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ANT COLONY OPTIMIZATION-BASED ROUTING FOR HUMANITARIAN AID DISTRIBUTION IN FLOOD AND LANDSLIDE-AFFECTED AREAS OF KEBUMEN REGENCY

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ABSTRACT
Natural disasters such as floods and landslides are recurring phenomena in Kebumen Regency, with the latest major incident occurring in March and May 2025 when extreme rainfall caused river overflows and road disconnections. In such conditions, rapid and efficient aid distribution is critical within the humanitarian logistics framework. This study aims to determine the optimal aid distribution route using the Ant Colony Optimization (ACO) method, considering both distance and travel time as evaluation criteria. A total of nine distribution points were analyzed, with five ACO parameter configurations tested using MATLAB. The results show that Parameter 5 produced the most optimal route with a total distance of 92.2 km and a travel time of 192 minutes. The resulting route was also visualized geospatially to support practical implementation by on-field decision makers. These findings confirm that ACO is capable of generating efficient routing solutions for emergency logistics under post-disaster conditions. The study contributes to the advancement of metaheuristic-based optimization in disaster response operations and provides a replicable framework for other regions facing similar challenges.

Keywords: ant colony optimization; disaster management; flood and landslide response; humanitarian logistics; kebumen regency; route optimization

INTRODUCTION
Indonesia is one of the countries with the highest levels of natural disaster vulnerability in the world. Located on the equator with tropical geographical and climatic conditions, various types of disasters such as floods and landslides occur almost every year in a number of regions (Djalante, 2018). Kebumen Regency is one of the areas that is often affected by these disasters, especially during the rainy season. Back in March and May 2025, major flooding hit Kebumen Regency again due to extreme rainfall that caused the Luk Ulo and Kedungbener Rivers to overflow, submerging at least seven subdistricts, including Karangsambung, Alian, Klirong, Sruweng, and Adimulyo. The Kebumen Regional Disaster Management Agency (BPBD) reported that more than a thousand residents were forced to evacuate and a number of roads connecting villages were cut off due to flooding and landslides that accompanied the disaster (BPBD Kebumen, 2025; Prasakti, 2025). This situation shows that the pattern of hydrometeorological disasters in Kebumen is recurring and becoming more intense from year to year, so that disaster management should not only focus on evacuating residents, but also ensure a rapid, measurable, and adaptive aid distribution scheme in response to uncertain field conditions.

In the context of disaster management, the process of resource management cannot be carried out spontaneously, but must follow the disaster management framework. According to (Carter, 1991), disaster management is “a systematic process of using administrative directives, organizations, and operational skills to implement strategies that lessen the impact of hazards and disasters.” This is in line with the (UNISDR, 2015) definition, which states that disaster management includes “the organization, planning and application of measures preparing for, responding to and recovering from disasters." Within this framework, aid distribution is in the emergency response phase, where speed and accuracy are factors that determine the safety of victims (Dimitriou dkk., 2018). Aid distribution in disaster situations falls within the realm of humanitarian logistics, which is the process of planning, procuring, managing, and distributing resources effectively in emergency conditions (Kovács & Spens, 2007). Unlike commercial logistics, which is profit-oriented, humanitarian logistics faces challenges such as limited fleets, damaged infrastructure, and the need to act quickly even though field information is often incomplete (Wassenhove, 2017). Therefore, the determination of aid distribution routes must be done optimally so that aid can reach all affected locations with the shortest distance and fastest travel time (Arifin dkk., 2024).

The problem of determining aid distribution routes mathematically can be categorized as a Vehicle Routing Problem (VRP), which is an optimization problem to find the best sequence of visits to a number of locations while considering distance or time efficiency (Toth & Vigo, 2015). Various methods have been developed to solve VRP, one of which is Ant Colony Optimization (ACO), introduced by (Dorigo et al., 2006). ACO works by mimicking the behavior of ants in finding the fastest path to food sources through a pheromone mechanism. This method has been proven to be capable of producing optimal solutions iteratively, even for large-scale problems. Studies on route optimization in the context of humanitarian logistics are growing due to the need for rapid response and limited resource allocation during disasters. Conceptual studies and metaheuristic reviews show that ACO is one of the most effective methods for route and scheduling problems in emergency situations due to its feromon-based adaptive mechanism that allows for balanced exploration and exploitation of solution space (Dorigo et al., 2006). In the Indonesian context, a number of academic and applied studies have applied ACO to various disaster-related problems, ranging from the optimization of aid distribution routes and the determination of evacuation routes to the coordination between land and air vehicles, demonstrating the potential of ACO in improving the speed and efficiency of field operations.

The use of the ACO method can be applied to optimize the distribution route of post-eruption aid in the Special Region of Yogyakarta (Mahendra & Asih, 2015). The research conducted by Mahendra & Asih (2015) compared ACO with Genetic Algorithms and found that ACO produced a smaller total distance traveled and better computational performance on the Merapi command post dataset. These results show that ACO is capable of providing practical solutions for determining disaster command post routes. In the case of natural disasters such as the eruption of Mount Merapi in Yogyakarta, the ACO method was used to determine the distribution route for post-eruption aid. This method can also be used to design coordination routes between Unmanned Aerial Vehicles (UAVs) and Ground Vehicles (GVs) in search-and-rescue operations (Aryasena & Sopha, 2022). This study shows that the routes generated by ACO can reduce operation time compared to the Depth-First Search approach in the case study tested, thus demonstrating the superiority of ACO in routing problems that require time constraints.

In the field of tsunami evacuation and emergency route planning, in Padang City, West Sumatra Province, Indonesia, ACO can be used to determine the fastest evacuation route for SAR teams (Fitriyani & Ahmad, 2024). Using distance and time data from Google Maps, ACO successfully reduced evacuation response times and provided practical routes for SAR teams, thereby strengthening the evidence that ACO can be implemented for various types of disaster threats in Indonesia. Several studies have also developed specific ACO variants for disaster logistics, such as multi-objective ACOs that incorporate distance, time, and road safety criteria, as well as hybrid methodologies that combine ACO with other techniques (e.g., Variable Neighborhood Search (Susilo et al., 2024), clustering, or decomposition) to improve solution stability in real-world cases (Robles et al., 2021). These studies suggest that the selection of ACO parameters (alpha, beta, rho, number of ants, iterations) and the adjustment of evaluation criteria (distance vs. time vs. priority of needs) greatly determine the quality of the solution, thus requiring systematic parameter experiments for each operational context (Ferrer et al., 2020).

Although numerous studies have demonstrated the effectiveness of Ant Colony Optimization (ACO) in various disaster-related routing problems across Indonesia, several research gaps still remain. Most previous works rely on static simulation data derived from online maps without accounting for real post-disaster accessibility constraints such as road blockages or damaged bridges. In addition, only a limited number of studies explicitly adopt multi-criteria evaluation, such as simultaneously considering both distance and travel time with priority weighting based on urgency, while systematic sensitivity analysis of ACO parameters in local humanitarian logistics contexts is also rarely conducted, despite the parameters' strong influence on convergence and solution quality. Addressing these limitations, the present study seeks to determine the optimal distribution route for aid delivery to landslide and flood victims in Kebumen Regency using the ACO method. Unlike prior works, this study simultaneously applies two evaluation criteria (distance and travel time), explores multiple parameter configurations, and visualizes the best-performing route on a geographical map to enhance applicability for on-field decision makers. Through this approach, the study is expected to contribute not only to methodological advancement in humanitarian logistics optimization but also to the strengthening of disaster management practices within the emergency response phase at the local government level.

METHOD

This research was conducted in several stages. The initial stage of the research involved identifying the problem. It was found that the Indonesian Red Cross (PMI) in Kebumen wanted to distribute aid to areas affected by landslides and floods in Kebumen Regency. This problem was then brought to the realm of distribution determination. To resolve this issue, a literature study on similar topics was conducted, determining that the core issue to be resolved was determining the distribution route for aid to natural disaster victims. After that, data collection was carried out in the form of distance and travel time between locations to be visited. The research continued with data processing to produce the optimal distribution route. After several trials, the best route was selected as a recommendation to be applied in the case at hand.

This research was conducted using the Ant Colony Optimization (ACO) method. Ant Colony Optimization (ACO) is a metaheuristic method that attempts to solve optimization problems by adopting the behavior of ants when searching for food or crossing areas with certain obstacles into an algorithm to obtain the optimal solution for the case being worked on (Santosa, 2017). During this process, ants release pheromones as a trail to the desired location. This trail also guides other ants to follow the same path so that the pheromones left behind are renewed and become thicker, making it easier for the ants to reach their destination (Dorigo et al., 2006). This method has been implemented in previous studies to produce distribution routes with minimal distance and travel time (Adhitama & Wibisono, 2024; Dinar et al., 2025). The following are the stages of the Ant Colony Optimization (ACO) method.

1. Determine the initial parameters consisting of pheromone weight or alpha (α), visibility weight or beta (β), pheromone evaporation coefficient or rho (ρ), number of ants (m), and

number of iterations (i). The list of parameter values to be used in this study is as follows (Adhitama, 2023).

Table 1.
Parameter *Ant Colony Optimization* (ACO)

Parameter	1	2	3	4	5
Pheromone Weight (α)	0,1	0,3	0,4	0,5	0,7
Visibility Weight (β)	1	2	3	4	5
Evaporation Coefficient (ρ)	0,1	0,2	0,3	0,4	0,5
Number of Iterations (Iter)	10	20	30	40	50
Number of Ants (m)	10	50	60	100	200

2. Selecting destination points based on the visibility matrix and updating the matrix after selection.
3. Updating existing pheromone values due to the selection of new nodes and reducing them in other nodes that have not been selected or have already been selected in the previous stage.
4. Determining the optimal final solution based on the largest pheromone value left by the ant parameter.

In more detail, Figure 1 shows the flowchart of this study from start to finish.

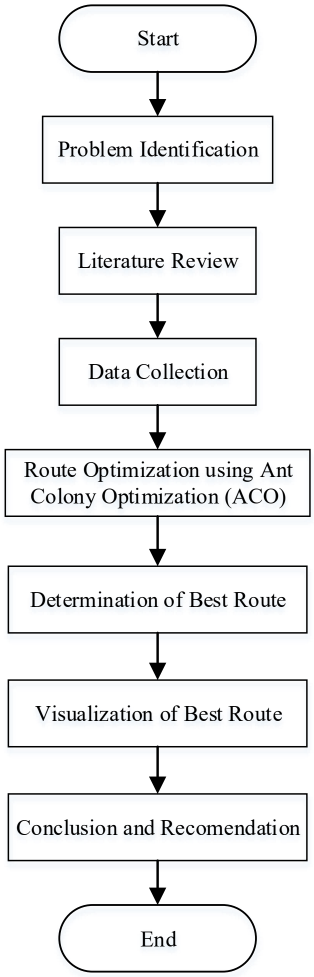

Figure 1. Research Flow Diagram

RESULT AND DISCUSSION

This study began by determining the starting point and destination for sending aid to victims of landslides and floods. It was known that the aid would be sent from the Indonesian Red Cross (PMI) in Kebumen Regency. The destination points in this case were divided into eight locations in five subdistricts. The complete list of destination locations in this study is as shown on Table 2 below.

Table 2.
List of Aid Distribution Locations

Code	**Location**
1	PMI KEBUMEN
2	Panjatan, Karanganyar
3	Plarangan Karanganyar
4	Arjosari, Adimulyo
5	Bonjok, Adimulyo
6	Candimulyo, Kebumen
7	Tanggeran, Sruweng
8	Karanggayam, Adimulyo
9	Totogan, Karangsambung

Based on the above locations, data on the travel time between locations were collected. The results of the travel time collection are shown in Table 3 below.

Tabel 3.
Travel Time Matrix Between Locations

Code	1	2	3	4	5	6	7	8	9
1	0	24	20	23	25	9	15	42	45
2	24	0	9	12	17	34	17	33	56
3	20	9	0	12	16	28	12	28	54
4	23	12	12	0	7	32	16	36	60
5	25	17	16	7	0	34	20	41	64
6	9	34	28	32	34	0	21	49	52
7	15	17	12	16	20	21	0	36	55
8	42	33	28	36	41	49	36	0	26
9	45	56	54	60	64	52	55	26	0

Based on Table 3 above, it is known that when determining travel time on Google Maps, several route options are sometimes available. The route selected for the travel time matrix data is taken from the shortest one. Considering that data collection coincided with the natural disaster in Kebumen Regency, some routes were detected as having obstacles. Furthermore, routes that did not show any obstacles could also be represented by long travel times. This long time can indicate obstacles due to the natural disaster, so selecting the shortest time for research data is part of post-disaster mitigation efforts. In addition to the travel time between locations, data on distance between locations is also required. The results obtained are as shown in Table 4 below.

Table 4.
Distance Matrix Between Locations

Code	1	2	3	4	5	6	7	8	9
1	0	15,3	13,3	15,4	15,6	4,4	9,3	24,6	24,3
2	15,3	0	3,7	3,8	5,5	19,2	8,5	14,5	25,3
3	13,3	3,7	0	4,6	7,1	17,3	5	12,3	23,1
4	15,4	3,8	4,6	0	2,4	19,4	8,6	15,9	26,7
5	15,6	5,5	7,1	2,4	0	34	11,3	17,7	29,2
6	4,4	19,2	17,3	19,4	34	0	12,8	28	27,7
7	9,3	8,5	5	8,6	11,3	12,8	0	17,8	30,7
8	24,6	14,5	12,3	15,9	17,7	28	17,8	0	10,8
9	24,3	25,3	23,1	26,7	29,2	27,7	30,7	10,8	0

Based on the two matrices obtained, data processing was carried out using Ant Colony Optimization (ACO). The processing was performed using MATLAB software accessed online.

Processing on the software was carried out five times using five different parameters. The processing results are shown in Table 5.

Table 5.
Results of Distribution Route Determination

Parameter	Route	Distance (km)	Time (minutes)
1	1→6→8→5→2→7→3→4→9→1	124,7	262
2	1→6→9→8→4→2→5→7→3→1	97,7	204
3	1→6→7→9→8→2→4→5→3→1	99,8	199
4	1→6→2→4→5→3→8→9→7→1	100	202
5	1→6→9→8→2→5→4→7→3→1	92,2	192

Based on the route results obtained, an assessment was conducted to select the best route. The best route is the one with the shortest distance and fastest time. The shortest time assessment received the highest score. Similarly, the fastest time was also given the highest score. The assessment scale ranged from 1 to 5. The assessment results are shown in Table 6.

Tabel 6.
Route Assessment

Route	**Assessment Based on Distance**	**Assessment Based on Time**	**Total Score**
1	1	1	2
2	4	2	6
3	3	4	7
4	2	3	5
5	5	5	10

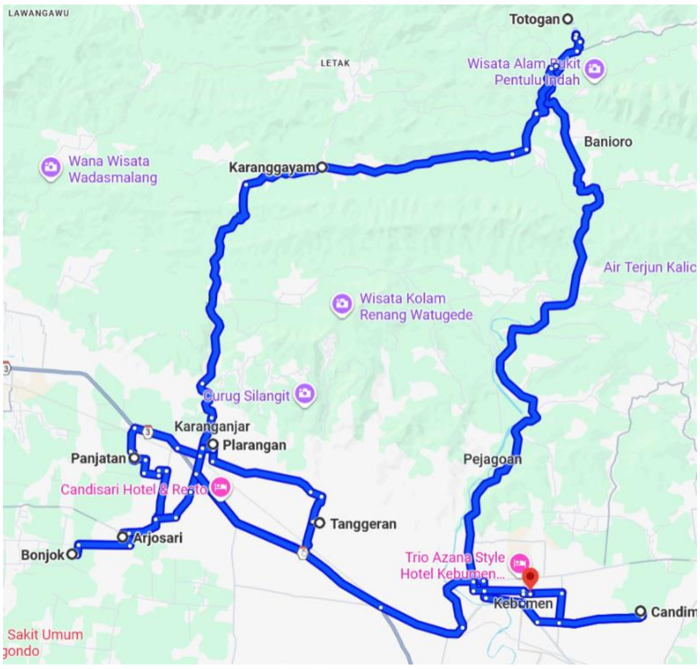

Figure 2. Route Visualization Results

The assessment of the routes that have been taken shows that Route 1 has the lowest total score. This result indicates that the performance is equally good in terms of both distance and travel time. The distance traveled on Route 1 is 124,7 km and the travel time is 262 minutes. These results show that Route 1 is the worst among the others because both the distance and travel time are the highest. The best result in determining this route was achieved by Route 5. This is evidenced by the highest score achieved in both distance and travel time categories for Route 5. The total distance traveled on Route 5 was 92,2 km. This distance can be covered in 192 minutes, or 3,2 hours, if the trip is made without any breaks. The best route results from this study achieved by parameter 5 are in the following order: 1→6→9→8→2→5→4→7→3→1.

When converted to actual locations, this result starts from PMI Kebumen to Candimulyo, then to Totogan, then to Karanggayam, then to Panjatan, then to Bonjok, then to Arjosari, then to Tanggeran, then to Plarangan, and back to the starting point, PMI Kebumen. When visualized in Google Maps, the result is as shown in Figure 2 below.

Based on the routing results obtained, ACO with parameter setting 5 is considered suitable for solving humanitarian logistics problems, particularly those related to aid distribution during natural disasters. However, the humanitarian logistics problem addressed in this study is relatively simple because, in general, it shares similarities with basic distribution routing problems. Nevertheless, the results can still be considered valid and applicable to the case studied. For similar problems, the same method and parameter settings may also be applied, or alternatively, different parameter settings may be tested.

CONCLUSION

Based on the results of data processing using the Ant Colony Optimization (ACO) method on nine aid distribution points affected by landslides and floods in Kebumen Regency, it can be concluded that ACO is effective in solving distribution routing problems in humanitarian logistics. Among the five tested parameter configurations, Parameter 5 generated the best route with a total travel distance of 92,2 km and an estimated duration of 192 minutes. This route follows the sequence 1→6→9→8→2→5→4→7→3→1, which corresponds to PMI Kebumen → Candimulyo → Totogan → Karanggayam → Panjatan → Bonjok → Arjosari → Tanggeran → Plarangan → back to PMI Kebumen. The results demonstrate that simultaneous evaluation using distance and travel time provides a more comprehensive decision basis for emergency logistics operations. Therefore, ACO can be recommended as a decision-support tool for regional disaster management agencies such as BPBD and PMI in optimizing real-time aid delivery, particularly during the emergency response phase. Future research can further integrate road accessibility constraints, priority-based weighting, and dynamic traffic data to enhance operational realism.

REFERENCES

Adhitama, L., & Wibisono, M. A. (2024). Perencanaan Alokasi dan Rute Distribusi Beras Kota Yogyakarta dengan Metode K-Means Clustering, Tabu Search dan Ant Colony System. *LOGISTIK*, *17*(02), 173–187. http://journal.unj.ac.id/unj/index.php/logistik/

Aryasena, A., & Sopha, B. M. (2022). A Comparison of Ant Colony Optimization and Depth First Search for Solving Unmanned Aerial Vehicle-Ground Vehicle Routing Problem in Humanitarian Logistics. *Proceedings of the 3rd Asia Pacific International Conference on Industrial Engineering and Operations Management*, 3118–3127.

BPBD Kebumen. (2025, May 22). *BPBD Kebumen Hujan Deras Picu Banjir dan Tanah Longsor di Wilayah Kebumen, Sejumlah Rumah dan Tempat Usaha Terdampak Kebumen, 22 Mei 2025*. Https://Bpbd.Kebumenkab.Go.Id/Index.Php/Web/Post/854/Bpbd-Kebumen-Hujan-Deras-Picu-Banjir-Dan-Tanah-Longsor-Di-Wilayah-Kebumen-Sejumlah-Rumah-Dan-Tempat-Usaha-Terdampak-Kebumen-22-Mei-2025.

Arifin, M., Uswatun Kasanah, Y., Noor Qisthani, N., & Hidaytuloh, S. (2024). A Novel Hybrid Model for Disaster Relief: Combining Operational Cost Minimization and Priority-Based Resource Allocation. *Jurnal Teknik*, *22*(2), 61–70. https://doi.org/10.37031/jt.v22i2.548

Dimitriou, L., Efthymiou, D., & Antoniou, C. (2018). Saving Lives through Faster Emergency Unit Response Times: Role of Accessibility and Environmental Factors. *Journal of Transportation Engineering, Part A: Systems*, *144*(9), 04018053. https://doi.org/10.1061/JTEPBS.0000169

Djalante, R. (2018). Review article: A systematic literature review of research trends and authorships on natural hazards, disasters, risk reduction and climate change in Indonesia. *Natural Hazards and Earth System Sciences*, *18*(6), 1785–1810. https://doi.org/10.5194/nhess-18-1785-2018

Santosa, B. (2017). *Pengantar Metaheuristik: Implementasi dengan Matlab*. ITS Tekno Sains.

Carter, W. N. (1991). Disaster management: A disaster manager's handbook. In *In Disaster management: A disaster manager's handbook*.

Dinar, S., Ramadhani, R., & Adhitama, L. (2025). Implementasi Algoritma Ant Colony System Pada Optimasi Rute Distribusi Bibit Tanaman Penahan Longsor Di Kabupaten Samosir. *Journal Of Industrial Engineering And Technology (Jointech) Universitas Muria Kudus Journal Homepage*, *5*(2), 163–171. http://journal.UMK.ac.id/index.php/jointech

Dorigo, M., Birattari, M., & Stützle, T. (2006). Ant Colony Optimization. *IEEE Computational Intelligence Magazine*, *1*(4), 28–39.

Ferrer, J. M., Ortuño, M. T., & Tirado, G. (2020). A new ant colony-based methodology for disaster relief. *Mathematics*, *8*(4). https://doi.org/10.3390/math8040518

Fitriyani, M., & Ahmad, D. (2024). Implementasi Ant Colony Optimization Algorithm (Aco) Untuk Pemilihan Jalur Tercepat Evakuasi Bencana Tsunami Oleh Tim Sar Di Kota Padang. *Jurnal Riset Dan Aplikasi Matematika*, *08*(01), 78–84.

Kovács, G., & Spens, K. M. (2007). Humanitarian logistics in disaster relief operations. *International Journal of Physical Distribution & Logistics Management*, *37*(2), 99–114. https://doi.org/10.1108/09600030710734820

Mahendra, M. Y., & Asih, A. M. S. (2015). *Optimasi rute distribusi bantuan logistik korban bencana merapi se-daerah Istimewa Yogyakarta* [Thesis]. Universitas Gadjah Mada.

Prasakti, A. D. (2025, March 28). *Cuaca Ekstrem di Kebumen: Banjir, Longsor, dan Pohon Tumbang*. BPBD Jawa Tengah: Https://Bpbd.Jatengprov.Go.Id/Main/Bencana-Cuaca-Ekstrem-Kebumen-28-Maret-2025/.

Robles, F. S., Hernández-Gress, E. S., Hernández-Gress, N., & Macias, R. G. (2021). Metaheuristics in the humanitarian supply Chain. In *Algorithms* (Vol. 14, Issue 12). MDPI. https://doi.org/10.3390/a14120364

Santosa, B. (2017). *Pengantar Metaheuristik: Implementasi dengan Matlab*. ITS Tekno Sains.

Susilo, N. R., Thawafani, L., Buchari, M. A., Valencia, B. R., & Rifai, A. P. (2024). Penerapan Algoritma Simulated Annealing dan Large Neighborhood Search pada Vehicle Routing Problem with Simultaneous Pickup and Delivery Di PT Pos Indonesia Yogyakarta. *Jurnal Optimasi Teknik Industri (JOTI)*, *6*(2), 50. https://doi.org/10.30998/joti.v6i2.24821

Toth, Paolo., & Vigo, Daniele. (2015). *Vehicle routing : problems, methods, and applications*. Society for Industrial and Applied Mathematics (SIAM, 3600 Market Street, Floor 6, Philadelphia, PA 19104).

UNISDR, (United Nations Office for Disaster Risk Reduction). (2015). *Making development sustainable: The future of disaster risk management. Global Assessment Report on Disaster Risk Reduction.*

Wassenhove, L. N. Van. (2017). Humanitarian aid logistics: supply chain management in high gear. *Journal of the Operational Research Society*, *57*(5), 475–489.