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Capacitated Vehicle Routing Problem In Optimization Of Waste Truck Routes Using The Particle Swarm Optimization Algorithm

Siti Rahmi Rambe[1)*], Fibri Rakhmawati[2)]
[1,2)]Universitas Islam Negeri Sumatera Utara Medan
[1)]siti0703192025@uinsu.ac.id , [2)]fibri_rakhmawati@uinsu.ac.id

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Abstract: In this research process, the aim is to determine the shortest route for transporting waste with the shortest or minimum total distance. In this case, what must be considered is the transportation of waste, regarding the distance between the location of the waste source to the landfills. The problem of waste transportation routes can be made in a mathematical method. The method used in waste transportation is the Capacitated Vehicle Routing Problem (CVRP) method. In solving the problem of transporting waste using the CVRP method, distance must be minimized or optimized using the Particle Swarm Optimization Algorithm. On the initial route of work area 1 there is the o-p-q-r-s-o route which has a total distance of 133.5 Km, in which there are several villages such as the Mambang Muda TPA - Belungihit Village - Aek Hitetoras Village - Brussel Plantation Village - Aek Tapa Village - Mambang Muda TPA. And after the latest garbage transportation route uses the PSO algorithm, the optimal distance is 132.5 Km with the o-s-q-r-p-o route where the village is Mambang Muda TPA - Aek Tapa Village - Aek Hitetoras Village - Brussels Plantation Village - Belungihit Village - Mambang Muda Landfill. In WK 2 there is an initial route o-p-q-r-s-o which has a total distance of 153.9 Km, in which the route has several TPA Mambang Muda villages - Marbau Village - Lobu Rampah Village - Simpang 4 Village - Pernantian Plantation Village - Mambang Muda TPA. And after the latest garbage transportation route uses the PSO algorithm, the optimal distance and route is 127.7 Km. In work area 3 with the initial route and distance of 150 and after using the PSO algorithm, the optimal route and distance is 137.1 Km. In work area 4 with a route and distance of 127.8 Km, the optimal route and distance using the PSO algorithm is 149.8 Km. Work area 4 has a route and initial distance of 157.8 Km and the optimal PSO route and distance is 149.8. The 5th working area has an initial distance of 180.3 and the PSO route is 134.3 Km. The working area of the 5 initial routes is 152.4 Km and the PSO route is 152.4.

Keywords: CVRP, Optimization, PSO, Transportation Routes.

.INTRODUCTION

Waste is part of the remains of human activity as well as the remains of natural processes and waste or goods that are no longer used. There are two different categories of waste, namely: organic and inorganic. Organic waste refers to easily degradable waste materials, usually from food waste, vegetables and fruits. Inorganic waste is waste that takes a long time to decompose, such as plastic, glass, metal and ceramics. Garbage allowed to accumulate causes natural damage such as air pollution, beauty damage, various diseases, floods, sewage blockage, etc.

*name of corresponding author

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In this case, it can be seen that the amount of garbage in the city of Marbau increases every year due to the increase in population. The current population of Marbau is about 36,532 people with an area of 355.90 km2 and there are 18 villages in Marbau sub-district (*Badan Statistik Kabupaten Labuhan Batu Utara*, 2019) .Basically, a lot of waste is generated by plant tax, which is created every day in different places (migration), and by household waste. It cannot be denied that floods occur frequently in Marbau Sub-Division, North Labuhanbatu and they always hit several villages such as Lobu Rampah Village, Simpang Empati Village, Kampung Jawa Village, Aek Tapa Village, Babussalam Village, Belongkut Village, Pulo Bargot Village. This happened because the river overflowed and the water could not flow because the ditch was blocked by debris.

Until now, Marbau sub-district is one of the areas that always suffer from flooding due to the increasing piles of garbage and improper cleaning services in Marbau sub-district, so this problem is solved by the method of Capacity Vehicular Road Problem (CVRP) This method includes a method to optimize garbage truck routes so that no storage location is missed. Solutions are provided so that the waste transportation carried out by officers is carried out properly, and makes it easier for officers to determine the optimal route and not waste work time,

The Condenser Vehicle Routing Problem is a fundamental concept in computing routing decisions and shows similarities to the Vehicle Routing Problem. According to Cahyaningsih, CVRP refers to an optimization problem that aims to find the shortest route with the least cost and certain characteristics set before the distribution process. Each means of transport is assigned only once, namely from the central location to each agent, then back to the central location (Cahyaningsih, Sari, & Hernawati, 2015)

In the study by Pratama et al Capacity Vehicle Routing Problem method can be applied to transport demand problems with limited car capacity. PT. Tiga Serangkai Pustaka Mandiri is a company specializing in book printing, publishing and distribution. The company has a comprehensive marketing system. To ensure efficiency, the system must be optimized to identify the most suitable routes and reduce the total cost of distribution(Pratama, Utomo, & Wibowo, 2022). Therefore, the research carried out by the researchers is the optimization of routes, distances and weights using the PSO algorithm.

Particle Swarm Optimization (PSO) is a type of intelligent algorithm inspired by the behavior of foraging birds(Hafidz, 2021). It is an evolutionary computational method that can generate global optimal solutions through the interactions of individual clustered particles(Putra. F.D, 2021). Each particle sends its best positional information to other particles and adjusts its position and velocity based on the received information(B, 2021). PSO can be visualized as a group of birds randomly feeding in a given area with only one meal. Birds do not know the location of food, but they do know the distance they can travel to eat and rest. Therefore, the most effective foraging strategy is to follow the bird closest to the food (Amin, 2020).

The purpose of this study was to optimize the cleaning service truck route in the Marbau sub-district by applying the Capacitated Vehicle Routing Problem method using the Particle Swarm Optimization algorithm in the garbage transportation route in the Marbau sub-district.Benefits of research can assist the Sanitation Service in determining the route of waste transportation from the place of origin to the final disposal site .Can help the community in overcoming air pollution and flooding caused by garbage.Can be used as a reference for developing insights, especially in the field of mathematics regarding mathematical calculations using the Capacitive Vehicle Routing Problem method using the Particle Swarm Optimization Algorithm.

LITERATURE REVIEW

One of the variations of the Vehicle Rounting Problem problem is the Capacitated Vehicle Routing Problem which uses capacity limits on the number of vehicles used. In this case each vehicle has a limited transport capacity. Each vehicle distributes waste once, namely from the central point to each destination point (market) and then returns to the central point, so that a distribution system for determining routes becomes more effective and efficient(Mappa & Sudaryanto, 2019).

Capacitated vehicle routing problem is a problem where there are a number of customer points or cities and a number of vehicles that are at one depot whose route must be determined in order to be able to serve all customers with capacity limits on each vehicle and get minimum costs. Capacitated

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vehicle routing problem is one of the NP-Hard problems, namely a problem that requires a large computational effort along with increasing the scope of the problem, in this case the number of customer points or cities. Because of this it is not possible to use exact methods to solve it.

The goal of the CVRP framework is to reduce the distance each vehicle travels at K. This equation is expressed as: $z = \sum_{k \in K}^{n} \sum_{i \in K}^{n} \sum_{j \in K}^{n} C_{ij} x_{ij}^{k}$ (1)

Particel Swarm Optimization was inspired by natural phenomena originating from observations of the behavior of flocks of birds and fish. The behavior of a bird and fish in a flock is called a swarm which is influenced by the social behavior of the organism. What is meant by social behavior is individual behavior or action as well as group action. In the Particel swarm optimization algorithm, a bird in a flock is called a particle. Each individual also behaves with his own intelligence (intelligence) and is influenced b group behavior (Budi, 2013).

In Particel swarm optimization, each particle or swarm moves in a certain space to find the right path or the best point needed to reach a food source (can be represented as an objective function value), then other particles or swarms follow that path even though the place is very far away based on the available information source. obtained. Even though flocks of birds are relatively less sophisticated with their limited abilities (intelligence), this ability can achieve the ultimate goal of solving problems related to behavior patterns and interactions through various sources of information .

Use the formula below to update the speed.

$$v_{ij}^{(t+1)} = v_{ij}^{(t)} + c_1 r_{1j}^{(t)} \left(P_{best,i}^{(t)} - X_{ij}^{(t)}\right) + c_2 r_{2j}^{(t)} \left(G_{best,i} - X_{ij}^{(t)}\right) \quad (2)$$

Where
vi,j = the jth velocity component of the ith entity in d dimension
W = parameter for inertial weight
C1, C2 = constants with values ranging from 0 to 1
r1, r2 = random values between 0 and 1
Pbest = Pbest (local best) – the best value of the particle temporarily
Gbest = Gbest (local best) - the best particle value among all Pbest values.

Citing international journals, there are also several studies raising the issue of vehicle routing problem, such as the study conducted by Hannan. This study raises the issue of Capacitated vehicle routing problem in relation to the route of waste collected from a collection point and then transported to a landfill. The proposed method uses the Particel swarm optimization algorithm(Hannan, Akhtar, begum, hussain, 2018).

This study raises the question that in today's era of rapid urbanization, people's daily activities produce large amounts of waste. As a result, CO2 emission increases, which can cause global warmin(Hartono, Puspita, 2018). This problem must be solved immediately by proper waste management. This includes determining efficient waste transport routes from the waste collection point to the landfill. However, without a clear system, most garbage trucks take inefficient routes, which increases transportation costs. Development of data mining market basket analysis methods to determine product placement models for management systems. The method proposed in this study creates a root optimization system for garbage collection using a particle swarm optimization algorithm. Based on the results of this study, the Capacitated vehicle routing problem model system can optimize routes by minimizing the distance traveled and the total cost. Systems using the Waste Threshold (TWL) model can reduce costs by almost 20% and travel by 4% compared to other systems. The difference between the survey conducted in this study is that this study only focuses on destinations and routes determined by distance. The factors that determine the path of this research are not sector specific either. This study explores several other business research-based route definitions. The determining factor is not only the distance on the route, but also different vehicle volumes, different product quantities, customer delivery priorities, driver working hours and intervals of certain customer delivery requests (Hartono, Puspita, 2018).

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METHOD

Research materials were taken and collected directly from the study site and were extracted and collected as data related to the variable under study, the route between waste transport sites to the TPA. The steps of the study can be seen in the flowchart below:

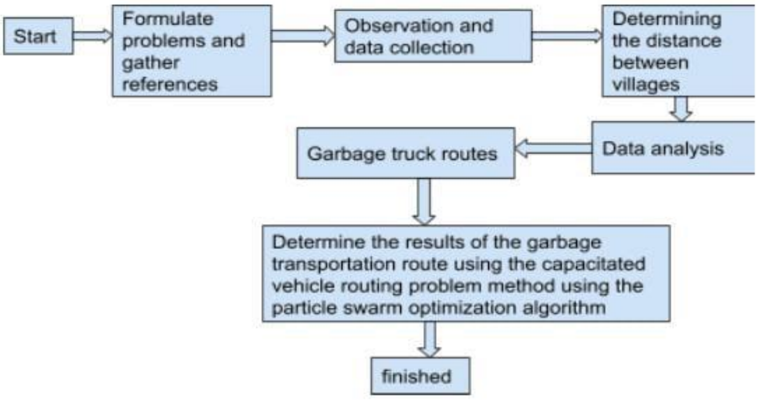

FIGURE 1. FLOWCHART

Research data collection is based on two types of data namely primary and secondary data. Primary data was collected through interviews and direct observation. The interviews completed research information that was not included in the corresponding official documentation. Direct observation involves observing work processes in the field and includes data on transit time, also known as fleet transit time.

While secondary data is obtained from official documents to support the research. Including searching for service information in the form of waste transport service distance and time. In addition, communication with operational personnel through the garbage collection system and consultation with temporary dump officials regarding the arrival schedule of garbage trucks. Other secondary data include the number of temporary dump in the area, travel plans during the transport process and the number of equipment/vehicles owned by the Ministry of Environment. This study uses an applied research methodology based on quantitative data analysis. Quantitative data refers to numerical variables that can be directly measured. This study uses secondary data obtained from an environmental service provider, Labuhanbatu Utara, and applies the particel swaram optimization algorithm to a capacitated vehicle routing problem mathematical model. The decision variables of the particel swaram optimization model are set to determine the optimal route for each vehicle such that each route starts and ends at a specified location. The query variables are then defined as follows:

Objective function value : the value of the distance traveled
Xz : matrix distance between villages
Particle : xy value to be optimized (optimal distance)
Pbest : Provisional best particle value
Gbest : Pbest best particle value. Number of Cells: The number of cells

Optimization is a field of mathematics that concentrates on systematically finding a minimum or maximum value in various scenarios by looking for features, prospects, and other values. Optimization is very useful in almost every domain for the efficient and effective operation of your business in achieving the desired results. This is of course done in line with the economic principle of always trying to minimize costs while still achieving the highest results. This optimization is also important because competition in all fields is very tight (Sistem et al., 2018).

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Another alternative form of the Vehicle Routing Problem problem is the Capacitated Vehicle Routing Problem , which imposes a limit on the number of vehicles used by limiting their capacity. Here, each fleet has a limited capacity. The duties of each vehicle include distributing waste from the central point to each destination (market) only once, before returning to the central point, ensuring that the distribution system operates more effectively and efficiently (Mappa & Sudaryanto, 2019). Capacitated Vehicle Routing Problem is a problem with many points or cities of customers, many vehicles in one depot, and limits on capacity per vehicle to serve all customers and minimize costs. The question is which route to define for Capacitated Vehicle Routing Problem is one of the NP-hard problems. . That is, it is a computationally intensive problem while broadening the scope of the problem (in this case, the number of customer points or cities). Because of this, it cannot be solved using proper methods. In research, CVRP is formally defined as an undirected graph G = (V, E), where V = {0,1, … , n} denotes a group of nodes and E = { i , j:i ,j V,i and i ; j} represents the edge set. Nodes 1,...,n stand for clients, each has a unique requirement for noodles, namely non-negative quantity. Node 0, however, represents a warehouse with a transport capacity Q for k fleets. The k fleet size is regulated by special regulations. The cost across each edge (i,j), denoted by Cij, is always non-negative.

In the Capacitated Vehicle Routing Problem problem, various criteria must be met for each route consisting of many vehicles. Specifically, (a) all routes start and end at a depot; (b) each client can only be visited once per vehicle (Tanjung, Hadiguna, & B.A, 2021); (c) the total demand must not exceed the vehicle capacity Q; (d) the total cost of all routes should be minimized. The connection between the two points is represented by each edge of the network, which also indicates the direction of travel. The number of routes in the network equals the number of vehicles in use, with each vehicle used for only one route. Distance calculation is an important step in minimizing transportation costs. The Capacitated Vehicle Routing Problem model takes the following form:

1. Each operational zone in the village is only visited once by one vehicle. These restrictions are set in the following way:

$$\sum_{k\in K}^{n} y_i^k = 1, \forall i \in V \quad (3)$$

2. Each vehicle's journey originates from the same counter, indicating that the number of vehicles departing from the station equals the number of available vehicles. This limitation is articulated in the following way:

$$\sum_{k\in K}^{n} y_i^k = |K|, \forall i \in V \quad (4)$$

3. Each car serves one customer and then moves on to the next, finally returning to the depot at the end of its journey. Therefore, the vehicle visiting customer i departs from customer i. These restrictions are clearly stated as:

$$\sum_{j\in V}^{n} x_{ij}^k = v_{ij}^k = \forall i, l \in V \cup D, \forall k \in k \quad (5)$$

4. Each car has the ability to withstand a certain load which is denoted as Ck. Therefore, the overall customer needs that should be met by a vehicle on one route must not exceed the capabilities of the vehicle. This limitation can be explained as follows:

$$\sum_{i\in V}^{n} d_i\, y_i^k \leq C_{k,i}\, \forall k \in K \quad (6)$$

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5. All vehicle lanes must be interconnected. Suppose there is a group of vehicles represented by the set S, and let |S| denotes the number of vehicles in S. If a vehicle moves to node i in S and there is a path to node j, then the number of paths taken by vehicles in S cannot exceed |S| - 1. This limitation can be stated as follows:

$$\sum_{i\in S}^{n} x_{ij}^{k} \leq |S| - 1, \forall S \subseteq V, |S| \geq 2, \forall k \in K \quad (7)$$

The goal of the CVRP framework is to reduce the distance each vehicle travels at K. This equation is expressed as:

$$z = \sum_{k\in K}^{n} \sum_{i\in K}^{n} \sum_{j\in K}^{n} C_{ij} x_{ij}^{k} \quad (8$$

Formulate a mathematical formulation of the waste transportation route problem whose goal is to minimize the distance traveled. The following forms of the Capacitated Vehicle Routing Problem model are(Aref, 2017):

objective function:

$$Z = \sum_{x\in V} \sum_{\substack{z\in V \\ x\neq z}} c_{xz} X_{xz} \quad (9)$$

Constraint Function:

$$\sum_{x\in V} X_{x,z} = 1 \qquad z = 1,2,3,\dots,n \quad (10)$$

$$\sum_{z\in V} X_{x,z} = 1 \qquad z = 1,2,3,\dots,n \quad (11)$$

$$\sum_{x\in V} X_{x,0} = 1 \qquad z = 1,2,3,\dots,n \quad (12)$$

$$\sum_{z\in V} X_{0,z} = 1 \qquad z = 1,2,3,\dots,n \quad (13)$$

$$\sum_{x\in V} \sum_{z\in V} X_{x,z} = \sum_{x\in V} \sum_{z\in V} X_{x,z} \qquad x,z = 1,2,3,..,n, x \neq z \quad (14)$$

$$d_x \leq U_x \leq Q \qquad x = 1,2,3,\dots,n \quad (15)$$

$$U_x - U_z + QX_{x,z} \leq Q - d_z \qquad x,z = 1,2,3,\dots,n, x \neq z \quad (16)$$

$$X_{x,z} \in (0,1) \qquad x,z = 1,2,3,\dots,n \quad (17)$$

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Information :
x : The starting point of the journey
z : The destination point of the trip
Xxz : Travel route from Village x to Village z
cxz : distance from village x to village z
n : the number of villages
v : the set of all villages
0 : Central point identity
Q : Fleet capacity
dx : volume of waste in village x
Ux : volume of waste transported when leaving the village x
dz : volume of waste in village z
Uz : Volume of waste transported when leaving the Village z

Particle Swarm optimization algorithm The technique described in (Xia et al., 2020) is a population-focused method that employs individuals to carry out exploration. In the Particle Swarm optimization framework, flocs are referred to as groups while particles are referred to as individuals. Each individual moves at a speed that is adjusted to the scope of the search and keeps a record of the most optimal position reached until then, as stated by (Sistem et al., 2018). (Naseem & Razzak, 2020) have outlined the various phases involved in the Particle Swarm optimization algorithm.

1. Initialization
   a. Starting initial speed. At iteration 0, it can be said that all particles have an initial velocity value of 0.
   b. Starting the initial position of the particle. At iteration 0, the initial position is solved by the equation:

$$X = X\text{min} + rand[0,1] \times (Xmax - Xmin) \quad (18)$$

   c. From lBest (local best) and gBest (world best). At iteration 0, lBest (local best) is set to the value of the particle's origin location. While gBest (global best) was chosen as one of the lBest with the highest fitness.

2. Speed updates
   Use the formula below to update the speed.

$$v_{ij}^{(t+1)} = v_{ij}^{(t)} + c_1 r_{1j}^{(t)} \left(P_{best,i}^{(t)} - X_{ij}^{(t)}\right) + c_2 r_{2j}^{(t)} \left(G_{best,i} - X_{ij}^{(t)}\right) \quad (19)$$

Where :

vi,j = the jth velocity component of the ith entity in d dimension
W = parameter for inertial weight
C1, C2 = constants with values ranging from 0 to 1
r1, r2 = random values between 0 and 1
Pbest = Pbest (local best) – the best value of the particle temporarily
Gbest = Gbest (local best) - the best particle value among all Pbest values.
3. . Update Position and Calculate Fitness
xi,j = Position of particle i in dimension j.
4. Update IBest (local best) and gBest (global best)

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The IBest (local best) from the previous iteration is matched against the position update results to determine which one produces the higher fitness value. IBest with a higher fitness value replaces the previous one. As a result, the current gBes (Afrianita, 2011) will be replaced by the new IBest which has the highest fitness value.

5. Determine the number of swarms

To determine the number of swarms for waste transportation, use the following formula:

$$R = (n-1)! \quad (19)$$

6. Determine the objective function value (fitness) of each swarm.

The fitness function is obtained by using an artificial network. The fitness function is obtained using the equation(Afrianita, 2011):

$$f(x) = \left(\sum_{j=1}^{n} \bar{x} - x_{(i+1)}\right) \quad (20)$$

7. Verify whether the existing solutions have reached convergence.

Convergence is achieved when all the particles occupy identical positions. If not, repeat step 2 and update iteration i=i 1 by calculating new values for P(best,i) and Gbest. This iterative procedure continues until all the particles meet at the same solution point. These are generally identified by a termination criterion. The difference between the current and previous solutions is very small.

The stopping condition covers various aspects, such as the following.

a. The PSO algorithm stops prematurely when it converges too fast.

b. The termination condition avoids oversampling by ensuring that its value is not exceeded. Oversampling is a technique used to balance class distribution by randomly replicating minority class instances. If in a stopped state it requires continuous calculations, it will add to the complexity of the search process.

c. The stop state is met when the maximum number of iterations has been reached.

d. The halt state occurs when there is no progress after several iterations (Engelbrecht, 2006).

RESULT

The research results obtained are the optimal distance on the garbage truck transportation route with the PSO algorithm, which in the data there are 6 work areas or routes that will be examined and which will be optimized. The calculation used is manual calculation with the PSO algorithm as shown below.

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Table 1. Initial Work Area Route

Working area	Village Route	Garbage Amount	Distance
Working area 1	0-7- 8-3-10-0	+- 3 tons	133,5 Km
Working area 2	0- 5- 1- 9-2-0	+- 2 tons	135,9 Km
Working area 3	0-14 - 6-12-0	+- 2,5 tons	150 Km
Working area 4	0-7-4-11-3- 0	+-3 tons	157,8 Km
Working area 5	0-14-15-1-5-0	+- 1,5 tons	180,3 Km
Working area 6	0-4-13-18-17-0	+- 2 tons	152,4 Km

Note the codes in table 1: 0 are the starting and ending points of the trucks, namely TPA, 1 Aek hitetoras Village, 2 Aek Tapa Village, 3 Babusalam Village, 4 Belongkut Village, 5 Bulungihit Village, 6 Lobu Rampah Village, 7 Marbau Village, 8 Marbau Village south, 9 Brussels plantation villages, 10 South marbau plantation villages, 11 milano plantation villages, 12 perantian plantation villages, 13 Pulo bargot villages, 14 Simpang Empat villages, 15 Middle Siparepare villages, 16 Downstream Sipare Pare villages, 17 Sumbermulyo villages, 18 Tubiran village.

The garbage truck transport route data was obtained from Labura Environmental Service Employees. Meanwhile, the distance traveled from the TPA, between villages to the TPA is again obtained from Google Maps.

The results obtained using the Particle Swarm Optimization (PSO) Algorithm and compared with the initial route for transporting waste in Marbau District are as follows:

Table. 2 Comparison of the End of the Initial Route and the Optimal Route and Their Minimum Distance

Working area	Initial Garbage Transport Route	Initial Distance	Latest Garbage Transport Routes	PSO Algorithm Optimal Distance
WK 1	o - p - q - r - s - o	133,5 Km	o - s - q - r - p -o	132,5 Km
WK 2	o - p - q - r - s - o	153,9 Km	o - r - q - p - s - o	127,7 Km
WK 3	o - p - q - r - s - o	150 Km	o - p - q - s - r - o	137,1 Km
WK 4	o - p - q - r - s - o	157,8 Km	o - p - q - s - r - o	149,8 Km
WK 5	o - p - q - r - s - o	180,3 Km	o - s - r - q - p - o	134,3 Km
WK 6	o - p - q - r - s - o	152,4 Km	o - p - q - r - s - o	152,4 Km

Based on Table 2, it can be seen that the results of the comparison of the optimal route and mileage obtained in each work area on each route using the PSO algorithm get optimal results.

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Below is an image of the optimal route that is carried out using the Capacitated Vehicle Routing Problem Method and the particle swarm optimization algorithm.

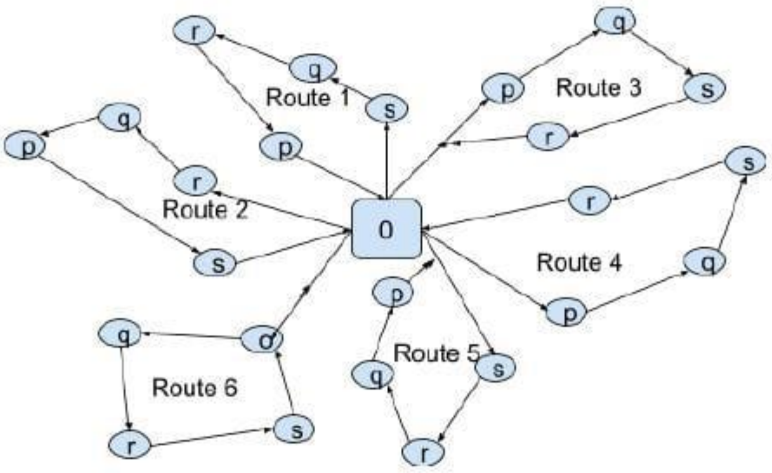

Figure 2. Route Optimal

On the initial route of work area one there is the o-p-q-r-s-o route which has a total distance of 133.5 Km, in which the route has several villages such as the Mambang Muda TPA - Belongkut Village - Aek Hitetoras Village - Brussel Plantation Village - Aek Tapa Village - Mambang Muda TPA. And after the latest garbage transportation route uses the PSO algorithm, the optimal distance is 132.5 Km with the o-s-q-r-p-o route where the village is Mambang Muda TPA - Aek Tapa Village - Aek Hitetoras Village - Brussels Plantation Village - Bulungihit Village - Mambang Muda Landfill. For work areas 2,3,4,5,6. can be seen from the table above.

DISCUSSIONS

The discussion obtained is the optimal distance on the garbage truck hauling route with the PSO algorithm, which in the data there are 6 work areas or routes that will be studied and which will be optimized. The calculation used is manual calculation with the PSO algorithm as below.

Data on Distance between TPA and Village in Work Area 1.

Table 3. Work Area 1 in Marbau District

Jarak (Km)	o	P	Q	r	S
O	0	54,6	80,2	58,9	64,5
P	54,6	0	7,5	8,6	13,9
Q	80,2	7,5	0	1,6	8,5
R	58,9	3,3	8,6	0	5,6
S	64,5	13,9	8,5	5,6	0

Information :

o = TPA Mambang Muda
p = Marbau Village
q = South Marbau village
r = Babussalam village
s = Perantian Plantation Village

WK 1 Garbage Transportation Optimization Route

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In working area 1 there are 4 villages namely Marbau, South Marbau, Babasalam and Perantian Plantations.

Define Swarm Route 1

At this step in the CVRP evaluation to determine the number of waste transport swarms that will be carried out using equation (0). Use the dots o,p,q,r,s.

$$R = (n-1)! = (5-1) = 4 = (4)(3)(2)(1) = 24\; swarm$$

There are 24 Swarms through which vehicles pass.

Table 4. Routes and total distance traveled for WK 1

Numb er	*Transport Route (Swarm)*	Total Mileage Wk 1 (x0) in kilometers
1	o – p – q – r – s – o	54,6 + 7,5 + 1,6 + 5,6 + 64,5 = 133,5
2	o – p – q – s – r – o	54,6 + 7,5 + 8,5 + 5,6 + 58,9 = 135,1
3	o – p – r – q – s – o	54,6 + 8,6 + 80,2 + 8,5 + 64,5 = 216,4
4	o – p – r – s – q – o	54,6 + 8,6 + 5,6 + 8,5 + 80,2 = 157,5
5	o – p – s – q – r – o	54,6 + 13,9 + 8,5 + 8,6 + 58,9 = 153
6	o – p – s – r – q – o	54,6 + 13,9 + 8,5 + 8,6 + 80,2 = 165,8
7	o – q – p – r – s – o	80,2 + 7,5 + 3,3 + 5,6 + 64,5 = 161
8	o – q – p – s – r – o	80,2 + 7,5 + 13,9 + 5,6 + 58,9 = 166,1
9	o – q – r – p – s – o	80,2 + 1,6 + 3,5 + 13,9 + 64,5 = 163,5
10	o – q – r – s – p – o	80,2 + 1,6 + 5,6 + 13,9 + 54,6 = 155,9
11	o – q – s – p – r – o	80,2 + 8,5 + 13,9 + 3,3 + 58,9 = 164,8
12	o – q – s – r – p – o	80,2 + 8,5 + 5,6 + 3,3 + 54,6 = 152,2
13	o – r – p – q – s – o	58,9 + 3,3 + 7,5 + 8,5 + 64,5 = 142,7
14	o – r – p – s – q – o	58,9 + 3,3 + 13,9 + 8,5 + 80,2 = 164,8
15	o – r – q – p – s – o	58,9 + 1,6 + 7,5 + 13,9 + 64,5 = 146,4
16	o – r – q – s – p – o	58,9 + 1,6 + 8,5 + 13,9 + 54,6 = 137,5
17	o – r – s – p – q – o	58,9 + 5,6 + 13,9 + 7,5 + 80,2 = 166,1
18	o – r – s – q – p – o	58,9 + 5,6 + 8,5 + 7,5 + 54,6 = 135,1
19	o – s – p – q – r – o	64,5 + 13,9 + 7,5 + 1,6 + 58,9 = 143,4
20	o – s – p – r – q – o	64,5 + 13,9 + 8,6 + 1,6 + 80,2 = 168,8
21	o – s – q – p – r – o	64,5 + 8,5 + 7,5 + 8,6 + 58,9 = 148
22	o – s – q – r – p – o	64,5 + 8,5 + 1,6 + 3,3 + 54,6 = 132,5
23	o – s – r – p – q – o	64,5 + 5,6 + 3,3 + 7,5 + 80,2 = 161,1
24	o – s – r – q – p – o	64,5 + 5,6 + 1,6 + 7,5 + 54,6 = 133,8

Table 4. Shows 24 routes with different mileage. The longest route is in the 20 th swarm with a distance of 168.8 Km and the shortest route is in the 22nd Swarm with a distance of 132.5 Km. In the first Swarm there is a route o – p – q – r – s – o stating that the transportation route starts from TPA - Marbau Village - Marbau Selatan Village - Babusalam Village - Perkebuk Pernantian Village - TPA with a distance of 133.5 Km.

Determining the f(x) Value of Each Work Area Swarm 1

The average fitness function for each swarm in Table 4 is hundreds, so the fitness function is expressed by the formula as in the equation below.

$$f(x) = (100 - x_i)^2$$
$$f(x) = (100 - 132{,}5)^2 = 1.056{,}25$$

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Gives Pbest and Gbest Values to Swarm WK 1

a. The Pbest value is obtained from the initial distance (x0) in each Swarm
b. The Gbest value is obtained from the Swarm with the minimum fitness value, namely the 22nd Swarm because it has an f(x) value of 1,056.25, which means that the Gbest value is 132.5.

Calculating New Speed (V1) in Swarm Work Area 1

The initial speed in each Swarm is made V0 = 0. Then the speed change is calculated with the help of the values c1=1, c2=1, r1=0.59721693, and r2=0.22120016 (random values obtained using Ms. Excel). To calculate the change, use the formula as in the equation below.

$$\mathrm{v}_1 = v_0 + c_1 r_1 (Pbest - x_0) + c_2 r_2 (Gbest - x_0)$$

So that:

For the 22nd Swarm

$$v_1 = 0 + 1 \times 0{,}59721693(132{,}5 - 132{,}5) + 1 \times 0{,}22120016(132{,}5 - 132{,}5)$$
$$v_1 = 0$$

Calculating Row Position Value (x1) for Each Swarm Work Area 1

Update the position of each Swarm with the formula below:

$x_1 = v_1 + x_0$=132,7212

Determining the f(x)' Value of Each Swarm Work Area 1

Calculating the fitness function this time, use the new x value (x1) so that the formula becomes

$$\mathrm{f}(x)' = (100 - x_1)^2 = 1.070{,}6793$$

Determining Pbest and Gbest Values in Work Area 1

The Pbest value is obtained from the x1 value in each Swarm. The Gbest value is obtained from the Swarm with the minimum fitness value, namely the 22nd Swarm because it has an f(x)' value of 132.7212, which means that the Gbest value is 132.5. Because for position calculations it has converged on calculations. then the most optimal Swarm to use is Swarm 22. For Swarm 22: o – s – q – r – p – o = 132.5 Km. the same method is repeated until it reaches the 6th working area route.

Previous research is research discussing "Completion of the Capacitated Vehicle Routing Problem (CVRP) Using the Sweep Algorithm for Optimization of the Distribution Route of the Sovereign People's Newspaper" which discusses the concept and workings of finding the shortest route with the sweep algorithm. While this research discusses the optimizing route for garbage trucks with the CVRP method using the PSO algorithm.

CONCLUSION

In this study, it can be seen that the problem that occurs in the 6 work areas is that the distance or route traversed by the garbage truck is not optimal due to the ineffectiveness of the initial path traversed and from the discussion and results it can be concluded that the capacitated vehicle routing problem is in the particle swarm optimization algorithm for determine the most recent and valid optimal route on the garbage truck transport route in Marbau District, it can be concluded as follows: On the initial route of work area 1 there is the o-p-q-r-s-o route which has a total distance of 133.5 Km, which route has several villages such as TPA Mambang Muda - Belungihit Village - Aek Hitetoras Village - Brussels Plantation Village - Aek Tapa Village - Mambang Muda Landfill. And after the latest garbage transportation route uses the PSO algorithm, the optimal distance is 132.5 Km with the o-s-q-r-p-o route

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where the village is Mambang Muda TPA - Aek Tapa Village - Aek Hitetoras Village - Brussels Plantation Village - Belungihit Village - Mambang Muda Landfill. In WK 2 there is the initial route o-p-q-r-s-o which has a total distance of 153.9 Km, in which the route has several TPA Mambang Muda villages - Marbau Village - Lobu Rampah Village - Simpang 4 Village - Pernantian Plantation Village - Mambang Muda TPA. And after the latest garbage transportation route uses the PSO algorithm, the optimal distance and route is 127.7 Km. In work area 3 with the initial route and distance of 150 and after using the PSO algorithm, the optimal route and distance is 137.1 Km. In work area 4 with a route and distance of 127.8 Km, the optimal route and distance using the PSO algorithm is 149.8 Km. Work area 4 has a route and initial distance of 157.8 Km and the optimal PSO route and distance is 149.8. The 5th working area has an initial distance of 180.3 and the PSO route is 134.3 Km. The working area of the 5 initial routes is 152.4 Km and the PSO route is 152.4. So the results found can change the route of the garbage truck to be more optimal and make it easier for garbage transport employees to transport garbage in Marbau District.

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