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Application of Vehicle Routing Problem Using Nearest Neighbor Method and Simulated Annealing Algorithm

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Abstract:

This paper discusses the problem of determining product delivery distribution routes. Requests often experience delays in delivery due to insufficient distribution capacity. This results in an inefficient distribution of mileage and travel time. This problem is included in the Vehicle Routing Problem (VRP) with multiple types of depots, multiple trips, and a heterogeneous vehicle fleet. Next, the initial route is determined using the nearest neighbor method. Then the route improvement is carried out using an annealing simulation algorithm to produce a route that is close to optimal. The solution gives better results in terms of distance and time compared to actual conditions.

Keywords **—Vehicle Routing Problem, Nearest Neighbor, Simulated Annealing**

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I. INTRODUCTION

According [1] distribution and transportation management allows products to move from factory locations to consumer locations which are limited by distance and must be delivered on time, in the right amount, and good condition. Distribution and transportation management is important for a company because it is responsible for all the process of transporting goods in the company. One of the activities undertaken is to deliver the finished product from the factory to the consumer. An optimal distribution system and channel can make the products reach the consumers on time and without defects, and minimize the company resources.

Distribution and transportation management is the process of regulating product delivery from the location where the product is produced to the place where the product will be used. The other terms of distribution and transportation management in some companies are called logistics management or physical distribution. The activities involved consist of physical activities such as storing and shipping products, as well as non-physical activities such as processing information and services to customers.

Logistics management is an integrated system that coordinates the entire process within the company in preparing and delivering products to consumers [2]. This process consists of various types of activities, namely planning (*plan*), *input* source (*source* such as raw materials from suppliers), transformation of raw materials into finished goods (*make*), transportation, distribution, warehousing (*deliver*), product information, and payment systems, until the product is consumed by consumers, and the last one is a product return service (*return*). All logistics activities can be carried out by the company itself or in collaboration with other companies that provide logistics services.

Application with a distributor has six depots with different distribution areas determined generally based on the region where the depots are located. An overview of the division of these areas can be seen in Figure 1.

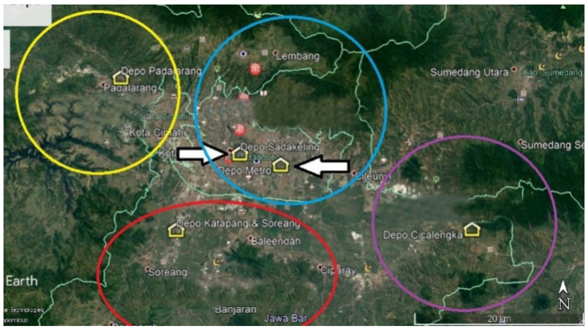

Figure 1 Distribution of Depot Distribution Area

Every depot has similar issues. Therefore, this research is conducted at the locations of the two depots are shown by arrows because the locations of the two depots are close together and have the highest number of requests compared to other depots. Product delivery is carried out based on a schedule made by the company and direct requests from consumers.

The demand often experiences delivery delays. Delays are marked by the arrival time of the product outside the operating hours of the consumer shops that disrupts the consumer shop activities. These routes cause some consumer demand to be sent from too far depots from the customer's location. Besides, some distribution processes also prioritize product delivery to farther consumer locations the location of consumers who are too far away and the extensive mileage can result in delivery delay times and the possibility of greater obstacles on the way. This problem can be categorized as a *Vehicle Routing Problem* (VRP).

II. METHODOLOGY

The research steps carried out are determining the type of VRP, applying nearestneighbormethod and the simulated annealing algorithm.

A. *Vehicle Routing Problem* (VRP)

Vehicle Routing Problem (VRP) has similarities with the *Travelling Salesman Problem* (TSP). TSP is a travel network configuration or *salesman* route to find the route with the smallest mileage[3]. Meanwhile, the *Vehicle Routing Problem* (VRP) is an extension of the problem of the *Traveling Salesman Problem* (TSP). According [4], VRP has several limitations including:

1. Each stop point has demands according to the capacity delivered amount
2. The vehicles used may have a different capacity
3. The maximum total driving time (without breaks) for each route is ten hours
4. Pick-up and delivery of products at each stop can be done at certain times (*time windows*)
5. Products pick-up on a route is allowed if previous products delivery has been carried out
6. Drivers are allowed to take breaks at certain times.

B. Type of *Vehicle Routing Problem* (VRP)

The following are several types of *vehicle routing problems*([5],[6],[7]):

1. *Vehicle Routing Problem, Multiple Trips* (VRPMT)
   This type of VRP allows more than one route to be worked within the boundary of the planning horizon. If the transported product has run out but the distribution process has not reached the planning horizon, the vehicle can return to the depot to refill capacity.
2. *Multiple Depot Vehicle Routing Problem* (MDVRP)
   This VRP uses more than one depot or warehouse that is scattered in its distribution area. The depot serves as a place for product collection and return. This type of VRP can minimize the occurrence of shortages and excess capacity on the way.
3. *Split Delivery Vehicle Routing Problem* (SDVRP)
   This VRP has another term, namely *Vehicle Routing Problem with Heterogeneous Fleet of Vehicles* (VRP HFV). This VRP also has a special characteristic, which is to use more than one type of transportation with various capacities. The purpose of this VRP is to minimize the number of vehicles and minimize

the total travel time.

C. *Nearest Neighbor Methods*

The nearest neighbor method is a simple method used to determine the delivery route with the working principles, the addition of shops that were located closest to the last consumer visit [1]. This can be done on the condition that the product in the transport capacity still can meet the demand for the product at the destination consumer. This method can be used if the mileage between each consumer and depot location, as well as the capacity conveyances already known. The steps are:

Step 1
Enter tour initiation (T) = 1 to start the first tour.

Step 2
Enter route initiation (R) = 1 to initiate the first route on tour T.

Step 3
Enter the depot according to the results of the customer.

Step 4
Select the vehicle and its capacity (K).

Step 5
Calculate the loading time (t_{load}) of products during the process of loading products into the vehicle and administration time (t_{adm}).

Step 6
Calculate completion time (C_t).

Step 7
Determine the location of the nearest consumer based on the smallest distance from the depot or the location of the previous consumer.

Step 8
Do a test whether the vehicle capacity (K) the number of targeted consumer demand (D_i). If "YES" then do the distribution to these consumers and continue to step 10. If "NO" then changes consumers and continue to step 9.

Step 9
Do a test whether the vehicle capacity (K) the number of targeted consumer demand (D_i). If "YES" then do the distribution to these consumers and continue to step 10. If "NO" then back to step 4 to replace the vehicle with a larger capacity.

Step 10
Calculate the distance and travel time from the distance matrix and the time matrix between the origin depot or the last consumer to the destination consumer. Then calculate the unloading time (t_{unload}) of products of contents from the vehicle to the consumer and the loading time (t_{load}) of empty products from the consumer to the vehicle, as well as the administration time (t_{adm}).

Step 11
Same as step 6

Step 12
Test whether the completion time (C_t) planning horizon (HP). If “YES” then go to step 13. If “NO” then go to step 17.

Step 13
Do a test to see if the capacity is still there (K> 0). If "YES" then return to step 7 to continue distribution to other consumers. If “NO” then return to the original depot and continue to step 14.

Step 14
Same as step 10

Step 15
Same as step 6

Step 16
Test whether the completion time (C_t) planning horizon (HP). If "YES" then do the addition of routes with route initiation (R) = R + 1 and back to step 3. If "NO" then goes to step 17.

Step 17
Delete the last customer location because the completion time has exceeded the planning horizon. Then return to the original depot and proceed to step 18.

Step 18
Same as step 10

Step 19
Same as step 6

Step 20
Test whether the completion time (C_t) planning horizon (HP). If “YES” then proceed to step 21. If “NO” then return to step 17.

Step 21
Test whether there are still consumer requests that have not been delivered (D> 0). If “YES” then do additional tours with tour initiation (T) = T + 1 and return to step 2. If “NO” then nearest neighbor is done.

D. ***Simulated Annealing Algorithm***

The simulated annealing algorithm is formed based on the analogy of cooling simulations of solid substances such as metals and solutions to large combinatorial optimization problems [3]. The cooling process (*annealing*) is a physical process when a solid substance is heated with a temperature that continues to increase to a maximum so that all the particles are arranged into a *liquid* phase, then the cooling process will take place with decreasing temperature. In this phase, the entire particles are structured with low energy on geometric bonds and generate a high enough temperature and produce cooling results slowly cooling.

The cooling process (*annealing*) can be described through the following statement. At any temperature *T*, the solid will reach thermal equilibrium. It is marked by the probability with a total energy *E* which can be calculated using the following Boltzmann distribution:

$$Pr\ \{E{=}E\} = \frac{1}{Z(T)}.exp\left(-\frac{E}{k_B T}\right) \quad (1)$$

At any temperature T, the solid will reach thermal equilibrium. It is marked by the probability with a total energy *E* which can be calculated using the following Boltzmann distribution: The value of *Z(T)* is a normalization factor or partition function which depends on the temperature T and k_B is the Boltzmann constant. Factor $exp\left(-\frac{E}{k_B T}\right)$ is a factor of Boltzmann. When the temperature decreases, the Distribution of Boltzmann will focus on the condition of the lowest energy, and finally, when the temperature approaches zero, only the minim energy which has a probability of occurrence is not zero.

III. RESULT

The following describes the process of collecting and processing data to solve distribution problems using thenearest neighbor and simulated annealing methods.

A. Data

The characteristics of *Vehicle Routing Problem* (VRP) problem in this study included the type of *Multiple Depot Vehicle Routing Problem* (MDVRP), *Vehicle Routing Problem Multiple Trips* (VRPMT), and *Vehicle Routing Problem with Heterogeneous Fleet of Vehicles* (VRPHFV) [8]. The detail explanation of the data collected are:

1. Depot (Warehouse)
   Depot at the company is a distribution warehouse that is used as a starting point for product delivery. In this case, it is limited to only two depots.
2. Consumers
   This study uses demand data from the general consumer types. Depot 1 with 83 consumers and depot 2 with 73 consumers.
3. The Vehicle Capacity
   The vehicles used for distribution consist of three types, namely the with large vehicle capacity of 100 units, a box truck with a capacity of 250 units, and a *double truck* with a capacity of 500 units.
4. Loading time, unloading time, and administration time.
   There are two types of loading and unloading time problems, they are filled products and empty products. Administration time is the time required to perform of administration process.
5. The Planning Horizon
   The planning horizon used in this study is the eight hours sales driver working time per day.
6. The route
   The route is a delivery sequence of product units to consumer according to the distribution area of the original depot.
7. Tour
   The tour consists of some of the routes on the planning horizon.

B. ***Initial Route Formation Using Nearest Neighbor Method***

Nearest neighbor method used in this study considers the vehicle type and capacity, and the amount of transported demand. Consumers will be grouped based on the number of requests with the following conditions.

1. The distribution for small orders (≤100) would be prioritized using large vehicles
2. The distribution for the large demand (>250) would be prioritized using the double truck
3. The distribution for medium orders (100-250) would be prioritized using truck box

The following was a recapitulation of the initial route using the nearest neighbor methods for depot 1 and depot 2 could be seen in Table 1 and Table 2.

TABLE 1
INITIAL ROUTE OF NEAREST NEIGHBOR METHOD DEPOT 1

Tour	No Route	Route	Distance (m)	*Completion Time* (hr)
1	1	A-50-48-A	8700	7,458
	2	A-74-62-A	13100	
	3	A-71-88-57-A	16550	
	4	A-2-108-A	12900	
	5	A-43-143-A	14000	
	6	A-75-115-A	12400	
2	1	A-20-37-A	19200	7,204
	2	A-102-A	12200	
	3	A-13-104-A	28300	
	4	A-99-58-A	20000	
	5	A-91-A	14400	
3	1	A-19-23-17-121-101-A	44200	7,926
	2	A-79-14-112-42-A	19300	
	3	A-33-35-A	19000	
4	1	A-61-100-153-A	50750	7,612
	2	A-45-105-A	24400	
	3	A-98-A	20800	
5	1	A-107-40-30-96-A	39100	6,757
	2	A-110-12-27-36-80-A	55300	
6	1	A-46-29-A	32300	7,855
	2	A-18-26-A	44400	
	3	A-103-97-A	34400	
7	1	A-72-4-34-A	59600	6,377
	2	A-68-85-139-A	42000	
8	1	A-60-A	35600	6,596
	2	A-8-116-A	69100	
9	1	A-82-A	41400	5,632
	2	A-70-89-A	57300	
10	1	A-16-39-55-28-A	27300	7,861
	2	A-25-92-93-86-87-A	24599	
11	1	A-47-56-15-77-59-A	22600	7,775
	2	A-11-32-22-76-A	20000	

TABLE 2
INITIAL ROUTE OF NEAREST NEIGHBOR METHOD DEPOT 2

Tour	No Route	Route	Distance (m)	*Completion Time* (hr)
1	1	B-84-127-135-126-133-B	10550	7,838
	2	B-142-124-147-B	13100	
	3	B-67-B	4800	
	4	B-51-154-150-129-148-137-B	19300	
	5	B-134-49-53-151-B	18800	
	6	B-122-B	6600	
2	1	B-132-52-83-146-140-B	24700	7,375
	2	B-130-149-144-155-136-9-B	18200	
	3	B-7-118-B	15800	
3	1	B-128-B	10200	7,184
	2	B-128-152-145-113-90-B	19190	
	3	B-125-24-65-117-3-B	29700	
4	1	B-10-6-109-66-B	53800	7,256
	2	B-54-5-B	13700	
	3	B-1-78-B	21300	
5	1	B-156-31-38-95-81-B	50800	7,556
	2	B-111-B	13800	
	3	B-111-119-B	21400	
6	1	B-63-94-114-B	22200	7,947
	2	B-44-B	16800	
	3	B-44-B	16800	
	4	B-21-B	20800	
7	1	B-41-120-106-138-B	51900	7,769
	2	B-123-131-141-64-B	76900	
8	1	B-73-69-B	53900	3,423

C. ***Route Improvement Using Simulated Annealing Algorithm***

Simulated annealing algorithm in this study used the maximum iteration value according to the number of consumers on the route being processed. Meanwhile, the $M_{axSucsess}$ value used in this study is two. Iterations to achieve $M_{axSucsess}$ was done by multiplying the value of $T_{time}$with dec$T_{time.}$ The decT_{time} value comes from simulated annealing *cooling rate*. Value decT_{timee} used in this study is of 0.95. The following was a recapitulation of the optimal route using *simulated annealing* algorithm for the distribution of depot 1 and depot 2 can be seen in Table 3 and Table 4

TABLE 3
ROUTE OF *SIMULATED ANNEALING* ALGORITHM
DEPOT 1

Tour	No Route	Route	Distance (m)	*Completion Time* (hr)
1	1	A-50-48-A	8700	7,459
	2	A-74-62-A	13100	
	3	A-57-88-71-A	16550	
	4	A-2-108-A	12900	
	5	A-43-143-A	14000	
	6	A-75-115-A	12400	
2	1	A-20-37-A	19200	7,204
	2	A-102-A	12200	
	3	A-13-104-A	28300	
	4	A-99-58-A	20000	
	5	A-91-A	14400	
3	1	A-19-23-17-121-101-A	44200	7,893
	2	A-14-42-112-79-A	18300	
	3	A-33-35-A	19000	
4	1	A-100-61-153-A	50550	7,613
	2	A-45-105-A	24400	
	3	A-98-A	20800	
5	1	A-107-40-30-96-A	39100	6,677
	2	A-12-80-36-27-110-A	52900	
6	1	A-46-29-A	32300	7,855
	2	A-18-26-A	44400	
	3	A-103-97-A	34400	
7	1	A-34-4-72-A	59600	6,377
	2	A-139-85-68-A	42000	
8	1	A-60-A	35600	6,596
	2	A-8-116-A	69100	
9	1	A-82-A	41400	5,632
	2	A-70-89-A	57300	
10	1	A-16-39-55-28-A	27300	7,861
	2	A-25-92-93-86-87-A	24599	
11	1	A-47-56-15-77-59-A	22600	7,775
	2	A-11-32-22-76-A	20000	

TABLE 4
ROUTE OF *SIMULATED ANNEALING* ALGORITHM
DEPOT 2

Tour	No Route	Route	Distance (m)	*Completion Time* (hr)
1	1	B-127-126-133-135-84-B	10000	7,820
	2	B-124-142-147-B	13100	
	3	B-67-B	4800	
	4	B-51-154-150-129-148-137-B	19300	
	5	B-134-49-53-151-B	18800	
	6	B-122-B	6600	
2	1	B-132-52-83-146-140-B	24700	7,375
	2	B-130-149-144-155-136-9-B	18200	
	3	B-7-118-B	15800	
3	1	B-128-B	10200	6,964
	2	B-128-152-145-113-90-B	19190	
	3	B-3-125-24-65-117-B	23100	
4	1	B-6-66-109-10-B	46700	7,020
	2	B-54-5-B	13700	
	3	B-1-78-B	21300	
5	1	B-156-31-38-95-81-B	50800	7,556
	2	B-111-B	13800	
	3	B-111-119-B	21400	
6	1	B-94-114-63-B	22200	7,947
	2	B-44-B	16800	
	3	B-44-B	16800	
	4	B-21-B	20800	
7	1	B-138-120-41-106-B	50800	7,732
	2	B-123-131-141-64-B	76900	
8	1	B-73-69-B	53900	3,423

The results of the comparison of the initial route using the nearest neighbor method with the repair route using the simulated annealing algorithm can be seen in Table 5.

TABLE 5
RESULT COMPARISON

Depo	Distance (m)		Total Time (hr)	
	Nearest Neighbour	*Simulated Annealing*	*Nearest Neighbour*	*Simulated Annealing*

1	955.199	951.599	79,308	78,940
2	625.040	609.690	56,348	42,782

In the actual conditions, the company implements a distribution system with a delivery area that is limited by the region according to the location of the depot and uses a certain scheduling system.

The delivery schedule is made by the company by estimating the expiration time (sold) of the products ordered by consumers in their consumers. When that time comes, the company will make a visit to the consumer as well as offer product refills. In addition, the company also accepts delivery schedules according to consumer wishes. Diverse delivery schedules and high demand make several delivery routes can be different on the same schedule. Schedule merging can also occur if the delivery period falls on the same day. This is like a customer with a schedule of every 2 days can be combined with the delivery on the 10th day with a customer who has a schedule of every 5 days. Conditions like this make irregular deliveries can even lead to delays due to too many requests on the same day. The total mileage generated based on the initial conditions is 1,941,529 meters. The calculation of this route is carried out on consumers with a delivery schedule of once every seven days. Delivery takes more than one day (> 8 working hours) so it can be said to be late.

The distribution system based on the research results can make the distribution area distribution and scheduling system better. The total mileage generated based on the proposed conditions is 1,561,289 meters. Delivery takes one day (< 8 working hours) so it can be said on time.

This aims to make deliveries more uniform and can use a fixed route according to schedule. The proposed route is also made to be effective and efficient in terms of time, cost, and other resources. While the uniformity of delivery can show the distribution priority that must be done. This results in a route with a shorter distance than the route from the company.

IV. CONCLUSION

Based on the results of the data collection, processing, and analysis that has been done, the following conclusions are obtained:

1. *Nearest neighbor* and *simulated annealing* algorithm are fairly good methods compared to other similar methods. The problem solving also can use heuristic methods, metaheuristic methods, analytical methods, and exact (numerical) methods.
2. The *nearest neighbor* method generates initial routes of 19 tours and 57 routes with a total mileage of 1,580,239 meters, a total time of 136 hours, and a work utility of 88.938%.
3. The *simulated annealing* algorithm generates an optimal route with a total mileage of 1,561,289 meters, a total time of 122 hours, and an average work utility of 87.474%.
4. The route improvement by annealing simulation algorithm provides a total mileage of 18,950 meters, a total time of 13,934 hours, and a work utility decrease to 2,928%.
5. The research results map better division of the distribution area and better scheduling system so that the resulting distribution route proposal can solve existing problems effectively and efficiently.

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