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A Study of Unmanned Aerial Vehicle Routing for Drugs and Medical Supplies Transportation in Flooded Areas by Using Heuristics Approach

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Abstract This research is the study on the unmanned aerial vehicle routing for drugs and medical supplies transportation in flooded areas where other vehicles are difficult to access by simulating flooded areas in Bangkok, Thailand, under the loading capacity limitation of the unmanned aerial vehicle considering the weight and quantity of drugs and medical supplies for the shortest routing and timing. The researchers chose vehicle routing using a saving algorithm by Clark & Wright, it is simple and good enough for finding answers in a limited time based on a fast calculation and is suitable for flooded areas. The researchers have simulated a distribution center of drugs and medical supplies and 70 locations of disaster victims by using the unmanned aerial vehicle of the community in Bangkok, Thailand, as a routing model. The result revealed that the routing of 70 locations was a total of 12.68 kilometers, which is time-effective for routing appropriately, and the Air Force could implement it as a guideline for the unmanned aerial vehicle routing for drugs and medical supplies transportation in flooded areas or other emergencies for helping people in the future.

Keywords Unmanned aerial vehicle; Geographic information systems; Vehicle routing problem; Heuristics approach; Clark & Wright saving

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Introduction

The increasing frequency and severity of natural disasters globally have underscored the relevance and urgency of research in disaster management. Climate change, urbanization, and environmental degradation contribute to the rise in natural disasters, including floods, hurricanes, earthquakes, and wildfires. According to the United Nations Office for Disaster Risk Reduction (UNDRR), climate-related disasters have increased significantly over the past two decades, resulting in substantial economic losses and human casualties. Between 2000 and 2019, there were approximately 7,348 major recorded disaster events, claiming over 1.23 million lives and affecting 4.2 billion people, leading to an estimated $2.97 trillion in economic losses (Ranasinghe et al., 2022).

In Thailand, floods are a recurrent issue due to its geographical location, which is influenced by monsoons from the South China Sea and the Bay of Bengal. The International Disaster Database reported 22 flood events in Thailand from 2010 to 2020, causing widespread damage to infrastructure, housing, and transportation routes (EM-DAT, 2021). For instance, the floods in 2018 impacted 66 provinces, 1,009,289 people, and 4,822 routes and caused damage to assets worth approximately 542,067,800 Baht (Department of Local Administration, 2020). These events highlight the need for effective disaster management strategies, particularly logistics and transporting essential supplies during emergencies.

Flooding is a significant issue that necessitates the development of adequate transportation and logistics strategies in humanitarian logistics, particularly for last-mile distribution. This is a critical challenge for academics and practitioners in disaster mitigation due to the difficulty of accessing flooded areas via road or water routes (Jitt-Aer et al., 2022; Rabta et al., 2018). Efficient delivery of essential supplies such as water, food, and medicine, especially for waterborne or hantaviral diseases, is crucial for disaster victims (Witoonsasiwimon & Kanjanarat, 2017).

The army, air force, navy, or other public sectors often transport drugs and medical supplies using rotary-wing aircraft. However, this method is expensive, requires specific infrastructure like airports, and involves risks to aircrews in many flooded areas. The use of unmanned aerial vehicles (UAVs) offers a promising alternative. UAVs can enhance the capacity to access flooded areas and decrease transportation costs due to their ability to fly in limited or difficult spaces (Bunphoei, 2019). Moreover, implementing developed models for UAV routing can help logistics providers increase their capability and competitiveness. Improved logistics operations can lead to better service delivery and higher operational efficiency (Setthachotsombut et al., 2022). Although UAVs are agile and have fewer flight restrictions in disaster areas, they face limitations in battery power and payload capacity (Thamwatharsaree, 2020). These constraints affect flight duration and limit the amount of cargo that can be transported, which makes routing UAVs a challenge for delivering drugs and medical supplies in flooded areas.

The Air Force Strategy for 2018-2037 emphasizes developing capacities in air, cyber, and space domains to ensure stability, assist the public, develop the country, and solve problems as assigned by the government. Research into UAV routing for drug and medical supply transportation in flooded areas aligns with the Air Force's policy for 2021, which includes developing supporting software, planning UAV routing, and creating guidelines for effective resource use based on UAV capacities and limitations.

This research addresses the challenge of efficiently delivering medical supplies during flood situations using Unmanned Aerial Vehicles (UAVs). Traditional methods, such as rotary-wing aircraft, face significant issues, including high costs and complex logistical constraints. While UAVs offer a promising alternative because they can navigate difficult terrains and reach inaccessible areas, but they also have limitations that must be carefully managed. Key constraints include battery life, payload capacity, and the need for optimized routing to minimize delivery time and distance.

This research applies the Vehicle Routing Problem (VRP) and heuristic approaches to address these challenges. We selected the Clarke & Wright Saving Algorithm for its simplicity and effectiveness in solving VRPs within constrained timeframes (Bodin, 1983). Unlike more complex algorithms, the Clarke & Wright method offers efficient solutions quickly, which is crucial in disaster scenarios where timely delivery is essential. The algorithm's capacity to handle constraints related to vehicle capacity and routing distance makes it particularly suitable for optimizing UAV routes in emergencies (Moryadee et al., 2019; Sripanamvan et al., 2022; Jitt-Aer, 2017). Therefore, this research aims to apply the Clarke & Wright Saving Algorithm to UAV routing for delivering medical supplies in flooded areas. By focusing on this heuristic approach, the research seeks to address the limitations of existing solutions, enhance the efficiency of disaster response logistics, and ultimately improve the timely delivery of aid to those in need.

The problem

Research on vehicle routing problems (VRP) has become increasingly significant and complex. Specifically, this study addresses the VRP related to the transportation of drugs and medical supplies in flood-affected areas. The challenge involves determining the optimal distribution center for drugs and medical supplies, managing the unmanned aerial vehicles (UAVs), considering distance limitations and addressing loading capacities within a capacitated vehicle routing problem (CVRP) framework. This research utilizes the Clarke & Wright Saving Algorithm to find more solutions that are efficient for VRPs in flooded regions. The Clarke & Wright Saving Algorithm demonstrated computational solid efficiency and solution quality performance in this research. It starts by treating each delivery point as a separate route and merges the route iteratively based on a "savings" metric, which measures the reduction in distance from combining routes. This speed is particularly advantageous in disaster scenarios where timely delivery is critical. Although more algorithms that are sophisticated might offer marginally better solutions, their computational demands make them less suitable for real-time applications in emergencies.

Methodology

The study follows a structured methodology, as shown in Figure 1, which outlines the steps from problem identification to data analysis and conclusion.

Location or disaster victims

The research simulation focuses on people living in flooded areas, specifically in Bangkok's academic setting. The simulation variables include:

- Distribution Center: The central point for storing and distributing drugs and medical supplies in Bangkok.
- 70 Locations of Disaster Victims: Simulated community areas where medical supplies are needed.
- Products for Transportation: Drugs and medical supplies.
- Requirements per Point: Determined randomly to reflect varying needs.
- UAV Specifications: Each UAV can carry 4.5 kilograms and has a flight time of 45 minutes.

Location details

The UAV routing plan involves transporting medical supplies from the distribution center to 70 flood-affected areas. Routing is determined using satellite data to ensure linear paths from the pickup to delivery points.

Data collection

Effective UAV routing requires detailed data on various factors, including:

- Drug and Medical Supplies: Each set weighs 500 grams, with quantities distributed based on area requirements.
- UAV Model: The Octopus 02 model can carry 9 sets of medical supplies with a 45-minute flight duration.
- Requirement Quantities: Randomly determined using data from the distribution center and 70 victim locations.
- Geographic Data: Coordinates for all points were gathered using the WGS 1984 geographic coordinate system via the "GPS test" mobile application.

The problem is modeled graphically as G = (V, A) where:

- V = {0, 1, 2,…, n}: Represents transportation routing points, with 0 being the distribution center.
- N = V – {0}: Represents the recipients.
- A = {(i, j): i, j € V}: Represents the set of routes between recipient points.
- C_{ij}: Represents the cost of routing between points i and j, measured by distance or time.
- K = {1, 2, …, m}: Represents the vehicles with limited loading capacities.
- Q: Represents the capacity of each vehicle.
- q_i: Represents the demand at recipient i which must not exceed the vehicle capacity Q and each vehicle must return to the distribution center (Jitt-Aer, 2017).

Simulations

This research is a study of the unmanned aerial vehicle routing for drugs and medical supplies transportation in flooded areas by using a heuristics approach by simulating flooded areas in the academy with a distribution center of drugs and medical supplies and 70 delivery points aimed at the minimum cost of routing that affects the decrease of transportation cost and time, and applying VRP Spreadsheet Solver and the process of finding problem shown in Figure 2.

The results from arranging a total of 20 routes, with a total distance of 12.68 kilometers, delivered 174 sets of drugs and medical, which, according to the conditions laid down, are divided into route details in Table 1 and Figure 3.

After developing a set of instructions to create answers for unmanned aerial vehicle routing to supply drugs and medical supplies, we found that one UAV made 20 trips, covering a total distance of 12.68 kilometers and delivering 174 sets or 87 kilograms of drugs and medical supplies.

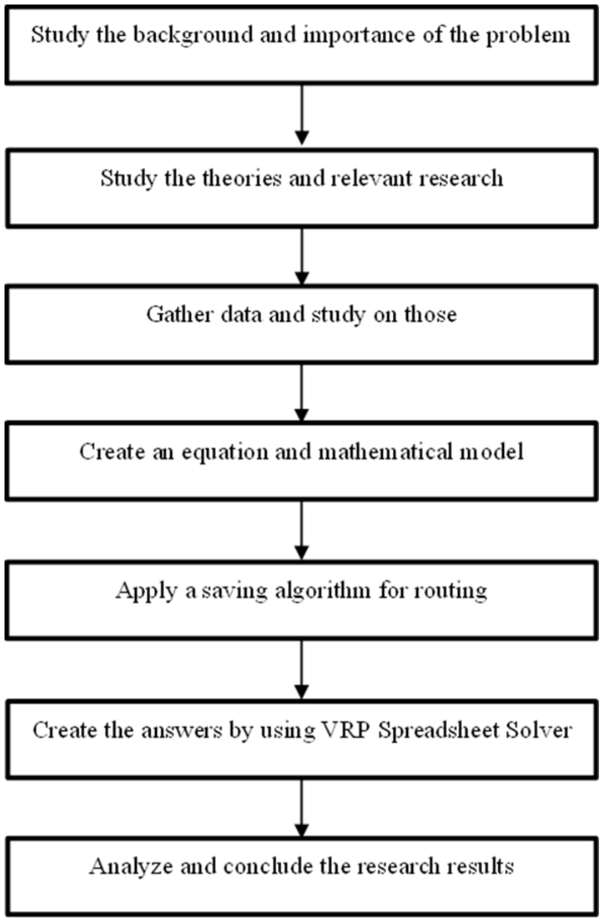

Figure 1 Process of the research methodology
Source: Research

Experimental results

This research focused on optimizing vehicle routing for UAVs transporting medical supplies in flooded areas using the Clarke & Wright Saving Algorithm via the VRP Spreadsheet Solver, implemented in Microsoft Excel on a system with an Intel Core i3-7130U processor. The primary objective was to minimize the total transmission distance while ensuring the efficiency of route planning. The study demonstrated that the Clarke & Wright Saving Algorithm effectively reduced the total transmission distance. In the initial experiment, the routing distance was 12.92 kilometers. After optimizing the algorithm and increasing the processing time to 300 seconds, the distance decreased to 12.68 kilometers, representing a reduction of 0.24 kilometers, as shown in Table 2. This result underscores the algorithm's ability to enhance route efficiency and demonstrates its practical applicability in reducing transportation distances. In addition, the research revealed that longer processing times led to more refined routing solutions, although the improvements in distance were relatively modest. This suggests that while the Clarke & Wright Saving Algorithm is efficient for real-time applications, extended processing can slightly enhance route optimization.

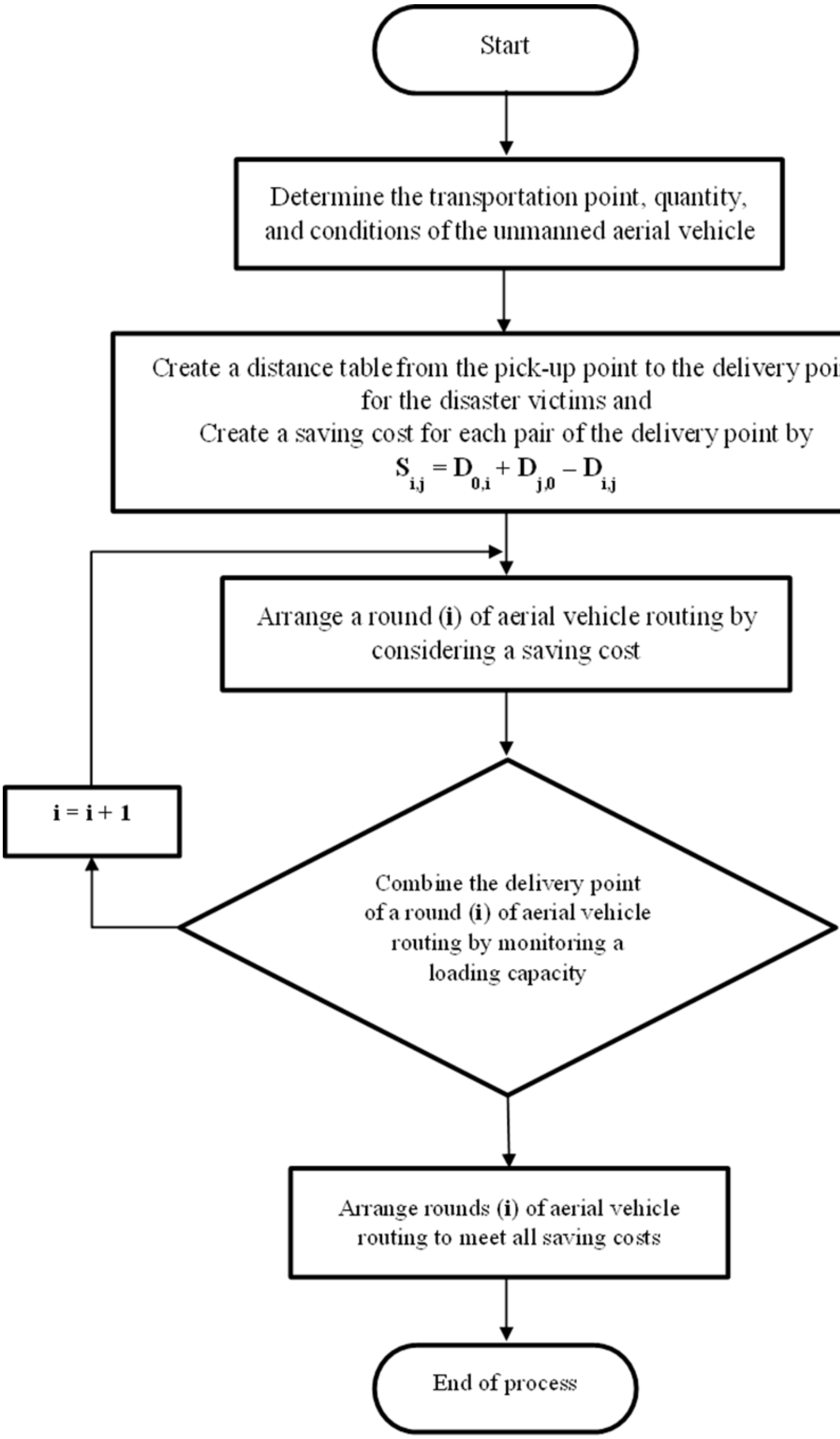

Figure 2 Process of finding answers by a saving algorithm
Source: Research

Table 1 Routing results

Route number	Routing	Route number	Routing
Route 1	0 - 44 - 45 - 46 - 47 - 0	Route 11	0 - 31 - 29 - 28 - 27 - 32 - 0
Route 2	0 - 16 - 15 - 0	Route 12	0 - 35 - 36 - 0
Route 3	0 - 51 - 6 - 41 - 0	Route 13	0 - 68 - 70 - 69 - 0
Route 4	0 - 40 - 52 - 53 - 42 - 0	Route 14	0 - 65 - 66 - 67 -0
Route 5	0 - 4 - 3 - 2 - 0	Route 15	0 - 25 - 23 - 22 - 21 - 55 - 0
Route 6	0 - 49 - 50 - 19 - 9 - 0	Route 16	0 - 8 - 37 - 7 - 38 - 0
Route 7	0 - 18 - 20 - 17 - 0	Route 17	0 - 33 - 26 - 34 - 0
Route 8	0 - 60 - 59 - 0	Route 18	0 - 54 - 24 - 58 - 56 - 48 - 0
Route 9	0 - 11 - 62 - 63 - 64 - 0	Route 19	0 - 5 - 57 - 1 - 30 - 0
Route 10	0 - 10 - 13 - 14 - 12 - 0	Route 20	0 - 39 - 43 - 61 - 0

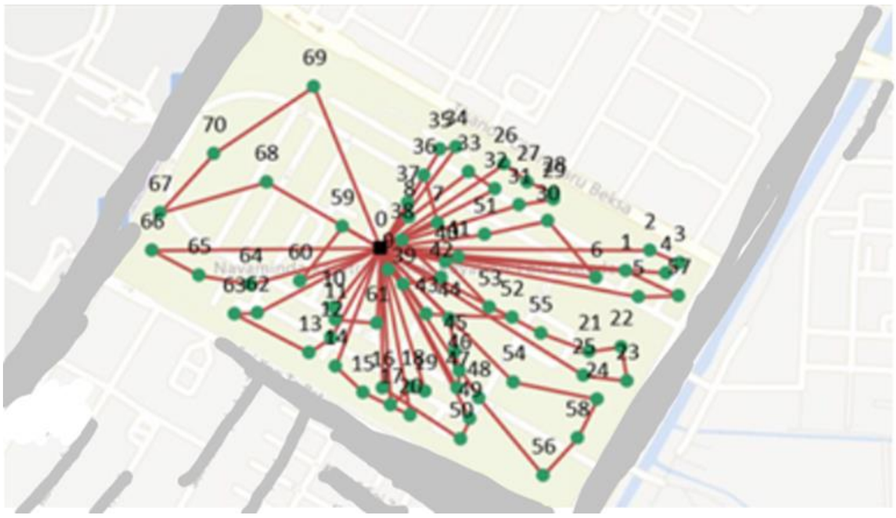

Figure 3 Routing results map
Source: Research

Table 2 Processing comparison results

Vehicle routing	Calculation period	Number of trips	Total distance (km.)
First time	240 seconds	20	12.92
Second time	300 seconds	20	12.68

The findings by objectives revealed as follows;

Objective 1: The research aimed to explore how effectively the Clarke & Wright Saving Algorithm solves vehicle routing problems for UAVs. Researchers widely recognize the Clarke & Wright approach for its simplicity and practicality in heuristic problem-solving. Despite not always providing the most optimal solution, it efficiently produces satisfactory results within a reasonable timeframe, making it particularly suitable for time-sensitive scenarios such as disaster response. The mathematical model was applied to simulate a distribution center for drugs and medical supplies with 70 delivery points in a community area in Bangkok, Thailand. The findings align with previous studies (Moryadee et al., 2019; Bodin et al., 1983; Chiang et al., 2019), confirming that Clarke & Wright Saving Algorithm, in conjunction with the VRP Spreadsheet Solver, effectively reduces UAV routing distances. The approach is considered suitable for small to medium-sized areas, where quick, near-optimal solutions are essential for efficient aid delivery.

Objective 2: The second objective focused on applying the Clarke & Wright heuristic for UAV routing in flooded areas. This research aligns with the work of Chiang et al. (2019) and Saengnoy and Srinual (2018), highlighting the algorithm's suitability for logistical challenges in disaster-stricken regions. The study demonstrated that, even in complex environments like flooded areas, the Clarke & Wright Saving Algorithm can effectively plan routes, ensuring timely delivery of medical supplies. The algorithm's performance in this study reflects its ability to address real-world challenges by optimizing routes under constraints. The practical implications are significant: the algorithm's use in emergency scenarios can enhance the efficiency of UAV operations, reducing response times and aiding disaster management efforts.

The Clarke & Wright Saving Algorithm is a valuable tool for routing UAVs in disaster management, particularly for small to medium-sized areas. While it may only sometimes yield the absolute optimal solution, its efficiency in providing near-optimal routes within limited timeframes makes it a practical choice for real-time applications. Future studies could further explore integrating additional factors, such as UAV loading and unloading times, to enhance routing efficiency and effectiveness in diverse disaster scenarios.

Conclusion

The research focuses on optimizing the routing of uncrewed aerial vehicles (UAVs) routing transporting drugs and medical supplies in flooded areas. By employing a heuristic approach, the study simulated flood scenarios in an academic environment and validated the results. The primary tool employed was the VRP Spreadsheet Solver with the Clarke & Wright Saving Algorithm. The results indicated that the total routing distance achieved for a network of 70 locations was 12.68 kilometers. The current research's approach might lead to different outcomes than those of Zhang et al. (2023), where finer data granularity and more complex simulations contribute to differing results. We observed that slightly increasing the processing time improved routing efficiency, although the improvements were marginal. Like many studies in UAV disaster management, this research shows that UAVs can significantly reduce delivery times for medical supplies. For instance, studies by Khedher et al. (2018) and Liao et al. (2020) confirm that UAVs offer a rapid means of delivering aid, which is crucial for addressing urgent needs in disaster scenarios. The findings align with research by Chien et al. (2021), which demonstrated that UAVs can substantially lower operational costs while providing similar or better performance in delivery tasks. Moreover, Research by Weng et al. (2019) supports this view, highlighting UAVs' capability to access hard-to-reach locations where traditional methods may fail. This suggests that while processing time influences outcomes, the Clarke & Wright Saving Algorithm remains effective for real-time solutions, making it a valuable tool for emergency response in flood-affected areas.

Many other studies employ more advanced optimization algorithms such as Tabu Search, Genetic Algorithms, or Ant Colony Optimization. Li et al. (2021) uses Tabu Search for UAV routing, achieving more precise solutions but requiring significantly more computational resources. However, this research's choice of the Clarke & Wright algorithm emphasizes real-time applicability and simplicity, reflecting a different balance between computational efficiency and solution optimality compared to other approaches. The Clarke & Wright Saving Algorithm demonstrates a practical balance between speed and solution quality in UAV routing for disaster management. Its efficiency in generating near-optimal solutions rapidly makes it suitable for real-time applications where swift decisions are paramount. Although more sophisticated algorithms like Tabu Search, Genetic Algorithms, and Ant Colony Optimization offer higher solution precision, their computational intensity limits their practicality in immediate disaster response scenarios (Liu et al., 2020; Chen et al., 2022; Wang et al., 2023). The choice of algorithm in this research reflects a preference for real-time applicability over absolute optimality, a crucial consideration for effective disaster management.

Suggestions

Vehicle routing by using a saving algorithm is a basic way of solving the vehicle routing problem, which is probably not the best answer. However, it could be a similar answer and adaptable. Other algorithms such as Tabu Search, Genetic Algorithm, or Ant Colony Algorithm should be applied to adapt the answer after using a saving algorithm for a more compelling answer. However, writing a computer program for more efficiency of the unmanned aerial vehicle routing is too complicated as it needs more capacity in developing more variables of the unmanned aerial vehicle routing such as wind speed, altitude, and aerodynamics which has to calculate a total routing of 3 axes and its complication. In addition, future research should calculate the total time of the whole routing, for example, installing the equipment on the unmanned aerial vehicle, timing from the pick-up point to the delivery point, and duration at the pick-up point.

References

Bodin, L. (1983). Routing and scheduling of vehicles and crews: The state of the art. *Computers & Operations Research, 10*(2), 69-211.

Bunphoi, I. (2019). How drone utilizes for investigation in the police station. *Journal of Crime and Security, 2*(1), 77-96.

Chen, J., Xu, Y., & Liu, L. (2022). Optimizing UAV routing with tabu search algorithm for disaster relief operations. *Journal of Optimization Theory and Applications, 184*(2), 455-478.

Chiang, W. C., Li, Y., Shang, J., & Urban, T. L. (2019). Impact of drone delivery on sustainability and cost: Realizing the UAV potential through vehicle routing optimization. *Applied Energy, 242*, 1164-1175.

Chien, C., Ding, Y., & Liu, C. (2021). Cost-effective solutions for UAV-based disaster management. *International Journal of Applied Aviation Studies, 21*(1), 67-80.

Department of Local Administration, Ministry of Interior. (2021). *Disaster risk reduction in Thailand: Status report 2020*. Retrieved from https://reliefweb.int/report/thailand/disaster-risk-reduction-thailand-status-report-2020

Jitt-Aer, K. (2017). Vehicle routing problem with stochastic demand. *NKRAFA Journal, 13*(13), 20-21.

Jitt-Aer, K., Wall, G., Jones, D., & Teeuw, R. (2022). Use of GIS and asymmetric mapping for estimating tsunami-affected population to facilitate humanitarian relief logistics: A case study from Phuket, Thailand. *Natural Hazards, 113*(1), 185-211.

Khedher, N. B., Rachidi, T., & Belkessam, M. (2018). Efficiency of UAVs in emergency medical supply delivery. *Journal of Unmanned Vehicle Systems, 6*(4), 291-303.

Li, X., Wang, Y., & Zhou, M. (2021). Advanced optimization algorithms for UAV routing in disaster response. *Computers & Operations Research, 129*, 105125.

Liao, X., Zhang, X., & Zhao, Y. (2020). *Speed and efficiency of UAV-based emergency delivery systems* (pp. 3458-3465). In Proceedings of the IEEE International Conference on Robotics and Automation. Paris, France: IEEE Robotics and Automation Society.

Liu, Y., Zhang, Q., & Zhou, S. (2020). Performance evaluation of genetic algorithms for UAV routing in crisis situations. *Transportation Research Part C: Emerging Technologies, 118*, 102723.

Moryadee, C., Aunyawong, W., & Shaharudin, M. R. (2019). Congestion and pollution, vehicle routing problem of a logistics provider in Thailand. *The Open Transportation Journal, 13*(1), 203-212.

Rabta, B., Wankmüller, C., & Reiner, G. (2018). *A drone fleet model for last-mile distribution in disaster relief operations* (Doctoral dissertation). Austria : Universitaet Klagenfurt.

Ranasinghe, P., Nagabhatla, N., & Vrijens, K. (2022). *Climate and water-related disasters and Eco-DRR sensitivity in island nations: Overview analysis* (pp. 183-206). In Proceedings of the International Conference on Trends and Recent Advances in Civil Engineering. Brugge, Belgium: Springer Nature Singapore.

Saengnoy, W., & Srinual, N. (2018). *Vehicle routing by using a saving algorithm: A case study of AAA Company Limited* (pp. 1173-1181). In Proceedings of the 9th National & International Conference. Bangkok, Thailand: Huachiew Chalermprakiet University.

Setthachotsombut, N., Aunyawong, W., Areerakulkan, N., Kerdpitak, C., Poolsawad, K., Sritapanya, K., & Bounnaphol, C. (2022). Optimization of Thai-Lao cross border transportation via R9 route for Thai shippers. *Uncertain Supply Chain Management, 10*(4), 1323-1330.

Sripanamvan, K., Phudetch, P., & Moryadee, C. (2022). Solving the problem of arranging garbage collection vehicle routes by creating a decision-making model with Microsoft excel solver: A case study of the administrative organization of Nong Kop Subdistrict, Ban Pong District, Ratchaburi Province. *Journal of Logistics and Supply Chain College, 8*(1), 62-73.

Thamwatharsaree, S. (2020). The development for using UAV in disaster victim relief. *Ratthaphirak Journal, 62*(3), 9-26.

Wang, H., Zhang, L., & Gao, X. (2023). Ant colony optimization for UAV routing in humanitarian logistics. *European Journal of Operational Research, 299*(1), 237-248.

Weng, J., Chen, Y., & Li, Y. (2019). Accessibility and delivery efficiency of UAVs in flooded areas. *Disaster Prevention and Management, 28*(6), 868-882.

Witoonsasiwimon, P., & Kanjanarat, P. (2017). Medication preparedness for emergency flooding situations of public hospitals in central Thailand: A case study of flooding crisis in 2011. *Isan Journal of Pharmaceutical Sciences, 13*(3), 25-27.

Yuan, X., Zhang, J., & He, L. (2022). Geographical and infrastructural constraints in UAV routing for disaster management. *International Journal of Disaster Risk Reduction, 67*, 102674.

Zhang, H., Yang, T., & Guo, X. (2023). Impact of data granularity on UAV routing efficiency in emergency situations. *Journal of Geographic Information Science, 27*(2), 217-232.