



Optimization in Determining Routes of Goods Distribution Vehicle Using the Ant Colony Optimization Algorithm Method at PT XYZ

Ranti Dwi Djayanti¹, Yani Iriani²

^{1,2}Department of Industrial Engineering, Widyatama University Bandung, West Java, Indonesia
Email: ¹ranti.dwi@widyatama.ac.id, ²yani.iriiani@widyatama.ac.id

Abstract

PT XYZ is one of freight forwarding companies in Indonesia, which is located in the city of Bandung. This company has managerial functions related to Collecting, Processing, Transporting, Delivery, and Reporting. However, the fact is in the process of Transporting this company still uses a zoning system which is a shipping system that still divides tertiary areas and each of these areas uses one vehicle. One problem that arises is that companies want effective and efficient performance in the distribution system of goods with the minimum total transportation costs. However, the company does not know yet whether the company's shipping routes have been effective and efficient or not. The company has tertiary network distribution route that are 2 routes with a total distance of 143.4 Km and a total transportation cost of Rp 5,681,484 /month. This research aims to determine the optimal goods distribution route using the Ant Colony Optimization Algorithm method, which is the method of finding the shortest path following ant behavior in taking food to its nest. Based on the results of the research, it is obtained a total distance of 109.2 Km because it becomes 1 route and total transportation costs Rp 3,337,992 /month, then it is obtained optimal results with a difference in distance is 34.2 Km and a total transportation cost of Rp 2,343,492 /month using one vehicle.

Keywords: Optimization, Distribution, Ant Colony Optimization Algorithm

1. INTRODUCTION

Recently the company's competition in the field of shipping goods and services is growing very rapidly. In expediting the business process there are logistical activities in it that are related to each other namely transportation and distribution, because the company must ensure the goods are delivered quickly and precisely to the customer. Transportation and distribution are the most important things in logistics activities because they can influence a company's quality. Transportation is also an inseparable part of all industrial sectors. That is because in various industrial sectors includes two processes namely distribution and logistics. Fuel and time spent for shipping are one of the significant costs for industries that are



routinely distributing to many locations or regions. Transportation will have a big effect on costs, and therefore affect the cost of production and distribution up to 10-20% of the total cost of a product. Therefore, efficiency in the transportation sector is very important and can significantly reduce total production and distribution costs [2]. Determining the route of distribution of goods from a distribution center is an important decision that must be made by a company in order to streamline distribution costs, delivery time, adjusting demand to the supply capacity of available vehicles. The distribution of goods is closely related to the cost of transportation through a predetermined route, because the longer the distribution of goods the greater the transportation costs that must be incurred. Vehicles that will depart to send goods from the Depot have a limited transport capacity, whereas each customer that is spread in a number of distribution areas have different demand for goods [6].

PT XYZ is a company engaged in the field of freight forwarding services. In the distribution of goods that will be sent, the company wants the best route for its delivery with a minimum transportation cost. However, the company does not know yet whether the route it already has is optimal or the best (shortest) that considers the transport capacity of the vehicle, so the total transportation costs cannot be guaranteed to be efficient. The company currently has 2 tertiary network routes, each using 1 vehicle. The distance traveled on route 1 is 41.3 km and route 2 is 106.8 km with a total distance of 148.1 km. Then the problem of this research is how to determine the route of distribution of goods to each location, in order to obtain the minimum total transportation costs. A good route arrangement can shorten the mileage, shorten the time of distribution activities, optimization can have an impact on cost savings. The determination of this distribution route is included in the Vehicle Routing Problem. Vehicle Routing Problem aims to determine the optimal route for sending a product to a number of customers in several different locations with various constraints that are determined. The optimal route here means the route that fulfills various operational constraints, those are the shortest total distance and travel time in meeting consumer demand and using a limited number of vehicles. One method for resolving Vehicle Routing Problems is the Ant Colony Optimization method [8].

According to Moyson and Manderick who first found the Ant Algorithm and then it was developed by Marco Dorigo. This method includes multi agent search techniques to solve optimization problems, especially combinatorials inspired by ant behavior in a colony. The behavior of each actor in imitating the behavior of living ants and how they interact with one another in order to find food sources and bring it to their colonies efficiently. During walking each ant will release pheromones which other ants will be sensitive to those pheromones, so that they provide hope to follow in their footsteps. More or less the intensity depends on the concentration of pheromones [3]. Several previous researches using the Ant

Colony Optimization (ACO) algorithm, according to Widyawati (2018), successfully applied to the Job Shop Scheduling Problem (JSSP) at PT Siemens Indonesia resulting in time savings for several days [9]. According to Irsyad, et al (2019), that research can provide solutions in determining the shortest route that can be used as effective routes traversed by the fleet in the transport of garbage [3]. In addition, according to Reimon (2014), his research succeeded in showing the fastest route in disaster evacuation [7] and according to Christopher et al (2018), in its application it is able to solve multiple salesman problem (M-TSP) cases related to research on the optimal route selection problem for passenger pickup on travel [1].

So it can be proven in previous researches that the Ant Colony Optimization (ACO) algorithm method is very suitable in solving route problems to find the optimal route. Based on the problems described above, the writer is interested in applying the Ant Colony Optimization (ACO) algorithm to the process of distributing goods to several locations in order to provide an optimal route and added with the calculation of transportation costs to provide a minimum total transportation cost.

2. RESEARCH METHODS

The model used in this research is the Ant Colony Optimization (ACO) method, which is a method that imitates a herd of ants looking for the shortest route to find food from their nest to where it is. ACO method can provide solutions for solving problems in the form of determining the shortest route so that it can reduce the distance resulting in a reduction in costs incurred by the company in distribution activities [5].

2.1. Data Collecting Method

This research used a qualitative descriptive approach. Data obtained from primary data are the results of interviews in the field of distribution and observation and are strengthened with secondary data sourced from documents related to the company. The data obtained are address data from each Distribution Center location, distance data, vehicle data, transportation cost data, data and the amount of bag shipment weight.

2.2. Stages in using the *Ant Colony Optimization (ACO)* Algorithm method

The following are the steps in data processing using the Ant Colony Optimization (ACO) Algorithm method, those are [5] :

1. Set the parameter value of Q , m , τ , α , β , ρ , NC_{max}

2. Determine the route of visit
3. Measure the distance traveled by the ant
4. Calculate the visibility between nodes (η_{ij})
5. Calculates the change in the intensity value of the ant footprint ($\Delta\tau_{ij}$)
6. Calculate the probability value (p_{ij}^k)

3. RESULTS AND DISCUSSION

3.1 Determination of Average Bag Weight

Based on the data that has been obtained regarding the weight of bags sent from distribution companies to several locations of Distribution Centers above, can be obtained for the average weight of each bag, the following is the formula to find out the average bag weight:

$$\text{Average bag weight} = \frac{\text{total bag weight}}{\text{total number of bag}}$$

$$\text{Average bag weight} = \frac{184}{14} = 13,143 \text{ rounded up to } 14 \text{ kg}$$

So, the average weight of each bag sent to each Distribution Center in the Bandung area is 14 kg.

3.2 Determination of Fleet Amount

To simplify the process of determining the tertiary transport shipping route to several locations of the Bandung Distribution Center, an appropriate number of fleets is needed, in order to know the maximum carrying capacity of each fleet. Following is the formula to find out the maximum number of bags that can be carried by one vehicle.

$$\text{Maximum number of bag} = \frac{\text{fleet capacity}}{\text{average bag weight}}$$

$$\text{Maximum number of bag} = \frac{700}{14} = 50 \text{ bags}$$

Note: The fleet used is Daihatsu Grand Max, considering that the number of bags shipping per day is only 14 bags transported in the car. Then calculating the number of fleets that can be used are as follows:

$$\text{Number of fleets} = \frac{\text{fleet capacity}}{\text{amount of bags maximum capacity}}$$

$$\text{Number of fleets} = \frac{14}{50} = 0,28 \text{ rounded up 1 vehicle}$$

So, the fleet that can be used in shipping is 1 vehicle.

3.3 Costs and Types of Fuel Oil

Following are data on fuel costs for vehicles used by the Company in distributing bags to each Distribution Center in the Bandung area, as follows:

- Vehicle type : Daihatsu GranMax
- Fuel type : Pertalite
- Price per liter : Rp.7.650/liter
- Usage per liter : 15 Km

3.4 Route Determination Using *Ant Colony Optimization* (ACO) Algorithm Method

The following parameters are used to determine the route of visit with the Ant Colony Optimization Algorithm method.

$$\begin{aligned} \alpha &= 1 & \tau_{ij} &= 0,5 \\ \beta &= 1 & Q &= 1 \\ \rho &= 0,5 & \text{NCmax} &= 1 \end{aligned}$$

The parameter values above are used to calculate the ant probability value with the following equation:

$$p_{ij}^k = \frac{[\tau_{ij}]^\alpha \cdot [\eta_{ij}]^\beta}{\sum_{\tau=1}^n [\tau_{ij}]^\alpha \cdot [\eta_{ij}]^\beta} \quad (1)$$

Notes :

- i = Initial node
- j = Destination node
- k = As an ant colony
- τ_{ij} = Ant footprints intensity
- η_{ij} = Visibility between nodes
- α = Ant footprints intensity controller
- β = Visibility controller
- Q = Ant cycle constant

3.5 Determination of Visit Routes for Distribution Centers

a. Distance Between Distribution Centers

In determining the route of visit required distance data between nodes. The following data is distance between nodes, presented in the following table:

Table 1. Data of Distance between Nodes

From/To	G	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8
G	0	10	15	9,4	10	8	23	25	28
DC 1	7	0	7,5	9,2	3,2	8,2	13,3	20,4	18,9
DC 2	15	7,5	0	6,4	6,6	14,8	10,2	13,5	17,8
DC 3	9,4	9,2	6,4	0	6	13,1	15	18	20,5
DC 4	10	3,2	6,6	6	0	19,5	10,6	18,5	21,4
DC 5	8	8,2	14,8	13,1	19,5	0	24	37	25,6
DC 6	23	13,3	10,2	15	10,6	24	0	19,9	8,2
DC 7	25	20,4	13,5	18	18,5	37	19,9	0	23,6
DC 8	28	18,9	17,8	20,5	21,4	25,6	8,2	23,6	0

b. Determination of Visit Routes

Determination of the visit route is started from the starting point and will return to the starting point, because the starting point is the first point and the last point on this visit route. The starting point and the last point are in the form of point G. The following table is the route of visit that each node passes.

Table 2. Visit Routes

No	Routes that Formed	Distance (Km)	Total Distance (Km)
1	G-DC 1-DC 2-DC 3-DC 4-DC 5-DC 6-DC 7-DC 8-G	10+7,5+6,4+6+19,5+24+19,9+23,6+28	144,9
2	G-DC 8-DC 1-DC 2-DC 7-DC 6-DC 5-DC 4-DC 3-G	28+18,9+7,5+13,5+19,9+24+19,5+6+9,4	146,7
3	G-DC 7-DC 6-DC 4-DC 3-DC 1-DC 2-DC 8-DC 5-G	25+19,9+10,6+6+9,2+7,5+17,8+25,6+8	129,6

4	G-DC 8-DC 6-DC 5- DC 7-DC 2-DC 3-DC 4-DC 1-G	28+8,2+24+37+13,5+6,4+6+3,2 +7	133,3
5	G-DC 5-DC 8-DC 7- DC 6-DC 4+DC 1-DC 3-DC 2-G	8+25,6+23,6+19,9+10,6+9,2+6,4 +3,2+15	121,5
6	G-DC 6-DC 8-DC 7- DC 5-DC 1-DC 4-DC 2-DC 3-G	23+8,2+23,6+37+8,2+3,2+6,6+6 ,4+9,4	125,6
7	G-DC 5-DC 6-DC 8- DC 7-DC 4-DC 3-DC 2-DC 1-G	8+24+8,2+23,6+18,5+6+6,4+7,5 +7	109,2
8	G-DC 7-DC 6-DC 8- DC 5-DC 3-DC 4-DC 2-DC 1-G	25+19,9+8,2+25,6+13,1+6+6,6+ 7,5+7	118,9
9	G-DC 6-DC 8 DC 7- DC 4-DC 2-DC 3-DC 1-DC 5-G	23+8,2+23,6+18,5+6,6+6,4+9,2 +8,2+8	111,7

c. Visibility Between Nodes Calculation (η_{ij})

The function of visibility η_{ij} is to find out the probability of the node that will be visited. Here is a way to calculate the visibility value of node G to DC 1 with a distance of 10,5 km.

$$\eta_{ij} = \frac{1}{d_{ij}} \quad (2)$$

Notes :

d = Distance

i = Initial Node

j = Nodes

$$\eta_{GDC1} = \frac{1}{d_{GDC1}} = \frac{1}{10} = 0,100$$

So the visibility value of node G to node DC1 is 0.100. Other visibility node values can be obtained in the same way. Following are the results of visibility calculation between nodes:

Table 3. Visibility Between Nodes

From/To	G	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8
G	0	0,100	0,067	0,106	0,100	0,125	0,043	0,040	0,036
DC 1	0,100	0	0,133	0,109	0,313	0,122	0,075	0,049	0,053
DC 2	0,067	0,133	0	0,156	0,152	0,068	0,098	0,074	0,056
DC 3	0,106	0,109	0,156	0	0,167	0,076	0,067	0,056	0,049
DC 4	0,100	0,313	0,152	0,167	0	0,051	0,094	0,054	0,047
DC 5	0,125	0,122	0,068	0,076	0,051	0	0,042	0,027	0,039
DC 6	0,043	0,075	0,098	0,067	0,094	0,042	0	0,050	0,122
DC 7	0,040	0,049	0,074	0,056	0,054	0,027	0,050	0	0,042
DC 8	0,036	0,053	0,056	0,049	0,047	0,039	0,122	0,042	0

d. Calculation of Change in Ant Footprints Intensity Value $\Delta\tau_{ij}$

Pheromone is a trail left by ants. On the path that ants often pass, it will cause evaporation and allow changes in the intensity value of the ant footprints between nodes. Here is the equation for the change in the ant footprints intensity value :

$$\Delta\tau_{ij} = \frac{Q}{L_k} = \sum_{k=1}^m \Delta\tau_{ij}^k \quad (3)$$

Notes :

Q = Ant cycle constant

L_k = Route length

m = Number of ants

$$\Delta\tau_{ij} = \frac{1}{Route\ 1} + \frac{1}{Route\ 2} + \frac{1}{Route\ 3} + \frac{1}{Route\ 4} + \frac{1}{Route\ 5} + \frac{1}{Route\ 6} +$$

$$\frac{1}{Route\ 7} + \frac{1}{Route\ 8} + \frac{1}{Route\ 9}$$

$$\Delta\tau_{ij} = \frac{1}{144,9} + \frac{1}{146,7} + \frac{1}{129,6} + \frac{1}{133,3} + \frac{1}{121,5} + \frac{1}{125,6} + \frac{1}{109,2} + \frac{1}{118,9}$$

$$+ \frac{1}{111,7} = 0,072$$

So the total change in the value of ant footprint intensity has the same value at each node that is 0,072. The following table is the changes of ant footprints intensity between nodes.

Table 4. Changes of Ant Footprints Intensity ($\Delta\tau_{ij}$)

From/To	G	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8
G	0	0,072	0,072	0,072	0,072	0,072	0,072	0,072	0,072
DC 1	0,072	0	0,072	0,072	0,072	0,072	0,072	0,072	0,072
DC 2	0,072	0,072	0	0,072	0,072	0,072	0,072	0,072	0,072
DC 3	0,072	0,072	0,072	0	0,072	0,072	0,072	0,072	0,072
DC 4	0,072	0,072	0,072	0,072	0	0,072	0,072	0,072	0,072
DC 5	0,072	0,072	0,072	0,072	0,072	0	0,072	0,072	0,072
DC 6	0,072	0,072	0,072	0,072	0,072	0,072	0	0,072	0,072
DC 7	0,072	0,072	0,072	0,072	0,072	0,072	0,072	0	0,072
DC 8	0,072	0,072	0,072	0,072	0,072	0,072	0,072	0,072	0

e. Calculation of Ant Footprints Value between Nodes for the Next Cycle

The value of ant footprints intensity between nodes ($\Delta\tau_{ij}$) at the beginning of the calculation is determined by a small initial number. In this research, the pheromone value uses an initial value of 0,5. Calculation of the price or value of the ant footprints intensity between nodes for the next cycle is calculated by the following equation:

$$\tau_{ij} = \rho \cdot \tau_{ij}(\text{initial}) + \Delta\tau_{ij} \quad (4)$$

Notes :

- ρ = Ant footprints evaporation constant
- $\tau_{ij}(\text{initial})$ = Ant footprints intensity between cities
- $\Delta\tau_{ij}$ = Changes in ant footprints intensity between cities

Then : $\tau_{G-DC1} = (0,5 \times 0,5) + 0,072 = 0,322$

So the value of ant footprints intensity between nodes for the next cycle is the same all in each node that is 0,322. The following table shows the intensity of footprints (τ_{ij}) on the route of visit.

f. Determination of Route by Finding Probability Value

To calculate the probability value in order to determine the node that will become the destination of the trip. The highest probability value of a node will be the next destination node, can be done with the following equation:

$$p_{ij}^k = \frac{[\tau_{ij}]^\alpha \cdot [\eta_{ij}]^\beta}{\sum_{\tau=1}^n [\tau_{ij}]^\alpha \cdot [\eta_{ij}]^\beta}$$

$$PG, G = \frac{[0]^1 \cdot [0]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0$$

$$PG, DC1 = \frac{[0,322]^1 \cdot [0,100]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,162$$

$$PG, DC2 = \frac{[0,322]^1 \cdot [0,067]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,108$$

$$PG, DC3 = \frac{[0,322]^1 \cdot [0,106]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,172$$

$$PG, DC4 = \frac{[0,322]^1 \cdot [0,100]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,162$$

$$PG, DC5 = \frac{[0,322]^1 \cdot [0,125]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,203$$

$$PG, DC6 = \frac{[0,322]^1 \cdot [0,043]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,070$$

$$PG, DC7 = \frac{[0,322]^1 \cdot [0,040]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,065$$

$$PG, DC8 = \frac{[0,322]^1 \cdot [0,036]^1}{[0]^1 [0]^1 + [0,322]^1 [0,100]^1 + \dots + [0,322]^1 [0,036]^1} = 0,058$$

Other probability value calculations are calculated the same way. Here is a table of calculation results of the probability value between nodes.

Table 5. Probability Value between Nodes

From/To	G	DC 1	DC 2	DC 3	DC 4	DC 5	DC 6	DC 7	DC 8
G	0	0,162	0,108	0,172	0,162	0,203	0,070	0,065	0,058
DC 1	0,162	0	0,156	0,127	0,366	0,143	0,088	0,057	0,062
DC 2	0,108	0,156	0	0,259	0,251	0,112	0,162	0,123	0,093
DC 3	0,172	0,127	0,259	0	0,403	0,184	0,161	0,134	0,118
DC 4	0,162	0,366	0,251	0,403	0	0,208	0,383	0,219	0,190
DC 5	0,203	0,143	0,112	0,184	0,208	0	0,387	0,251	0,363
DC 6	0,070	0,088	0,162	0,161	0,383	0,387	0	0,292	0,708
DC 7	0,065	0,057	0,123	0,134	0,219	0,251	0,292	0	1,000
DC 8	0,058	0,062	0,093	0,118	0,190	0,363	0,708	1,000	0

Based on the table of probability values between nodes with the initial node G, the highest probability chosen is DC 5 = 0,203 so that the ant walks from node G to node DC 5. Then to node DC 6 = 0,387, then to DC 8 = 0,708, DC 7 = 1,000, DC 4 = 0,219, DC 3 = 0,403, DC 2 = 0,259, DC 1 = 0,156 and finally back to G = 0,162. Nodes that formed are as follows G-DC 5-DC 6-DC 8-DC 7-DC 4-DC 3-DC 2-DC 1-G. So the total distance traveled based on the ACO method is 109,2 Km and the best route chosen is the route that passed by the 7th ant.

3.6 Transportation Cost Calculation

The vehicles used for distribution to customers are 2 units of Daihatsu GranMax. Transportation costs include Vehicles Fixed Cost and Vehicles Variable Cost with the description as follows:

- Vehicles Fixed Cost

Daily wages for drivers include the total fixed costs included in the distribution costs in this research. The fee for the driver is Rp. 1,500,000 /month. The company has 2 units of cars so the driver's salary is IDR 3,000,000 /month

- Vehicles Variable Cost

The fuel used is pertalite with details :

$$\text{Fuel Cost} = \frac{\text{Rp } 6750}{15 \text{ km}} = \text{Rp } 510 / \text{km}$$

$$\text{Toll fee} = \text{Rp } 15.000 / \text{day}$$

$$\text{Fuel Cost} = \frac{\text{Distance traveled}}{\text{Fuel Consumption per liter}} \times \text{Fuel price}$$

$$\text{Fuel Cost} = \frac{109,2 \text{ km}}{15 \text{ km}} \times \text{Rp } 7,650 = \text{Rp } 55,692 / \text{ day}$$

The total Variable Cost is Rp 55,692 + Rp 15,000 = Rp 70,692 /day and in a month is Rp 1,837,692/ month with 1 route and 1 vehicle.

So the total transportation cost is the sum of Vehicle Fixed Cost and Variable Cost. The results obtained are Rp. 1,500,000 + Rp Rp 1,837,692= Rp 3,337,692 /month. Whereas the company has 2 routes and transportation costs respectively Rp 2,419,074 /month and Rp 3,262,410 month for a total of Rp 5,681,484 /month.

3.7 Comparison of Routes and Transportation Costs Before and After Using the Ant Colony Optimization (ACO) Algorithm

After doing the calculations using the ACO Algorithm method for determining the company's shipping route to each location of the Distribution Center above. The following table compares the routes and costs currently used by the PT XYZ company with those generated from calculations using the ACO Algorithm method.

Table 6. Comparison Before and After Using the Ant Colony Optimization Algorithm Method

Before ACO	Route	Mileage (Km)	Total Cost/ month
Route 1	G-DC 1-DC 2-DC 3-DC 4-G	39,9	Rp 2,419,074
Route 2	G-DC 5-DC 6-DC 7-DC 8-G	103,5	Rp 3,262,410
Total		143,4	Rp 5,681,484
After ACO	Route	Mileage (Km)	Total Cost/ month
Route	G-DC 5-DC 6-DC 8-DC 7-DC 4-DC 3-DC 2-DC 1-G	109,2	Rp 3,337,692
Total Difference		34,2	Rp 2,343,492

Based on the table above calculations using the Ant Colony Optimization Algorithm method it is obtained the difference of the route or distance to 34.2 Km with a total transportation cost of Rp 2,343,492 /month using a vehicle. This shows the optimal results of the route and the cost with the research using the ACO method.

4. CONCLUSION

Based on the results obtained, it can be concluded that the research of goods distribution at PT XYZ produces optimal routes and transportation costs compared to the company. The results from the company previously had 2 routes with a total distance of 143.4 Km and a total transportation cost of Rp 5,681,484 /month. While based on the results of the research, obtained the results with a total distance of 109,2 Km and total transportation costs becomes Rp 3,337,692 /month, so that the optimal results are obtained with the difference in distance is 34.2 Km and total transportation costs is Rp 2,343,492 /month using one vehicle. Then the obtained results prove that the distribution can be 1 route as follows G-DC 5-DC 6-DC 8-DC 7-DC 4-DC 3-DC 2- DC 1-G.

REFERENCES

- [1] Christopher, Y,S., Dewi, C., Cahya, R,W.Pemilihan Rute Optimal Penjemputan Penumpang *Travel* Menggunakan Ant Colony Optimization Pada Multiple Travelling Salesman Problem (M-Tsp). *Jurnal Pengembangan Teknologi Informasi Dan Ilmu Komputer* Vol. 2, No. 9, September 2018, Page 3138-3145. E-Issn: 2548-964x.
- [2] Gunawan., Maryati I., & Kurniawan H,W. Optimasi Penentuan Rute Kendaraan Pada Sistem Distribusi Barang Dengan Ant Colony Optimization. *National Seminar of Applied Information & Communication Technology (Semantics)* 2012.
- [3] Irsyad, M., Iskandar, I., & Fista F.,T. Optimasi Jalur Pengangkutan Sampah Menggunakan Metode Ant Colony Optimization Di Kota Pekanbaru. *Jurnal Core IT*, Vol.5, No.1, June 2019. ISSN 2599-3321 (Online).
- [4] Karjono, Moedjiono.,& Kurniawan, D.Ant Colony Optimization. *Jurnal Ticom* Vol.4 No.3 May 2016.
- [5] Kurniaty, D.,S. & Guslan, D. Analisis Rute Pendistribusian Dengan Menggunakan Metode Ant Colony Optimization Dalam Persoalan *Vehicle Routing Problem* Pada Kantor Pos Boyolali. *Jurnal Logistik Bisnis*, Vol 9, No.1, May 2018.
- [6] Purnomo, A. Penentuan Rute Pengiriman dan Biaya Transportasi dengan Menggunakan Metode *Clarke and Wright Saving HeuristiC*. *Jurnal Logistik Bisnis Politeknik Pos Indonesia*, Vol. 1, No. 2, 97 – 117. December 2017.

-
- [7] Reimon, J.B. Algoritma Ant Colony Optimization(ACO) Untuk Pemilihan Jalur Tercepat Evakuasi Bencana Gunung Lokon Sulawesi Utara.*Jurnal Teknologi Informasi-Aiti*, Vol. 14. No.1, 1 – 103., February 2016.
 - [8] Suliantoro, H., Susanty, A., & Bachtar, F.,S. Perancangan Rute Distribusi Beras Sejahtera Menggunakan Algoritma Ant Colony Optimization(Studi Kasus Di Bulog Kabupaten Semarang).
 - [9] Widyawati.Penerapan Algoritma Ant Colony Optimization(ACO) Pada Job Shop Scheduling Problem(JSSP) Di PT. Siemens Indonesia (Cilegon Factory).*Jurnal Sistem Informasi Dan Informatika (Simika)* Vol.1 No.1 Year 2018.