IDENTIFYING THE POTENTIAL OF UNMANNED AERIAL VEHICLE ROUTING FOR BLOOD DISTRIBUTION IN EMERGENCY REQUESTS

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ABSTRACT - This study is focusing on identifying the potential of Unmanned Aerial Vehicle (UAV) routing for blood distribution in emergency requests in Sri Lanka compared to existing transportation modes. Capacitated Unmanned Aerial Vehicle Routing Problem was used as the methodology to find the optimal distribution plan between blood banks directing emergency requests. The developed UAV routing model was tested for different instances to compare the results. Finally, the proposed distribution process via UAVs was compared with the current distribution process for the objective function set up in the model and other Key Performance Indicators (KPIs) including energy consumption savings and operational cost savings. The average percentage of distribution time reduction, energy consumption cost reduction, and operational cost per day reduction utilizing UAVs were determined to be 48.24%, 95.65%, and 60.13%, respectively, for the instances tested using the model highlighting the potential of UAVs. Therefore, the deficiencies in Sri Lanka's present blood delivery system can be addressed using UAVs' potential for time, cost, and energy savings. The ability to save time through the deployment of UAVs to the fleet during emergency situations plays a crucial role in preventing the loss of human lives.

Keywords: Unmanned Aerial Vehicle; Vehicle Routing Problem; Blood distribution; Emergency requests

1. INTRODUCTION

The complexity of blood supply chain management has made the accessibility of blood and blood products challenging in many countries. Demand for blood in hospitals fluctuates and is not easily predictable, perishable, and having a short lifespan, and longer delivery times for remote locations are the major reasons behind the complexity of blood supply chain management [1]. According to the comprehensive analysis conducted by [1]; blood distribution between health facilities in Rwanda by UAVs has been proven to save 79 mins over existing road distribution modes based on estimated driving times, and 98 mins based on Google Maps estimates. Additionally, after the commencement of UAV distribution, there was a 7.1 decrease in blood unit expirations each month, which converted to a 67% reduction at 12 months. Moreover, a separate study conducted by [2] tested the temperature changes during blood transportation by UAVs, and according to the findings, there were no significant temperature changes in Red Blood Cells, Platelets, and Plasma units placed in a cooler. Therefore, these findings suggest that UAV distribution systems are a viable option for transporting blood products. When it comes to the Sri Lankan context, the National Blood Transfusion Service (NBTS) is solely responsible for supplying blood and blood products to government hospitals and a considerable portion of private-sector hospitals in the country. During emergencies, requests for rare blood groups such as Bombay can be raised from any of the blood banks spread across the country. At present, in such instances, a vehicle from the respective hospital, regardless of its distance, needs to travel to the National Blood Centre to acquire even 1 or 2 units of blood. This procedure causes delays that could have serious repercussions, potentially resulting in loss of lives. Therefore, this study is inspired by [3],[4] to use UAV Routing to address current gaps in the blood distribution process in Sri Lanka.

2. MATERIALS AND METHODS

Unmanned Aerial Vehicle Routing Problem was used as the methodology for this study. Capacitated Vehicle Routing Problem (CVRP) was used as the form of VRP since CVRP considers the limited carrying capacity of UAVs to ensure that the packages to be delivered do not exceed the maximum carrying capacity of UAVs [5]. The hybrid method of heuristic and metaheuristic was used as the approach to solving VRP. That approach was selected due to the easiness of finding near-optimal solutions within feasible computational time and the ability to customize for different types of problems [6]. ‘Path Cheapest Arc (PCA)’, a widely used heuristic algorithm for vehicle routing problems, was selected as the first solution strategy in the UAV routing model. The metaheuristic chosen for the UAV routing model was ‘Guided Local Search’, which is widely recognized as the highly efficient metaheuristic for vehicle routing problems, as indicated by [7]. A comparative analysis was conducted to identify the potential of using UAVs in the blood distribution process compared to existing transportation modes. The Traveling Salesman Problem (TSP) model was developed to find the optimal route for the ambulance at the National Blood Centre considering blood units are distributed to the respective blood banks on the night before the respective date by the National Blood Center, Narahenpita itself. Open-source software and Visual Studio Code were used to develop the UAV routing model and Python was used as the programming language.

Zipline’s Medical Delivery Drone used for blood delivery in Rwanda was used as the most suitable type of UAV for this study. Characteristics of the UAV are; Payload: 1.75 kg, Range: 160 km, Speed: 101 km/h, and Energy source: Lithium-ion battery packs [8]. Based on the maximum distance a UAV can travel on a single battery charge, the total distance covered by a UAV per route was set at 160 km. It was assumed that no temperature change occurs during transport by UAV as the blood packs are kept in a cool box. 500 g of the payload capacity of the UAV was allocated for the cool box.

3. RESULTS AND DISCUSSION

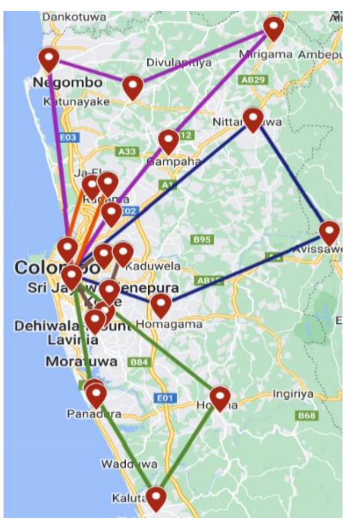

Figure 1. Optimal route provided by the UAV routing model for Instance 1

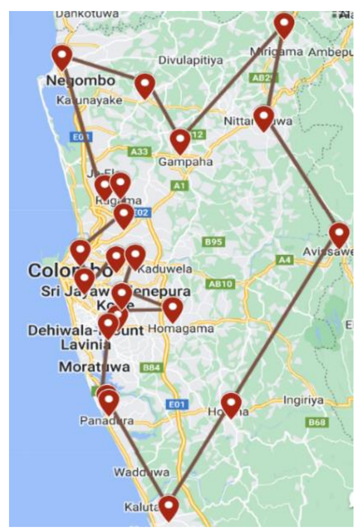

Figure 2. Optimal route provided by the TSP model for Instance 1

ISSN: 2513-2504

The models were tested using different instances by changing the number of blood banks per data set.

Table 1. The average percentage of reductions for all tested instances

KPI	The average percentage of reductions
Total distribution time	48.24%
Energy consumption cost	95.65%
Operational cost per day	60.13%

The significant 48.24% reduction in distribution time achieved using UAVs can significantly improve patient outcomes and increase the chances of survival for individuals in need of emergency blood transfusions. Moreover, the use of UAVs resulted in a remarkable average reduction of 95.65% in energy consumption costs, demonstrating a significant improvement in cost efficiency compared to current blood transportation methods. Additionally, the substantial 60.13% reduction in daily operational costs provides a significant financial benefit for healthcare facilities involved in blood distribution.

4. CONCLUSION

The research findings suggest that using UAVs for blood distribution can greatly improve time efficiency, save energy, and reduce operational costs, leading to potential life-saving benefits and better resource allocation in healthcare. However, further research is needed to conduct a comprehensive cost-benefit analysis to assess the economic viability and long-term stability of implementing UAVs. Additionally, future studies should consider the impact of aviation regulations on the UAV routing model. Temperature changes during transportation were not examined in the current study assuming that no temperature variations occur during the flight due to the use of cooler boxes. However, investigating this aspect could provide more valuable insights for emergency blood distribution using UAVs.

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