chain needs to pay attention to several processes (Rosanti et al. 2019), like customers placing orders, planning, purchasing, inventory and production. Inventory is a general term that shows everything or organizational resources that are stored in anticipation of meeting demand (Handoko 2015). In this case, the inventory in question is the raw materials and supporting materials needed by the company. Raw materials are imported from several suppliers so that suppliers become one of the important external parties for the existence and sustainability of a manufacturing company (Hidayati et al. 2020). A company that produces a product also needs a good distribution system for its distribution (Febriandini and Sutopo 2020). No exception for companies engaged in newspaper printing, such as XYZ Ltd., which must send newspapers every day to agents who are widely spread in various geographical areas, to be later distributed to readers. However, the distribution of newspaper products is different from the distribution of other products (Sartika et al. 2018). This is because the distribution of newspapers has a time limit in its distribution, so that the news is still up to date (Aqidawati et al. 2018).

In distributing its products, XYZ Ltd. currently sends goods based on the grouping of agents' areas without considering the route and capacity used. Therefore, it is necessary to determine distribution routes in order to minimize costs and accelerate newspaper distribution. In this case, the Capacitated Vehicle Routing Problem is a problem in determining the route for distribution to several depots or agents with the same starting and ending points of distribution. There are several limitations used in this problem, such as homogeneous product, vehicle capacity, in time windows. The Capacitated Vechile Routing Problem has been raised by several research, such as solving taboo search and simulated annealing, then continued some research such as solving Agent Based Simulation (Febriandini et al. 2019), time windows (Jodinesa et al. 2019), Capacitated Vehicle Routing Problem (CVRP) using saving matix nearest neighbor. Rizwanullah and Nilofer (2018), Sarjono (2014), and Virgiawan (2014) in their research comparing the saving algorithm with the sweep algorithm in determining the distribution of the mineral water Club case study in Balikpapan City. The results of his research show that the sweep algorithm produces a more optimal solution than the saving algorithm.

The daily distribution process for newspapers in the Kartasura - Klaten area is carried out with one fleet with a capacity of around 3000 copies. One fleet is used to distribute daily newspapers to 9 agents. The number of daily requests for newspapers for each agent is also different, the demand is between 189 to 995 copies in February 2017. Each agent has a different rate of return. Each vehicle distributes one delivery, namely from the depot to each customer/agent area and then back to the depot, so that a service system in determining distribution routes becomes more effective and efficient so that it can increase the company's ability to meet product demands more quickly so that trust and increased consumer satisfaction. The novelty in this research is discussed in solving problems regarding the Capacitated Vechile Routing Problem (CVRP) using the sweep algorithm method, nearest neighbor method and local search algorithm in determining the best distribution route to minimize the total cost, so that the use of the transport fleet can be optimal. In previous studies, the absence of a combination of these three methods made the route determination not maximized so that it had an effect on costs. Cost minimization is the basic rule used by producers to determine what mix of labor and capital produces the output at the lowest cost (Nugraha et al. 2020). In other words, what is the most cost-effective method of delivering goods and services while maintaining the desired level of quality.

The supply chain system for distributing newspapers at XYZ Ltd. is currently still limited to certain areas starting from the nearest agent but does not yet have a fixed route. The purpose of this research is to determine the best route of newspaper distribution by minimizing the total cost, so that the use of the carrier fleet can be optimal. In addition, nearest neighbor method and local search algorithm are used to obtain shorter routes. The benefit of this research for producers and agents is as a supporting study in analyzing and providing recommendations in making decisions regarding the determination of newspaper distribution routes so as to increase customer satisfaction.

2. Literature Review

Cost minimization is the basic rule used by producers to determine what mix of labor and capital produces the output at the lowest cost. In other words, the most cost-effective method of delivering goods and services while maintaining the level of quality that most manufacturers desire. The optimal route can be determined using the Differential Evolution Algorithm to calculate the shortest route for each agency and maximize the use of vehicles using agency coordinates and requests (Saputra et al. 2018). In other literature, the application of the sweep algorithm is also used. The sweep algorithm is an algorithm that uses a two-phase method with the first phase being the grouping of customers based on the available area and vehicles, and the second phase being the development route for each cluster (Saraswati

et al. 2017). Other research also discusses how to overcome the problem of determining routes at newspaper companies in the city of Surakarta with the saving matrix method and the nearest neighbor method so that time and cost minimization can be obtained and the best delivery route can be obtained (Adam et al. 2020). Currently the product distribution process is still limited to certain areas starting from the nearest agent but does not yet have a fixed route. Therefore, it is necessary to determine a good route so that distribution operational time and costs are effective and efficient. The main consideration is how to reduce distribution costs by creating distribution routes using the Capacitated Vehicle Routing Problem method in order to obtain shorter routes and consider optimal vehicle capacity (Saraswati et al. 2017). The problem of vehicle route capacity or CVRP is the problem of determining the most optimal route by considering the carrying capacity of the vehicle. The process of completing the CVRP model using a sweep algorithm requires two phases, namely the clustering phase and the route development phase (Saraswati et al. 2017). Local search algorithm is an algorithm used to get a shorter route. Several local search algorithms used in this research are 1-Insertion Intra Route, Swap Intra Route, 1-Insertion Intra Route, and Swap Intra Route.

3. Methods

The method used in this research is Sweep Algorithm. Meanwhile, at the stage of establishing the distribution route, each cluster will be solved using the Nearest Neighbor algorithm so that the travel route for each cluster is obtained. Furthermore, local search algorithm calculations are used to get a shorter route. Here is a flowchart of this research (figure 1).

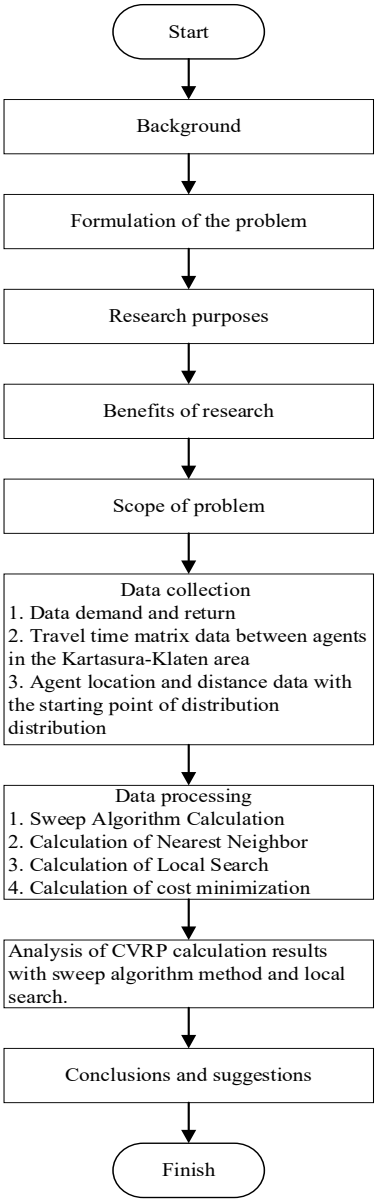

Figure 1. Research flowchart

1. Sweep Algorithm Calculation

The process of completing the VRP model using the Sweep algorithm requires two stages, namely the clustering stage and the route formation stage (Saraswati et al. 2017). Here is the stage of grouping (clustering) (figure 2).

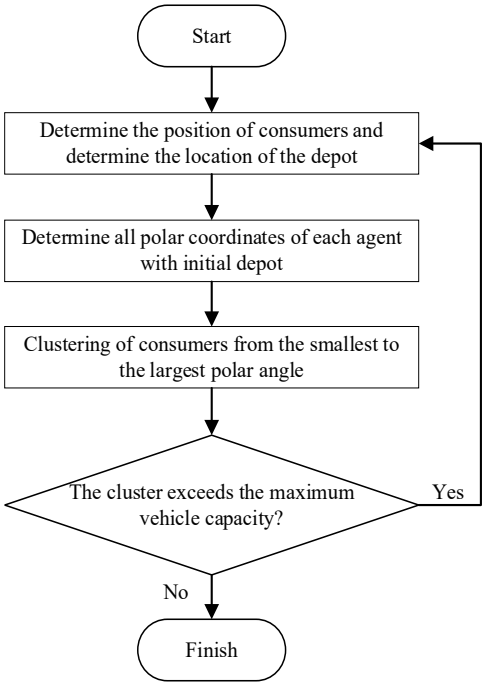

Figure 2. Stage of grouping (clustering)

Here is the formula to determine the distance matrix. Data on the distance between the company and its location and location to other locations is very necessary. After knowing the coordinates of each location, the distance between the two locations can be calculated using the formula (Iriani and Asmara, 2020):

$J(1,2)=\sqrt{(Xa-Xb)^2+(Ya-Yb)^2}$.....(1)

Note : J (1,2) = Distance between points 1 and 2
X1,Y1= Coordinate of point 1
X2,Y2= Coordinate of point 2

2. Nearest Neighbor Calculation

Here are the stages of route formation using the nearest neighbor (Pulansari et al. 2021). The Stages of establishing distribution routes are shown in figure 3.

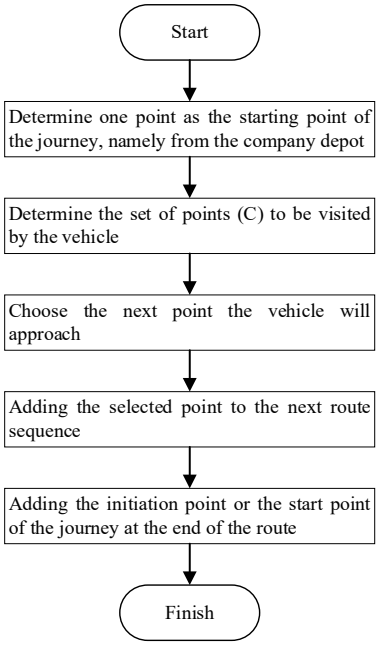

Figure 3. Stages of establishing distribution routes

3. Calculation of Local Search

Meanwhile, the next CVRP model completion process is to use a local search algorithm. Local search algorithm is an algorithm used to get a shorter route. Several local search algorithms used in this research are 1-Insertion Intra Route, Swap Intra Route, 1-Insertion Inter-Route and Swap Inter-Route. These algorithms have been previously applied to solve various types of CVRP. An example of the application of these algorithms can be seen in Imran et al. (2016), Salhi et al. (2014), and Imran (2013). in Figure 4.

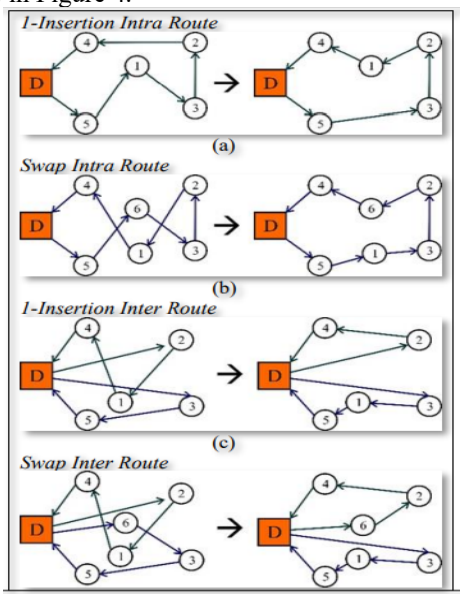

Figure 4. Visualization of Local Search Algorithm

In the 1-Insertion Intra Route algorithm, route improvement is done by moving 1 point to another place in one route. In Figure 4(a), initially the sequence in the route is D-5-1-3-2-4-D. By moving point 1 between point 2 and point 4 we get a shorter total distance. The route becomes D-5-3-2-1-4-D. Intra-Route Swap Algorithm is a route improvement algorithm performed by exchanging the positions of two points on the same route. For example, in Figure 4(b) the starting route is D-5-6-3-2-1-4-D. By using the Intra-Route Swap algorithm, the positions of point 1 and point 6 are swapped. So that the new route D-5-1-3-2-6-4-D is obtained which has a shorter total distance. The 1-Insertion Inter-

Route Algorithm is a route improvement algorithm performed by inserting points between different routes (Figure 4(c)). In the Swap Inter-Route algorithm, route improvement is carried out by exchanging the positions of two points between different routes (Figure 4(d)). (Ruben and Imron 2020).

4. Fuel Cost Calculation

After that, the value of each alternative is collected and evaluated on the criteria of distance, time, and fuel costs per day. The fuel cost is calculated based on the assumption that the vehicle consumption is 13 km/L with a diesel price of IDR 9,400. Calculation of fuel costs using the following formula.

$$fuel\ cost = \frac{distance\ driven \times diesel\ fuel\ price\ per\ litres}{vehicle\ consumption} \quad \text{.....(2)}$$

4. Data Collection

The data used for this study are XYZ Ltd. daily distribution data for February 2017 for the Kartasura-Klaten area, which is shown in table 1. This area was chosen because it has a daily sales percentage of newspapers in the Solo Raya area with the lowest value of 41%. In addition, the data used include the number of fleets, the capacity of the fleet for delivery, the number of newspaper agents and the location of the agents, as well as the service time at each agent. This study only focuses on the distribution of newsagents in the Kartasura-Klaten area. In addition, data is also obtained from google maps about the travel time. Additional data used in this study include data on demand and return for the Kartasura and Klaten areas, the location and distance of agents from the starting point for the distribution of the Kartasura area. Meanwhile, the assumption data used include the number of fleets of 2 units and the maximum capacity per fleet of 3000 copies.

Table 1. Demand and return data

Code	Agent Name	Demand (Copies)	Return (Copies)
A1	Abdul basyir	189	110
A2	Yudistira	270	210
A3	Icah	830	445
A4	Sulomo	560	170
A5	Handoyo/Wardoyo	700	522
A6	Multimediawara	540	412
A7	Ibra	204	65
A8	Handayani	995	275
A9	Sami	405	405
A10	Endang	540	305
A11	Lili	350	152

The travel time of each agent from the location is shown in table 4. The travel time is obtained through google maps by entering the agent's address data that has been obtained from the company. While the location and distance of the agent with the starting point of the distribution distribution is shown in table 2.

Table 2. Location and distance of agents with starting point of distribution

Code	Agent Name	Location	Distance from depot (km)
A1	Abdul basyir	Sedahromo Lor Kartasura	8,9
A2	Yudistira	SDN Wirogunan 01	9,8
A3	Icah	MEA Kios parfum dan refill	37,2
A4	Sulomo	Jalan Raya Delanggu Utara	20
A5	Handoyo/Wardoyo	Jl Raya Karangwuni Ceper Klaten	28,1
A6	Multimediawara	Pasar Srago Klaten	34,9
A7	Ibra	PAUD RA Kartini	36,2
A8	Handayani	Jalan Kartini Klaten	36,1
A9	Sami	Terminal Klaten	35,8
A10	Endang	Pasar Gawok	14,1
A11	Lili	Pasar Masaran Cawas Klaten	38,4

5. Results and Discussion

1. Sweep Algorithm Calculation

Data processing is carried out from the input data that has been collected. By using the Sweep Algorithm, a cluster determination is made from each agent location by taking into account the capacity limit. The criteria in agent clustering are the minimum pole angle and the capacity of the vehicle assigned to the cluster. The cluster formation starts with the smallest pole angle node and continues to sweep through the agent nodes by increasing the pole angle. The sweep (sweep process) is terminated when the next agent node included will violate the maximum vehicle capacity limit. The demand from all agents selected in a cluster must be less than or equal to the capacity of the vehicles assigned to the cluster. A new cluster is created by continuing the sweeping process. The process of adding agent nodes to the cluster is repeated until all agent nodes have been added to the cluster. The clusters that have been determined are listed in table 3 and are depicted on the map in Figure 5.

Table 3. Clustering using Sweep Algorithm Result

	Agent						Capacity (Copies)
CLUSTER 1	A1	A2	A10	A4	A5	A6	2799
CLUSTER 2	A8	A7	A3	A9	A11		2784

By taking the map from Google Maps and adding information using CorelDraw X7 software, the following is an overview of each cluster.

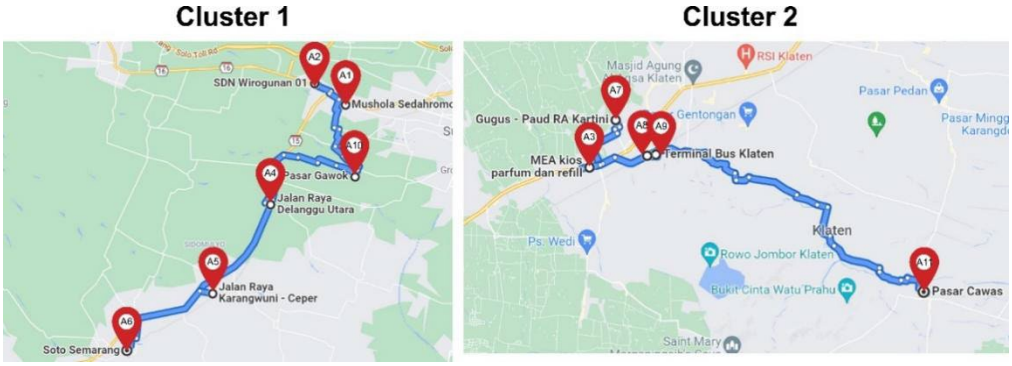

Figure 5. *Cluster* 1 and *Cluster* 2

2. Nearest Neighbor Calculation

Furthermore, a route search is carried out using the Nearest Neighbor method. Agent locations in the cluster formed from the Sweep Algorithm stage will be sorted and scheduled for vehicle travel routes. After that, the making of a travel matrix between agents in the Kartasura – Klaten area which can be seen in table 4 was carried out to find out the lowest travel time between locations. Distribution routes are created based on the travel time from the last point the vehicle visited the next closest point in the network. The procedure starts from the starting point, namely the depot, then goes to the node closest to the last node included in the travel route. This procedure is repeated until all nodes have been added to the travel route. The first and last nodes in the path are then connected to create a complete travel route from departure to return. The following is a picture of the newspaper distribution route in Figure 6.

Table 4. Matrix of travel time between agents in the Kartasura-Klaten area (in minutes)

	Depot	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
Depot	0	17	19	58	34	42	53	55	56	55	27	61
A1	17	0	7	45	17	28	39	40	40	44	17	48
A2	19	7	0	42	20	28	38	40	40	44	20	48
A3	58	45	42	0	29	23	11	6	7	9	42	34
A4	34	17	20	29	0	12	22	24	24	28	19	31

	Depot	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
A5	42	28	28	23	12	0	14	18	18	22	27	23
A6	53	39	38	11	22	14	0	11	7	10	38	27
A7	55	40	40	6	24	18	11	0	6	8	40	31
A8	56	40	40	7	24	18	7	6	0	41	40	29
A9	55	44	44	9	28	22	10	8	41	0	40	43
A10	27	17	20	42	19	27	38	40	41	40	0	44
A11	61	48	48	34	31	23	27	31	28	43	44	0

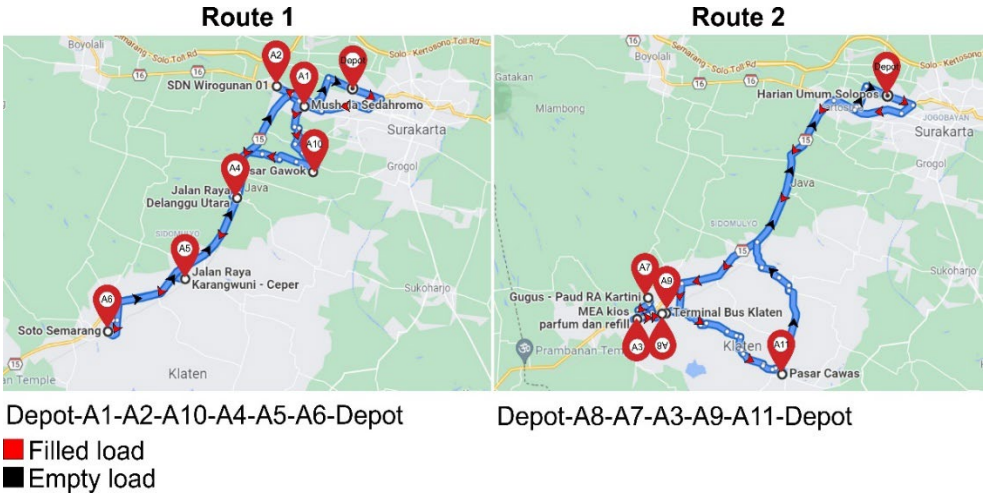

Figure 6. Distribution Route 1 and Distribution Route 2 with Nearest Neighbor

Based on route determination using the Nearest Neighbor method, route 1 is obtained as follows Depot-A1-A2-A10-A4-A5-A6-Depot, and route 2 as follows Depot-A8-A7-A3-A9-A11-Depot. The results of the Nearest Neighbor method can find the minimum distance. The minimum distance obtained is 81.4 km and the time is 2 hours 21 minutes for route 1, then 95.4 km and 2 hours 46 minutes for route 2.

1. Calculation of Local Search

Based on data processing using the Sweep and Nearest Neighbor Algorithms, the results obtained are a total distance of 81.4 km and a time of 2 hours 21 minutes for route 1, then 95.4 km and 2 hours 46 minutes for route 2. The results of this data processing are then improved to find the route with the smallest distance and time using the Local Search algorithm. The first Local Search is with 1-Insertion intra route. On Route 1, A10 is sent at the end, where it was previously sent in third. The order of distribution to agents changed to Depot-A1-A2-A4-A5-A6-A10-Depot. Furthermore, with the Swap Insertion intra route, the distribution order is exchanged between agents A1 and A2, so that the sequence becomes Depot-A2-A1-A10-A4-A5-A6-Depot. Then a combination of the two Local Search methods is carried out so that the sequence becomes Depot-A2-A4-A5-A6-A10-A1-Depot. A picture of the route of each repair can be seen in Figure 7.

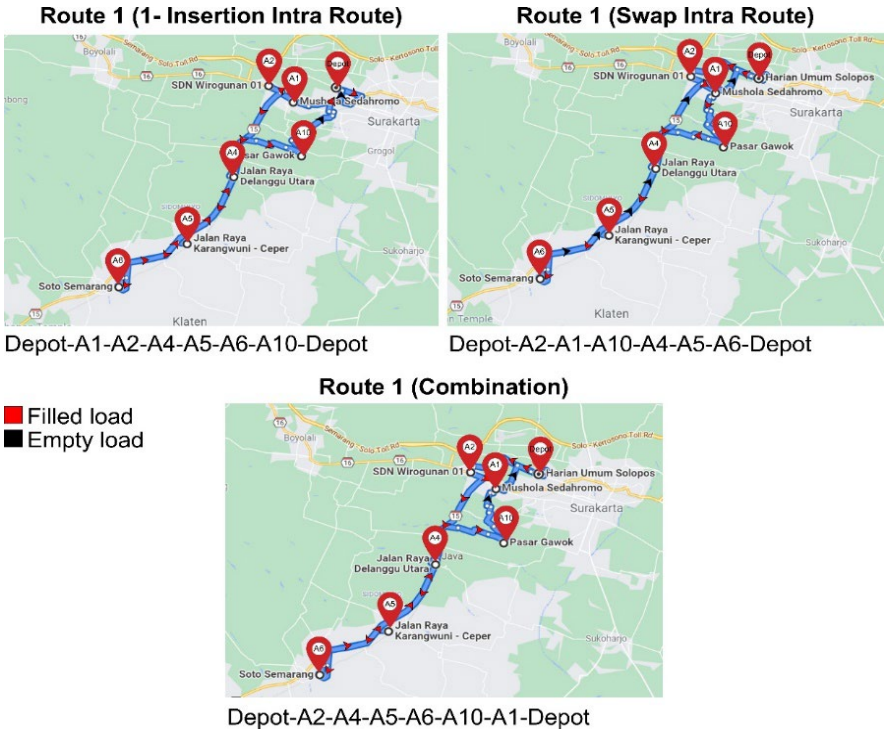

Figure 7. Distribution Route 1 after Improvement

The results of data processing Sweep and Nearest Neighbor algorithms are improved to find the route with the smallest distance and time using the Local Search algorithm. The first Local Search method applied to Route 2 is 1-Insertion intra route. In this method, agent A9 is sent first, which was previously sent after agent A3. The order of distribution to agents changed to Depot-A9-A8-A7-A3-A11-Depot. Then the repair was carried out with Swap intra route, the order of distribution between A8 and A7 agents was exchanged so that the order became Depot-A7-A8-A3-A9-A11-Depot. Next, a combination of the two Local Search methods is carried out so that the sequence becomes Depot-A7-A3-A8-A9-A11-Depot. A picture of the route of each repair can be seen in Figure 8.

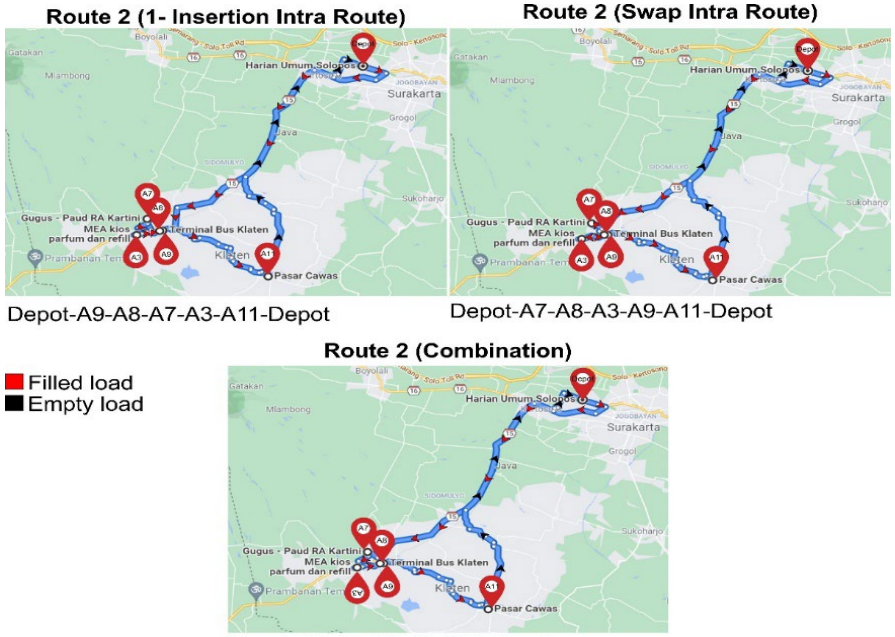

Figure 8. Distribution Route 2 after Improvement

2. Fuel Cost Calculation

After that, the value of each alternative is collected and evaluated on the criteria of distance, time, and fuel costs per day. The fuel cost is calculated based on the assumption that the vehicle consumption is 13 km/L with a diesel price of IDR 9,400. Calculation of fuel costs using the following formula.

$$fuel\ cost = \frac{distance\ driven\ \times\ diesel\ fuel\ price\ per\ litres}{vehicle\ consumption}$$

The results of data processing and comparisons between methods are presented in table 5.

Table 5. Results and comparison of methods used

Route	Delivery Order	Methods	Distance (km)	Traveling Time (minutes)	Fuel Cost/day
Route 1	Depot-A1-A2-A10-A4-A5-A6-Depot	Nearest Neighbour	81.4	141	IDR 58,858
	Depot-A1-A2-A4-A5-A6-A10-Depot	1- Insertion Intra Route	77.2	133	IDR 55,822
	Depot-A2-A1-A10-A4-A5-A6-Depot	Swap Intra Route	79.6	137	IDR 57,557
	Depot-A2-A4-A5-A6-A10-A1-Depot	Combination	77.1	133	IDR 55,749
Route 2	Depot-A8-A7-A3-A9-A11-Depot	Nearest Neighbour	95.4	166	IDR 68,982
	Depot-A9-A8-A7-A3-A11-Depot	1- Insertion Intra Route	94.8	165	IDR 68,548
	Depot-A7-A8-A3-A9-A11-Depot	Swap Intra Route	94.6	165	IDR 68,403
	Depot-A7-A3-A8-A9-A11-Depot	Combination	92.6	160	IDR 66,957

Based on table 5, it can be seen that by using Local Search improvements, the results obtained from the Nearest Neighbor method can produce smaller routes and travel times. Based on these results, a combination local search method was chosen on both routes, because it has the smallest distance, time, and fuel cost. On route 1, the improvement of the distribution route is able to minimize fuel costs from IDR 58,858 to IDR 55,749 or can save IDR 3,109 per day and can save IDR 1,119,323 per year. On route 2 the improvement of the distribution route was able to minimize fuel costs from IDR 68,982 to IDR 66,957 or was able to save IDR 2,025 per day and could save IDR 728,862 per year.

6. Conclusion

This paper seeks to determine the distribution route of daily newspapers and minimize fuel costs at XYZ Ltd. to 11 agents in the Kartasura-Klaten area. Based on the results of data processing using the sweep algorithm to determine the cluster and then determining the route using Nearest Neighbor, and improved using Local search, the best route was obtained by applying the local search method a combination of 1-Insertion intra route and Swap intra route. On route 1, the distance and time are 77.1 km and a time of 2 hours 13 minutes with a fuel cost of IDR 55,749, there is a decrease in distance and time from the previous route of 81.4 km and a time of 2 hours 21 minutes with a fuel cost of IDR 58.858. On route 2, the result is 92.6 km with a time of 2 hours 40 minutes and fuel costs of IDR 66,857. These results decreased in distance, time, and fuel cost from the previous route which was 95.4 km and 2 hours 46 with a fuel cost of IDR 68,982. With the new distribution route, it can save fuel costs of IDR 1,119,323 per year for route 1 and IDR 728,862 per year for route 2.

This research still has several weaknesses, such as not considering environmental factors by calculating fuel consumption, electricity consumption values, and carbon emissions and not considering social factors. Suggestions from this research that can be given to the problem of determining newspaper distribution routes at XYZ Ltd. using the Sweep, Nearest Neighbor, and Local Search algorithms are in the process of making newspaper distribution routes. Consider implementing Local Search improvements, especially the combination of 1-Insertion intra route and Swap. intra route that has been done by researchers in solving the capacitated vehicle routing problem in the distribution of newspapers to every agent in the Kartasura-Klaten area. So that it can reduce the distance and travel time as well as the costs incurred on newspaper distribution. This research can be developed again such as considering environmental and social factors as well as calculating the value of fuel consumption, electricity consumption, and carbon emissions so that companies can apply the concept of sustainable supply chain management. The use of other methods such as the taboo search algorithm, genetic algorithm, ant colony and so on can also be done by adding constraints or uncertainties.

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