Available online at http://scik.org

J. Math. Comput. Sci. 2022, 12:59

https://doi.org/10.28919/jmcs/7078

ISSN: 1927-5307

ANT COLONY OPTIMIZATION MODEL FOR DETERMINING THE SHORTEST ROUTE IN MADURA-INDONESIA TOURISM PLACES

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Abstract: Travel planning is important, especially in areas that often-become tourist destinations. Each region must have an interesting tour, one of which is on the island of Madura. With so many tours available, it confuses tourists in determining tourist routes. In addition, on the island of Madura, many traditional markets spill onto the streets on certain days which can cause traffic jams so that tourists' journeys are hampered. In this study, a research method using Ant Colony Optimization (ACO) is proposed to determine the shortest route to tourist sites on Madura Island. Ant Colony Optimization method is one method that can solve an optimization problem. In solving the problem this method is inspired by the behavior of a collection of ants. Ants function as agents assigned to find solutions to a problem. Based on the experiments carried out, the accuracy value in finding the shortest route solution was 80%. In addition, the number of tours and the magnitude of the distance also affect the execution time of the process of determining the shortest route. The more tours that are visited and the greater the distance traveled, the longer the execution time of the process of determining the shortest route.

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Received December 13, 2021

Keywords: ant colony optimization (ACO); tourist routes; optimization problem.

2010 AMS Subject Classification: 37N40.

1. INTRODUCTION

Each area has interesting tourist attractions, one of which is tourism on the island of Madura. Madura Island has various types of tourism objects, ranging from natural, cultural, and religious tourism spread in various regions, namely Bangkalan, Sampang, Pamekasan, and Sumenep.[1] Based on data from the Department of Culture and Tourism for each district on Madura Island, there are 21 tours in Bangkalan Regency, 12 tours in Sampang Regency, 6 tours in Pamekasan Regency, 22 tours in Sumenep Regency. Some of the tourist attractions in the Madura Island area include Jaddih Limestone Hill, Camplong Beach, Talang Siring Beach, Gili Labak, Lombang Beach, and so on [2][3].

Each tourist spot has various potentials, but from these potential problems arise to reach these tourist attractions such as determining the shortest route. To be able to go to tourist destinations, there will be a choice of routes that are passed in each area. In addition to route selection, to reach tourist attractions on Madura Island, many traditional markets spill onto the streets on certain days or commonly called market days which can cause traffic jams so that tourist trips on tours on Madura Island are slightly hampered. From the problems above, a system that supports tourists is needed, namely the shortest tourist route. This route will take tourists to the tourist places to be visited to be able to save time, distance, and cost [4][5].

Planning a trip before going on a tour is an important thing. With a travel plan, tourists can easily see an overview of the trip and the desired shortest route options to be able to shorten the time to arrive at the tourist destination. In this study, to determine the shortest route to this tourist location using the Ant Colony Optimization (ACO) method. ACO is an algorithm that adopts the behavior of an ant colony. Ants can find the shortest route in finding food sources, this is the nature of ants. It is based on footprints on the trajectory that has been traversed. The more ants that pass through a track, the clearer the footprints will be.

2. PRELIMINARIES

2.1 Shortest Route

Traveling Salesmen Problem (TSP) is one of the optimization problems such as determining the shortest route [5]. The problem of determining the shortest route can be categorized into optimization problems. Determination of the shortest route is to determine the most optimal path, namely the path with the shortest route and the smallest cost. Time can be related to the distance traveled, the shorter the distance, the shorter the time needed to cover the distance [5][6]. Calculation of the shortest route plays an important role in everyday life because it must be done in a short time and at the same time so that it can immediately be known which route is the shortest to pass [7].

The optimal value can be found in two ways. The first is the conventional method, which is to try all the possibilities by recording the values obtained, this method is less effective because the optimization will run slowly. The two heuristic methods are using a formula to get the optimal value quickly and precisely. One of the heuristic methods is the Ant Colony Optimization algorithm. This algorithm is one of the best algorithms in solving problems regarding determining the shortest route such as the Traveling Salesman Problem (TSP) [8].

2.2 Ant Colony Optimization *(ACO)*

This optimization problem is solved in several well-known ways, including using the simulated annealing algorithm, genetic algorithm, bee colony, A*, Dijkstra's Algorithm, and Ant Colony Optimization [9]. Ant Colony Optimization or ACO was introduced by Moyson and Manderick and developed by Marco Dorigo. This algorithm is called bioinspired metaheuristic which is included in the Swarm Intelligence group, which is one type of paradigm development used to solve optimization problems where the inspiration used to solve the problem comes from the behavior of the insect swarm. Ant Colony Optimization is generally used to solve discrete optimization problems and complex problems where there are many variables. The results obtained using the ACO algorithm are close to the optimal value [10].

Ant Colony Optimization algorithm is adopted from the behavior of ant colonies in finding food

sources. Ant colonies can find the shortest path between the nest and the food source based on the footprints they have passed. The more ants that pass through one track, the clearer the footprints will be. This causes the trajectory that is rarely passed by ants, the density of ants passing through it will decrease or even no one will pass through it. On the other hand, the trajectory traversed by ants in large numbers will increase the density of ants that pass through it or even all ants pass through the trajectory [11].

Ant colonies have a unique behavior when looking for food sources [12]. The ants spread out looking for the shortest path to find the food source. In the process of searching for food sources, ants communicate with each other through a liquid chemical substance left behind as footprints called pheromones. So that other ants will follow and choose a path with a higher pheromone level. This is because the more pheromones in a path, the more ants pass through that path. The pheromone will later experience evaporation, but because many ants pass through this path, the pheromone value will remain strong and the route is the shortest distance traveled. This is what underlies the concept of the Ant Colony Optimization algorithm [13][14].

2.3 Accuracy

To calculate the accuracy value using equation (9) which uses the number of correct data compared to the test data [15].

$$accuracy = \frac{\sum correct\ test\ data}{\sum total\ test\ data}\ x\ 100\% \qquad (9)$$

3. MAIN RESULTS

3.1 Data Collection

Tourism data on Madura Island is based on data from the Culture and Tourism Office of each Regency in Madura in 2020 as many as 61 tours, namely Bangkalan Regency as many as 21 tours, Sampang Regency as many as 12 tours, Pamekasan Regency as many as 6 tours and Sumenep Regency as many as 22 tours.

Distance data is the distance between tourist sites, distance data is taken from Google Maps,

traditional market data that causes congestion (on certain market days) is also taken from Google Maps as many as 36 markets, namely Bangkalan district as many as 11 markets, Sampang district as many as 6 markets, district Pamekasan as many as 7 markets, Sumenep district as many as 12 markets

3.2 Traditional Market

On the island of Madura, many traditional markets always cause crowds or overcrowding to spill over to the highway axis. In addition, in the Madura traditional market, there is also a daily market or Laki market. This daily market or Laki market sells various animals such as cows and goats. This market occurs once a week with market visitors who are more crowded than other days causing traffic jams that are worse than usual. Thus causing congestion at several points of the highway which has an impact on residents who want to pass by in the area around the market, including tourists who want to travel on the island of Madura. The output generated from the calculation of the shortest route is shown in Figure 1 in the form of maps using Leaflet javascript, Open Street Map, Geolocation, and Leaflet Direction Routing.

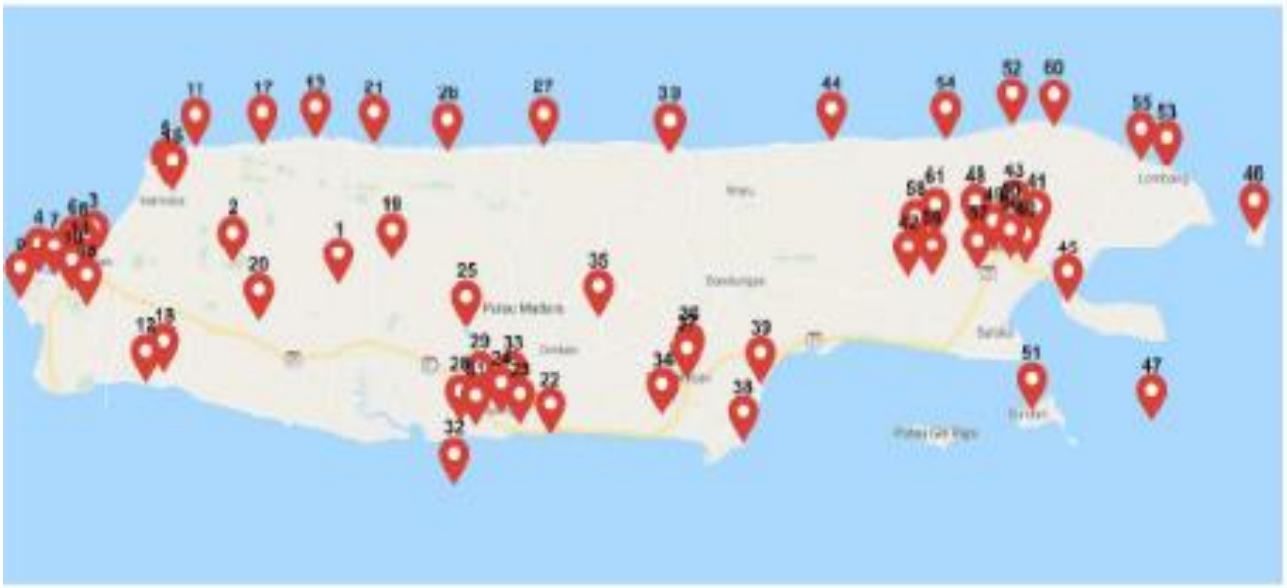

Figure 1. Base Map with Location Mark on Tourism in Madura

https://www.google.co.id/maps/place/Pulau+Madura

3.3 Ant Colony Optimization (ACO)

The algorithm used in this research is the Ant Colony Optimization algorithm. The following flowchart of the Ant Colony Optimization algorithm can be seen in Figure 2.

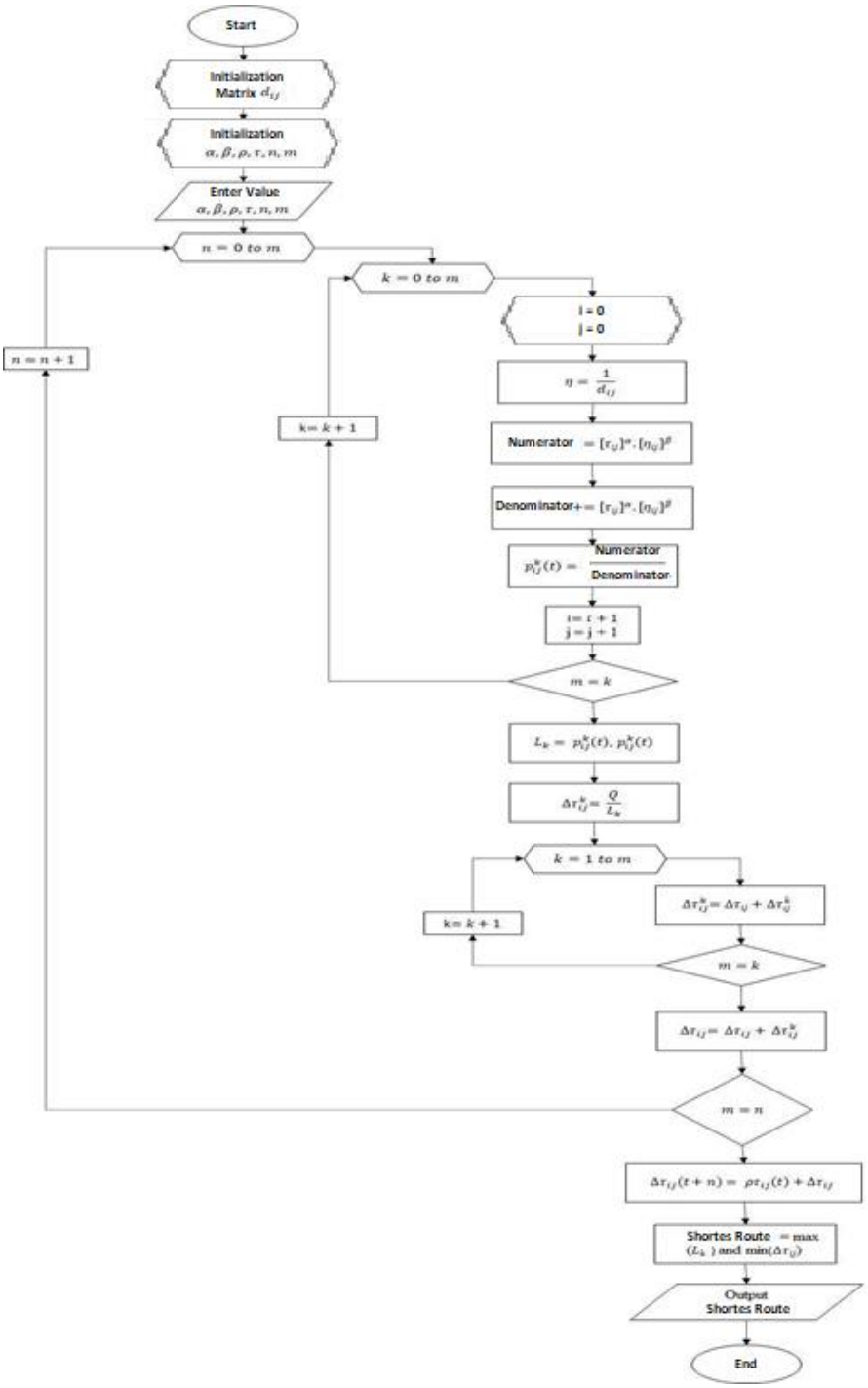

Figure 2. Ant Colony Optimization Model Flowchart

Based on Figure 2, in determining the shortest route using the Ant Colony Optimization method, there are several steps, including [10][11]:

a. Matrix initialization d_{ij} , d_{ij} is the distance from one tour to another in Bangkalan district as shown in Table 1.

Table 1. Matrix d_{ij}

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	0	34.7	12.7	57.4	41.4	34.8	30.7	55.5	61.7	40.9	56.4	49.5	59.8	66.7	61.1	25	34.7	51	23.6	56.4	59
2	34.7	0	26.6	29.3	35.3	21.4	40.3	29.3	36.8	35.1	30.3	21.5	35.3	41.8	33.1	54.4	39.9	23	47.2	30.2	32.1
3	12.7	26.6	0	49.3	36.8	30	36.9	49.1	56.7	36.5	50.2	41.4	53.6	61.7	53	32.3	37	42.9	30.9	50.2	52
4	57.4	29.3	49.3	0	25.8	27.9	43.4	10.4	9.7	27	10.1	21	8.2	14.7	7.1	60.6	40.3	16.2	53.1	9.6	8.1
5	41.4	35.3	36.8	25.8	0	16.8	21.5	16.7	22.9	0.4	17.6	33	21	27.9	22.9	36.4	18.4	34.3	29.2	17.6	20.2
6	34.8	21.4	30	27.9	16.8	0	20.8	27.9	35.3	16.6	28.8	20	32.2	40.3	31.7	35.6	20.9	21.5	28.4	28.8	30.7
7	30.7	40.3	36.9	43.4	21.5	20.8	0	33	39.2	23.3	33.9	38.1	37.3	44.2	39.2	16.2	6.2	39.6	9.9	33.9	36.5
8	55.5	29.3	49.1	10.4	16.7	27.9	33	0	7.5	16.4	2.4	20.9	5.5	12.7	4.6	47.9	29.9	22.4	40.6	2.3	4.1
9	61.7	36.8	56.7	9.7	22.9	35.3	39.2	7.5	0	22.6	5.3	27	2	5.4	4.4	55.3	36	24.8	46.8	5.3	4.5
10	40.9	35.1	36.5	27	0.4	16.6	23.3	16.4	22.6	0	18.7	32.7	22.1	29	22.8	38.2	19.8	34.2	30.9	17.3	20.5
11	56.4	30.3	50.2	10.1	17.6	28.8	33.9	2.4	5.3	18.7	0	21.8	3.4	10.4	3	50	30.7	23.3	41.5	0.4	2.5
12	49.5	21.5	41.4	21	33	20	38.1	20.9	27	32.7	21.8	0	25.4	28.2	24.7	53	38.3	1.8	45.8	21.9	25.7
13	59.8	35.3	53.6	8.2	21	32.2	37.3	5.5	2	22.1	3.4	25.4	0	7	2.3	53.4	34.2	23.2	44.9	3.4	2.6
14	66.7	41.8	61.7	14.7	27.9	40.3	44.2	12.7	5.4	29	10.4	28.2	7	0	9.4	60.3	41.1	25.9	51.9	10.5	9.9
15	61.1	33.1	53	7.1	22.9	31.7	39.2	4.6	4.4	22.8	3	24.7	2.3	9.4	0	52.3	36	22.2	46.8	2.5	1
16	25	54.4	32.3	60.6	36.4	35.6	16.2	47.9	55.3	38.2	50	53	53.4	60.3	52.3	0	21.5	54.5	8.8	49.9	51.8
17	34.7	39.9	37	40.3	18.4	20.9	6.2	29.9	36	19.8	30.7	38.3	34.2	41.1	36	21.5	0	39.7	14	30.7	33.8
18	51	23	42.9	16.2	34.3	21.5	39.6	22.4	24.8	34.2	23.3	1.8	23.2	25.9	22.2	54.5	39.7	0	47.2	23.3	25.2
19	23.6	47.2	30.9	53.1	29.2	28.4	9.9	40.6	46.8	30.9	41.5	45.8	44.9	51.9	46.8	8.8	14	47.2	0	41.5	44.6
20	56.4	30.2	50.2	9.6	17.6	28.8	33.9	2.3	5.3	17.3	0.4	21.9	3.4	10.5	2.5	49.9	30.7	23.3	41.5	0	2
21	59	32.1	52	8.1	20.2	30.7	36.5	4.1	4.5	20.5	2.5	25.7	2.6	9.9	1	51.8	33.8	25.2	44.6	2	0

Description of tourist attraction nodes:

1. Dhurjan Bidadari Waterfall, 2. Kec. Waterfall. Galis, 3. Konang Natural Fire, 4. Jaddih Limestone Hill, 5. Arosbaya Pelalangan Hill, 6. Geger Mountain, 7. Mangrove Forest, Kec. Ten, 8. Kerapan Sapi, 9. Kolla Langgundih, 10. Tomb of Mother's Tears, 11. Tomb of Sultan Abdul Kadirun, 12. Tomb of Sunan Cendana, 13. Tomb of Syeichona Cholil, 14. Lighthouse, 15. Museum of Bangkalan, 16. Beach Bumi Anyar, 17. Maneron Beach, 18. Rongkang Beach, 19. Siring Kemuning Beach, 20. Paseban Park, 21. City Recreation Park

b. Parameter Declaration Alpha, Beta, Rho, Initial Pheromone, Ant Number

Alpha is a constant for controlling the intensity of the ant's distance. Beta is the visibility control constant, the initial Pheromone is the evaporation constant of the ant trail.

$\alpha = 1$, $\beta = 2$, $r = 1$, $\rho = 0{,}5$, m = 21

c. Entering the number of ants and the number of iterations

d. Create tabulist

Ants placed on each node start to tour and generate a path or route. The number of tabulists will be proportional to the number of ants, then the number of tabulists will be equal to the number of tours

- Put the ant on the i-th node

Suppose in the 1st tabulist by the 1st ant. Initially, the ant is placed at node 1, then node i is the same as node 1. Then the ant goes to node j.

- Determine node j, Node j is a node between nodes 1 to 50 on the attraction.

The way to determine it is based on the greatest probability value, to find out, formula (1) is used:

$$P_{ij}^{k}(t) = \frac{[\tau_{ij}]^{\alpha}.[\eta_{ij}]^{\beta}}{\Sigma[\tau_{ij}]^{\alpha}.[\eta_{ij}]^{\beta}} \quad (1)$$

e. Calculating the Probability on a path with formula (2)

$$L_k = p_{ij}^{k}(t), p_{ij}^{k}(t) \quad (2)$$

f. Counting pheromones while on path

$\Delta\tau_{ij}^{k} = \frac{Q}{L_k}, Q$ is iteration (3)

g. Counting *pheromone global*

$$global = \Delta\tau_{ij}^{k} = \sum_{k=1}^{m} \Delta\tau_{ij}^{k} \quad (4)$$

h. Counting pheromones for each tabulist

$$\Delta\tau_{ij} = \Delta\tau_{ij} + \Delta\tau_{ij}^{k} \quad (5)$$

i. Obtained results such as Table 2

j. Do iterations as many ants

k. Update *pheromone*

$$\Delta\tau_{ij}(t+n) = \rho\tau_{ij}(t) + \Delta\tau_{ij} \quad (6)$$

Table 2. Tabulist

Path	Probability value	Pheromone Each Tabulist
1-3-2-6-10-5-8-20-11-21-15-13-9-14-4-18-12-7-17-19-16	5.8557717374991	3.7644561331075
2-6-10-5-8-20-11-21-15-13-9-14-4-18-12-7-17-19-16-1-3	5.8397032857154	3.7649260262569
3-1-19-16-7-17-5-10-8-20-11-21-15-13-9-14-4-17-12-6-2	5.8279865889100	3.7652702936309
4-15-21-20-11-8-13-9-14-18-12-6-10-5-17-7-19-16-1-3-2	5.8455034068703	3.7647561141340
5-10-8-20-11-21-15-13-9-14-4-18-12-6-7-17-19-16-1-3-2	5.7779719934592	3.7667555546537
6-10-5-8-20-11-21-15-13-9-14-4-18-12-2-3-1-19-16-7-17	5.8792855216625	3.7637731439074
7-17-19-16-1-3-2-6-10-5-8-20-11-21-15-13-9-14-4-18-12	5.9023540364804	3.7631083763334
8-20-11-21-15-13-9-14-4-18-12-6-10-5-17-7-19-16-1-3-2	5.9395036240926	3.7620486869348
9-13-15-21-20-11-8-4-14-18-12-6-10-5-17-7-19-16-1-3-2	6.0252275323199	3.7596532852037
10-5-8-20-11-21-15-13-9-14-4-18-12-6-7-17-19-16-1-3-2	5.7781642049938	3.7667497974163
11-20-21-15-13-9-14-8-4-18-12-6-10-5-17-7-19-16-1-3-2	5.6610739124089	3.7703293783525
12-18-4-15-21-20-11-8-13-9-14-5-10-6-5-17-19-16-1-3-2	5.6888391457203	3.7694672362626
13-9-15-21-20-11-8-4-14-18-12-6-10-5-17-7-19-16-1-3-2	5.6979319305111	3.7691867213193
14-9-13-15-21-20-11-8-4-18-12-6-10-5-17-7-19-16-1-3-2	6.3054395950318	3.7522776741662
15-21-20-11-8-13-9-14-4-18-12-6-10-5-17-7-19-16-1-3-2	5.7259761068304	3.7683271619060
16-19-7-17-5-10-8-20-11-21-15-13-9-14-4-18-12-6-1-3-2	6.0502863718700	3.7589658819677
17-7-19-16-1-3-2-6-10-5-8-20-11-21-15-13-9-14-4-18-12	6.0226258100939	3.7597249823044
18-12-6-10-5-8-20-11-21-15-13-9-14-4-2-3-1-19-16-7-17	5.8560201666364	3.7644488884839
19-16-7-17-5-10-8-20-11-21-15-13-9-14-4-18-12-6-2-3-1	5.7913364687506	3.7663561641979
20-11-8-21-15-13-9-14-4-18-12-6-10-5-17-7-19-16-1-3-2	5.7074512289046	3.7688940059846
21-15-13-9-11-20-8-4-14-18-12-6-10-5-17-7-19-16-1-3-2	5.6212009596436	3.7715823765936

The value of k (number of ants) is used when searching for ant-visiting paths. Testing the value of k will be carried out to analyze how the influence of the value of k on the distance results obtained by the ACO method. The value must be greater than 0, therefore the value of k used in the test is 21. The test results for the value of k can be seen in Table 3 and Figure 3.

Table 3. Comparison of the number of ants and the fastest distance

Number of Ants (k)	Distance (km)
1	210,1
7	197
14	193,8
21	188,5

After getting the results of several k parameters tested, at a k value of 21, the smallest distance value is 188.5 km. Then the value of the parameter k of 21 or as many as tours is the most optimal because it produces the smallest distance value.

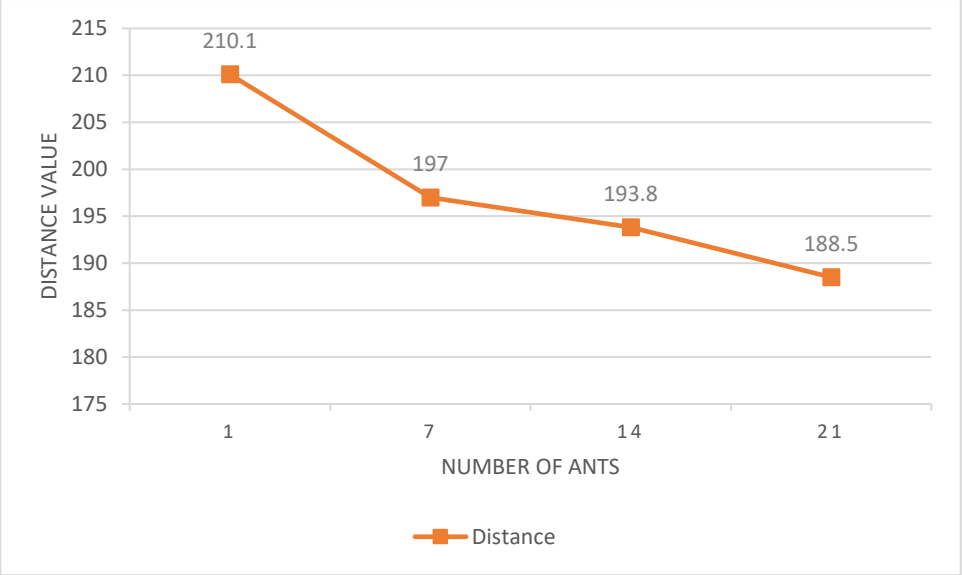

Figure 3. Comparison of the number of ants with the distance traveled

3.4 ACO for tourism routes with the center point of University of Trunojoyo Madura (UTM)

The existence of traditional markets also affects determining the shortest route to tourist sites. For example, on Sundays from 05.00 to 12.00 WIB, Pasar Baru Kwanyar is operating. The following are Figure 4 and Figure 5 which show the different routes that pay attention to the existence of traditional markets and those that ignore the existence of traditional markets.

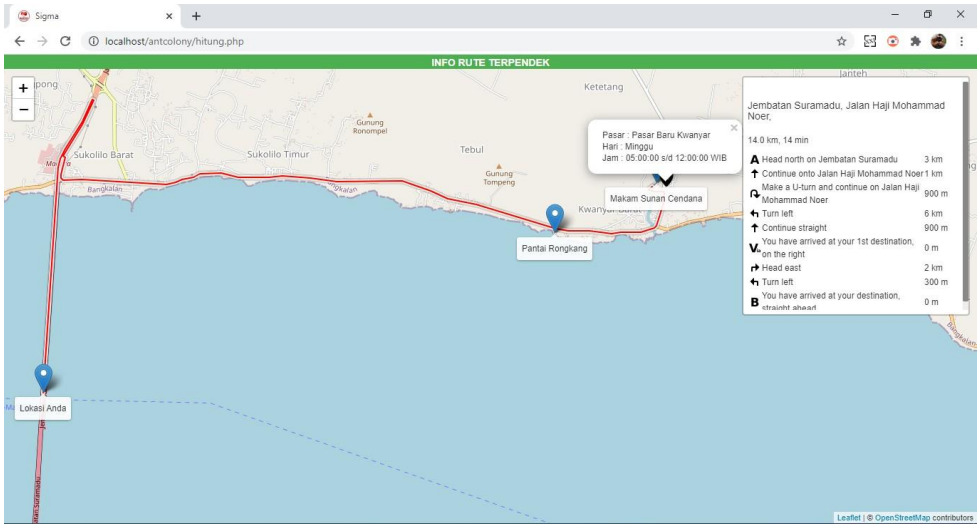

Figure 4. Tourist routes with traditional markets operating

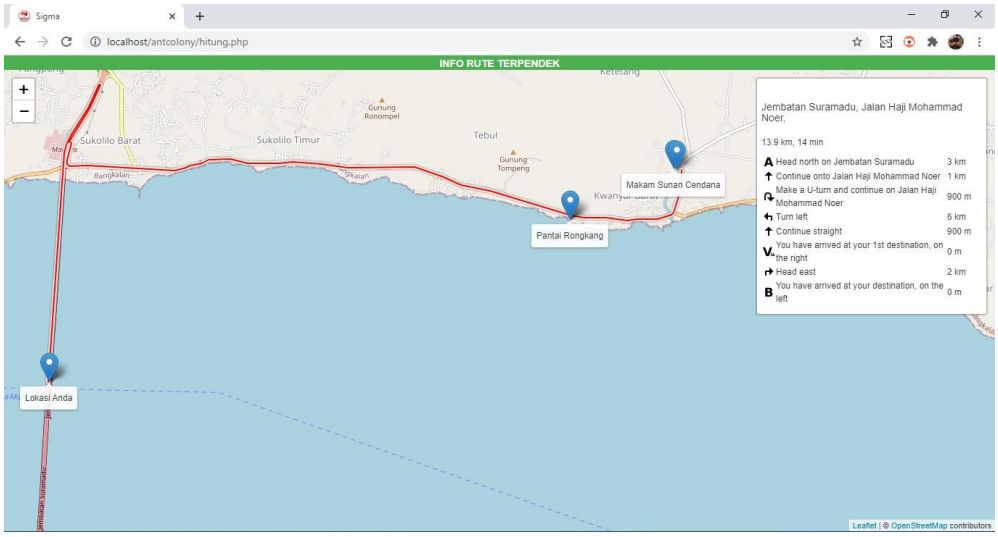

Figure 5. Tourist route without traditional markets operating

3.5 **Trial of the Ant Colony Optimization model**

To determine the accuracy value of Ant Colony Optimization in determining the shortest route to tourist sites on Madura Island, a test has been carried out by comparing the results of the shortest route obtained from the system using Ant Colony Optimization with the possible routes formed. Based on 20 experiments by comparing the distance between the route formed by the system and the route formed by Google Maps, it was found that 16 trials resulted in the optimal route, 3 times the experiment resulted in a non-optimal route, and 1 trial that

could not find the route. After analysis, it is possible that the route generated by the system is not optimal because the library from the javascript leaflet and OpenStreetMap can not recognize routes with narrow roads. Unlike Google Maps, which can recognize routes with narrow roads. So that Google Maps can generate accurate routes. Meanwhile, the shortest route was not found due to tours across the island such as Gili Labak, Gili Lyang, and others so that neither the system nor Google Maps could recognize tourist locations, distances, and routes to these tours. This shows the accuracy results using ACO have a success rate of 80%.

Table 4 Comparison of the distance between the route formed by the system and the route formed by Google Maps

Test	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
1	UTM	21	217.9	224,3	Optimal
	Scope of Area	Bangkalan district			
	Shortest Route	UTM - Bukit Kapur Jaddih - Bangkalan Museum - City Recreation Park - Paseban Park - Tomb of Sultan Abdul Kadirun - Kerapan Sapi - Tomb of Syeichona Cholil - Kolla Langgundih - Lighthouse - Rongkang Beach - Tomb of Sunan Cendana - Gunung Geger - Tomb of Mother's Tears - Pelalangan Hill Arosbaya-Maneron Beach - Mangrove Forest Kec. Ten - Siring Kemuning Beach - Bumi Anyar Beach - Bidadari Dhurjan Waterfall - Api Alam Konang - Waterfall District. Galis			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
2	UTM	12	232,3	234,9	Optimal
	Scope of Area	Sampang district			
	Shortest Route	UTM - Klampis Reservoir - Aji Mountain Fishing Pond - Wide Cave - Trunojoyo Site - Seven Panji Laras Tomb and Well - Queen Mother Site - Sumber Otok Swimming Pool - Mandangin Sea Coral - Camplong Beach - Toroan Waterfall - Nepa Monkey Forest - Sayid Uthman's Tomb			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
3	UTM	6	165,9	173	Optimal
	Scope of Area	Pamekasan district			
	Shortest Route	UTM - Batu Ampar - Mandilaras Public Museum - Ronggo Sukowati Tomb - The Fire Never Goes Out - Jumiang Beach - Talang Siring Beach			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
4	UTM	22	332,4	333,53	Optimal

	Scope of Area	Sumenep district			
	Shortest Route	UTM - Asta Panaongan - Slopeng Beach - Badur Beach - Limestone Tour - Sand Mattress House - Lombang Beach - Gili Iyang - Asta Jokotole -Asta Katandur - Museum and Keraton - Jamik Sumenep Mosque - Batugong Site - Waterpark Sumekar - Tomb of Asta Tinggi - Tirta Sumekar Indah - Asta K. Faqih - Bukit Tinggi Tour - Asta Gumuk - Fort Site - Asta Sayid Yusuf - Sembilan Beach - Gili Labak			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
5	UTM	8	238,8	237	Not Optimal
	Scope of Area	Mangrove Forest - Syeichona Cholik Tomb - Lighthouse - Toroan Waterfall - Nepa Monkey Forest - The Fire Never Goes Out - Asta K. Faqih - Jamik Sumenep Mosque			
	Shortest Route	UTM - Lighthouse - Syeichona Cholil's tomb - Mangrove Forest - Nepa Monkey Forest - Toroan Waterfall - Asta K. Faqih - Sumenep Jamik Mosque - The Fire Never Goes Out			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
6	UTM	2	122,3	119	Not Optimal
	Scope of Area	The Fire Never Goes Out - Talang Siring Beach			
	Shortest Route	UTM - The Fire Never Goes Out - Talang Siring Beach			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
7	UTM	2	31,1	31,1	Optimal
	Scope of Area	Tomb of Sunan Cendana - Jaddih Hill			
	Shortest Route	UTM - Jaddih Hill - Sunan Cendana's Tomb			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
8	UTM	3	32,7	32,7	Optimal
	Scope of Area	Arosbaya Hill - Paseban Park - City Recreation Park			
	Shortest Route	UTM - City Recreation Park-Paseban Park - Jaddih Hill			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
9	UTM	3	190,8	187	Optimal
	Scope of Area	Jami' Sumenep Mosque - Lombang Beach - Keraton Museum			
	Shortest Route	UTM - Jami' Sumenep Mosque - Keraton Museum - Lombang Beach			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
10	UTM	4	140	140	Optimal
	Scope of Area	Toroan Falls - Wide Cave - Nepa Monkey Forest - Camplong Beach			
	Shortest Route	UTM - Nepa Monkey Forest - Toroan Waterfall - Wide Cave – Camplong Beach			
	Starting Location	Number of Tourist	Distance using ACO	Distance using Google	Description

		Attractions		Maps	
11	UTM	8	207,1	215	Optimal
	Scope of Area	Konang Nature Fire - Mount Geger- Bangkalan Museum- Maneron Beach- Rongkang Beach- Yellow Siring- Toroan Waterfall- Nepa's Monkey Forest			
	Shortest Route	Kamal Pier - Rongkang Beach - Gunung Geger - Maneron Beach - Siring Kemuning Beach - Monkey Forest Nepa - Toroan Waterfall - Konang Natural Fire - Bangkalan Museum			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
12	UTM	5	85	85	Optimal
	Scope of Area	City Recreation Park - Paseban Park - Kerapan Sapi - Waterfall District. Galis - Bidadari Dhurjan Waterfall			
	Shortest Route	Kamal Pier - City Recreation Park - Paseban Park - Kerapan Sapi - Waterfall District. Galis - Bidadari Dhurjan Waterfall			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
13	Kamal Harbor	2	194,1	188	Not Optimal
	Scope of Area	Talang Siring Beach - Lombang Beach			
	Shortest Route	Kamal Pier - Talang Siring Beach - Lombang Beach			
14	Kamal Harbor	6	169,8	155	Not Optimal
	Scope of Area	Batu Ampar - Mandilaras Public Museum - Ronggo Sukowati Tomb - The Fire Never Goes Out - Jumiang Beach - Talang Siring Beach			
	Shortest Route	Kamal Pier - Batu Ampar - Mandilaras Public Museum - Ronggo Sukowati Tomb - The Fire Never Goes Out - Jumiang Beach - Talang Siring Beach			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
15	Suramadu Bridge	3	51,4	53,2	Optimal
	Scope of Area	Paseban Park - Tomb of Sultan Abdul Kadirun - Maneron Beach			
	Shortest Route	Suramadu Bridge - Paseban Park - Tomb of Sultan Abdul Kadirun - Maneron Beach			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
16	Suramadu Bridge	3	51,4	53,2	Optimal
	Scope of Area	Paseban Park - Tomb of Sultan Abdul Kadirun			
	Shortest Route	Suramadu Bridge - Paseban Park - Tomb of Sultan Abdul Kadirun			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
17	Suramadu Bridge	2	37,5	37,6	Optimal
	Scope of Area	Mother's Tears Cemetery -- Pelalangan Hill Arosbaya			
	Shortest Route	Suramadu Bridge - Tomb of Mother's Tears - Pelalangan Arosbaya Hill			

	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
18	Town Square Sumenep	5	-	-	No Route
	Scope of Area	Badur Beach - Slopeng Beach - Lombang Beach - Gili Lyang - Gili Labak			
	Shortest Route	Town Square - Sumenep Square - Badur Beach - Slopeng Beach - Lombang Beach - Gili Iyang - Gili Labak			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
19	Town Square Sumenep	2	1,6	1,6	Optimal
	Scope of Area	Jamik Mosque Sumenep - Museum and Palace			
	Shortest Route	Town Square - Sumenep Square - Sumenep Jamik Mosque - Museum and Palace			
	Starting Location	Number of Tourist Attractions	Distance using ACO	Distance using Google Maps	Description
20	Town Square Sumenep	3	5,5	5,7	Optimal
	Scope of Area	- Sumenep Jamik Mosque - Museum and Palace - Sumekar Waterpark			
	Shortest Route	Town square - Sumenep Square - Sumenep Jamik Mosque - Museum and Palace - Waterpark Sumekar			

Based on Table 5-8, it can be seen that the Ant Colony Optimization method in finding the shortest route solution to tourist sites on Madura Island produces a different average execution time each time a route search is performed. This is because the search is based on chance. Execution times with more locations and larger distance values tend to be longer. So, the more tours and the distance traveled, the longer the execution time of the route search process.

Table 5 Estimated travel time for Bangkalan district

No	Number of tourist attractions	Mileage (km)	Estimated time (ms)
1	21	217.9	118.393798828125
2	21	217.9	104.469970703125
3	21	217.9	126.421142578125
Average Time			116.428304036458

Table 6 Estimated travel time for Sampang district

No	Number of tourist attractions	Mileage (km)	Estimated time (ms)
1	12	232,3	111.242919921875
2	12	232,3	129.693115234375
3	12	232,3	89.81494140625
Average Time			110.250325520833

Table 7 Estimated travel time for Pamekasan district

No	Number of tourist attractions	Mileage (km)	Estimated time (ms)
1	6	165,9	101.23193359375
2	6	165,9	89.877197265625
3	6	165,9	83.216064453125
Average Time			91,441731770833

Table 8 Estimated travel time for Sumenep district

No	Number of tourist attractions	Mileage (km)	Estimated time (ms)
1	22	332,4	142.718017578125
2	22	332,4	155.010986328125
3	22	332,4	232.47729492187
Average Time			176,735432942708

CONCLUSION

Based on the research and system testing that has been done, it can be concluded that first, comparative results. Testing the system using ACO in determining tourist routes for all tours in Bangkalan Regency, with the center point at Trunojoyo Madura University without market barriers, resulting in a k parameter value of 21 which is 188.5 km, while the distance traveled if there are traditional market barriers as much as 217.9 km. Second, the system for determining the shortest route to tourist sites on Madura Island using the Ant Colony Optimization method has an accuracy of 80% in finding the shortest route solution. System for determining the shortest route to tourist sites in Madura

ACKNOWLEDGMENT

The authors would like to thank University of Trunojoyo Madura and the Government tourism office for the completion of this research. And for the opportunity to make research with contract number 3048/UN46.4.1/PT.01.03/2021.

CONFLICT OF INTERESTS

The author(s) declare that there is no conflict of interest.

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