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Minimizing Nail Distribution Routes Using the Ant Colony Optimization Method With MATLAB

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Abstract

This research aims to determine the delivery route for nails to minimize the total distribution distance in CV. XYZ. This research method is quantitative with primary data analysis consisting of consumer location, distance between consumers, vehicle capacity and product demand data. The findings from this research are that the most optimal route was obtained after running the MATLAB program using the Ant Colony Optimization Algorithm with the most optimal distance of 99 Km. The difference distance between the company's method and the proposed method is 70.4 km, fuel consumption difference is 8,8 liters, fuel cost difference is IDR 59.840, with a percentage savings is 41.5%. Factors that influence this success include choosing a route that is different from the company's initial route so that optimizing the route obtained from the Ant Colony Optimization Algorithm produces optimal and effective results. Factors that influence this success include choosing a route that is different from the company's initial route so that optimizing the route obtained from the Ant Colony Optimization Algorithm produces optimal and effective results. Recommendations for further research are that researchers analyze the results from using 2 methods or add variables that will help the research process in the future, such as road conditions or vehicle performance in carrying out distribution.

Introduction

In the economy, distribution activities have an important role in involving the distribution of goods or services from producers to consumers. This distribution activity can be carried out by individuals or by a company. Distribution routes are also needed for distributing a product. Accuracy in sending products directly to their destination must have a good and precise route in order to maximize existing resources. Accurate product delivery will increase efficiency and increase customer satisfaction.

One of the important components of economic activity is distribution, which is basically the process of distributing products from the producer to the party who needs them, namely the consumer (Dewantara, 2020). According to Basu Swastha in Zulkarnaen et al. (2020) Distribution can be defined as the marketing channels used by product makers to distribute their products to end customers, be they industry or consumers. The institutions involved in the distribution channel include producers, consumers, and final customers, be they industry or consumers. According to Suryanto (2016) The Japanese company distribution system is an example of the most complex company distribution, where Japan uses distribution networks from various layers, namely agents, wholesalers, and retailers. This is different from China, where most use the direct selling method. Where using human power or vehicles such as

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bicycle couriers and motor vehicle couriers. Swastha said in Sumaryana et al. (2019) There are three functions carried out by partners or consumers, namely Exchange Function, Physical Provider Function, Support Function.

Vehicle Routing Problem (VIDR) is a combinatorial optimization problem by considering a limit on demand capacity. The main goal is to find and determine the most efficient route for vehicles in order to meet customer requests. In this context, efficiency can be inteIDRreted as an effort to reduce the total distance traveled in product distribution in a company (Ferdiansyah et al., 2021). The route that is considered optimal in VIDR is the route that has the shortest total distance traveled. Apart from that, when determining this route, you must consider the limited number of vehicle capacities in accordance with the available capacity. According to Patmawati & Nugroho (2022) The Vehicle Routing Problem is a search method for optimal use of vehicles when traveling to several locations to send or pick up goods. Determine several combinations of vehicles according to the capacity of each vehicle in one transportation to reduce the transportation costs required. According to Heitasari & Ghifari (2022) VIDR (Vehicle Routing Problem) is an optimization problem related to distribution activities, especially in determining the route of the distribution activity. Vehicle Routing Problem is a name used to refer to the method used to determine a delivery route for goods or products from transportation. The Vehicle Routing Problem is one of the solutions to problems that often arise in the transportation sector.

Metaheuristics is a problem-solving technique based on intuition or simple rules. Which aims to search for efficient space in order to find a solution that is close to optimal. Metaheuristic can be defined as a method that has a higher level than the previous heuristic method. Metahuristic has the puIDRose of finding a faster solution to problems and can solve complex problems. (Prasetyo & Tjong, 2020). According to Nggego & Setyanto (2020) Metaheuristics is an algorithmic framework inspired by the characteristics or behavior of an object or living creature in nature, which is aimed at solving complex optimization problems. According to Osman and Laporte in Iqbal et al. (2020) Metahuristic is a recurring process that directs subheuristic in a clever way to combine different concepts to describe and exploit search spaces, learning strategies applied to organize information so that it can be searched efficiently near the optimal solution.

Metaheuristics has many methods, and one of them is Ant Colony Optimization (ACO). This method is a method that is often used by many people in solving optimization problems. Some optimization problems do need to be solved with one of the metaheuristic methods. Dorigo provides understanding in Cahyono et al. (2019) Ant Colony Optimization (ACO) is an algorithm that models the behavior of carrion ants and groups ant larvae. In this context, the ants effectively determine the shortest route by exploiting pheromones, chemicals that they leave along their paths (Ary, 2022).The principle of ants in collecting and grouping ant larvae is used as a reference in this algorithm. As seen in the picture below, the ants leave the nest at the same time. Then the ants arrive at branch 1 together and make an equal probability decision to choose which branch to pass next. In the third stage, it is seen that a group of ants go through a shorter branch and reach the food source first, and then take the food to make the journey back to the nest. Then, when it arrives at branch 2, the ant detects the pheromone on path A, so path A has a higher probability of being taken than path B, which does not contain pheromone on branch 2 because no ants have passed yet. So the ants will ultimately only take route A to get the food source. Path B does not experience reinforcement again because there are no ants that put pheromone on this path, so the ants will walk on the short path, namely path A.

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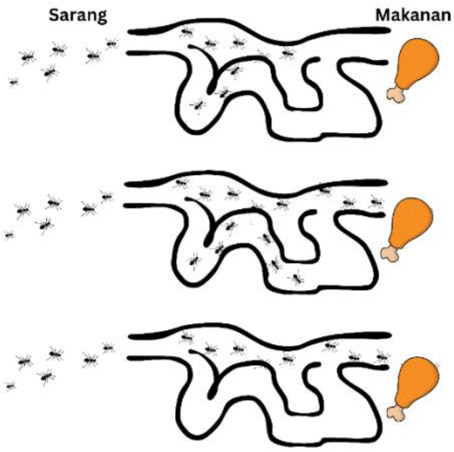

Figure 1. Ilustration of Ant Colony Optimization

CV. XYZ is one of the private companies engaged in manufacturing. This company is located in Kab. Sidoarjo, East Java. CV. XYZ is a company that produces nails, and this nail product has very high demand from consumers because of its high demand among the public. However, currently, CV. XYZ is shipping nail products, but the route taken for delivery is still not optimal, causing high distribution costs. This research uses the Ant Colony Optimization (ACO) method, which is inspired by the natural behavior of ants in looking for the shortest route to reach food sources. This process starts at the ant nest and ends at the food location. The process of working with the ACO method is also assisted by MATLAB software to make it easier for researchers to carry out research.

The Ant Colony Optimization (ACO) method is used because it is often used in many previous studies, such as Liu (2020) research. This model aims to maximize profits for logistics companies that receive subsidies from the government. In addition, this research also aims to overcome the final distribution challenges in rural areas and provide a solid basis for solving the final distribution problems in RECL. and also in other research on Iskandar & Irsyad (2019) with the research title Optimizing Waste Transport Routes Using the Ant Colony Optimization Method in Pekanbaru City. The optimal results of this ACO method can be seen from the computational results and also the short computing time in its application. And in another study, using the same method, the most optimum route for carrying out the shipment of bakpia pathok 25 so that the delivery activity can be more efficient and optimum (Syahr et al., 2023).

Therefore, given the company's problems above, it is necessary to carry out this research in the hope that it can provide an effective solution to overcome the problem of distributing nails by minimizing the distance of the delivery route taken by delivery vehicles from CV. XYZ.

Methods

The data in this research uses primary data, which was obtained by direct observation and interviews. The data collected is consumer location data, distance data between consumers, vehicle capacity data, and product demand data.

Table 1. Consumer Location Data

Node Code	Name
1 (Depot)	CV. XYZ
2	UD. TJ
3	PD. BA
4	TB. KP
5	UD. SK

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6	TB. SJ
7	BM
8	UD. ABB
9	TB. SA
10	SJ
11	TB. GP
12	TB. R
13	UD. SB
14	Toko MJ
15	Toko SBR
16	TB. J
17	TB. MR

Based on interview research, 16 consumer locations were obtained with various different location points. The distance between consumers can be seen in Table 2.

Table 2. Distance Matrix

Matrix (Km)	1 (Depot)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	0	20	20,7	5,3	17	4,8	11	30	33	32	1,3	2,1	1,5	5,5	10	12	14
2	20	0	3,9	14	4,7	15	12	12	15	14	21	20	21	22	22	25	26
3	20,7	3,9	0	15	3,9	16	13	17	20	19	22	20	22	22	22	25	27
4	5,3	14	15	0	12	1,3	5,5	23	26	25	6	6,6	7,9	11	11	14	16
5	17	4,7	3,9	12	0	13	9,5	16	19	18	18	17	19	20	19	21	23
6	4,8	15	16	1,3	13	0	6,3	26	29	28	5,5	6,1	7,4	10	10	12	15
7	11	12	13	5,5	9,5	6,3	0	24	26	26	12	10	12	12	12	14	17
8	30	12	17	23	16	26	24	0	4	3,3	28	29	31	31	31	33	35
9	33	15	20	26	19	29	26	4	0	1	32	33	34	34	34	37	39
10	32	14	19	25	18	28	26	3,3	1	0	31	32	33	34	34	36	38
11	1,3	21	22	6	18	5,5	12	28	32	31	0	1,5	2	5,9	11	13	15
12	2,1	20	20	6,6	17	6,1	10	29	33	32	1,5	0	1,5	5,6	10	13	15
13	1,5	21	22	7,9	19	7,4	12	31	34	33	2	1,5	0	4,2	7,6	9,8	12
14	5,5	22	22	11	20	10	12	31	34	34	5,9	5,6	4,2	0	2,6	5,3	6,6
15	10	22	22	11	19	10	12	31	34	34	11	10	7,6	2,6	0	2,7	5,4
16	12	25	25	14	21	12	14	33	37	36	13	13	9,8	5,3	2,7	0	3,1
17	14	26	27	16	23	15	17	35	39	38	15	15	12	6,6	5,4	3,1	0

The distance between consumers, or distance matrix, is processed according to data from the company. This data is important for continuing research because it is used to determine the distance from each consumer point.

Table 3. vehicle type, capacity, and fuel consumption data

Vehicle Type	Capacity	Fuel Cosumption	Solar Fuel Price
Truck Canter	230 Box	8 km / 1 liter	IDR 6.800

In the delivery of nails in this company used a truck with a capacity of 230 boxes with a weight of 1 box is 30 Kg, and can be seen also the fuel consumption of the truck fleet of delivery owned by the company has a consumer of 8 km / 1 liter.

Then the next delivery time according to the company's route can be seen in table 5 with a total travel distance of 169.4 km and in this study the speed of the vehicle is considered constant is 40 km/h so obtained the travel time of the delivery vehicle to deliver the whole

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product to the entire consumer is 4 hours 14 minutes. The entire delivery process has the assumption that the conditions of the road are considered normal without congestion.

Table 4. Product Demand Data

Node Code	Customer Name	Demand (Box)						Average Demand (Box)
		Septermber 2023	Oktober 2023	November 2023	Desember 2023	Januari 2024	Februari 2024	
2	UD. TJ	15	15	17	10	13	13	14
3	PD. BA	13	13	13	17	12	15	14
4	TB. KP	12	15	14	15	10	15	14
5	UD. SK	13	13	16	12	12	17	14
6	TB. SJ	12	13	16	12	12	14	13
7	BM	10	13	17	11	17	16	14
8	UD. ABB	16	10	10	15	11	11	12
9	TB. SA	13	15	17	17	14	13	15
10	SJ	14	14	11	12	17	16	14
11	TB. GP	10	13	14	13	13	15	13
12	TB. R	11	13	17	14	12	12	13
13	UD. SB	13	15	15	10	12	11	13
14	Toko MJ	13	10	12	11	15	10	12
15	Toko SBR	15	12	14	12	17	11	14
16	TB. J	14	10	13	15	17	15	14
17	TB. MR	16	14	10	15	12	11	13
Total								**214**

On this demand data I use average data for my handling because it can be seen in the last 6 months data demand from consumers not far from the result data demand. After the data is collected, the data obtained will be processed using the Ant Colony Optimization method with the help of MATLAB software. The steps for analyzing the data above using the ACO method are as follows. Initialize ACO parameters, namely: (a) Ant pheromone intensity between points (τ_{ij}); (b) Distance between points (d_{ij}); (c) Vehicle capacity; (d) Total requests; (e) Determining the point of origin and destination; (f) Ant pheromone intensity control constant (α); (g) Visibility control constant (β); (h) Visibility between points (η_{ij} = 1 d_{ij}); (i) Number of ants (m); (j) Ant pheromone evaporation constant (ρ);(k) Maximum number of iterations (NC_{max})

Place m ant at the starting node. Enter the first point into the tabu list. The tabu list is a place provided for temporary storage of the solutions produced in each iteration. If s denotes the index of the order of visits and k denotes the index of the ant that is traveling, then the visited point is expressed as $tabu(k, s)$. Calculate the probability that the node will be visited by the ant using the following formula:

$$P_k(r,s) = \left\{\frac{\tau(r,s)^{\alpha}.\pi(r.s)^{\beta}}{\sum \tau(r,s)^{\alpha}.\pi(r,s)^{\beta}}\right\} \quad (1)$$

Calculate the length of each ant's route. The closed route length (L_k) for each ant is calculated after all ants have completed one travel cycle. The minimum value of the closed route length for each cycle (L_{min}) will be obtained after L_k for each ant is known.

Update the pheromone intensity using the following formula:

$$\tau_{ij}^{(t)} = \tau_{ij}^{old} + \Sigma_k \Delta\tau^{(k)} \quad (2)$$

where τ_{ij}^{old} is the amount of pheromone from the previous iteration that remains after pheromone evaporation.

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$$\Delta\tau^{k}{}_{ij} = \frac{K}{L_k} \qquad 3)$$

for *(i,j)* ∈ the origin and destination points in the *tabu*$_k$ and *K* is a constant.

Calculate the ant pheromone intensity value between points for the next cycle using a formula:

$$\tau_{ij} = \rho\tau_{ij} + \Delta\tau_{ij} \qquad (4)$$

Emptying the tabu list to be filled again with a new sequence of points in the next cycle. If the maximum number of cycles has not been reached, then the algorithm is repeated again from step three using the updated ant pheromone intensity parameter between points (τ_{ij}).

These steps will be carried out with the help of MATLAB software by inputting the formula used into MATLAB software to be executed automatically to speed up the desired results.

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ACO.m* | RLP.m | +

```
clc;
clear;

disp('Ant Colony Optimization (ACO)');

% Demand for each city (including depot)
addpath('Demand');

% Capacity of the vehicle
vehicle_capacity = 230;

D = DistanceMatrix();
nCity = size(D, 1);

rng(23)

etha = 1./D;
etha(find(etha == inf)) = 0.0000001;

tau0 = 1;
tau = tau0 * ones(nCity, nCity);

alpha = 0.5;
beta = 3;

rho = 0.5;

nAnt = 10;

empty_ant = struct();
empty_ant.Tour = [];
empty_ant.L = 0;
empty_ant.P = [];
empty_ant.load = 0;

```

Figure 2. Input Coding into MATLAB Software

Results and Discussion

In the initial stage, the results determine the distribution route on CV. XYZ carried out an initial calculation of the company's route first to find out which routes the company's delivery vehicles took, and the total distance traveled by the company's delivery vehicles can be seen in the table below.

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Table 5. Company Distribution Routes

Delivery Route	Distance (Km)	Milage (Km)
CV. XYZ – UD. ABB – TB. SA – SJ – TB. J – Toko MJ – UD. SB – Toko SBR – TB. MR – TB. R – TB. GP – UD. TJ – PD. BA – UD. SK – TB. KP – TB. SJ – BM – CV. XYZ	30 + 4 + 1 + 36 + 5,3 + 4,2 + 7,6 + 5,4 + 15 + 1,5 + 21 + 3,9+ 3,9 + 12 + 1,3 + 6,3 + 11	169,4

The company calculated the distance above by adding up the initial total delivery distance from the start point to each point until the end of the distribution trip and obtained the company's calculation result of 169,4 km.

The next stage, with the help of MATLAB software, the required data will be processed directly by MATLAB with coding that has been created to solve existing problems using the Ant Colony Optimization method, which can be seen below the results of running the program from MATLAB.

Figure 3 shows the results of the MATLAB program where the output produced is a best tour length of 99 km and the best tour achieved shows the results 1 – 11 – 12 – 13 – 14 – 15 – 17 – 16 – 7 – 5 – 3 – 2 – 10 – 9 – 8 – 4 – 6 – 1 where the two outputs are calculated until they reach the most optimal iteration and are carried out repeatedly to find the most optimal solution.

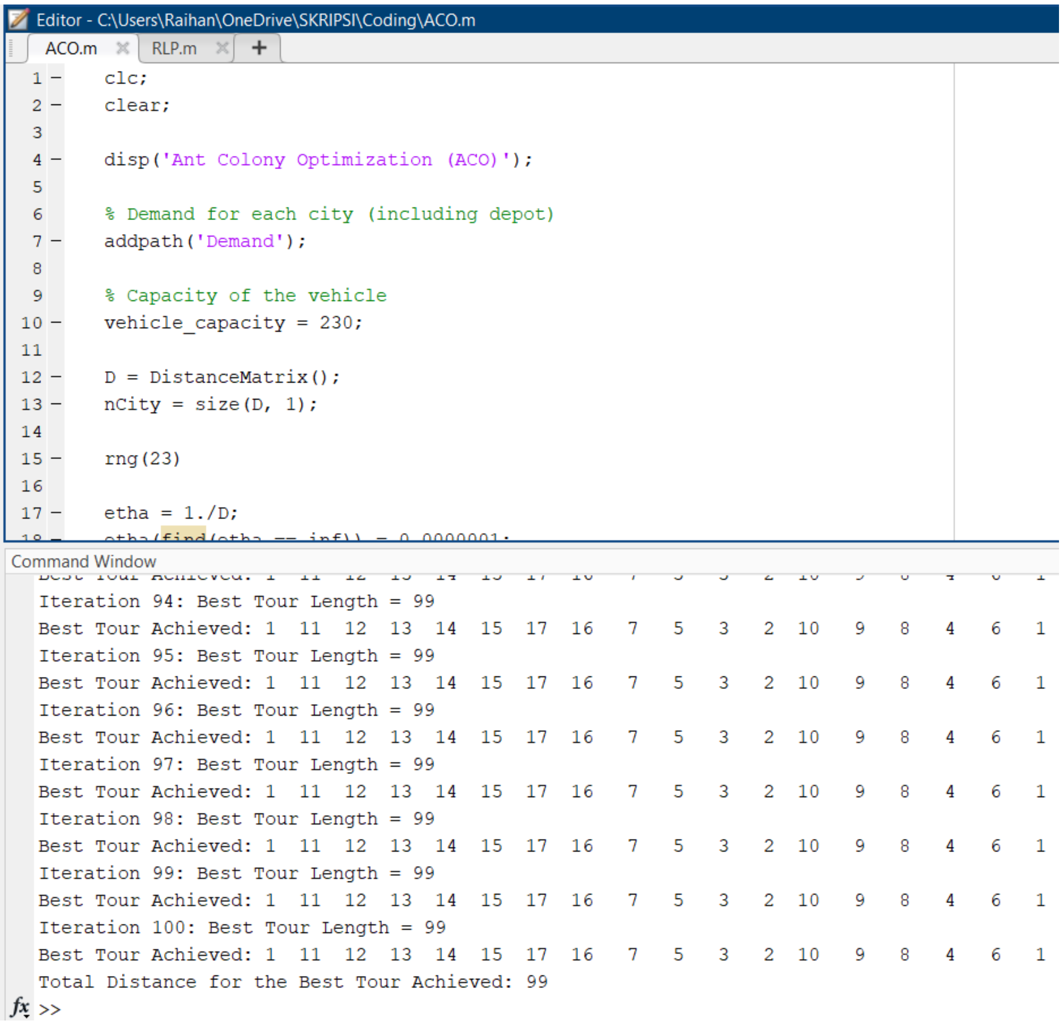

Figure 3. Results of Running MATLAB Software

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Figure 4 shows the graph at which iteration the graph will show optimal results, so it is known that the programming method with the Ant Colony Optimization algorithm is carried out several iterations to achieve the desired results in order to ensure that the route selection is correct and optimal.

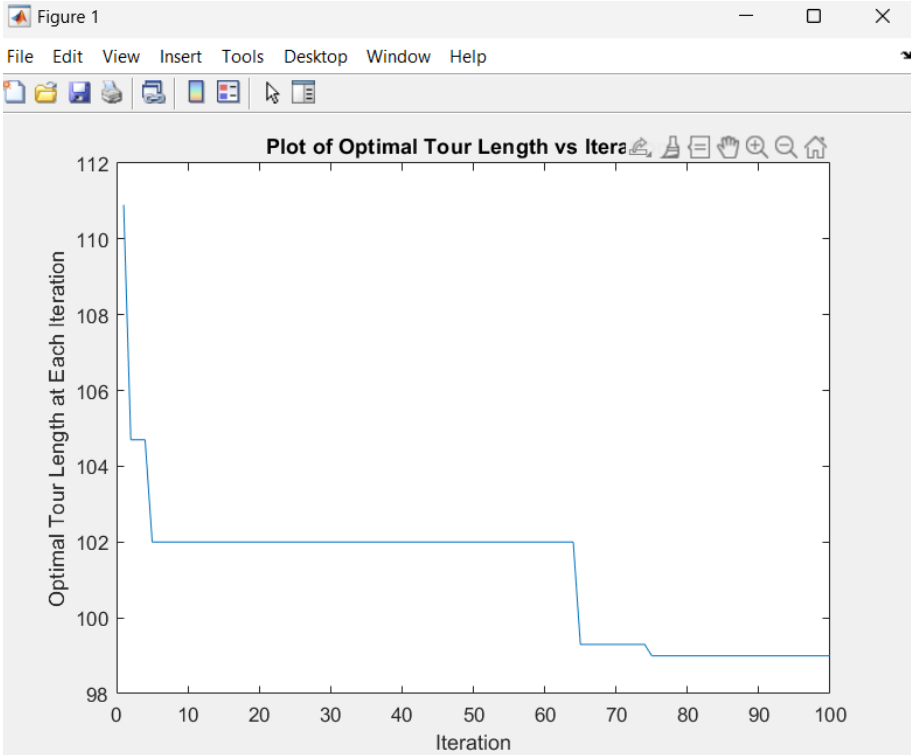

Figure 4 MATLAB Running Software Graphic Output

Figure 5 shows that the route generated by entering the algorithm in MATLAB software with a vehicle capacity of 230 boxes, delivery vehicles can make one delivery according to the number of requests of 214 boxes with a total optimal route of 99 km.

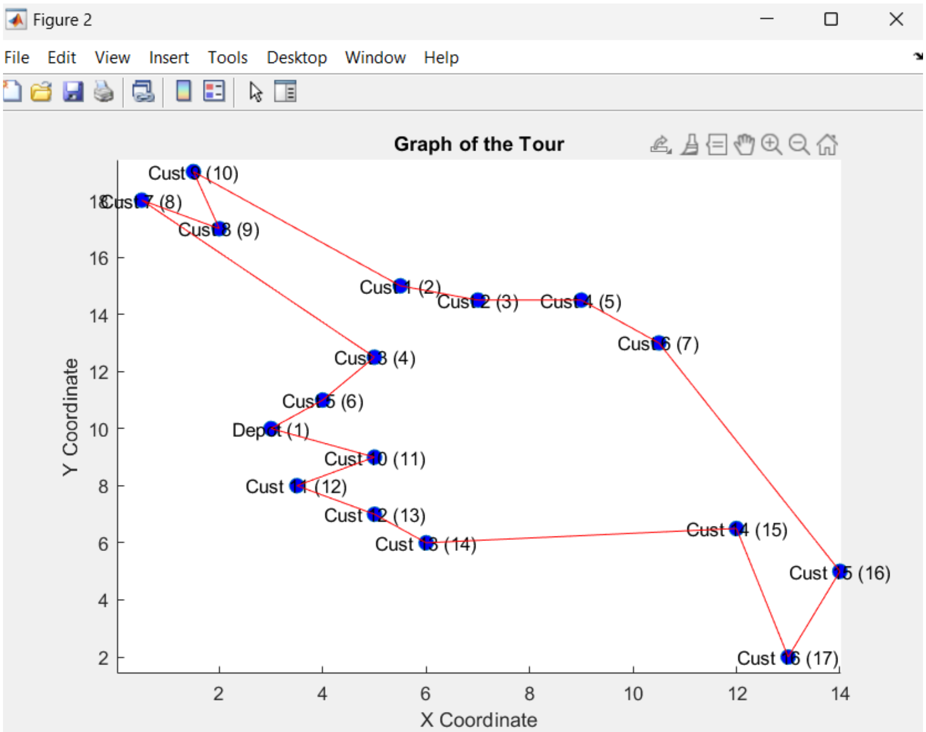

Figure 5. Distribution Route Patterns Resulting from the Ant Colony Optimization Method

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Based on calculations from two different methods, namely company calculations and ACO method calculations, a method comparison is carried out to determine whether the proposed method produces more optimal results than the company calculation method or otherwise. A comparison of the distribution distance between companies and the Ant Colony Optimization algorithm must be carried out so that the results of the company's method and the proposed method can be used as a reference for which one is most optimal and helps the company in carrying out distribution. It can be seen in the comparison table below,

Table 6. Comparison of method results

Route	**Delivery Route**	**Milage (Km)**	**Fuel Consumption (Liters)**	**Fuel Cost**
Company	CV. XYZ – UD. ABB – TB. SA – SJ – TB. J – Toko MJ – UD. SB – Toko SBR – TB. MR – TB. R – TB. GP – UD. TJ – PD. BA – UD. SK – TB. KP – TB. SJ – BM – CV. XYZ	169,4	21,175	IDR 143.990
Ant Colony Optimization	CV. XYZ – TB. GP – TB. R – UD. SB – Toko MJ – Toko SBR – TB MR – TB J – BM – UD. SK – PD. BA – UD. TJ – SJ – TB. SA – UD. ABB – TB. KP – TB. SJ– CV. XYZ	99	12,375	IDR 84.150

Distance Difference = Company Distribution Route Distance – Route Distance ACO Algorithm Distribution

= 169,4 – 99

= 70,4 Km

Fuel Consumption Difference = Company Distribution – ACO Algortihm Distribution

= 21,175 – 12,375

= 8,8 Liters

Fuel Cost Difference = Company Distribution – ACO Algortihm Distribution

= IDR 143.990 - IDR 84.150

= IDR 59.840

$$\text{Savings Percentage} = \frac{\text{Company Distribution Route Distance} - \text{Route Distance ACO Algorithm Distance}}{\text{Company Distribution Route Distance}} \times 100\%$$

$$= \frac{169{,}4 - 99}{169{,}4} \times 100\%$$

= 41,5%

Conclusion

The company's distribution route has a total distance of 169.4 km, and the distribution route proposed by the Ant Colony Optimization Algorithm has a total distance of 99 km. The difference between the distance between the company's method and the proposed method is 70.4 km, fuel consumption difference is 8,8 liters, fuel cost difference is IDR 59.840, with a percentage savings in the distance obtained after using Ant Colony Optimization is 41.5%. This shows that the distribution route proposed by the Ant Colony Optimization Algorithm is more optimal.

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