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Analysis and Implementation of 3kg Gas Cylinder Distribution Route Determination using the Ant Colony Algorithm at PT. Haritsah

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Abstract

The distribution of 3 kg LPG cylinders plays a vital role in the household energy supply chain in Indonesia. PT. Haritsah, as a distributor, faces challenges in determining efficient distribution routes, as manual methods relying on drivers' experience often result in high transportation costs and delivery delays. This study aims to analyze and implement the Ant Colony Optimization (ACO) algorithm in determining optimal distribution routes. The research data includes the distance between LPG bases in Medan and vehicle capacity. ACO was applied through iterative simulations with parameters such as the number of ants, evaporation rate, and route search iterations. The results indicate that ACO successfully generated shorter distribution routes compared to the company's manual method, thus reducing operational costs, minimizing delivery time, and improving resource efficiency. Therefore, applying the ACO algorithm provides an effective solution for optimizing the distribution routes of 3 kg LPG cylinders at PT. Haritsah.

Keywords: *LPG Distribution; Vehicle Routing Problem (VRP); Ant Colony Optimization; Route Optimization.*

1. Introduction

The distribution of products from the producer to the consumer is a process called distribution [1]. The effort to make it easier for consumers to get the desired product is the main priority of every company to achieve customer satisfaction. In a distribution system, route selection plays a critical role in determining the distance traveled and the costs incurred. If the chosen route is optimal, the distribution system will run more effectively and efficiently because the route taken has a minimum distance, thus minimizing all elements related to distance. One example of a distribution activity is the delivery of liquid petroleum gas (LPG) cylinders. The shift from using kerosene to gas fuel has caused the need for LPG gas to continuously increase. The distribution process for LPG cylinders starts with the procurement of LPG produced from domestic refineries and procurement through imports [2]. This LPG, originating from refineries or imports, is then channeled to LPG depots. From these depots, the LPG is then distributed to LPG filling stations (SPBE). At the SPBE, the LPG product is filled into 3 kg, 12 kg, and 50 kg LPG cylinders, which are then distributed to LPG agents. The LPG agents then distribute the gas to sub-agents or LPG bases. Subsequently, if market conditions require LPG supply, the sub-agents or LPG bases will distribute the gas to retailers or directly to the end consumer [3].

The distribution of 3kg gas cylinders holds a vital role in Indonesia's household energy supply chain. PT. Haritsah, as one of the distributors, faces challenges in optimizing distribution routes to ensure timely and efficient supply to customers. This efficiency is crucial not only for customer satisfaction but also for reducing the company's operational costs. The main problem faced by PT. Haritsah is the determination of the optimal distribution route. Manual practices that rely on driver experience often result in less efficient routes, leading to high transportation costs, delivery delays, inefficient resource use, and difficulties in coping with changes in demand.

Constraints often arise when the distribution system must visit many locations or nodes without repetition and return to the starting point. This situation generates a variety of possible routes that must be taken. This problem is known as the vehicle routing problem (VRP). VRP is defined as the effort to determine the distribution routes for goods or services to customers with different locations and known demands, from one or more depots, while satisfying certain constraints [4]. As it develops, VRP is divided into several types based on the specific constraints and conditions applied. One type is the capacitated vehicle routing problem (CVRP), where each vehicle has a limited capacity. An example of a CVRP case is the problem of distributing LPG gas cylinders from PT. Harum Ossamac, an LPG agent in Grobogan, to several sub-agents or bases. To overcome this, a systematic and computerized approach is needed. The Ant Colony Optimization (ACO) algorithm, inspired by the behavior of ants in finding the shortest path, offers an effective solution. By considering factors such as distance, travel time, vehicle capacity, and customer location, the ACO algorithm is expected to generate more efficient and effective routes. Several studies on the Ant Colony algorithm include Daniel Udjulawa and Serly Oktarina in 2022, who conducted research titled "Application of

Ant Colony Optimization Algorithm for Searching the Shortest Route of Tourist Locations," which found that the application of the Ant Colony Optimization algorithm showed that the shortest route value obtained was 205.12025621393 distance units. This calculation was based on determining a single starting point, which serves as the center in determining the route to the various tourist locations addressed [5].

Another study was conducted by Nur Alfa Husna, Desvita Hendri, Hilmi Zalnel Haq, and Akhas Rahmadeyan in 2023, titled "Implementation of Ant Colony Optimization Algorithm for Determining the Shortest Path to Clinics from Accident-Prone Locations in Pekanbaru City," which found that this research successfully established the most efficient route from accident-vulnerable locations in Pekanbaru City to the nearest health facilities, utilizing the Ant Colony Optimization (ACO) algorithm [6]. The initial process of this research involved the implementation of ACO facilitated by Google Maps and MATLAB software. Based on the explanation outlined above, the author is interested in conducting research titled "Analysis and Implementation of 3Kg Gas Cylinder Distribution Route Determination Using the Ant Colony Algorithm at PT. Haritsah."

2. Research Methodology

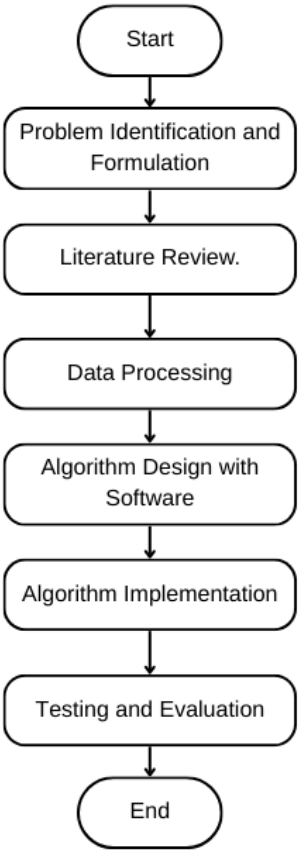

Fig. 1: Flowchart Design

2.1 Type of Research

This research is categorized as applied analytical research using computational and quantitative approaches.

2.2 Data Collection

Data were obtained through interviews and secondary sources, including the coordinates and distances between LPG distribution bases in Medan, vehicle capacity, and delivery demand.

2.3 Algorithm Design

The Ant Colony Optimization (ACO) algorithm was designed to address the Vehicle Routing Problem (VRP). The algorithm was initialized with parameters such as the number of ants, evaporation rate, visibility, and maximum iterations. Google Maps API was used to calculate distances and travel times.

2.4 Implementation

The designed algorithm was implemented in a software application to simulate and optimize LPG distribution routes.

The developed system was tested using real data from PT. Haritsah. The optimized routes generated by ACO were compared with the company's existing manual distribution routes in terms of total travel distance, delivery time, and operational cost efficiency.

3. Result and Discussion

3.1 Result

The results of the Analysis and Implementation of the 3kg Gas Cylinder Distribution Route Determination Using the Ant Colony Algorithm at PT. Haritsa can be seen as follows:

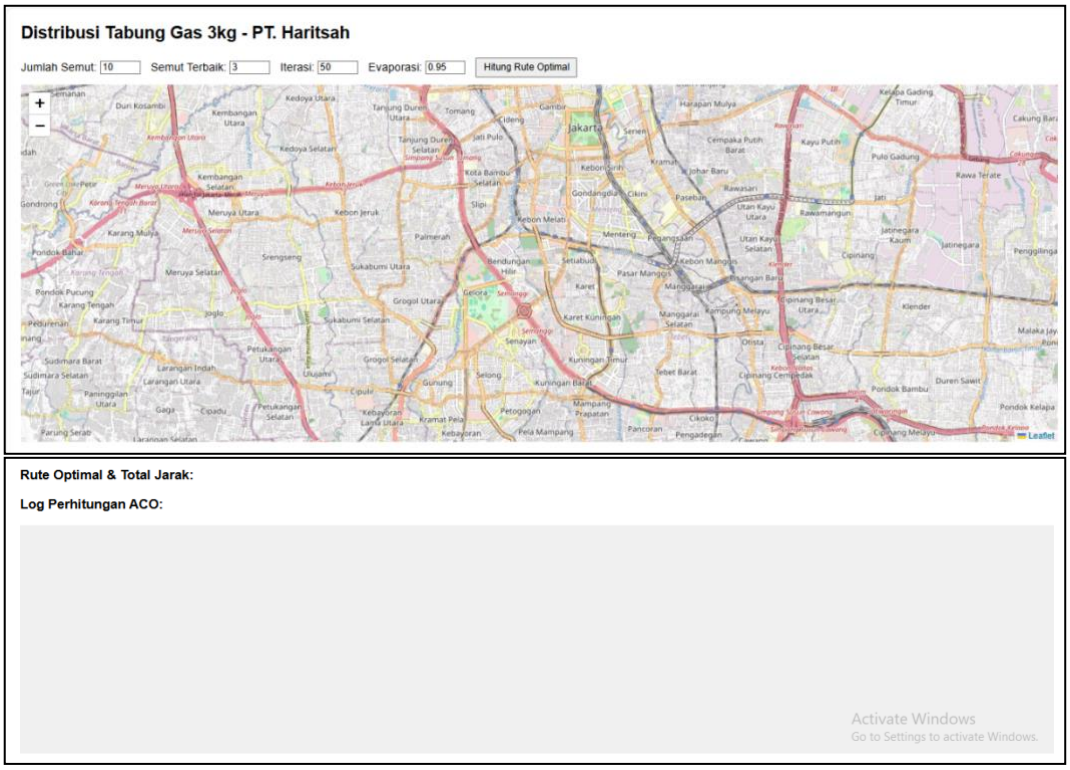

Fig. 2: Ant Colony Optimization

Description:
Ant Colony determines the number of ants in action.
Best Ants refers to selecting the three ants with the shortest distances.
Iteration signifies the computational loop for the Ant Colony Optimization process.
Evaporation represents the accuracy value for the distance search.

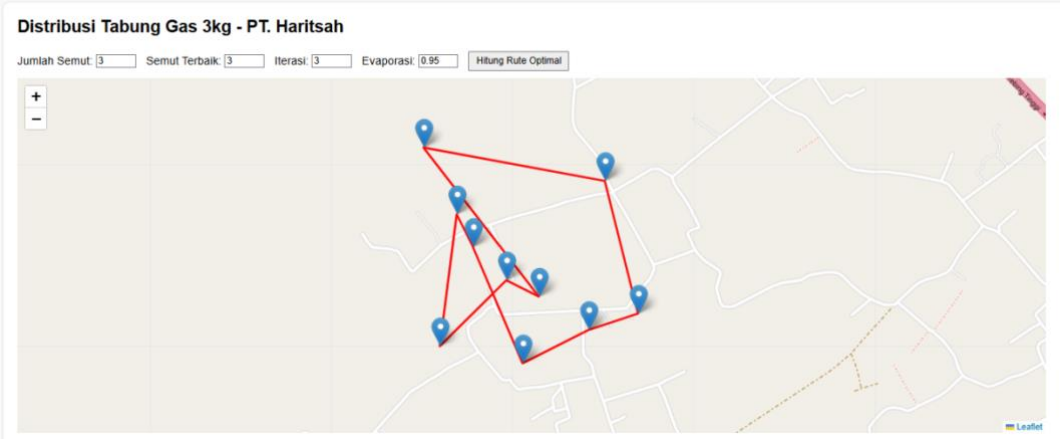

Fig. 3 : Map Result

3.2 Discussion

The discussion includes device requirements, the results used, and testing in this research.

1. Device Requirements

The hardware and software requirements for developing the application are as follows:

a. **One laptop unit with the following specifications:**

1) Minimum processor: Core 2 Duo
2) Minimum RAM: 1 GB
3) Minimum hard drive: 80 GB

b. **Software with the following specifications:**

1) Windows Operating System
2) Notepad++
3) Appserv/XAMPP

2. Ant Colony Method

This research uses the Ant Colony Method, which is applied as a process for searching results.
The stages of the Ant Colony Method are as follows:

Customer Data and Location:

PT. Haritsah, "lat": 3.4880, "lng": 99.0800 (Starting Location)
Base Abdul Khair, "lat": 3.4865, "lng": 99.0825
Base Agus Muliawan, "lat": 3.4900, "lng": 99.0785
Base Arton Sembiring, "lat": 3.4875, "lng": 99.0810
Base Bakti, "lat": 3.4890, "lng": 99.0790
Base Baktiadi, "lat": 3.4910, "lng": 99.0830
Base Berlian Lumban Raja, "lat": 3.4855, "lng": 99.0805
Base Beslan Simatupang, "lat": 3.4920, "lng": 99.0775
Base Budi Sugiarto, "lat": 3.4860, "lng": 99.0780
Base Dermawan Hutapea, "lat": 3.4870, "lng": 99.0840

Ant Colony Settings:

Number of Ants: 3
Best Ants: 3
Iterations: 3

Ant Colony Calculation:

=== Iteration 1 ===
Ant 1, position at Base Arton Sembiring: calculating probability of the next city

- Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 64.8945
- Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 24.9494
- Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 6.4822
- Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 12.9712
- Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.9816
- Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 19.0342
- Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.4920
- Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 7.2105
- Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 8.7751

→ Choosing city PT. Haritsah
Ant 1, position PT. Haritsah: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 9.5410
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 12.9577
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 40.5140
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.5016

Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 12.4445
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 3.6388
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 10.1285
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.7742
-> Chooses city Base Bakti
Ant 1, position Base Bakti: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 4.3825
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 64.7503
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.0559
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.5810
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 7.1945
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 8.0908
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.7978
-> Chooses city Base Berlian Lumban Raja
Ant 1, position Base Berlian Lumban Raja: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 16.2236
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.3372
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 2.2172
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.5791
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 12.4871
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 5.5953
-> Chooses city Base Budi Sugiarto
Ant 1, position Base Budi Sugiarto: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 3.9597
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.9774
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 1.6206
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.2312
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.1938
-> Chooses city Base Dermawan Hutapea
Ant 1, position Base Dermawan Hutapea: calculating the probability of the next city
Probability of Base Abdul Khair: pheromone^1 * (1/distance)^2 = 32.4592
Probability of Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.0665
Probability of Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.7586
Probability of Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.2055
→ Choosing Base Abdul Khair
Ant 1, position Base Abdul Khair: calculating the probability of the next city
Probability of Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.8690
Probability of Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.9454
Probability of Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.4663
→ Choosing Base Baktiadi
Ant 1, position Base Baktiadi: calculating the probability of the next city
Probability of Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.8195
Probability of Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.5974
→ Choosing Base Agus Muliawan
Ant 1, position Base Agus Muliawan: calculating the probability of the next city
Probability of Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 16.1876
→ Choosing Base Beslan Simatupang
Ant 1: Route = Base Arton Sembiring -> PT. Haritsah -> Base Bakti -> Base Berlian Lumban Raja -> Base Budi Sugiarto -> Base Dermawan Hutapea -> Base Abdul Khair -> Base Baktiadi -> Base Agus Muliawan -> Base Beslan Simatupang, Total Distance = 3.74 km
Ant 2, position Base Agus Muliawan: calculating the probability of the next city
Probability of PT. Haritsah: pheromone^1 * (1/distance)^2 = 12.9577
Probability of Base Abdul Khair: pheromone^1 * (1/distance)^2 = 2.8690
Probability of Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 6.4822
Probability of Base Bakti: pheromone^1 * (1/distance)^2 = 64.7503
Probability of Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.8195
Probability of Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 3.3372
Probability of Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 16.1876
Probability of Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 4.9774
Probability of Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.0665
→ Choosing Base Berlian Lumban Raja
Ant 2, position at Base Berlian Lumban Raja: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 12.4445
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 16.2236
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 19.0342
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 5.5810
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 2.2172
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.5791
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 12.4871

Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 5.5953
→ Choosing city Base Abdul Khair
Ant 2, position at Base Abdul Khair: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 9.5410
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 24.9494
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 4.3825
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.9454
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.4663
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 3.9597
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 32.4592
→ Choosing city Base Arton Sembiring
Ant 2, position at Base Arton Sembiring: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 64.8945
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 12.9712
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.9816
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.4920
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 7.2105
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 8.7751
→ Choosing city Base Dermawan Hutapea
Ant 2, position at Base Dermawan Hutapea: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 4.7742
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 2.7978
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.7586
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.2055
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.1938
→ Choosing city PT. Haritsah
Ant 2, position at PT. Haritsah: calculating the probability of the next city
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 40.5140
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.5016
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 3.6388
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 10.1285
→ Choosing city Base Bakti
Ant 2, position at Base Bakti: calculating the probability of the next city
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.0559
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 7.1945
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 8.0908
→ Choosing city Base Baktiadi
Ant 2, position Base Baktiadi: calculating probability of the next city
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.5974
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 1.6206
-> Choosing city Base Budi Sugiarto
Ant 2, position Base Budi Sugiarto: calculating probability of the next city
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.2312
-> Choosing city Base Beslan Simatupang
Ant 2: Route = Base Agus Muliawan -> Base Berlian Lumban Raja -> Base Abdul Khair -> Base Arton Sembiring -> Base Dermawan Hutapea -> PT. Haritsah -> Base Bakti -> Base Baktiadi -> Base Budi Sugiarto -> Base Beslan Simatupang, Total Distance = 4.15 km
Ant 3, position Base Arton Sembiring: calculating probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 64.8945
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 24.9494
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 6.4822
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 12.9712
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.9816
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 19.0342
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.4920
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 7.2105
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 8.7751
-> Choosing city Base Bakti
Ant 3, position Base Bakti: calculating probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 40.5140
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 4.3825
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 64.7503
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.0559
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.5810
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 7.1945
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 8.0908
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.7978
-> Choosing city PT. Haritsah
Ant 3, position PT. Haritsah: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 9.5410

Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 12.9577
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.5016
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 12.4445
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 3.6388
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 10.1285
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.7742
-> Choosing city Base Budi Sugiarto
Ant 3, position Base Budi Sugiarto: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 3.9597
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.9774
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 1.6206
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 12.4871
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.2312
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.1938
-> Choosing city Base Dermawan Hutapea
Ant 3, position at Base Dermawan Hutapea: calculating the probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 32.4592
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.0665
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.7586
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.5953
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.2055
-> Choosing city Base Abdul Khair
Ant 3, position at Base Abdul Khair: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.8690
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.9454
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 16.2236
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.4663
-> Choosing city Base Baktiadi
Ant 3, position at Base Baktiadi: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.8195
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 2.2172
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.5974
-> Choosing city Base Berlian Lumban Raja
Ant 3, position at Base Berlian Lumban Raja: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.3372
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.5791
-> Choosing city Base Beslan Simatupang
Ant 3, position at Base Beslan Simatupang: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 16.1876
-> Choosing city Base Agus Muliawan
Ant 3: Route = Base Arton Sembiring -> Base Bakti -> PT. Haritsah -> Base Budi Sugiarto -> Base Dermawan Hutapea -> Base Abdul Khair -> Base Baktiadi -> Base Berlian Lumban Raja -> Base Beslan Simatupang -> Base Agus Muliawan, Total Distance = 4.21 km
Pheromone update Base Arton Sembiring->PT. Haritsah: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update PT. Haritsah->Base Bakti: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Bakti->Base Berlian Lumban Raja: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Berlian Lumban Raja->Base Budi Sugiarto: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Budi Sugiarto->Base Dermawan Hutapea: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Dermawan Hutapea->Base Abdul Khair: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Abdul Khair->Base Baktiadi: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Baktiadi->Base Agus Muliawan: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Agus Muliawan->Base Beslan Simatupang: 1/3.74 + previous 0.9500 = 1.2177
Pheromone update Base Agus Muliawan->Base Berlian Lumban Raja: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Berlian Lumban Raja->Base Abdul Khair: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Abdul Khair->Base Arton Sembiring: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Arton Sembiring->Base Dermawan Hutapea: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Dermawan Hutapea->PT. Haritsah: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update PT. Haritsah->Base Bakti: 1/4.15 + previous 1.2177 = 1.4588
Pheromone update Base Bakti->Base Baktiadi: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Baktiadi->Base Budi Sugiarto: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Budi Sugiarto->Base Beslan Simatupang: 1/4.15 + previous 0.9500 = 1.1911
Pheromone update Base Arton Sembiring->Base Bakti: 1/4.21 + previous 0.9500 = 1.1874
Pheromone update Base Bakti->PT. Haritsah: 1/4.21 + previous 0.9500 = 1.1874
Pheromone update PT. Haritsah->Base Budi Sugiarto: 1/4.21 + previous 0.9500 = 1.1874
Pheromone update Base Budi Sugiarto->Base Dermawan Hutapea: 1/4.21 + previous 1.2177 = 1.4551
Pheromone update Base Dermawan Hutapea->Base Abdul Khair: 1/4.21 + previous 1.2177 = 1.4551
Pheromone update Base Abdul Khair->Base Baktiadi: 1/4.21 + previous 1.2177 = 1.4551
Pheromone update Base Baktiadi->Base Berlian Lumban Raja: 1/4.21 + previous 0.9500 = 1.1874

Pheromone update Base Berlian Lumban Raja->Base Beslan Simatupang: 1/4.21 + previous 0.9500 = 1.1874
Pheromone update Base Beslan Simatupang->Base Agus Muliawan: 1/4.21 + previous 0.9500 = 1.1874
=== Iteration 2 ===
Ant 1, position Agus Muliawan Base: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 12.3099
Probability of city Abdul Khair Base: pheromone^1 * (1/distance)^2 = 2.7255
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 6.1581
Probability of city Bakti Base: pheromone^1 * (1/distance)^2 = 61.5128
Probability of city Baktiadi Base: pheromone^1 * (1/distance)^2 = 3.6285
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 3.9748
Probability of city Beslan Simatupang Base: pheromone^1 * (1/distance)^2 = 19.7118
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 4.7285
Probability of city Dermawan Hutapea Base: pheromone^1 * (1/distance)^2 = 1.9632
-> Choosing city PT. Haritsah
Ant 1, position PT. Haritsah: calculating the probability of the next city
Probability of city Abdul Khair Base: pheromone^1 * (1/distance)^2 = 9.0640
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 61.6498
Probability of city Bakti Base: pheromone^1 * (1/distance)^2 = 59.1007
Probability of city Baktiadi Base: pheromone^1 * (1/distance)^2 = 4.2765
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 11.8223
Probability of city Beslan Simatupang Base: pheromone^1 * (1/distance)^2 = 3.4568
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 12.0269
Probability of city Dermawan Hutapea Base: pheromone^1 * (1/distance)^2 = 4.5354
-> Choosing city Bakti Base
Ant 1, position Bakti Base: calculating the probability of the next city
Probability of city Abdul Khair Base: pheromone^1 * (1/distance)^2 = 4.1634
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 12.3226
Probability of city Baktiadi Base: pheromone^1 * (1/distance)^2 = 4.8308
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 6.7960
Probability of city Beslan Simatupang Base: pheromone^1 * (1/distance)^2 = 6.8348
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 7.6862
Probability of city Dermawan Hutapea Base: pheromone^1 * (1/distance)^2 = 2.6579
-> Choosing city Beslan Simatupang Base
Ant 1, position Beslan Simatupang Base: calculating the probability of the next city
Probability of city Abdul Khair Base: pheromone^1 * (1/distance)^2 = 1.3930
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 2.3674
Probability of city Baktiadi Base: pheromone^1 * (1/distance)^2 = 2.4675
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 1.5002
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 2.1196
Probability of city Dermawan Hutapea Base: pheromone^1 * (1/distance)^2 = 1.1452
-> Choosing city Baktiadi Base
Ant 1, position Baktiadi Base: calculating the probability of the next city
Probability of city Abdul Khair Base: pheromone^1 * (1/distance)^2 = 3.7482
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 4.7326
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 2.6328
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 1.9302
Probability of city Dermawan Hutapea Base: pheromone^1 * (1/distance)^2 = 4.5206
-> Choosing city Abdul Khair Base
Ant 1, position Abdul Khair Base: calculating the probability of the next city
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 29.7163
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 15.4124
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 3.7617
Probability of city Dermawan Hutapea Base: pheromone^1 * (1/distance)^2 = 30.8363
-> Choosing city Dermawan Hutapea Base
Ant 1, position Dermawan Hutapea Base: calculating the probability of the next city
Probability of city Arton Sembiring Base: pheromone^1 * (1/distance)^2 = 8.3364
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 5.3155
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 2.0841
-> Choosing city Arton Sembiring Base
Ant 1, position Arton Sembiring Base: calculating the probability of the next city
Probability of city Berlian Lumban Raja Base: pheromone^1 * (1/distance)^2 = 18.0825
Probability of city Budi Sugiarto Base: pheromone^1 * (1/distance)^2 = 6.8500
-> Choosing city Berlian Lumban Raja Base
Ant 1, position: Base Berlian Lumban Raja – calculating probability of next city
Probability of city *Base Budi Sugiarto*: pheromone^1 * (1/distance)^2 = 15.2058
-> Choosing city *Base Budi Sugiarto*
Ant 1: Route = Base Agus Muliawan -> PT. Haritsah -> Base Bakti -> Base Beslan Simatupang -> Base Baktiadi -> Base Abdul Khair -> Base Dermawan Hutapea -> Base Arton Sembiring -> Base Berlian Lumban Raja -> Base Budi Sugiarto, Total Distance = 3.41 km

Ant 2, position: Base Beslan Simatupang – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 3.4568
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 1.3930
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 19.2216
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 2.3674
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 6.8348
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 2.4675
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 1.5002
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.1196
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 1.1452
-> Choosing city *Base Bakti*
Ant 2, position: Base Bakti – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 48.1075
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 4.1634
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 61.5128
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 12.3226
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.8308
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 6.7960
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 7.6862
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.6579
-> Choosing city *Base Agus Muliawan*
Ant 2, position: Base Agus Muliawan – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 12.3099
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 2.7255
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 6.1581
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.6285
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 3.9748
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 4.7285
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 1.9632
-> Choosing city *Base Budi Sugiarto*
Ant 2, position: Base Budi Sugiarto – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 9.6221
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 3.7617
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 6.8500
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 1.5395
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 11.8628
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 3.1923
-> Choosing city *Base Berlian Lumban Raja*
Ant 2, position: Base Berlian Lumban Raja – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 11.8223
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 19.3233
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 18.0825
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 2.1064
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 5.3155
-> Choosing city *Base Arton Sembiring*
Ant 2, position: Base Arton Sembiring – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 79.0229
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 23.7019
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.7326
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 10.4517
-> Choosing city *Base Abdul Khair*
Ant 2, position: Base Abdul Khair – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 9.0640
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 5.7412
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 30.8363
-> Choosing city *Base Dermawan Hutapea*
Ant 2, position: Base Dermawan Hutapea – calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 5.6863
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.5206
-> Choosing city *PT. Haritsah*
Ant 2, position: PT. Haritsah – calculating probability of next city
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.2765
-> Choosing city *Base Baktiadi*
Ant 2: Route = Base Beslan Simatupang -> Base Bakti -> Base Agus Muliawan -> Base Budi Sugiarto -> Base Berlian Lumban Raja -> Base Arton Sembiring -> Base Abdul Khair -> Base Dermawan Hutapea -> PT. Haritsah -> Base Baktiadi, Total Distance = 3.38 km
Ant 3, position Base Berlian Lumban Raja: calculating probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 11.8223
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 19.3233

Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.1703
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 18.0825
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 5.3019
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 2.1064
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.8751
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 15.2058
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 5.3155
-> Choosing city Base Bakti
Ant 3, position Base Bakti: calculating probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 48.1075
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 4.1634
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 61.5128
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 12.3226
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 4.8308
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 6.8348
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 7.6862
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.6579
-> Choosing city Base Baktiadi
Ant 3, position Base Baktiadi: calculating probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 4.2765
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 3.7482
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.6511
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 4.7326
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.4675
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 1.9302
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.5206
-> Choosing city PT. Haritsah
Ant 3, position PT. Haritsah: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 9.0640
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 12.3099
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 61.6498
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 3.4568
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 12.0269
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.5354
-> Choosing city Base Arton Sembiring
Ant 3, position Base Arton Sembiring: calculating probability of the next city
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 23.7019
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 6.1581
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.3674
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 6.8500
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 10.4517
-> Choosing city Base Abdul Khair
Ant 3, position Base Abdul Khair: calculating probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.7255
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.3930
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 3.7617
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 30.8363
-> Choosing city Base Dermawan Hutapea
Ant 3, position Base Dermawan Hutapea: calculating probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 1.9632
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.1452
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.0841
-> Choosing city Base Budi Sugiarto
Ant 3, position Base Budi Sugiarto: calculating probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.7285
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.6575
-> Choosing city Base Agus Muliawan
Ant 3, position Base Agus Muliawan: calculating probability of the next city
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 19.7118
-> Choosing city Base Beslan Simatupang
Ant 3: Route = Base Berlian Lumban Raja -> Base Bakti -> Base Baktiadi -> PT. Haritsah -> Base Arton Sembiring -> Base Abdul Khair -> Base Dermawan Hutapea -> Base Budi Sugiarto -> Base Agus Muliawan -> Base Beslan Simatupang, Total Distance = 4.06 km
Pheromone update
Base Beslan Simatupang->Base Bakti: 1/3.38 + previous 0.9025 = 1.1981
Base Bakti->Base Agus Muliawan: 1/3.38 + previous 0.9025 = 1.1981
Base Agus Muliawan->Base Budi Sugiarto: 1/3.38 + previous 0.9025 = 1.1981
Base Budi Sugiarto->Base Berlian Lumban Raja: 1/3.38 + previous 0.9025 = 1.1981
Base Berlian Lumban Raja->Base Arton Sembiring: 1/3.38 + previous 0.9025 = 1.1981
Base Arton Sembiring->Base Abdul Khair: 1/3.38 + previous 0.9025 = 1.1981

Base Abdul Khair->Base Dermawan Hutapea: 1/3.38 + previous 0.9025 = 1.1981
Base Dermawan Hutapea->PT. Haritsah: 1/3.38 + previous 1.1315 = 1.4271
PT. Haritsah->Base Baktiadi: 1/3.38 + previous 0.9025 = 1.1981
Base Agus Muliawan->PT. Haritsah: 1/3.41 + previous 0.9025 = 1.1962
PT. Haritsah->Base Bakti: 1/3.41 + previous 1.3858 = 1.6795
Base Bakti->Base Beslan Simatupang: 1/3.41 + previous 0.9025 = 1.1962
Base Beslan Simatupang->Base Baktiadi: 1/3.41 + previous 0.9025 = 1.1962
Base Baktiadi->Base Abdul Khair: 1/3.41 + previous 0.9025 = 1.1962
Base Abdul Khair->Base Dermawan Hutapea: 1/3.41 + previous 1.1981 = 1.4918
Base Dermawan Hutapea->Base Arton Sembiring: 1/3.41 + previous 0.9025 = 1.1962
Base Arton Sembiring->Base Berlian Lumban Raja: 1/3.41 + previous 0.9025 = 1.1962
Base Berlian Lumban Raja->Base Budi Sugiarto: 1/3.41 + previous 1.1568 = 1.4505
Base Berlian Lumban Raja->Base Bakti: 1/4.06 + previous 0.9025 = 1.1489
Base Bakti->Base Baktiadi: 1/4.06 + previous 1.1315 = 1.3779
Base Baktiadi->PT. Haritsah: 1/4.06 + previous 0.9025 = 1.1489
PT. Haritsah->Base Arton Sembiring: 1/4.06 + previous 0.9025 = 1.1489
Base Arton Sembiring->Base Abdul Khair: 1/4.06 + previous 1.1981 = 1.4445
Base Abdul Khair->Base Dermawan Hutapea: 1/4.06 + previous 1.4918 = 1.7382
Base Dermawan Hutapea->Base Budi Sugiarto: 1/4.06 + previous 0.9025 = 1.1489
Base Budi Sugiarto->Base Agus Muliawan: 1/4.06 + previous 0.9025 = 1.1489
Base Agus Muliawan->Base Beslan Simatupang: 1/4.06 + previous 1.1568 = 1.4032
=== Iteration 3 ===
Ant 1, position at Arton Sembiring Base: calculating probability of next city
Probability of PT. Haritsah city: pheromone^1 * (1/distance)^2 = 75.0717
Probability of Abdul Khair Base city: pheromone^1 * (1/distance)^2 = 36.0395
Probability of Agus Muliawan Base city: pheromone^1 * (1/distance)^2 = 5.8502
Probability of Bakti Base city: pheromone^1 * (1/distance)^2 = 14.6323
Probability of Baktiadi Base city: pheromone^1 * (1/distance)^2 = 4.4959
Probability of Berlian Lumban Raja Base city: pheromone^1 * (1/distance)^2 = 22.7682
Probability of Beslan Simatupang Base city: pheromone^1 * (1/distance)^2 = 2.2491
Probability of Budi Sugiarto Base city: pheromone^1 * (1/distance)^2 = 6.5075
Probability of Dermawan Hutapea Base city: pheromone^1 * (1/distance)^2 = 9.9291
-> Choosing PT. Haritsah city
Ant 1, position at PT. Haritsah: calculating probability of next city
Probability of Abdul Khair Base city: pheromone^1 * (1/distance)^2 = 8.6108
Probability of Agus Muliawan Base city: pheromone^1 * (1/distance)^2 = 11.6944
Probability of Bakti Base city: pheromone^1 * (1/distance)^2 = 68.0434
Probability of Baktiadi Base city: pheromone^1 * (1/distance)^2 = 5.3934
Probability of Berlian Lumban Raja Base city: pheromone^1 * (1/distance)^2 = 11.2312
Probability of Beslan Simatupang Base city: pheromone^1 * (1/distance)^2 = 3.2840
Probability of Budi Sugiarto Base city: pheromone^1 * (1/distance)^2 = 11.4255
Probability of Dermawan Hutapea Base city: pheromone^1 * (1/distance)^2 = 4.3087
-> Choosing Abdul Khair Base city
Ant 1, position at Abdul Khair Base: calculating probability of next city
Probability of Agus Muliawan Base city: pheromone^1 * (1/distance)^2 = 2.5892
Probability of Bakti Base city: pheromone^1 * (1/distance)^2 = 3.9552
Probability of Baktiadi Base city: pheromone^1 * (1/distance)^2 = 5.4541
Probability of Berlian Lumban Raja Base city: pheromone^1 * (1/distance)^2 = 14.6418
Probability of Beslan Simatupang Base city: pheromone^1 * (1/distance)^2 = 1.3233
Probability of Budi Sugiarto Base city: pheromone^1 * (1/distance)^2 = 3.5737
Probability of Dermawan Hutapea Base city: pheromone^1 * (1/distance)^2 = 56.4198
-> Choosing Dermawan Hutapea Base city
Ant 1, position at Dermawan Hutapea Base: calculating probability of next city
Probability of Agus Muliawan Base city: pheromone^1 * (1/distance)^2 = 1.8650
Probability of Bakti Base city: pheromone^1 * (1/distance)^2 = 2.5250
Probability of Baktiadi Base city: pheromone^1 * (1/distance)^2 = 4.2946
Probability of Berlian Lumban Raja Base city: pheromone^1 * (1/distance)^2 = 5.0497
Probability of Beslan Simatupang Base city: pheromone^1 * (1/distance)^2 = 1.0879
Probability of Budi Sugiarto Base city: pheromone^1 * (1/distance)^2 = 2.5204
-> Choosing Bakti Base city
Ant 1, position at Bakti Base: calculating probability of next city
Probability of Agus Muliawan Base city: pheromone^1 * (1/distance)^2 = 77.5787
Probability of Baktiadi Base city: pheromone^1 * (1/distance)^2 = 5.5886
Probability of Berlian Lumban Raja Base city: pheromone^1 * (1/distance)^2 = 6.4562
Probability of Beslan Simatupang Base city: pheromone^1 * (1/distance)^2 = 8.6058
Probability of Budi Sugiarto Base city: pheromone^1 * (1/distance)^2 = 7.3019
-> Choosing Agus Muliawan Base city
Ant 1, position Base Agus Muliawan: calculating probability of next city
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.4471

Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 3.7761
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 22.7146
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 5.9635
-> Choosing city Base Beslan Simatupang
Ant 1, position Base Beslan Simatupang: calculating probability of next city
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.1070
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 1.4252
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.0136
-> Choosing city Base Budi Sugiarto
Ant 1, position Base Budi Sugiarto: calculating probability of next city
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 1.4626
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 14.9611
-> Choosing city Base Berlian Lumban Raja
Ant 1, position Base Berlian Lumban Raja: calculating probability of next city
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 2.0011
-> Choosing city Base Baktiadi
Ant 1: Route = Base Arton Sembiring -> PT. Haritsah -> Base Abdul Khair -> Base Dermawan Hutapea -> Base Bakti -> Base Agus Muliawan -> Base Beslan Simatupang -> Base Budi Sugiarto -> Base Berlian Lumban Raja -> Base Baktiadi, Total Distance = 3.67 km
Ant 2, position Base Bakti: calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 45.7021
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 3.9552
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 77.5787
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 11.7065
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 5.5886
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 6.4562
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 8.6058
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 7.3019
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 2.5250
-> Choosing city Base Abdul Khair
Ant 2, position Base Abdul Khair: calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 8.6108
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.5892
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 28.2305
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 5.4541
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 14.6418
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.3233
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 3.5737
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 56.4198
-> Choosing city Base Budi Sugiarto
Ant 2, position Base Budi Sugiarto: calculating probability of next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 9.1409
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.7184
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 6.5075
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 1.4626
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 14.9611
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.5246
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 3.0327
-> Choosing city PT. Haritsah
Ant 2, position PT. Haritsah: calculating probability of next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 11.6944
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 74.5562
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 5.3934
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 11.2312
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 3.2840
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.3087
-> Choosing city Base Baktiadi
Ant 2, position Base Baktiadi: calculating probability of next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.4185
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 4.4959
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 2.5012
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.3442
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.2946
-> Choosing city Base Dermawan Hutapea
Ant 2, position Base Dermawan Hutapea: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 1.8650
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 10.4966
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.0497
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.0879
-> Choosing city Base Arton Sembiring

Ant 2, position Base Arton Sembiring: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.8502
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 22.7682
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.2491
-> Choosing city Base Berlian Lumban Raja
Ant 2, position Base Berlian Lumban Raja: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.0118
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.7814
-> Choosing city Base Agus Muliawan
Ant 2, position Base Agus Muliawan: calculating the probability of the next city
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 22.7146
-> Choosing city Base Beslan Simatupang
Ant 2: Route = Base Bakti -> Base Abdul Khair -> Base Budi Sugiarto -> PT. Haritsah -> Base Baktiadi -> Base Dermawan Hutapea -> Base Arton Sembiring -> Base Berlian Lumban Raja -> Base Agus Muliawan -> Base Beslan Simatupang, Total Distance = 3.96 km
Ant 3, position Base Beslan Simatupang: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 3.2840
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 1.3233
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 18.2605
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 2.2491
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 8.6199
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.1070
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 1.4252
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.0136
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 1.0879
-> Choosing city Base Baktiadi
Ant 3, position Base Baktiadi: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 5.1718
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 4.7194
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.4185
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 4.4959
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 3.6605
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 2.5012
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 1.8337
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.2946
-> Choosing city Base Dermawan Hutapea
Ant 3, position Base Dermawan Hutapea: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 6.8133
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 44.8712
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 1.8650
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 10.4966
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 2.5250
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.0497
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.5204
-> Choosing city Base Arton Sembiring
Ant 3, position Base Arton Sembiring: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 75.0717
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 36.0395
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.8502
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 14.6323
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 22.7682
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 6.5075
-> Choosing city Base Abdul Khair
Ant 3, position Base Abdul Khair: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 8.6108
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.5892
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 3.9552
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 14.6418
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 3.5737
-> Choosing city Base Berlian Lumban Raja
Ant 3, position Base Berlian Lumban Raja: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 11.2312
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.0118
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 6.4119
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 18.1126
-> Choosing city Base Budi Sugiarto
Ant 3, position Base Budi Sugiarto: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 9.1409
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.7184

Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 7.3019
-> Choosing city Base Agus Muliawan
Ant 3, position Base Agus Muliawan: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 15.4997
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 58.4372
-> Choosing city Base Bakti
Ant 2, position Base Dermawan Hutapea: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 1.8650
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 10.4966
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.0497
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.0879
-> Choosing city Base Arton Sembiring
Ant 2, position Base Arton Sembiring: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.8502
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 22.7682
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 2.2491
-> Choosing city Base Berlian Lumban Raja
Ant 2, position Base Berlian Lumban Raja: calculating the probability of the next city
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.0118
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 1.7814
-> Choosing city Base Agus Muliawan
Ant 2, position Base Agus Muliawan: calculating the probability of the next city
Probability of city Base Beslan Simatupang: pheromone^1 * (1/distance)^2 = 22.7146
-> Choosing city Base Beslan Simatupang
Ant 2: Route = Base Bakti -> Base Abdul Khair -> Base Budi Sugiarto -> PT. Haritsah -> Base Baktiadi -> Base Dermawan Hutapea -> Base Arton Sembiring -> Base Berlian Lumban Raja -> Base Agus Muliawan -> Base Beslan Simatupang, Total Distance = 3.96 km
Ant 3, position Base Beslan Simatupang: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 3.2840
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 1.3233
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 18.2605
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 2.2491
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 8.6199
Probability of city Base Baktiadi: pheromone^1 * (1/distance)^2 = 3.1070
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 1.4252
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.0136
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 1.0879
-> Choosing city Base Baktiadi
Ant 3, position Base Baktiadi: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 5.1718
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 4.7194
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 4.4185
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 4.4959
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 3.6605
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 2.5012
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 1.8337
Probability of city Base Dermawan Hutapea: pheromone^1 * (1/distance)^2 = 4.2946
-> Choosing city Base Dermawan Hutapea
Ant 3, position Base Dermawan Hutapea: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 6.8133
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 44.8712
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 1.8650
Probability of city Base Arton Sembiring: pheromone^1 * (1/distance)^2 = 10.4966
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 2.5250
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 5.0497
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 2.5204
-> Choosing city Base Arton Sembiring
Ant 3, position Base Arton Sembiring: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 75.0717
Probability of city Base Abdul Khair: pheromone^1 * (1/distance)^2 = 36.0395
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.8502
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 14.6323
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 22.7682
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 6.5075
-> Choosing city Base Abdul Khair
Ant 3, position Base Abdul Khair: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 8.6108
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 2.5892
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 3.9552
Probability of city Base Berlian Lumban Raja: pheromone^1 * (1/distance)^2 = 14.6418

Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 3.5737
-> Choosing city Base Berlian Lumban Raja
Ant 3, position Base Berlian Lumban Raja: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 11.2312
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 3.0118
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 6.4119
Probability of city Base Budi Sugiarto: pheromone^1 * (1/distance)^2 = 18.1126
-> Choosing city Base Budi Sugiarto
Ant 3, position Base Budi Sugiarto: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 9.1409
Probability of city Base Agus Muliawan: pheromone^1 * (1/distance)^2 = 5.7184
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 7.3019
-> Choosing city Base Agus Muliawan
Ant 3, position Base Agus Muliawan: calculating the probability of the next city
Probability of city PT. Haritsah: pheromone^1 * (1/distance)^2 = 15.4997
Probability of city Base Bakti: pheromone^1 * (1/distance)^2 = 58.4372
-> Choosing city Base Bakti

Optimal Route & Total Distance:
Optimal Route: Beslan Simatupang Base -> Bakti Base -> Agus Muliawan Base -> Budi Sugiarto Base -> Berlian Lumban Raja Base -> Arton Sembiring Base -> Abdul Khair Base -> Dermawan Hutapea Base -> PT. Haritsah -> Baktiadi Base
Distance Details:

1. Beslan Simatupang Base -> Bakti Base = 0.37 km
2. Bakti Base -> Agus Muliawan Base = 0.12 km
3. Agus Muliawan Base -> Budi Sugiarto Base = 0.45 km
4. Budi Sugiarto Base -> Berlian Lumban Raja Base = 0.28 km
5. Berlian Lumban Raja Base -> Arton Sembiring Base = 0.23 km
6. Arton Sembiring Base -> Abdul Khair Base = 0.20 km
7. Abdul Khair Base -> Dermawan Hutapea Base = 0.18 km
8. Dermawan Hutapea Base -> PT. Haritsah = 0.46 km
9. PT. Haritsah -> Baktiadi Base = 0.47 km
10. Baktiadi Base -> Beslan Simatupang Base = 0.62 km

Total Distance: 3.38 km

4. Conclusion

The conclusion that can be drawn from this research is that the Ant Colony algorithm has proven effective in determining the distribution routes for 3kg gas cylinders at PT. Haritsa. By applying the principles of ant colonies, the algorithm is able to gradually discover the shortest paths that minimize the total travel distance, thus making distribution more efficient. The implementation results show that as the number of iterations increases, the ants tend to choose more optimal routes, significantly reducing travel distances compared to the initial random routes. Therefore, the use of Ant Colony Optimization not only assists in route planning but also supports the company in saving both time and operational costs.

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