Analysis of the Shortest Route from Cikampek to Purwokerto using Ant Colony Algorithm

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Abstract − Finding the shortest path sometimes makes most people confused in choosing a path, especially if there are many paths that must be taken to reach one destination. Tracing various routes from Cikampek to Purwokerto is a challenge, with the risk of spending excessive time and money. To solve this problem, this research uses the Ant Colony Algorithm to determine the most efficient path. One of the problems that often arises is that the Cikampek area has 3 routes that can be used to reach Purwokerto, namely the Cikampek - Indramayu (Patrol), Cikampek - Subang, and Cikampek - Bandung routes. The purpose of determining the shortest path is to provide the shortest path solution to users so that they can reach their destination faster and save time and costs. In this study, we use Ant Algorithm because the route from Cikampek to Purwokerto depends on many road factors and other conditions that could change from time to time. For example, traffic congestion and road repairs are major factors. The ant algorithm has strong customization capabilities to determine the shortest path based on the pheromone trails left by ants during exploration. This means that the ant algorithm can work optimally even if there are many factors in road conditions. In addition, the ant algorithm has the ability to handle problems with a large number of nodes, so it can explore various possibilities efficiently. The ant algorithm is an appropriate choice for finding the shortest path in a journey involving complex and diverse routes. There are six steps required to complete the ant algorithm. The first step is initialization, the second step is path selection, and the third step is setting the ant trail and communication between the ants hit by the trail in path selection. The fourth step is to look for visibility, the fifth step is to stop the criterion until it reaches a certain condition, and the last step is to determine the path by calculating probabilities. The results of this study indicate that the ant algorithm can be used to determine the shortest path which is then displayed. This research aims to assist the community in making decisions and determining the location of the city that must be passed. This study took 8 location points with starting point A and destination point H. Based on the results of the discussion it can be concluded that the shortest route from Cikampek to Purwokerto is with 3 routes, namely first (A → D → E → F → H) with a distance of 355 KM, second (A → D → G → F → H) with a distance of 431 KM and the third (A → D → E →H) with a distance of 317 KM.

Keywords: Shortest Route, Ant Algorithm, Map

I. INTRODUCTION

The growth of road and transportation infrastructure has had a positive impact on connections between various cities and regions. However, the reality that must be faced is the many paths available to achieve certain goals. This can cause confusion and doubt for road users, which ultimately affects the effectiveness and efficiency of travel, especially on the Cikampek route to Purwokerto. In this case study we took the Cikampek to Purwokerto route because Cikampek has 3 different routes that we can take to Purwokerto, namely the Cikampek - Indramayu (Patrol), Cikampek - Subang, and Cikampek - Bandung routes. Many people have difficulty in determining the shortest path to reach Purwokerto. The purpose of determining the shortest path is to provide users with the shortest path solution so that they can reach their destination faster and save time and money.Therefore, there is an urgent need to have a method that can assist road users in choosing the shortest path.

One algorithm that has been widely used to address this problem is the Ant Colony Algorithm. The ant colony algorithm is a paradigm for designing metaheuristic algorithms for combination optimization problems. The essence of the ant colony algorithm is the combination of information about the structure of the promised solution with information about the structure of the previously obtained good solution [1].

The study used sample data taken from Google Maps to calculate the fastest path. By utilizing Google Maps data, researchers can obtain accurate and up-to-date information about traffic conditions, toll roads, congestion, and alternative routes that can be considered by ant algorithms [2].

The main objective of this research is to provide practical solutions for those users who are often faced with confusion in choosing the fastest and most efficient path to achieve their goals. The Cikampek area is an interesting example for the shortest route analysis, because of the limited literature discussing the Cikampek to Purwokerto route that we can see digitally has branch lines passed. Therefore, to make it easier for readers to know which path is efficient from using the ant algorithm without having to go through all existing paths. So that being able to determine the most optimal route can save travel time and costs.

Through this research, it is hoped that readers will gain a better understanding of how the Ant Colony Algorithm can be applied in solving the shortest route determination problem and provide useful guidance for users in choosing the best path to reach their destination.

II. RESEARCH METHODS

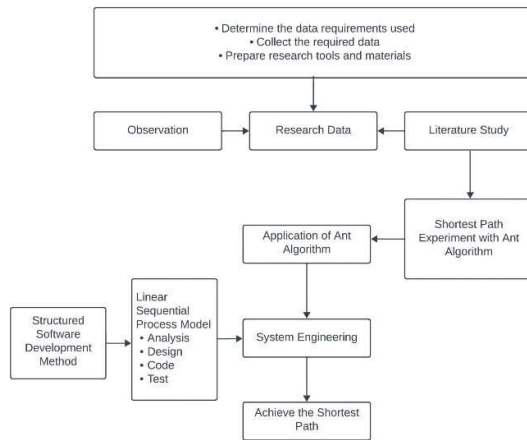The following is a framework of the stages of research carried out.

Fig 1. Frame of mind

There are several things that must be done before collecting research data, including determining data needs, collecting data, and preparing tools and materials. If the research data has been obtained, it is necessary to conduct observations and literature studies. Then the ant algorithm can be applied using existing methods to get the shortest path.

2.1 Artificial Intelligence

Artificial Intelligence is a machine that is implanted with human intelligence and programmed so that the machine can think like humans. So, without human power or intelligence the work that is usually done by humans can be completed with computers [3]. The ant algorithm is one of the artificial intelligences, namely computational intelligence.

2.2 Basic Theory of Graphs

A graph is a collection of points connected by lines/sides [4]. Dots on graphs can be used as signs for place names, the names of objects and so on which are usually numbered or letters in the dot. G=(V,E) notation is a notation usually used for Graph, the empty set of vertices that are V and the side set that makes a pair of connected vertices namely E (Munir, 2005) [5]. If the node and the v node are connected by a side that is e then e=(u,v) (Figure 2).
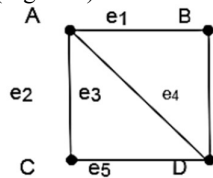

Fig2. Graphs G (4,5)

The graph with the V knot repertoire and the E side group is G (4,5) is:
V = { A, B, C, D }
E = { (A, B), (A, C), (A, D), (B,D), (C, D) }
= {e1, e2, e3, e4, 35}

2.3 Shortest Path

There are two commonly used methods for determining the shortest path. The first is applied by ordinary mathematical calculations, namely conventional algorithm methods, while the second is by calculating artificial intelligence and determining the knowledge base and calculations are heuristic methods [6].

a. Conventional methods for determining the shortest path of the Djikstra, Floyd-Warshall, and Bellman-Ford algorithms. It is common to use this conventional method and this method tends to be easier to understand.
b. Heuristic methods are methods that are actually more difficult to understand than conventional but the results obtained are more varied and the time for calculation is shorter, one example is the ant algorithm.

2.4 Application of the Ant Algorithm

There are several problems that can be solved using ant algorithms to solve problems in finding the shortest path in everyday life (Triandi, 2012) [7]. Among them: Quadratic Assignment Problem (QAP), Job-shop Scheduling Problem (JSP), Vehicle Routing Problem (VRP) and Traveling Salesman Problem (TSP).

2.5 Ant Algorithm

This ant algorithm is taken from the example of ant colonies that work to find food sources where ants can find the shortest route naturally. Because when looking for food sources, ants leave pheromones so that other ants know that the path has been passed, therefore it can happen. The more pheromones left by the ants that have passed by, the clearer the footprints left behind. So that the longer it will increase the density of ants passing through the road, or even all ants will follow to pass the path (Ambarsari 2017) [8]. Here is an illustration of an ant's journey in finding a feeding source (Figure 3).
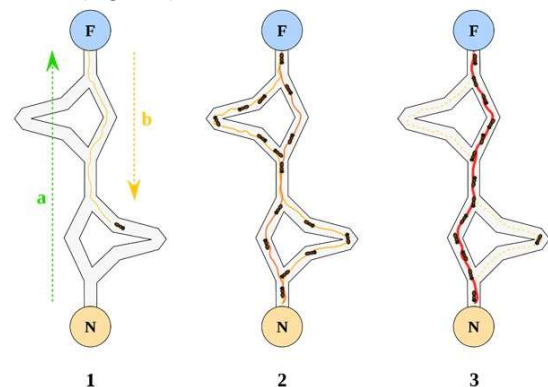

Fig 3. Ants travel in search of food sources

Steps to Solve the Ant Algorithm in the US The steps are (Bronson, 1882 Zukhri, 2005):
Step 1:
a. The price of the parameters of the algorithm is initialized.
b. The first city of each ant is given a name or initial.

Step 2: The first city is put on the taboo list.
Step 3: The route of each ant's visit to each city is drawn up.
Step 4:
    a. The route of each ant is calculated in length.
    b. Shortest route search.
    c. The price of the intensity of intercity ant footprints is calculated.
Step 5:
    a. The price of the intensity of intercity ant footprints for the next cycle is calculated.
    b. Repetition or reset of prices changes the intensity of ant footprints between cities.
Step 6: The taboo list is cleared, and step 2 is repeated if necessary.

III.   RESULTS AND DISCUSSION

In this study, researchers obtained 8 (eight) location points that were passed to travel from the city of Cikampek to Purwokerto, each point representing the city passed. The selection of location points is determined directly by researchers as many as 8 (eight) points by considering the path that can be passed. Each point is stored at each intersection where point A is the starting point and point H is the destination point. Here are some points that can be passed on the Cikampek route to Purwokerto, namely:

A = Cikampek   E = Cirebon
B = Patrol   F = Kuningan
C = Bandung   G = Tasikmalaya
D = Subang   H = Purwokerto

Where the site map of the path passed from Cikampek to Purwokerto can be shown in figure 4 below:
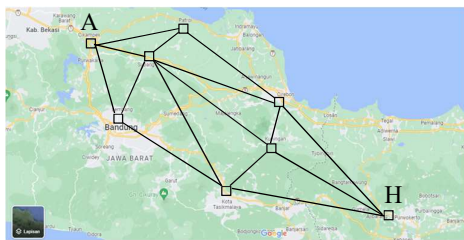

Fig 4. Map of 8 points on the Cikampek route to Purwokerto.

The initial stage in solving this problem is to describe the points passed on the Cikampek to Purwokerto route into points contained in the graph, then the weight of the side in the graph is the distance between the location points between the routes (Figure 6).
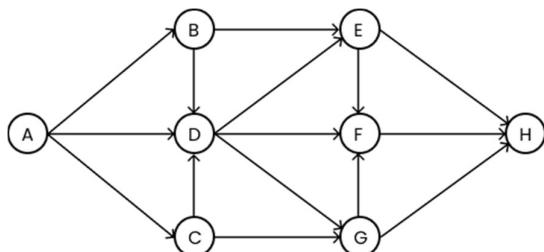

Fig 5. Complete graph of 8 points of destination location

Based on the data obtained, the route distance from Cikampek to Purwokerto can be arranged in kilometers (Km) from each point in table 1 as follows:

Table 1. Route distance from Cikampek to Purwokerto (Km) 8 points

Distance (Km)	A	B	C	D	E	F	G	H
A	0	67	92	55				
B	67	0		47	93			
C	92		0	59			109	
D	55	47	59	0	119	140	151	
E		93		119	0	35		143
F				140	35	0	79	146
G			109	151		79	0	143
H					143	146	143	0

Based on table 1, the graph in figure 6 can be valued according to the distance listed in table 1 using the graph model in figure 7 as follows:
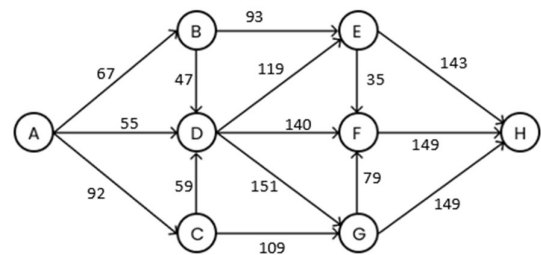

Fig 6. Distance at each point of the graph

Next, the application of the ant algorithm to obtain the shortest (optimal) route. The first step is to set the initial values of the algorithm parameters. The parameters used are:

$\beta = 1,00$
$\alpha = 1,00$
$\dot{p} = 1.00$
Many ants (k) = 8
The initial pheromone can be calculated using the formula:

$$\tau ij = \tau 0 = \frac{k}{c\ greedy} \tag{1}$$

Calculations using greedy algorithms are:
    a. Determine the starting point that is point A
    b. Point A has a route at B each with a distance (67). Furthermore, the smallest or shortest distance is taken so that the selected one is B so that the first route is A→B
    c. Perform an action similar to the second step where starting from the selected point i.e. B. B has routes in D and E with distances (47) and (93) respectively. Furthermore, the selected point is E, because if you go to point E, it will increase the final value of the resulting distance so that a second route is obtained namely A→B→E

d. Perform an action similar to the third step where starting from the selected point that is E. E has routes in D, F and H with distances of (119), (35) and (143) respectively. Furthermore, the selected point is H, because if you go to point F, it will increase the final value of the resulting distance so that a third route is obtained namely A→B→E→H

e. Furthermore, because there are no other points, the last point is H so that the path A→B→E→H is obtained. Thus, obtained minimum distance Cgreedy = 67 + 93 + 143 = 303

Then, proceed from the Greedy algorithm above to get the initial pheromone:

$$\tau ij = \tau 0 = \frac{k}{c\ greedy} = \frac{8}{303} = 0{,}0264026403$$

The second step is to find the visibility value between points by using formula(2):

$$\varphi ij = \frac{1}{dij} \qquad (2)$$

Where φij is the distance between known points. Sehingga didapatkan :

$$\varphi ij\ A, B = \frac{1}{dA,B} = \frac{1}{67} = 0.014925373$$

$$\varphi ij\ A, C = \frac{1}{dA,C} = \frac{1}{92} = 0.010869565$$

$$\varphi ij\ A, D = \frac{1}{dA,D} = \frac{1}{55} = 0.018181818$$

$$\varphi ij\ B, A = \frac{1}{dB,A} = \frac{1}{67} = 0.014925373$$

$$\varphi ij\ B, D = \frac{1}{dB,D} = \frac{1}{47} = 0.021276596$$

$$\varphi ij\ B, E = \frac{1}{dB,E} = \frac{1}{93} = 0.010752688$$

In the same way obtained visibility values between points in Table 2 below:

Table 2. Visibility between points

φij	A	B	C	D	E	F	G	H
A	0	0,01493	0,01087	0,01818	0	0	0	0
B	0,01492	0	0	0,02128	0,01075	0	0	0
C	0,01087	0	0	0,01695	0	0	0,00917	0
D	0,01818	0,02128	0,01695	0	0,00840	0,00714	0,00662	0
E	0	0,01075	0	0,00840	0	0,02857	0	0,00699
F	0	0	0	0	0,02857	0	0,01265	0,00685
G	0	0	0,00917	0	0	0,01266	0	0,00699
H	0	0	0	0	0,00699	0,00685	0,00699	0

The next step involves drawing up travel routes to each location point. In this context, researchers use the term "ant" to refer to the method used in finding the shortest route from Cikampek to Purwokerto. In this scenario, ants scattered throughout the point of location will travel from the starting point of each as the point of origin to another point as the destination point. After this stage, the ants will travel randomly, taking into account not visiting the path that has been traveled before. The ant's journey will continue until all points have been visited, forming a complete path. Below is a probability calculation that applies to the first cycle (NC=1).

B. 1st cycle (NC=1)

1st ant(k1)
Taboo list = A

$$p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* \ [\tau ij]^{\beta}}{\sum_{k'\in\{N-tab\ _k\}}[\tau ik']^{\alpha}* \ [\tau ik']^{\beta}} \qquad (3)$$

To $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k'\in\{N-tab\ _k\}}[\tau ik']^{\alpha}* \ [\tau ik']^{\beta} =$
$= (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0{,}014925373)^1 + (0{,}0264)^1 * (0{,}010869565)^1 + (0{,}0264)^1 * (0{,}018181818)^1$

$= 0.001160986$

city A $= p\frac{k}{ij} = 0$

city B $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* \ [\tau ij]^{\beta}}{\sum_{k'\in\{N-tabu_k\}}[\tau ik']^{\alpha}* \ [\tau ik']^{\beta}}$
$= \frac{(0{,}0264)^{1.00}*(0{,}014925373)^{1.00}}{0.001160986} = 0{,}3393$

city C $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* \ [\tau ij]^{\beta}}{\sum_{k'\in\{N-tabu_k\}}[\tau ik']^{\alpha}* \ [\tau ik']^{\beta}}$
$= \frac{(0{,}0264)^{1.00}*(0{,}010869565)^{1.00}}{0.001160986} = 0.2471$

city D $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * \ [\tau ij]^{\beta}}{\sum_{k'\in\{N-tabu_k\}}[\tau ik']^{\alpha} * \ [\tau ik']^{\beta}}$
$= \frac{(0{,}0264)^{1.00}*(0{,}018181818)^{1.00}}{0.001160986} = 0.4134$

city E $= p\frac{k}{ij} = 0$

city F $= p\frac{k}{ij} = 0$

city G $= p\frac{k}{ij} = 0$

city H $= p\frac{k}{ij} = 0$

Table 3. 1st ant probability between point A to another

Ket	A	B	C	D
A	0	0.3393	0.2471	0.4134
Cumulative	0	0,339	0.586	1

Ket	E	F	G	H
A	0	0	0	0
Cumulative	1	1	1	1

Number of random numbers raised between 0-1 by using the function in Excel, namely Rand(), then 0.406 is selected so that the selected city is city D so that the taboo list becomes A => D.

2nd ant(k1)
Taboo list = B

$$p\frac{k}{ij} = \frac{[\tau i\ ]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}} \tag{4}$$

Untuk $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta} =$

$= (0,0264)^1 * (0,0149)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,0212)^1 + (0,0264)^1 * (\ 0,01075)^1$

$= 0.001239603$

city A $= p\frac{k}{ij} = \frac{[\tau i\ ]^{\alpha} * [\tau i\ ]^{\beta}}{\sum_{k' \in \{N-tab\ k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$

$= \frac{(0,0264)^{1.00} * (0,014925373)^{1.00}}{0.001239603} = 0,3178$

city B $= p\frac{k}{ij} = 0$

city C $= p\frac{k}{ij} = 0$

city D $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$

$= \frac{(0,0264)^{1.00} * (0,021276596)^{1.00}}{0.001239603} = 0,4531$

city E $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$

$= \frac{(0,0264)^{1.00} * (0,010752688)^{1.00}}{0.001239603} = 0.2290$

city F $= p\frac{k}{ij} = 0$

city G $= p\frac{k}{ij} = 0$

city H $= p\frac{k}{ij} = 0$

Table 4. 2nd ant probability between point B to another point

Ket	A	B	C	D
B	0,317	0	0	0,453
Cumulative	0,317	0,317	0,317	0,770

Ket	E	F	G	H
B	0,229	0	0	0
Cumulative	1	1	1	1

A random number generated between 0-1 using a function in Excel is Rand(), then 0.586 is

chosen so that the selected city is city D so that the taboo list becomes B => D.

3rd ant(k1)
Taboo list = C

$$p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}} \tag{5}$$

Untuk $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta} =$

$= (0,0264)^1 * (0,010869565)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,016949153)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,009174312)^1$

$= 0.000976616$

city A $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$

$= \frac{(0,0264)^{1.00} * (0,010869565)^{1.00}}{0.000976616} = 0,2938$

city B $= p\frac{k}{ij} = 0$

city C $= p\frac{k}{ij} = 0$

city D $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$

$= \frac{(0,0264)^{1.00} * (0,016949153)^{1.00}}{0.000976616} = 0,4581$

city E $= p\frac{k}{ij} = 0$

city F $= p\frac{k}{ij} = 0$

city G $= p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$

$= \frac{(0,0264)^{1.00} * (0,009174312)^{1.00}}{0.000976616} = 0.2480$

city H $= p\frac{k}{ij} = 0$

Table 5. 3rd ant probability between point C to another point

Ket	A	B	C	D
C	0,293	0	0	0.458
Cumulative	0.293	0.293	0.293	0,751

Ket	E	F	G	H
C	0	0	0,248	0
Cumulative	0,751	0,751	1	1

Random numbers that are generated between 0-1 using functions in Excel are Rand(), then 0.155 is chosen so that the selected city is city G so that the taboo list becomes C => G.

4th ant(k1)
Taboo list = D

$$p_{ij}^{k} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}} \qquad (6)$$

To $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta} =$

$= (0,0264)^1 * (0,018181818)^1 + (0,0264)^1 * (0,021276596)^1 + (0,0264)^1 * (0,016949153)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,008403361)^1 + (0,0264)^1 * (0,0071422857)^1 + (0,0264)^1 * (0,006622517)^1$

$= 0.020744144$

city A = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,018181818)^{1.00}}{0.020744144} = 0,2313$

city B = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,021276596)^{1.00}}{0.020744144} = 0,2707$

city C = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau i]^{\beta}}{\sum_{k' \in \{N-tab_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,016949153)^{1.00}}{0.020744144} = 0,2157$

city D = $p\frac{k}{ij} = 0$

city E = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,008403361)^{1.00}}{0.020744144} = 0,1069$

city F = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,0071422857)^{1.00}}{0.020744144} = 0,0909$

city G = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,006622517)^{1.00}}{0.020744144} = 0.0842$

city = $p\frac{k}{ij} = 0$

Table 6. 4th ant probability between point D to another point

Ket	A	B	C	D
D	0,231	0,270	0,215	0
Cumulative	0,231	0.502	0.717	0,717

Ket	E	F	G	H
D	0,106	0	0,090	0
Cumulative	0,824	0,915	1	1

A random number generated between 0-1 using a function in Excel is Rand(), then 0.065 is chosen so that the selected city is city G so that the taboo list becomes D => G.

5th ant(k1)
Taboo list = E

$$p_{ij}^{k} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}} \qquad (7)$$

Untuk $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tab\ k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta} =$

$= (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,010752688)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,008403361)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,028571429)^1 + (0,0264)^1 * (0)^1 + (0,0264)^1 * (0,006993007)^1$

$= 0.014446208$

city A = $p\frac{k}{ij} = 0$

city B = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,010752688)^{1.00}}{0.014446208} = 0,1965$

city C = $p\frac{k}{ij} = 0$

city D = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,008403361)^{1.00}}{0.014446208} = 0,1535$

city E = $p\frac{k}{ij} = 0$

city F = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,028571429)^{1.00}}{0.014446208} = 0,5221$

city G = $p\frac{k}{ij} = 0$

city H = $p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$
$= \frac{(0,0264)^{1.00} * (0,006993007)^{1.00}}{0.014446208} = 0.1277$

Table 7. 5th ant probability between point E to another point

Ket	A	B	C	D
E	0	0,196	0	0,153
Cumulative	0,00	0,196	0,196	0,35

Ket	E	F	G	H
E	0	0,522	0	0,127
Cumulative	0,35	0,872	0,872	1

A random number generated between 0-1 using a function in Excel is Rand(), then 0.524 is chosen so that the selected city is city F so that the taboo list becomes E => F.

6th ant(k1)
Taboo list = F

$$p_{ij}^{k} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tab\ k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}} \qquad (8)$$

To $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta =$

$= (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0{,}007142857)^1 + (0{,}0264)^1 * (0{,}028571429)^1 + (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0{,}012658228)^1 + (0{,}0264)^1 * (0{,}006849315)^1$

$= 0.014578563$

$city\ A = p\dfrac{k}{ij} = 0$

$city\ B = p\dfrac{k}{ij} = 0$

$city\ C = p\dfrac{k}{ij} = 0$

$city\ D = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau i\ ]^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}007142857)^{1.00}}{0.014578563} = 0{,}1293$

$city\ E = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau i\ ]^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}028571429)^{1.00}}{0.014578563} = 0{,}5173$

$city\ F = p\dfrac{k}{ij} = 0$

$city\ G = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tab\ k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}012658228)^{1.00}}{0.014578563} = 0{,}2292$

$city\ H = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}006849315)^{1.00}}{0.014578563} = 0{,}1240$

Table 8. 6th ant probability between point F to another point

Ket	A	B	C	D
F	0	0	0	0,129
Cumulative	0,00	0,00	0,00	0,129

Ket	E	F	G	H
F	0,517	0	0,229	0,124
Cumulative	0,646	0,646	0,875	1

Random numbers that are generated between 0-1 using functions in Excel are Rand(), then 0.05 is chosen so that the selected city is city H so that the taboo list becomes F => H.
7th ant(k1)
Taboo list = G

$p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$ (9)

To $j \in \{N - tabu_k\}$

$p\dfrac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta =$

$= (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0{,}009174312)^1 + (0{,}0264)^1 * (0{,}006622517)^1 + (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0{,}012658228)^1 + (0{,}0264)^1 * (0)^1 + (0{,}0264)^1 * (0{,}006993007)^1$

$= 0.009358289$

$city\ A = p\dfrac{k}{ij} = 0$

$city\ B = p\dfrac{k}{ij} = 0$

$city\ C = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}009174312)^{1.00}}{0.009358289} = 0{,}2588$

$city\ D = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}006622517)^{1.00}}{0.009358289} = 0{,}1868$

$city\ E = p\dfrac{k}{ij} = 0$

$city\ F = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tab\ k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}012658228)^{1.00}}{0.009358289} = 0{,}3570$

$city\ G = p\dfrac{k}{ij} = 0$

$city\ H = p\dfrac{k}{ij} = \dfrac{[\tau ij]^\alpha * [\tau ij]^\beta}{\sum_{k' \in \{N-tabu_k\}} [\tau ik']^\alpha * [\tau ik']^\beta}$
$= \dfrac{(0{,}0264)^{1.00} * (0{,}006993007)^{1.00}}{0.009358289} = 0.1972$

Table 9. 7th ant probability between point G to another point

Ket	A	B	C	D
G	0	0	0,258	0,186
Cumulative	0,00	0,00	0,258	0,445

Ket	E	F	G	H
G	0	0,357	0	0,197
Cumulative	0,445	0,802	0,802	1

A random number generated between 0-1 using a function in Excel is Rand(), then 0.398 is chosen so that the selected city is city F so that the taboo list becomes G => F.

In this case, not all routes can be used as optimal path solutions, there are several routes that can be used as optimal path solutions, namely:
1) A => D => E => F => H
2) A => D => G => F => H
3) A => D => E => H

C. 2nd Cycle (NC=2)

1. 1st ant(k1)
β = 1,00
α = 1,00
ṗ = 1,00
Taboo list = D
Then perform the local pheromone() update process τ.
$\tau ij(baru) = (1 - \dot{p})\tau ij + \Delta \tau i\ jk$
$= (1 - 0{,}01) * (0{,}2313) + ((0{,}01) * (1/0{,}2313))$
$= 0{,}27222$

$$p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}} \qquad (10)$$

To $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tab_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta} =$
$= (0,27222)^1 * (0,01818)^1 + (0,27222)^1 * (0,2128)^1 +$
$(0,27222)^1 * (0,01695)^1 + (0,27222)^1 * (0)^1 +$
$(0,27222)^1 * (0,00840)^1 + (0,27222)^1 * (0,00714)^1 +$
$(0,27222)^1 * (0,00662)^1$
$= 0,021390$

$$city\ A = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,018181818)^{1.00}}{0,021390041} = 0,231$$

$$city\ B = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha} * [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,21276596)^{1.00}}{0,021390041} = 0,2707$$

$$city\ C = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,016949153)^{1.00}}{0,021390041} = 0,2157$$

Table 10. The journey of ants in the first cycle

Ant	Point Beginning	Probabilitas								Selected Point	Taboo List
		A	B	C	D	E	F	G	H		
K1	A	0	0,3393	0,2472	0,4134	0	0	0	0	D	A → D
K2	B	0.3179	0	0	0,4531	0,229	0	0	0	D	B → D
K3	C	0,2938	0	0	0,4581	0	0	0,2480	0	G	C → G
K4	D	0.2314	0,2708	0,2157	0	0,1069	0,0909	0,0842	0	G	D → G
K5	E	0	0,1965	0	0,1536	0	0,5221	0	0,1278	F	E → F
K6	F	0	0	0	0,1293	0,5174	0	0,2292	0,1240	H	F → H
K7	G	0	0	0,2589	0,1868	0	0,3570	0	0,1972	F	G → F

$city\ D = p\frac{k}{ij} = 0$

$$city\ E = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,008403361)^{1.00}}{0,021390041} = 0,1069$$

$$city\ F = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,007142857)^{1.00}}{0,021390041} = 0,0909$$

$$city\ G = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tab_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,006622517)^{1.00}}{0,021390041} = 0,0842$$

$city\ H = p\frac{k}{ij} = 0$

Table 11. 1st ant probability between point D to another point

Ket	A	B	C	D
D	0,231	0,2707	0,2157	0
Cumulative	0,231	0,5021	0,717	0,717

Ket	E	F	G	H
D	0,1069	0,0909	0,0842	0
Cumulative	0,824	0,915	1	1

A random number generated between 0-1 using the Excel function Rand() is chosen 0.1067 so that the selected city is city E. So the Taboo list becomes A => D => E.

1. 1st ant(k5)
Taboo list = E

$$p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}} \qquad (11)$$

to $j \in \{N - tabu_k\}$

$p\frac{k}{ij} = 0$, for the other j with i as the origin city index and j as the destination city index.

$\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha} * [\tau ik']^{\beta} =$
$= (0,27222)^1 * (0)^1 + (0,27222)^1 * (0,010752688)^1 +$
$(0,27222)^1 * (0)^1 + (0,27222)^1 * (0,008403361)^1 +$
$(0,27222)^1 * (0)^1 + (0,27222)^1 * (0,028571429)^1 +$
$(0,27222)^1 * (0)^1 + (0,27222)^1 * (0,006993007)^1$
$= 0,01489601$

$city\ A = p\frac{k}{ij} = 0$

$$city\ B = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,010752688)^{1.00}}{0,01489601} = 0,1965$$

$city\ C = p\frac{k}{ij} = 0$

$$city\ D = p\frac{k}{ij} = \frac{[\tau i]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,008403361)^{1.00}}{0,01489601} = 0,153$$

$city\ E = p\frac{k}{ij} = 0$

$$city\ F = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau i]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,028571429)^{1.00}}{0,01489601} = 0,522$$

$city\ G = p\frac{k}{ij} = 0$

$$city\ H = p\frac{k}{ij} = \frac{[\tau ij]^{\alpha}* [\tau ij]^{\beta}}{\sum_{k' \in \{N-tabu_k\}}[\tau ik']^{\alpha}* [\tau ik']^{\beta}}$$
$$= \frac{(0,27222)^{1.00} *(0,006993007)^{1.00}}{0,01489601} = 0,127$$

Table 12. 1st ant probability between point D to another point

Ket	A	B	C	D
E	0	0,1965	0	0,153
Cumulative	0	0,196	0,196	0,350

Ket	E	F	G	H
E	0	0,522	0	0,127
Cumulative	0,350	0,872	0,872	1

Random numbers that are generated between 0-1 using the Excel function, namely Rand(), then **0.057** is chosen so that the selected city is city H. So that the Taboo list becomes **A = > D = > E = > H.**

The first cycle has been completed and pheromone renewal is obtained, the next step is to find a better route in the second cycle. If there is a better route than the first cycle in this case it has a smaller route length then the pheromone will be renewed again, but when the second cycle is not better than the first cycle then what is taken is the route in the first cycle. Likewise for the third, fourth and so on cycles until it reaches NC max or the specified iteration limit. In manual searches, it is only limited to the first cycle or first iteration (NC = 1) so that the shortest route is obtained on the Cikampek to Purwokerto route with 3 routes 1). A→D→E→F→H with a distance obtained on the route of 355 Km; 2). A→D→G→F→H with the distance obtained on the route which is 431 Km; 3). A→D→E→H with the distance obtained on the route which is 317 Km.

IV. CONCLUSION

This study confirms the effectiveness of the ant colony algorithm in finding the shortest route between Cikampek and Purwokerto. The algorithm models the behavior of ants in search of food and applies this concept to finding the shortest route on the road network.

Through the application of an ant colony algorithm, this study succeeded in finding the shortest path connecting Cikampek and Purwokerto. This has the potential to provide efficient solutions to route planning problems in a variety of contexts, such as transportation and logistics.

From the search for the shortest path from Cikampek city to Purwokerto using the ant algorithm, the shortest path was found through two cycles, namely cycles A and N. This path only passes the shortest route on line 3, which includes points (A→D→E→H), with a total length of 317 Km. In its implementation with cities that have been analyzed, the path formed is through Cikampek → Subang→ Cirebon → Purwokerto. Thus, the ant algorithm is effective in finding the shortest path to travel from Cikampek to Purwokerto through these important points.

The weakness of this research is that it is only limited to finding the shortest route, it cannot determine the fastest time on the path traveled. Because in reality there are several factors on each path traveled.

This research still has a lot to be improved, it is hoped that there will be further research to find out the efficiency of finding the shortest path using the ant algorithm. It is hoped that there will be research that can compare the ant algorithm with other methods/algorithms.

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