Dijkstra Algorithm and Ant Colony Optimization Algorithm for Fertilizer Distribution Route Problems

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Abstract. Distribution is the activity of distributing goods from a company to consumers to maintain the continuity of the company. Distribution of fertilizer by land transportation to the warehouse location requires the shortest path and distance. The shortest route from the problem of distributing fertilizer to warehouse locations can be searched using the Dijsktra algorithm and the Ant Colony Optimization Algorithm (ACO). Our research discusses how to determine the optimal route using the Dijkstra algorithm and the Ant Colony Optimization algorithm for the fertilizer distribution route problem so that all fertilizer warehouse locations can be served. Distribution of fertilizer via land transportation to the warehouse location requires the shortest route and distance. Evaluation of these two algorithms was carried out on a real example of fertilizer distribution in the city of Palembang. The solutions of these two algorithms were compared and it was found that the Djikstra algorithm showed more optimal results than the Ant Colony Optimization algorithm for the fertilizer distribution route problem.

Keywords: distribution, Dijkstra algorithm, Ant Colony Optimization algorithm, vehicle routing problem

1 Introduction

Indonesia is known as an agricultural country with the majority of the Indonesian population working as farmers. Farmers need fertilizer to increase production yields. The role of fertilizer companies as distributors is important in the fertilizer distribution process. Distribution is a marketing activity that seeks to facilitate the delivery of goods into the hands of consumers effectively. Fertilizer companies must prepare fertilizer stocks that exceed the provisions so that distribution throughout the region can be carried out because at any time there could be a surge in demand by farmers. Distribution is the activity of distributing goods from a company to consumers to maintain the continuity of the company [1–3].

The fertilizer distribution system to each warehouse location is visited once by one vehicle in one fertilizer distribution process. Distribution of fertilizer by land transportation to the warehouse location requires the shortest path and distance. The shortest route from the problem

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of distributing fertilizer to warehouse locations can be searched using the Dijsktra algorithm and the Ant Colony Optimization Algorithm (ACO). The Dijsktra algorithm is an exact and effective method for searching shortest path while the ACO algorithm is a metaheuristic method [4,5].

Dijkstra's algorithm was introduced in 1959 by Dutch Scientist Edsger Wybe Dijkstra [6]. Dijkstra's algorithm is a well-known classical shortest path selection or optimal path in routing problems in planning for a single source shortest path problem, which can effectively calculate the shortest path to all destinations [7–9]. Dijkstra's algorithm solves the problem of finding the shortest path from a point in the graph (source) to the destination [10–12].

Determining the shortest route in the fertilizer distribution route problem is also solved using the ACO algorithm which adopts the behavior of ants to travel from the nest to the food source based on the pheromone trail on the path that has been traversed. There are studies that have compared the ACO algorithm with Dijkstra's algorithm such as [13] and [14].

This research will discuss the optimal route for determining fertilizer distribution routes using the Dijkstra algorithm and the ACO algorithm.

2 Research Methods

This research uses the Dijkstra algorithm and the Ant Colony Optimization algorithm to determine the shortest route for fertilizer distribution. The beginning of this research is to describe distance data between distribution locations using Google Maps. The steps of Dijkstra's algorithm are as follows:

Form a weighted graph matrix $W\ (G) = [\boldsymbol{a_{i\,j}}]$ and determine the vertex that will be the starting vertex. Initialize $L = \{\ \}$ as a set of permanent vertices of $V(G))$ that have been selected for the shortest route and $V(G) = \{v_{2,}\ v_3, \ldots, v_n\ \}$ is a weighted graph with its vertices.

For the initial iteration, given $D(V) = 0$. At the initial node v_1 is the departure node or first permanent node and at the other nodes it is symbolized ∞, $D\ (v_2\ ) =\ D\ (v_3\ ) = \cdots\ D\ (v_n\ ) = \infty$. This indicates that the shortest route from the permanent node v_1 to the other nodes has not been found. and the symbol ∞ in the solution is considered a very large number.

$D = (v_j\ )$ represents the shortest route vertex from v_i to v_j , for $i = 2, \ldots, n$; $D = (v_j\ ) = W\ (v_{i,}\ v_j\ )$ and represents $W\ (v_{i,}\ v_j\ )$ the weight of vertices v_i to v_j . From the permanent node v_1 consider the neighboring nodes that are traversed directly from v_1 with the edge weight from node v_i to v_j being $W(v_{i,}, v_j)$for $j = 2, \ldots, n$. The destination node $v_n\ \notin L$ which means v_n has not been selected in the set of L shortest route solutions. For $v_j\ \in V - L$,, each node that is directly adjacent to the permanent node v_1 is calculated:

$$D(v_j\ ) = \text{Min}\ \{\ D\ (v_j\ ), D\ (v_1\ ) + W\ (v_{1,j})\} \qquad (1)$$

The smallest value of $D(v_j\ )$ is taken as $D(v_k\ )$ with node $v_k\ \in V - L$ as the next permanent node and is included in the solution set $L = L \cup \{v_k\ \}$ and is not considered again in next iteration. The value $D(v_k\ )$ is the starting node in the next iteration.

The iteration stops until the destination node becomes a permanent node again or $v_j\ \in L$.

Ant Colony Optimization is a metaheuristic algorithm for solving combinatorial problems which is widely applied to goods distribution problems [15–19].

ACO algorithm is inspired by the behavior of ants to search for food sources in order to obtain an optimal solution. Ants will work together globally between all colonies together [20–22]. The ACO algorithm works as follows: In the first stage, *m* ants are placed to search for a new route at *n* points and find information about the state of the route passed to find the destination [23]. The ant's work process begins to spread randomly. If the ants have found a food source, they return and leave pheromones as a food trail. The pheromones found by other ants are followed in their footsteps to find the same path. The food is carried by the ants to their nest in a path filled with pheromones for the ants to pass along the same path. If more ants follow the same path, the path becomes stronger. For long paths, the pheromone scent is not stronger than for short paths. This process of pheromone inheritance is known as stigmery, pheromones are an environmental modification process that not only aims to remember the way back to the nest, but also for ants to communicate with their colony.

The ACO algorithm in general is preparing the visiting route for each ant, calculating the route length for each ant, and calculating pheromones for the next iteration. The advantage of the ACO algorithm is that this algorithm always finds a solution that is close to optimal for all problems and is able to provide value with a single solution for several tests. The procedure for the ACO algorithm is as follows:

2.1 Determine the visibility matrix or inverse of the distance

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

In here, η_{ij} is the visibility or inverse of the distance d_{ij}, d_{ij} is the distance between distribution nodes, i is the index of the origin and j is the destination node index.

2.2 Probability of ant *k* walking from node *i* to node *j*

$$p_{ij}^{k} = \frac{(\tau_i)^{\alpha}\,(\eta_{ij})^{\beta}}{\sum_{j\,\epsilon\,J_i^k}(\tau_{ij})^{\alpha}\,(\eta_{ij})^{\beta}} \quad (3)$$

In Equation (3), p_{ij}^{k} is the probability for ant k to walk from node i to node j, τ_{ij} is the intensity for the ant pheromone trail, J_i^k is the set of points visited by ant k which is at node i, α is a condition for controlling the intensity of ant trails ($\alpha \geq 0$) and β is the visibility control provision ($\beta \geq 0$).

2.3 Cumulative Probability

$$q_k = q_{k-1} + p_{ij} \quad (4)$$

In Equation (4), q_k is the cumulative probability k, q_{k-1} is the cumulative probability k – 1for k = 2, … , n and p_{ij} is the probability of an ant walking from node i to node j.

2.4 Random number

A random number (r) generated between 0 and 1 with

$$q_{k-1} < r \leq q_k \tag{5}$$

3 Result and Discussion

It is assumed that the road conditions are smooth and not congested, it is assumed that the distance between location i and location j is the same as the distance between location j and location i or is considered symmetrical, and distribution of fertilizer to customers uses land transportation in one operation.

Fertilizer distribution location visited by one vehicle. Fertilizer factory as the central point of distribution aimed at several warehouse locations such as Os Warehouse in Palembang, Palembang fertilizer storage warehouse, Tanjung Api-Api warehouse Palembang, Lubuk Linggau fertilizer storage warehouse, Belitang Martapura warehouse, Martapura fertilizer storage warehouse and Lahat warehouse.

Data on distance to warehouse locations and distances between other warehouse locations using google maps is presented as follows:

$$d_{ij} = \begin{bmatrix} 0 & 0,95 & 15 & 37 & 313 & 241 & 242 & 229 \\ 0,95 & 0 & 15 & 36 & 504 & 241 & 241 & 228 \\ 15 & 15 & 0 & 26 & 302 & 241 & 241 & 228 \\ 37 & 36 & 26 & 0 & 298 & 263 & 242 & 250 \\ 313 & 504 & 302 & 298 & 0 & 321 & 263 & 144 \\ 241 & 241 & 241 & 263 & 321 & 0 & 322 & 175 \\ 242 & 241 & 241 & 263 & 322 & 0,65 & 0,65 & 175 \\ 229 & 228 & 228 & 250 & 144 & 175 & 175 & 0 \end{bmatrix} \tag{6}$$

3.1 Dijkstra Algorithm

Based on the distance data from equation (6), then a directed weighted graph is formed to represent fertilizer distribution locations and the distance between locations as in Figure 1.

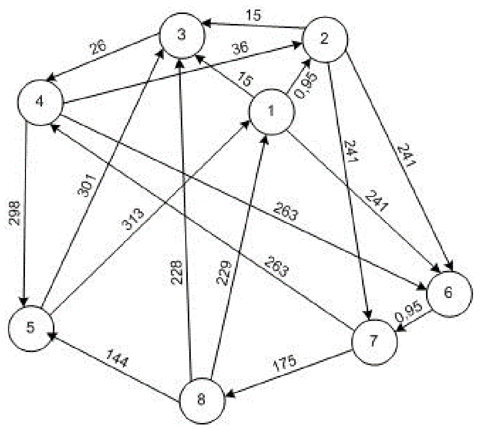

Fig. 1. Fertilizer distribution route on the graph

The matrix $\boldsymbol{W}\ (\boldsymbol{G})$ whose input is the weight of the location of warehouse 1 to other warehouses and for the entry ∞ (undefined) symbolizing no arc to other locations is presented as follows

$$W\ (G) = \begin{bmatrix} \infty & 0.95 & 15 & \infty & 313 & 241 & \infty & 229 \\ 0.95 & \infty & 15 & 36 & \infty & 241 & 241 & \infty \\ 15 & 15 & \infty & 26 & 302 & \infty & \infty & 228 \\ \infty & 36 & 26 & \infty & 298 & 263 & 263 & \infty \\ 313 & \infty & 302 & 298 & \infty & \infty & \infty & 144 \\ 241 & 241 & \infty & 263 & \infty & \infty & 0,65 & \infty \\ \infty & 241 & \infty & 263 & \infty & 0,65 & \infty & 175 \\ 229 & \infty & 228 & \infty & 144 & \infty & 175 & \infty \end{bmatrix} \quad (7)$$

Initialization, $L = \{\ \}$ as a set of permanent vertices of $V(G)$) that have been selected for the shortest route and $V = \{v_{2,}\ v_3, \dots, v_8\}$. The starting point or point 1 is determined as the first permanent point and given a value of zero, $D(v_1) = D(1) = 0$. Nodes are not yet permanent and are directly adjacent to permanent node 1 or node 1 is located at location 1 for other nodes, $D = (v_4) = \infty$ and $D = (v_7) = \infty$. Meanwhile, the point that is directly adjacent to permanent point 1 or node 1 is located at location 1 which has the value $D = (v_2) = W\left(v_{1,}\ v_2\right) = 0.95$, $D = (v_3) = W\left(v_{1,}\ v_3\right) = 15$, $D = (v_5) = W\left(v_{1,}\ v_5\right) = 313$, $D = (v_6) = W\left(v_{1,}\ v_6\right) = 241$, $D = (v_8) = W\left(v_{1,}\ v_8\right) = 229$for *i* = 2, 3, 4, 5, 6, 7, 8. The destination node $v_i \notin L$ can then be calculated using Equation (1) for *j* = 2, 3 ,4 ,5 ,6 ,7, 8 is obtained $D(v_2) = 0{,}95$, $D(v_3) = 15$, $D(v_5) = 313$, $D(v_6) = 24$, $D(v_8) = 229$.

Based on the results of calculations using the Dijkstra algorithm, the fertilizer distribution route results are as follows: Fertilizer factory – Os warehouse in Palembang – Palembang fertilizer storage warehouse – Tanjung Api-Api warehouse in Palembang – Belitang Martapura warehouse – Martapura fertilizer storage warehouse – Lahat warehouse – Lubuk Linggau fertilizer storege warehouse– Fertilizer factory with total distance traveled 937.60 km.

3.2 Ant Colony Optimization Algorithm

At the beginning of solving the ACO algorithm, it is necessary to determine parameter values which are referred to as initialization parameters such as $\alpha, \beta, n, m, Q, \tau_{ij}, NC_{max}$ as in Table 1.

Table 1. Parameter

Parameter	Value
n	8
α	1
β	1
τ_{ij}	0.01
m	1
Q	1
NC_{max}	1

The results of calculating the Visibility matrix between companies and distribution location nodes and between distribution location nodes using Equation (2) are in Table 2.

Table 2. Visibility Matrix

$\eta_{i\,j}$	1	2	3	4	5	6	7	8
1	0	1.0526	0.0667	0.027	0.0032	0.0041	0.0041	0.0044
2	1.0526	0	0.0667	0.0278	0.002	0.0041	0.0041	0.0044
3	0.0667	0.0667	0	0,0385	0.0033	0.0041	0.0041	0.0044
4	0.027	0.0278	0.0385	0	0.0034	0.0038	0.0038	0.004
5	0.0032	0.002	0.0033	0.0034	0	0.0031	0.0031	0.0069
6	0.0041	0.0041	0.0041	0.0038	0.0031	0	1.5385	0.0057
7	0.0041	0.0041	0.0041	0.0038	0.0031	1.5385	0	0.0057
8	0.0044	0.0044	0.0044	0.004	0.0069	0.0057	0.0057	0

where: Fertilizer factory as node 1, Os warehouse in Palembang as node 2, Palembang fertilizer storage warehouse as node 3, Tanjung Api-Api warehouse Palembang as node 4, Lubuk Linggau fertilizer storage warehouse as node 5, Belitang Martapura warehouse as node 6, Martapura fertilizer storage warehouse as node 7, Lahat warehouse as node 8

Solution of the probability of fertilizer distribution between companies and distribution location points and between distribution location points using Equation (3) as in Table 3.

Table 3. Probability of fertilizer factory

$p_{i\,j}^{1}$	1	2	3	4	5	6	7	8
1	0	0.9057	0.0574	0.0233	0.0027	0.0036	0.0036	0.0038

Calculation of the cumulative probability of fertilizer distribution is calculated using Equation (4) as in Table 4.

Table 4. Cumulative probability of a fertilizer factory

q_k	1	2	3	4	5	6	7	8
1	0	0.057	0.9631	0.9864	0.9891	0.9927	0.9961	1

The random number (r) between 0 and 1 is 0.960244 which was generated from Microsoft Excel. Based on Equation (5). It is obtained that the selected distribution location is Palembang fertilizer storage warehouse. The calculation process stops, once all points have been visited.

The distance traveled for fertilizer distribution based on the Dijkstra algorithm and the ACO algorithm is presented in Table 5.

Table 5. Fertilizer distribution routes

Algorithm	Travel route	Distance (km)
Dijkstra Algorithm	Fertilizer factory – Os warehouse in Palembang – Palembang fertilizer storage warehouse – Tanjung Api-Api warehouse Palembang – Belitang Martapura warehouse – Martapura fertilizer storage warehouse – Lahat warehouse – Lubuk Linggau fertilizer storage warehouse – Fertilizer factory	937.60
Ant Colony Optimization Algorithm	Fertilizer factory – Palembang fertilizer strorage warehouse – Lahat warehouse – Martapura fertilizer stroge warehouse – Belitang Martapura warehouse – Os warehouse in Palembang – Tanjung Api-Api warehouse – Lubuk Linggau fertilizer storage warehouse – Fertilizer factory	1306.65

The distance traveled with the Dijkstra algorithm is shorter than the distance traveled by the ACO algorithm.

4 Conclusion

The solution results of determining the route for fertilizer distribution vehicles using the ACO algorithm produce a greater distance than the distance used using the Dijkstra algorithm. The calculation process using the ACO algorithm is more complex than the Dijsktra algorithm. This is because the ACO algorithm is inspired by the behavior of ants who always look for better travel possibilities so they can reach the best solution.

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References

[1] Yuliza E, Octarina S, Eliyati N, Maya F.: Application of The Robust Capacitated Vehicle Routing Problem with Time Windows Model on Gallon Water Distribution. AIP Conf Proc. 020076(2577), pp. 13–9 (2022).

[2] Yuliza E, Puspita FM, Yahdin S, Emiliya R.: Solving Capacitated Vehicle Routing Problem Using of Clarke and Wright Algorithm and LINGO in LPG distribution. J Phys Conf Ser. 1663:012027 (2020).

[3] Yuliza E, Puspita FM, Supadi SS.: The Robust Counterpart Open Capacitated Vehicle Routing Problem with Time Windows on Waste Transport Problems. Bull Electr Eng Informatics. 9(5):2074–81 (2020).

[4] Gunawan RD, Napianto R, Borman RI, Hanifah I.: Implementation of Dijkstra'S Algorithm in Determining the Shortest Path (Case Study: Specialist Doctor Search in Bandar Lampung). IJISCS (International J Inf Syst Comput Sci. 3(3):98 (2019).

[5] Iqbal M, Zhang K, Iqbal S, Tariq I.: A Fast and Reliable Dijkstra Algorithm for Online Shortest Path. Int J Comput Sci Eng. 5(12) pp.24–7 (2018).

[6] Huang Y.: Research on the Improvement of Dijkstra Algorithm in the Shortest Path Calculation. 150(Macmc):745–9 (2018).

[7] Luo M, Hou X, Yang J.: Surface Optimal Path Planning Using an Extended Dijkstra Algorithm. IEEE Access. 8:147827–38 (2020).

[8] Chen YZ, Shen SF, Chen T, Yang R.: Path Optimization Study for Vehicles Evacuation Based on Dijkstra Algorithm. In: Procedia Engineering [Internet]. Elsevier B.V. Available from: http://dx.doi.org/10.1016/j.proeng.2014.04.023 pp.159-165 (2014)

[9] Rosita YD, Rosyida EE, Rudiyanto MA.: Implementation of Dijkstra Algorithm and Multi-Criteria Decision-making for Optimal Route Distribution. In: Procedia Computer Science [Internet]. Elsevier B.V. Available from: https://doi.org/10.1016/j.procs.2019.11.136 pp. 378-385 (2019)

[10] Broumi S, Talea M, Bakali A, Smarandache F.: Applying Dijkstra Algorithm for Solving Neutrosophic Shortest Path Problem. Proc Int Conf Adv Mechatron Syst. 2016;412–6 (2016).

[11] Deepa G, Kumar P, Manimaran A, Rajakumar K, Krishnamoorthy V.: Dijkstra Algorithm Application: Shortest Distance between Buildings. Int J Eng Technol. 7(4.10):974 (2018).

[12] Jaiswal U, Aggarwal S.: Ant Colony Optimization. Int J Sci Eng Res.2(7). pp.1–7 (2011).

[13] Sachithraj T, Piruthiviraj P, Sharan P.: Comparison of Dijkstra Algorithm With Ant Colony Optimization Algorithm Using Random Topology in All-Optical Network Using Rwa. Int J Res Eng Technol. 04(17). pp.66–69 (2015).

[14] Ibrahim Ata K, Che Soh A, Ishak AJ, Jaafar H.: Guidance system based on Dijkstra-ant colony algorithm with binary search tree for indoor parking system. Indones J Electr Eng Comput Sci. 24(2). pp.1173–1182 (2021).

[15] Ramli N, Othman RR, Fauzi SSM.: Ant Colony Optimization Algorithm Parameter Tuning for T-way IOR Testing. J Phys Conf Ser. 2018;1019(1).

[16] Akhtar A.: Evolution of Ant Colony Optimization Algorithm -- A Brief Literature Review. Available from: http://arxiv.org/abs/1908.08007(2019)

[17] Liu Y, Cao B.: A Novel Ant Colony Optimization Algorithm with Levy Flight. IEEE Access. 8:67205–13 (2020).

[18] Lopez-Ibanez M, Stutzle T, Dorigo M.: Ant Colony Optimization : A Component-Wise Overview. (2015).

[19] Singh G, Kumar N, Kumar A.: Ant colony algorithms in MANETs : A review. J Netw Comput Appl. 35(6). http://dx.doi.org/10.1016/j.jnca.2012.07.018. pp. 1964-1972 (2012)

[20] Duan P, AI Y.: Research on an Improved Ant Colony Optimization Algorithm and its Application.

Int J Hybrid Inf Technol. 9(4) pp. 223–234 (2016).

[21] Deng W, Xu J, Zhao H.: An Improved Ant Colony Optimization Algorithm Based on Hybrid Strategies for Scheduling Problem. IEEE Access. 7:20281–92 (2019).

[22] Fahmi H, Zarlis M, Nababan EB, Sihombing P.: Ant Colony Optimization (ACO) Algorithm for Determining the Nearest Route Search in Distribution of Light Food Production. J Phys Conf Ser. 1566(1) (2020).

[23] Wei X.: Parameters Analysis for Basic Ant Colony Optimization Algorithm in TSP. Int J u- e-Service, Sci Technol. 7(4) pp. 159–170 (2014).