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Paper Distribution Route Optimization Using Ant Colony Method at PT. XY

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A B S T R A C T

In distributing their products, companies need to determine distribution routes to optimize the distanceof distribution process and minimize losses, such as distribution by PT. XY is carried out randomly without regard to the location betweenthe customers to be addressed, so that the distance and time taken is excessive resulting in a lot of costs to be incurred. Therefore, planning needs to be done to optimize the distance and time of distribution. The purpose of this study was to determine the paper distribution routes at PT. XY so that the distance and travel time traveled are much more optimal by using the Ant Colony Optimization method. Based on research, the distribution of PT. XY using the Ant Colony Optimization method obtained more optimal results than using the company's initial route design. The total route distance was originally 423.4 km to 310.4 km, and the original total time was 695 minutes to 554 minutes. So it was concluded that there was a total route distance saving of 113 km and a distribution time of 141 minutes. Thus, in the distribution process at PT. XY with the application of this method can minimize costs that must be incurred by the company.

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1. INTRODUCTION

The development of the paper industry in Indonesia is very rapid. The paper industry produces processed wood as a raw material for pulp, paper, boards and other cellulose-based products. Even though we have now moved into the digitalization era, it is undeniable that paper is still widely used for personal, business, and many more. Paper consumption in Indonesia in 2021 is recorded at around 32.6 kg per capita, which can be said to be still very low compared to paper consumption per capita abroad, such as the United States which reaches around 324 kg (Perindustrian, 2021). This condition shows that the opportunity for the development of the paper industry in Indonesia is very large, moreover the use of plastic is increasingly limited, both as a packaging material for various products for public consumption and so on, so that over the years, the need for paper is increasing. Thus causing the growth of the paper industry to increase accompanied by high demand and competition between paper industries. The results of the paper production will then be distributed to consumers. However, before it is distributed, the company must

determine the distribution route to optimize the distribution distance and time. If the distribution is not well planned, it will have an impact on the company both in terms of product quality and consumer satisfaction. Therefore, companies must design the right distribution strategy to minimize losses that will occur, this is because distribution is an interrelated chain (Karundeng et al, 2018). Seeing this situation, PT. XY is one of the paper industry companies that is expanding to increase production capacity by building additional paper mills. This company produces Brown Paper, White Paper to Color Paper according to customer demand. It is recorded that demand for paper products in 2022 will reach 939 tons. Seeing the high demand for these products, it is certain that distribution activities to customers are also increasing. But the distribution process of PT. XY is still carried out randomly without regard to the location between the depots or the intended consumers, so that the distance and travel time are not optimal or excessive, therefore resulting in a lot of costs to be incurred. On the other hand, speed and accuracy are the main goals to provide satisfaction to consumers. Therefore, in this study, updating the distribution route using the Ant Colony Optimization method was carried out. This method is inspired by the natural life of ants regarding the habits of ants in searching for food. Naturally ant colonies are able to determine the shortest route on the way from the nest to the food places based on the footprints on the trajectory that has been traversed (Risqiyanti et al., 2019).

Research by (Risqiyanti et al., 2019), it was found that the use of the Ant Colony Optimization method was more effective for determining the shortest route than the company's initial route. The proposed method can maximize the shortest distance of 114.62 Km with the fastest time of 232 minutes. Research by (Manuputty et al., 2021), determined the shortest path for mineral water distribution using ant colony optimization. based on the results of research on determining the company's initial route using the google maps application with a total distance of 19.6 Km. After applying the Ant Colony Optimization method, a shorter total distance of 18.14 Km was obtained. (Eraniola & Suhendar, 2021), based on the results of research using the Ant Colony Optimization Algorithm Method, it is a solution for companies to estimate distance and time, the approach in this method for company problems produces optimal distance and time, namely the driver can cover a distance of 47.1 Km and the driver can return to the company at 14.40 WIB. Based on the research that has been cited, it can be seen that the Ant Colony Optimization algorithm method is an effective method based on the behavior of ant colonies in finding the shortest travel distance, so the Ant Colony method is very appropriate to use for solving optimization problems in determining the shortest path to get the lowest distribution costs. optimal. This method will be implemented at PT. XY to determine the shortest route for distribution of paper products, in order to minimize costs and provide customer satisfaction.

2. LITERATURE REVIEW

Distribution is defined as a marketing effort to distribute products and services from producers to consumers. According to Kotler and Armstrong, distribution is a company activity so that products and or services are easily obtained by target consumers (Tegar, 2019). Distribution activities are one of the most important parts of a company's logistics (Arifian & Pulansari, 2023). In addition to distributing goods and services, distribution is useful for achieving equal distribution of production, so that the viability of production activities is guaranteed and the use value of goods and services increases (Subagyo et al., 2018). In general, the distribution strategy is divided into 3 strategies, namely: direct delivery, delivery through the warehouse and cross-docking (Pujiawan & Er, 2010). Transportation methods are used when someone determines how to distribute something types of goods from several sources to several destinations can minimize costs. (Lasmana, 2021) According to Chopra and Meindl, there are six types of distribution channels, including: manufacturer storage with direct shipping, manufacturer storage with direct shipping and in-transit merge, distributor storage with carrier delivery, distributor storage with last mile delivery, manufacturer/distributor storage with customer pickup, and retail storage with customer pickup.

Distance and time are one of the main factors in the continuity of distribution activities. If the distribution route is not well planned, then the distance and time traveled will not be optimal. This will have an impact on losses for the company because it requires large costs as well. Distance is a number that indicates how far the object changes position through a certain route. Distance can be interpreted as the length of cycles in a graph-weight, namely the sum of the minimum weights of all edges on the cycle (Purnomo, 2014). A graph is represented by a problem which is described by a set of points connected by a set of lines, then given a letter or number symbol. Therefore, the company must determine the shortest lane to get the optimal distance and time. The minimum path to get a place from a certain place. The problem of finding the shortest path in the graph is an optimization problem. Optimization is the process of finding the best value based on the objective function with a defined origin (Purnomo, 2014). The graph needed in the shortest path liquefaction is a weighted graph, which is a graph that is given a weight or value on each side. The weights or values for the edges of the graph can prove the distance between cities, delivery time, shipping costs and so on.

To determine the route when someone will come to all specified locations can use TSP (Silalahi et al., 2019).The Traveling Salesman Problem is defined as a search sequence for all locations that must be visited, starting from the citycertain time and return to that city (Risqiyanti et al., 2019). According to Helsgaun and Purnomo, the traveling salesman problem (TSP) is a condition in which a traveling salesman visits a city with the rule that each city visits a maximum of once and minimizes the total distance traveled and then has to return to his hometown. The problem that often arises is how to visit a node in a graph from the starting point to another exactly once with minimum weight (cheapest cost) to return to the starting point. The method that can be used to determine the optimal distance and time can use the ant colony optimization method. Ant Colony Optimization (ACO) Methodis the brainchild of Dorigo and Gambardellain 1997 which was used forfind the shortest route on the Traveling Salesman Problem (Bimantara et al., 2021). The Ant Colony Optimization algorithm was introduced by Moyson and Manderick, and was extensively developed by Marco Dorigo. The ant algorithm is a bioinspired metaheuristic which has a special group that resembles the behavior characteristics of social insects, namely ant colonies. Each actor imitates the behavior of live ants and their social interactions in order to efficiently find food sources and bring them to the ant colony (Eraniola & Suhendar, 2021). Ants are able to sense their complex environment in search of food and then return to their nest by leaving pheromone substances in their paths. That's what the pheromone will become reference to other ants in doing search (Hasna et al., 2021). When the path is shortervisit, then the less evaporation that occurs and increasingly high levels of pheromone trails in the trails (Nurharyanto & Perdana, 2021). The process of leaving behind this pheromone is called stigmergy, which is a process of modifying the environment that not only aims to remember the way back to the nest, but also becomes an ant's tendency to follow the path that has been passed by other ants and find the shortest path or the optimal path (Risqiyanti et al., 2019). After all the ants have completed their respective tours, the Pheromone is updated. Each ant is given a tabulist, which is a data structure that stores the points visited by ants and prohibits ants from revisiting these points before they complete a tour. When a tour is completed, the tabulist is used to calculate the solutions that the ants found on that tour.

3. RESEARCH METHOD

This study uses field research and library research methods with a qualitative approach and is used based on perceptions of social phenomena that occur (Sahir, 2021). The data sources used are primary data and secondary data. Primary data obtained from interviews and observations. While secondary data obtained from books, journals and literature from companies as well as other literature related to research. To process and analyze the data that has been collected using the Ant Colony Optimization. The following flow to solve this problem can be seen in Figure 1.

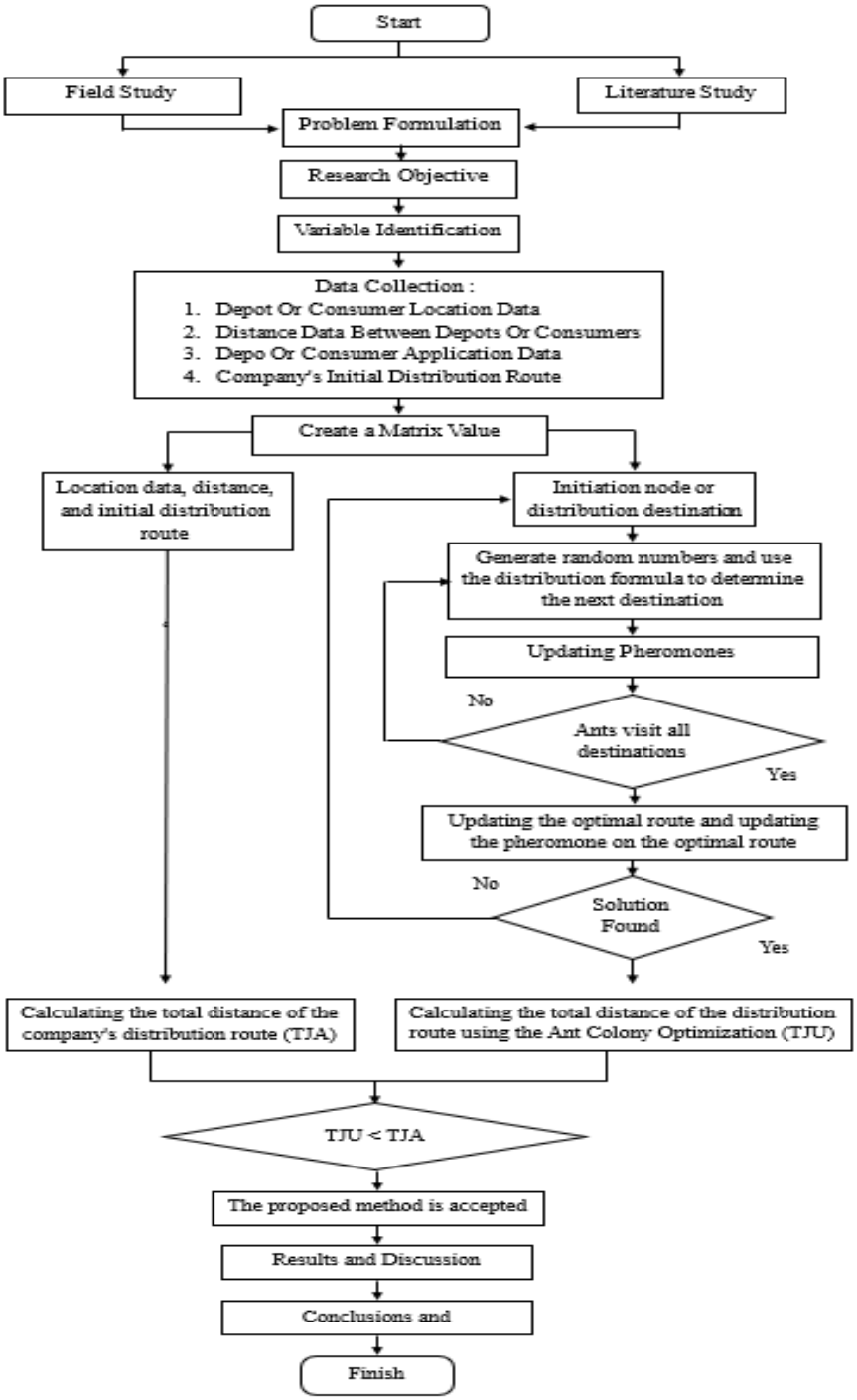

Figure 1. Research stage

4. RESULT AND DISCUSSION

4.1. Matrix Distance Between Agents

The distribution distance carried out by the company in November 2022 can be seen in the distance matrix table below:

Table 1. Distance matrix data between agents

Matrix (km)	1	2	3	4	5	6	7	8	9	10	11	Information
1	0	8	53	63	53	37	36	38	34	38	36	1 : PT. XY
2	8	0	60	69	60	44	43	45	41	44	38	2 : PT. NP
3	53	60	0	18	2,4	20	22	23	32	24	53	3 : PT. ST
4	63	69	18	0	21	34	36	39	42	39	66	4 : PT. IU
5	53	60	2,4	21	0	18	20	23	29	22	51	5 : PT. MG

6	37	44	20	34	18	0	7,5	8,1	15	9,6	36	6	: PT. AB
7	36	43	22	36	20	7,5	0	5,5	12	15	34	7	: PT. SC
8	38	45	23	39	23	8,1	5,5	0	7,8	16	31	8	: PT. WB
9	34	41	32	42	29	15	12	7,8	0	12	34	9	: PT. CM
10	38	44	24	39	22	9,6	15	16	12	0	45	10	: PT. SL
11	36	38	53	66	51	36	34	31	34	45	0	11	: PT. CC

4.2 Company's Initial Distribution Route

The initial route data is the route used by the company in distributing milk to all agent locations spread across the Pasuruan area to meet consumer targets or demands. The regular route used starts and ends at the same node, namely PT. XY with node 1.

Table 2. Initial distribution route

Route	Distribution Route	Distance (km)	Mileage (km)	Demand (kg)	Traveling Time (minute)
1	PT. XY – PT. NP – PT. ST – PT. MG – PT. XY	8+60+2,4+53	123,4	21,582	201
2	PT. XY – PT. IU – PT. AB – PT. SL – PT. XY	63+34+9,6+38	144,6	21,951	231
3	PT. XY –PT. SC – PT. WB – PT. CM – PT. XY	36+5,5+7,9+34	83,4	14,926	143
4	PT. XY – PT. CC – PT. XY	36+36	72	14,882	120
Total			423,4	73,341	695

4.3 Ant Colony Optimization Results Routes

The results of running the program from the matlab application using the Ant Colony Optimization algorithm can be seen in the image below. The results of this matlab application show how optimal the Ant Colony Optimization algorithm method is in solving solutions to the Traveling Salesman Problem at PT. XY.

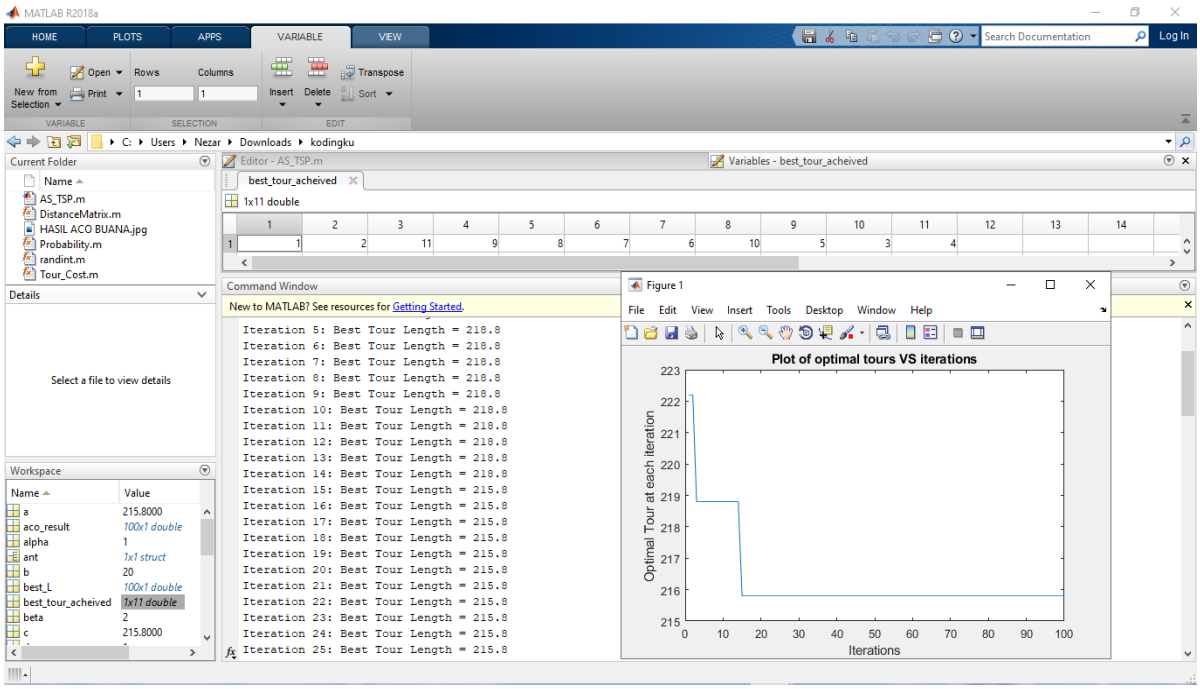

Figure 2. Ant colony optimization algorithm program

The picture above shows the matlab program to form a tour salesman to travel from the starting point to the ending point. It also shows how big the solution is optimal.

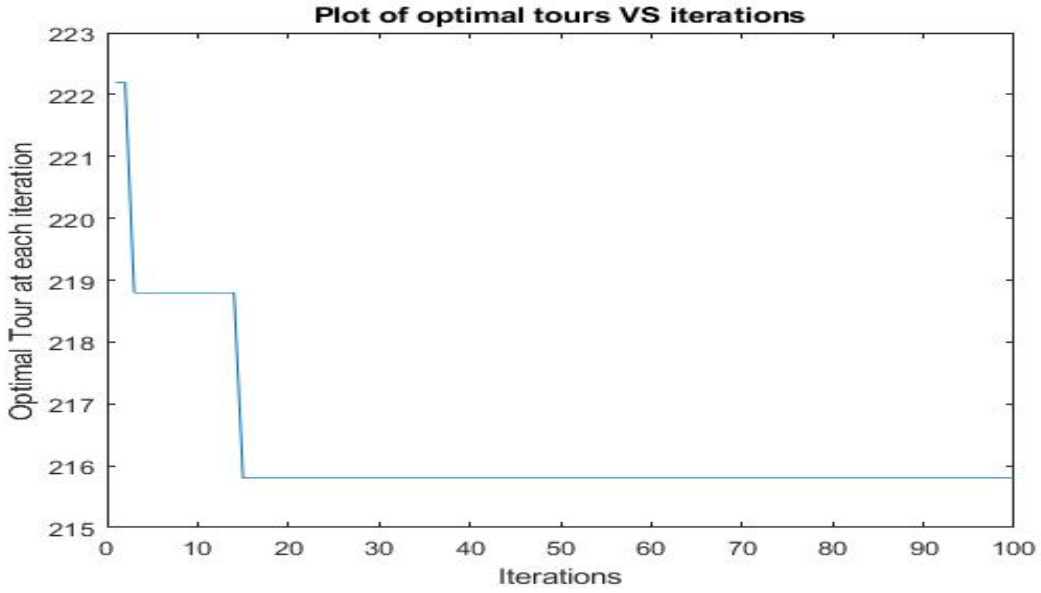

Figure 3. Number of iterations in finding the newest route using the ant colony optimization method

The figure above shows that the calculation using the Ant Colony Optimization method obtained the optimal route in the 14th iteration, but to ensure that the route selection is correct and optimal, the iterations are continued until the 100th iteration. The results obtained show that in the 1st iteration the total is obtained a distance of 222.2 then in the 2nd to 13th iteration a distance of 218.8 is obtained and in the 14th to 100th iteration a distance of 215.8 is obtained. Route calculations using the Ant Colony Optimization algorithm show the same results continuously so that it can be concluded that the optimal route is obtained in the 14th iteration. The following is a table explaining the output of the Ant Colony Optimization program

Table 3. Ant colony optimization program output route

No	Tour Salesman Route	Mileage (Km)	Total Mileage (Km)
1	PT. XY – PT. NP – PT. CC – PT. CM – PT. WB – PT. SC – PT. AB – PT. SL – PT. MG – PT. ST – PT. IU	8+38+34+7,8+5,5+7,5 +9,6+22+2,4+18+63	215,8

4.4 Calculation of Distance and Total Time of Visit Route Based on Vehicle Capacity

It can be seen by the limited capacity of the product transport fleet to get to each agent. So the delivery process is divided into 3 routes, as follows:

1. First Route

Table 4. First route

No	Tour Salesman Route	Mileage (Km)	Total Mileage (Km)	Total Travel Time (Minutes)
1	PT. XY – PT. NP – PT. CC	8+38+36	82	135

On the first Salesman tour route, namely delivery to PT. NP with a request of 8,574 Kg - PT. CC is 13,203 Kg, so the total distance is 82 Km, the total capacity is 21,777 Kg and the total time is 135 minutes.

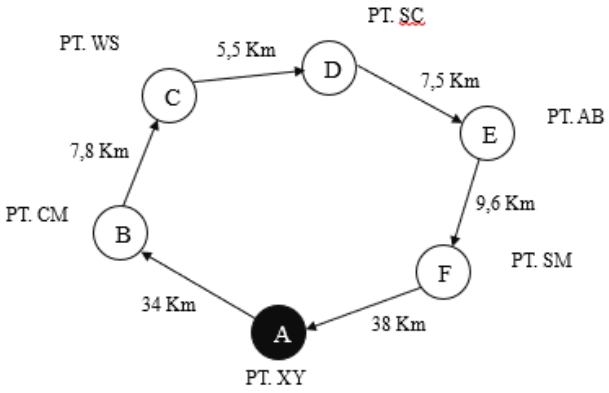

Figure 4. Route 1 ant colony optimization method

2. Second Route

Table 5. Second route

No	Tour Salesman Route	Mileage (Km)	Total Mileage (Km)	Total Travel Time (Minutes)
1	PT. XY – PT. CM – PT. WB – PT. SC – PT. AB – PT. SL	34+7,8+5,5 +7,5 +9,6+38	102,4	176

On the first Salesman tour route, namely delivery to PT. CM with a request of 5,280 Kg – PT. WB of 3,356 Kg – PT. SC as much as 6,290 Kg – PT. AB as much as 4,903 Kg – PT. SL of 4,832 Kg, a total distance of 102.4 Km and a total capacity of 24,661 Kg and a total time of 176 minutes.

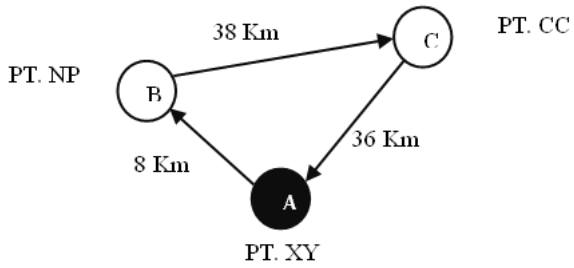

Figure 5. Route 2 ant colony optimization method

3. Third Route

Table 6. Third route

No	Tour Salesman Route	Mileage (Km)	Total Mileage (Km)	Total Travel Time (Minutes)
1	PT. XY – PT. MG – PT. ST – PT. IU	53+2,4+18+63	126,4	243

On the first Salesman tour route, namely delivery to PT. MG with a request of 3,965 Kg – PT. ST as much as 8,718 Kg – PT. IU is 12,216 the total distance is 126.4 Km, the total capacity is 24,899 Kg and the total time is 243 minutes.

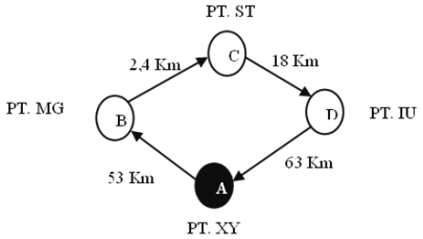

Figure 6. Route 3 metode ant colony optimization

4.5 Comparison of Distance and Time of Distribution of Companies with Distance and Time of Distribution of the Ant Colony Optimization Method

Comparing distribution distances and companies with distribution distances using the Ant Colony Optimization method. Following are the results of a comparison of distribution distances after and before using the Ant Colony Optimization method (Table 6).

Table 6. Comparison of total distance and time of the company's initial route with the ant colony optimization method

Route	Company Distribution Route	Total Distance (km) and Time (Minute)	Ant Colony Optimization Method Distribution Route	Total Distance (km) & Time (Minute)
1	PT. XY– PT. NP – PT. ST – PT. MG – PT. XY	123,4 & 201	PT. XY – PT. UI – PT. CC – PT. XY	82 & 135
2	PT. XY – PT. IU – PT. AB – PT. SL– PT. XY	144,6 & 231	PT. XY – PT. CM – PT. WB – PT. SC – PT. AB – PT. SL -PT. XY	102,4 & 176
3	PT. XY – PT. SC – PT. WB – PT. CM – PT. XY	83,4 & 143	PT. XY – PT. MG – PT. ST – PT. IU – PT. XY	126,4 & 243
4	PT. XY – PT. CC – PT. XY	72 & 120		
		423,4 & 695		**310,4 & 554**

Information:
Distance difference
= Company Distance – ACO Method Distance
= 423,4 – 310,4
= 113 Km

Savings Percentag
$= \frac{\text{Company Distance} - \text{ACO Method Distance}}{\text{Company Distance}} \text{x} 100\%$
$= \frac{423{,}4 - 310}{423{,}4} \text{ x } 100\%$
= 26,7%

Minutes Different
= Company Time – ACO Method Time
= 695 – 554
= 141 Minutes

4.6 Sequence of Routes Before and After Using the Ant Colony Optimization Method

The following table describes the order o milk distribution from the warehouse to the agent to the warehouse using the company's initial route and the Ant Colony Optimization method:

Table 7. Sequence of routes before and after using the ant colony optimization method

Initial Route and Mileage From the Company			Proposed Routes and Mileage Using the Ant Colony Optimization Method		
Route	Node	Transport Load (Kg)	Route	Node	Transport Load (Kg)
1	1-2-3-5-1	21,582	1	1-2-11-1	23,781
2	1-4-6-10-1	21,951	2	1-9-8-7-6-10-1	24,661
3	1-7-8-9-1	14,926	3	1-5-3-4-1	24,899
4	1-11-1	14,882			
Total Transport Load (Kg)		**73,341**	Total Transport Load (Kg)		**73,341**

From the results above, it can be concluded that there was a decrease in the route after using the Ant Colony Optimization method and there were changes regarding the flow of the distribution, namely route 1 (1-2-11-1) with a load of 23,781 kg, route 2 (1 -9-8-7-6-10-1) with a payload of 24,661 kg, and route 3 (1-5-3-4-1) with a payload of 24,899 kg, with a total load of transport is 73,341 kg.

4.7 Recapitulation Results and Percentage of Distance Savings

Table 8. Recapitulation of distance and time saving results

Total Distance (Km)		Distance Saving (Km)	Distance Saving (%)	Time Saving (Minutes)
Initial Route	Ant Colony Optimization Method			
423,4	310,4	113	26,7%	141

From the above results it can be concluded that the Ant Colony Optimization method is better than that applied by the company. Thus the results obtained from the Ant Colony Optimization method will be selected as the proposed route, with a total distance of 310.4 km with a total time of 554 minutes and the company's initial total distance of 423.4 km with a total time of 695 minutes, then a total distance savings is obtained 113 km and a time saving of 141 minutes with a saving percentage of 26.7%. From the data above, it can be seen that the paper distribution routes are shorter and the time needed for distribution is reduced after the Ant Colony Optimization method is applied, so companies can optimize the distance and distribution time compared to using the company's initial route, the results obtained are the same as some previous studies.

5. CONCLUSION

Based on the results of data processing and data analysis, it can be concluded that the Company's routes produce a total route distance of 423.4 km with a total time of 695 minutes while for the optimal total distance the Ant Colony Optimization method is with a total route distance of 310.4 km with a total time 554 minutes. Thus, the optimal route for paper distribution using the Ant Colony Optimization method is better than the company's initial route with a total distance savings of 113 km. As for the distribution time saver for all routes between the company method and the Ant Colony Optimization method with a difference of 141 minutes. Based on the results of research that has been done, for PT. XY is expected to be able to use the distribution route resulting from the application of the Ant Colony Optimization method with matlab software to obtain the optimal route. For future research, can use the Nearest insert method as a comparison so that the results obtained are more optimal.

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