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Analysis of Book Distribution Routes Using the Capacity Vehicle Routing Problem (CVRP) Method Using the Sweep Algorithm

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Abstract: Distribution is the process of distributing products from producers to consumers. The ease of consumers in obtaining the desired product is the top priority of every company. In the distribution system, the chosen route is the most important element in determining the distance to be traveled and the costs to be incurred. If the chosen route is optimal, then the distribution system becomes more effective and efficient. Basedon the results of the author's observations, the delivery of goods in the company is still manual and irregular, where the goods are sent from the depot to the consumer and back to the depot so that it takes a lot of time and costs. One solution in solving the distribution problem is the Capacity Vehicle Routing Problem (CVRP). The Sweep algorithm is the simplest clustering method to solve CVRP. In this study, the author used a sweep algorithm because this algorithm is one of the methods that can solve the problem of the distribution route of Quranic books. Based onthe results of the study, researchers compared the distribution route usingthe sweep algorithm and the distributionroute of the previous company, obtained a percentage of total mileage savings of 35.35%, namely from the previous total company mileage of 135.2 Km to 87.4 Km by using the Sweep algorithm. This shows that the CVRP method using the sweep algorithm can provide optimal distance and save company expenses.

Keywords: CVRP; Sweep algorithm; Distribution; Route; Distance

INTRODUCTION

Distribution is the process of distributing products from producers to consumers. The ease of consumers in obtaining the desired product is the top priority of every company to satisfy its customers(Tjaja & Saiful, 2021). Good distribution and transportation are important so that the product can be delivered to the consumer in a timely manner, right at a predetermined place and the product is in good condition. In the distribution system, the chosen route is the most important element in determining the distance to be traveled and the costs to be incurred(Patmawati & Nugroho, 2022). If the route chosen is optimal, then the distribution system becomes more effective and efficient because it will pass a route with a minimum distance, so that elements involving distance are minimal as well, such as transportation costs, travel time, the level of pollution produced, and energy expended. One of the companies engaged in distribution is CV WirakaryaTalenta.

CV WiraKaryaTalenta is the official distributor of quranic books written for madrasah and school levels in the city of Medan. Based on the author's observations, the delivery of goods is carried out manually and irregularly where the goods are sent from the depot to the consumer and back to the depot so that it takes a lot of time and costs. Distribution problems are part of the problem of providing goods or services from warehouses to be sent to consumers(Dian, 2022). One solution in solving the distribution problem is *Capacity Vehicle Routing Problem* (CVRP).

Capacitated Vehicle Routing Problem (CVRP) is one of the most common variations of the VRP problem, where there is an additional constraint in the form of vehicle capacity that is *homogeneous* (identical) to visit a number of agents according to the request/*demand* respectively. The CVRP problem has the purpose of minimizing the total mileage of the vehicle travel route used in distributing goods from the place of delivery (depot) to each agent. Based on this, the author is interested in conducting a study entitled Book Distribution Route Analysis with the *Capacitated Vehicle Routing Problem* (CVRP) Method on CV WiraKaryaTalenta in Medan City. In this case using the *Sweep*Algorithm , which aims to find the shortest route in distributing the book of the Quran Tulis to the destination school.(Fatnita& Lukmandono, 2020)

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LITERATURE REVIEW

Vehicle Routing Problem (VRP)

VRP is used to define multiple routes where each route is carried out by a vehicle that starts the journey from the depot to end at the depot to meet consumer demands and orders without violating restrictions in order to reduce transportation costs(Chandra & Setiawan, 2018). The total of each customer request and order in one delivery does not exceed the predefined capacity limit. (Sopian, 2020)

According to Toth and Vigo, there are several characteristics in a VRP that need attention. The following are the component components contained in the VRP:

a. Network (*link*)

In transport on a route, each available road is a working network (links) and each location represents each *node*. *Link* can be lived in one direction (*directed*) or bidirectional (*undirected*). Each *link* relates to the length or time of the trip, the type of vehicle and the time period of travel made on *of that* link so that *link* can be said to relate to costs.

b. *Costumers*

The specific characteristics of *costumers* are as follows:

1. The number of requests (*demand*) of *costumers* varies, there are *costumers* whose number of requests is known for certain (deterministic cases) but there are also uncertain number of requests (stochastic cases).
2. There are *costumers*who have *time windows* which is a time period indicating the period of time *costumers* can be served due to the special time period of *costumers* .(Kushariyadi & Sugtito, 2022)

c. depot

Depot is the starting and ending point of a route to be taken in delivering goods to *customers*. Each depot is characterized by the type and number of vehicles associated with the depot as well as the number of items available there.

d. Vehicle (*vehicle*)

The specific characteristics of *costumers* are as follows:

1. Have maximum vehicle capacity (maximum weight and volume) in transporting goods.
2. Have a total working time from the beginning of departure from the depot until arrival back to the depot, according to the regulations imposed by the company for the driver's working hours (time *loading*) and a number of time periods that are not taken into account (time *nonloading*), e.g. driver rest time.
3. Requiring a fee to make a delivery, the cost of using the vehicle is calculated on a per unit of distance, per unit of time, and per route.

e. Driver (*driver*)

The driver operating the vehicle must meet all the constraints set out in the employment contract and the rules of the company. (Nugroho & Yatmoko, 2021)

Capacitated Vehicle Routing Problem (CVRP)

Capacitated Vehicle Routing Problem (CVRP) is the most basic form of VRP, which can be seen as a formulation of two well-known pre-existing problems namely, *Travelling Salesman Problem* and *Bin Packing Problem*. First introduced through a paper entitled " *The Truck Distpaching Problem*", CVRP as the most basic form of VRP, has attracted a lot of attention for scientists to research about the problem. (Muna, 2022)

CVRP or *capacitated vehicle routing problem* is a problem related to determining the optimal route by paying attention to the constraints of each vehicle having a certain capacity. 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 as to improve the company's ability to meet product demand more quickly so that consumer trust and satisfaction increase.(Kushariyadi& Sugtito, 2022)

Distribution

Distribution is the flow through which goods pass from the manufacturer or seller until they reach the user. Tandjung argues that a distribution channel is a road or route that a product travels from the manufacturer to the hands of the end customer. Distribution is an activity of sending goods or products from a producer to consumers. The distribution process is influenced by certain factors to run smoothly, such as distribution systems, distribution routes and distribution transportation(Kasus et al., 2022). The distribution process must have obstacles, one of which is a suboptimal route so that there are complaints from consumers in the form of delays in the arrival of goods. In addition, the magnitude of the cost of transportation expenses. Reducing transportation costs, optimal transportation routes are needed to minimize mileage. A route is defined as a simple

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cycle of the s graph passing through depot 0 and so that the total demand of the nodes visited is no more than the predefined capacity.(Ammalia, 2022)

METHOD

Algorithm Sweep

The *sweep* algorithm is an algorithm using a two-phase method with the first phase being *clustering* customers based on regions and available vehicles, and the second phase being constructing routes for each *cluster*(Taptajani, 2021). The *Sweep* algorithm is a type of metaheuristic method that has an independent *problem* which means it does not depend on the subject matter, this method is often integrated with heuristic methods for its implementation(Ammalia, 2022). In completing the VRP model using the *sweep* algorithm, two stages or phases are needed, namely the clustering phase (*clustering*) and the establishment of the following route.(Nugroho & Yatmoko, 2021)

1. Grouping Stages (*Clustering*)
   The steps of the grouping stages are:
   a. Describe each agent in cartesian coordinates and set the location of the depot as the coordinate center.
   b. Specifies all the polar coordinates of each agent associated with the depot. Step to convert cartesian coordinates (*x, y*) to polar coordinates (*r,*) as follows:

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

$$\theta = arc\ tan\ \frac{y}{x} \quad (2)$$

   c. Grouping (*clustering*) starts from the agent that has the smallest polar angle and so on sequentially to the agent that has the largest polar angle with regard to the capacity of the vehicle.(Rozalina et al., 2020)
   d. Ensure all agents are "swept away" in the current *cluster* .
   e. Grouping is stopped when in one *cluster* it will exceed the capacity of the vehicle.
   f. Create a new cluster with the same steps as step c from the agent that has the smallest polar angle that has not been included in the previous *cluster* (the last abandoned agent).
   g. Review steps c – f, until all agents have been included in a *cluster*.(Nugroho & Yatmoko, 2021)
2. Route Formation Stage
   The second stage in the *sweep* algorithm is to form routes based on *clusters* that have been obtained in the *clustering*stage. Each cluster will be served by one vehicle on each route to be obtained. Each *cluster* will be a TSP problem so that the completion of the route formation stage will be carried out by the method *Nearest Neighbour*. (Paillin, 2021)

RESULTS

The calculation of the distance can be done by the calculation of the distance *Euclidean*. *Euclidean distance* is a calculation of the distance of two points in *Euclidean space* that studies the relationship between angle and distance. Here is the equation *Euclidean distance* :

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

Notes:

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

The first step in the grouping stage in the sweep algorithm is to describe each agent and depot in a cartesian diagram and establish the location of the depot as the coordinate center. CV WiraKaryaTalenta as a depot is placed at coordinates (0,0) on a two-dimensional plane. At this stage, the depiction and determination of coordinate points is carried out with the help of *software* QGIS. The areas of agents and depots after being described in the cartesian diagram can be seen in the figure below.

Agent and Depot Regions Image

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Polar angle search can be done using the help of *software* QGIS. The calculation of the angle is carried out counterclockwise with the help of QGIS software tools to find *measure angle*. The calculation of the angle is carried out by making a straight line from the central point i.e. the depot to the coordinate point of the agent and a straight line against the x-axis.

Grouping (*clustering*) starts from the agent that has the smallest polar angle and so on sequentially to the agent that has the largest polar angle with regard to the capacity of the vehicle. The order of polar angles by the number of weight of each agent's delivery requests can be seen in the table below.

Polar Angle Table

No	School	Distance (KM)	Lattitude	Longitude	θ (°)	Weight (kg)
1	MIN 1	8,1	3,59986049	98,70680509	154,992	103
2	MIN 2	21,2	3,72423482	98,68478426	177,26	44
3	MIN 3	8,6	3,61119892	98,67967606	177,559	64
4	MIN 4	8,6	3,61112606	98,67076519	175,474	74
5	MIN 5	26,7	3,77374873	98,68188243	178,643	54
6	MIN 6	7,6	3,58323451	98,62825156	135,967	52
7	MIN 7	7,4	3,58483282	98,71858892	140,01	64
8	MIN 8	6,8	3,59206962	98,65784170	162,59	27
9	MIN 9	5,3	3,51557680	98,71910376	67,434	79
10	MIN 10	24,5	3,75336044	98,69419144	175,327	31
11	MIN 11	4,6	3,55291312	98,63853489	117,922	52
12	MIN 12	9,2	3,59334177	98,73266569	136,252	95

Grouping (*clustering*) starts from the agent that has the smallest polar angle and so on sequentially to the agent that has the largest polar angle with regard to the capacity of the vehicle. The order of polar angles by the number of weight of each agent's delivery requests can be seen in the table below.

Polar Angle Table

Polar Angle (°)	Point	Weight (kg)
67,434˚	MIN 9	79
117,922˚	MIN 11	52
135,252˚	MIN 12	95
135,967˚	MIN 6	52
140,01˚	MIN 7	64
154,992˚	MIN 1	103
162,59˚	MIN 8	27
175,327˚	MIN 10	31
175,474˚	MIN 4	74
177,26˚	MIN 2	44
177,559˚	MIN 3	64
178,643˚	MIN 5	54

Based on the order of polar angles, agents are grouped into routes with an eye on the demand and capacity of the vehicle. Grouping all agents from the smallest to the largest polar angle. Grouping is carried out counterclockwise. Grouping is stopped when in one cluster it will exceed the capacity of the vehicle. The grouping of each agent is carried out by order of polar angles until the capacity is met. If the vehicle capacity is insufficient, the agent will be put into the next group. And so on until the whole agent was swept away. The route groups formed are shown in the table below.

Route Group Table

Vehicle Route	Agent	Request (kg)	Number of Requests (kg)
1	MIN 1	103	739
	MIN 2	44	
	MIN 3	64	
	MIN 4	74	
	MIN 5	54	
	MIN 6	52	
	MIN 7	64	

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	MIN 8	27	
	MIN 9	79	
	MIN 10	31	
	MIN 11	52	
	MIN 12	95	

Based on clustering tables can be divided into one group of submissions. This is because the capacity of vehicles still has free space to transport the demand for blood bags in each school. The number of requests to be sent to all schools is 739 kg.

Route Formation Stage

At the route formation stage, the first, second and third groups that have been obtained at the grouping stage will be completed using the *Nearest Neighbour* method so that the best route will be obtained on each group. The steps in determining the formation of the route are:

1. Initializing
   a. Determining a point that will be the starting point of the journey where in this research it has been determined that the starting point of the journey starts from the beginning of the company's depot.
   b. Specifies $C = \{1,2,3,4,\ldots,n\}$ as the set of visited points.
2. The selection of the next point.
   If n_1 is the point that is in the initial order of the R route, the next point will be found, n_2 which has the minimum distance with $n_1$where n_2 is a member of C. If there are many optimal options, it means that there is more than one point that has the same distance from the last point in the R route and that distance is the minimum distance then choose it randomly.
3. Close the route.
   If all the points to visit have been included in the route or $C = \emptyset$, then no more points exist in C. Next close the route by adding an initialization point or start point of travel at the end of the route. In other words, the route is closed by returning again to the point of origin. If it's the other way around, revert to doing step 1.

Route 1

The first route starts from point 0 or depot, namely CV WiraKaryaTalenta to the agent and then back to the depot. $C = \{11,6,8,4,3,1,7,12,9,2,10,5\}$.

Mileage Table From Depot To Agent Area (in Km)

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
0	**0**	8.1	21,2	8,6	8,6	26,7	7,6	7,4	6,8	5,3	24,5	4,6	9,2
1	8,1	**0**	14	3,3	4,2	19,5	8,9	2,1	5,5	9,5	17,1	9,2	3
2	21,2	14	**0**	12,6	12,7	5,5	16,9	15,9	15	23,5	3,4	19,7	15,5
3	8,6	3,3	12,6	**0**	1	18,1	6,5	5,2	3,2	11,5	15,9	7,9	6,2
4	8,6	4,2	12,7	1	**0**	18,1	5,6	6,1	2,6	11,9	16	7,4	7,1
5	26,7	19,5	5,5	18,1	18,1	**0**	22	21,4	20,4	29	2,6	25	20,9
6	7,6	8,9	16,9	6,5	5,6	22	**0**	10	3,4	12,6	20,3	3,6	11,6
7	7,4	2,1	15,9	5,2	6,1	21,4	10	**0**	6,8	7,7	18,9	9,6	1,8
8	6,8	5,5	15	3,2	2,6	20,4	3,4	6,8	**0**	10,9	18,4	4,9	8,3
9	5,3	9,5	23,5	11,5	11,9	29	12,6	7,7	10,9	**0**	26,6	9,9	8,8
10	24,5	17,1	3,4	15,9	16	2,6	20,3	18,9	18,4	26,6	**0**	23,1	18,3
11	4,6	9,2	19,7	7,9	7,4	25	3,6	9,6	4,9	9,9	23,1	**0**	11,4
12	9,2	3	15,5	6,2	7,1	20,9	11,6	11,6	8,3	8,8	18,3	11,4	**0**

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The routes formed by using *Nearest Neighbour* are:

a. The route starts from the depot (point 0). The closest point to point 0 is point 11, so the temporary route formed is 0 – 11 with a distance of 4,6 Km.
b. The closest point to point 11 is point 6, so the temporary route formed is 0 –11 – 6 with a distance of 3,6 Km.
c. The closest point to point 6 is point 8, so the temporary route formed is 0 –11 – 6 – 8 with a distance of 3,4 Km.
d. The closest point to point 8 is point 4, so the temporary route formed is 0 –11 – 6 – 8 – 4 with a distance of 2,6 Km.
e. The closest point to point 4 is point 3, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3 with a distance of 1 Km.
f. The closest point to point 3 is point 1, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1with a distance of 3,3 Km.
g. The closest point to point 1 is point 7, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1 – 7with a distance of 2,1 Km.
h. The closest point to point 7 is point 12, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1 – 7 – 12 with a distance of 1,8 Km.
i. The closest point to point 12 is point 9, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1 – 7 – 12 – 9 with a distance of 8,8 Km.
j. The closest point to point 9 is point 2, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1 – 7 – 12 – 9 – 2 with a distance of 23,5 Km.
k. The closest point to point 2 is point 10, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1 – 7 – 12 – 9 – 2 – 10 with a distance of 3,4 Km.
l. The closest point to point 10 is point 5, so the temporary route formed is 0 –11 – 6 – 8 – 4 – 3– 1 – 7 – 12 – 9 – 2 – 10 – 5 with a distance of 2,6 Km.

h route starts and ends at the depot, then the route 1 sequence is 0 – 11 – 6 – 8 – 4 – 3 – 1 – 7 – 12 – 9 – 2 – 10 – 5 – 0 with a distance of 87.4 km.
Then the route of the results using the *sweep* algorithm can be seen in the table below.

Sending Route Table Using *Sweep*Algorithm

No	Route	Weight (kg)	Mileage (km)
1	0 –11 – 6 – 8 – 4 – 3 – 1 – 7 – 12 – 9 – 2 – 10 – 5 – 0	739	87,4

Route comparison using *sweep* algorithm with enterprise route

The routes obtained from Company As many as 2 routes of delivery of goods with 1 vehicle.

Enterprise Route Table

No	Route	Weight (kg)	Mileage (km)
1	0 – 1 – 2 – 4 – 6 – 9 – 0	352	58,3
2	0 – 3 – 8 – 7 – 5 – 10 – 12 – 11	387	76,9
	Total	739	135,2

From the table above, a comparison of company routes and routes using the *sweep* algorithm is obtained as follows.

Company Route Mileage Comparison Table and Route Algorithm *Sweep*

Route	Company Route Mileage (km)	Route Mileage Algorithm *Sweep* (km)
1	58,3	87,4
2	76,9	
Total Mileage (km)	135,2	87,4

Based on the route using the *sweep* algorithm and the route from the company, the percentage of total mileage savings is obtained as follows.

$$= \frac{the\ total\ route\ distance\ of\ the\ sweep\ algorithm\ -\ the\ total\ route\ distance\ of\ the\ sweep\ algorithm}{the\ total\ route\ distance\ of\ the\ sweep\ algorithm} \times 100\%$$

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$$= \frac{135{,}2 - 87{,}4}{135{,}2} \times 100\%$$
$$= 35{,}35\%$$

Thus, a percentage of total route mileage savings of 35.35% was obtained. This shows that the sweep algorithm can minimize the distance which also saves the company's expenses.

CONCLUSION

The establishment of a distribution route for qur'an written books in the city of Medan using the *Sweep* Algorithm to obtain optimal results and minimal mileage is as follows.The route formed based on *Map* above is centered fromCenter – MIN 11 – MIN 6 – MIN 8 – MIN 4 – MIN 3 – MIN 1 – MIN 7 – MIN 12 – MIN 9– MIN 2 – MIN 10 – MIN 5 – Center. The results of the discussion carried out using the Method Algorithm *Sweep*, can minimize the distance by 47.8 km. The initial distance before use of the *Sweep* Algorithm Method was 135.2 km. With the Sweep Algorithm Method obtained distribution repair route with a distance of 87.4 km.

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