BENEFITS OF USING UNMANNED AERIAL VEHICLES FOR LAST-MILE VACCINE DELIVERY IN SRI LANKA

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ABSTRACT – The faster speed, low maintenance cost, and absence of dependency on roads in unmanned aerial vehicles (UAV) have propagated their application as a successful alternative to road delivery. Hence, it is suggested as a solution to overcome the distribution inefficiencies in the vaccine cold chain of Sri Lanka. Because of the last-mile delivery problems and routine distribution of vaccines, UAV delivery is recommended for the network arc between the Regional Medical Supplies Division (RMSD) and its respective Medical Officer of Health (MOH) units. An existing delivery plan was compared against UAV delivery solutions using 5 key performance indices (KPI) to determine the potential advantages of using UAVs in the above-mentioned distribution arc. From the comparison, it was revealed that when UAVs are included, the time consumption and carbon dioxide emission are reduced significantly resulting in a more efficient and environmentally friendly delivery network. However, due to the limited number of flights in the current context, economic benefits can be realized only if the cost of the Unmanned Aerial System (UAS) is funded. Instead, if the UAS cost is borne by the government, the high capital cost exceeds the operational savings, leading to a higher cost per vial compared to the status quo. Nonetheless, once the initial setup cost is overcome UAVs can reduce the operational cost vastly, ensuring the longevity of the vaccine program. Moreover, even though the homogenous (i.e., Only UAV) solution yields better savings than the heterogeneous (i.e., Truck and UAV) solution, considering the higher capital resources required to implement the homogeneous solution, later is recommended for the initial execution.

Keywords: *Drone, UAV, Vaccine delivery, Vehicle routing problem, Healthcare supply chain*

1. INTRODUCTION

The Expanded Program on Immunization (EPI) is the mandatory vaccination program introduced by the World Health Organization, for pregnant mothers and children under the age of 1 year to be prevented from infectious diseases[1]. Since its implementation in Sri Lanka in 1978, the program has been the main component of the National Immunization Program. Currently, Sri Lanka has covered more than 90% of the effective population in all vaccines under the program[2]. However, the vaccine supply chain is suffering from last-mile distribution issues, imposing a heavy financial burden on the government along with severe wastage and time consumption[1]. The main sources of such inefficiencies are the reliance on the road network and the persisting issues in the cold chain[1]. Therefore, analyzing technological advancements to overcome such inadequacies is timely.

UAV is one of the foremost findings in industry 4.0, which has been effective in being a way out of the physical and economical impediments in conventional delivery networks[3]. Additionally, previous studies and pilot projects have assured UAV's potential in successfully delivering healthcare products, whilst ensuring a significant positive impact on financial, environmental, and social aspects[4]. Therefore, UAVs could be a likely candidate to overcome the existing vaccine distribution inefficiencies in Sri Lanka. Hence, our study determines the potential benefits of its implementation in vaccine last-mile delivery.

2. METHODOLOGY

A comparative analysis was conducted to realize the benefits of using UAVs for vaccine last-mile delivery[4]. Under the comparative analysis, 5 KPIs were calculated and compared between the current delivery plan and the UAV delivery solutions[4]. The UAV inclusive delivery solutions include 2 distribution plans with a heterogeneous fleet (i.e., Truck with UAV) and a homogenous fleet (i.e., UAV only). The 5 KPIs calculated were (1) Cost per vial; when the UAS cost is funded (Includes energy cost and employee salaries), (2) Cost per vial; when the UAS cost is not funded (Includes energy cost, employee salaries, and UAS infrastructure cost), (3) Time consumption per delivery round, (4) Annual energy consumption and (5) Annual carbon dioxide emission.

The Vehicle Routing Problem (VRP) technique was utilized from a plethora of route optimization techniques to determine the UAV delivery solutions[5],[6]. To solve the VRP, the Open Source Vehicle Routing Problem Spreadsheet Solver by Dr. Erdoğan[7] was used. The solver is a metaheuristic algorithm with the objective function of minimizing cost, coded through visual basic[7].

3. DATA COLLECTION

Given the inefficiencies of last-mile delivery and routine distribution, UAV delivery solutions were proposed for the distribution arc between the RMSDs and MOH units. Out of the 26 RMSDs, Gampaha RMSD was selected for the data collection and analysis because of the existence of a systematic and comparable delivery plan. Gampaha RMSD distributes vaccines to 15 MOH units every month using four truck rounds. However, the existing delivery plan (i.e., Only trucks) does not utilize optimized routes. Therefore, when compared with the UAV solutions derived from the solver, a false benefit is shown. Hence, for accurate evaluation and comparison, the current delivery plan was also optimized using the same spreadsheet solver, before being associated with the UAV solutions[3].

4. RESULTS

4.1. VRP spreadsheet solver results

Figure 1, Figure 2, and Figure 3 display the optimized current delivery plan, heterogeneous fleet delivery solution, and homogeneous fleet delivery solution respectively.

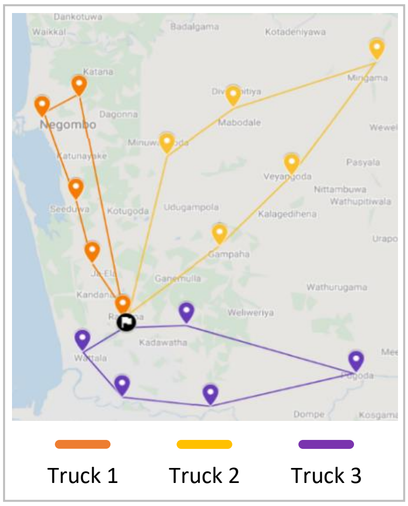

Figure 1. Optimized current delivery plan

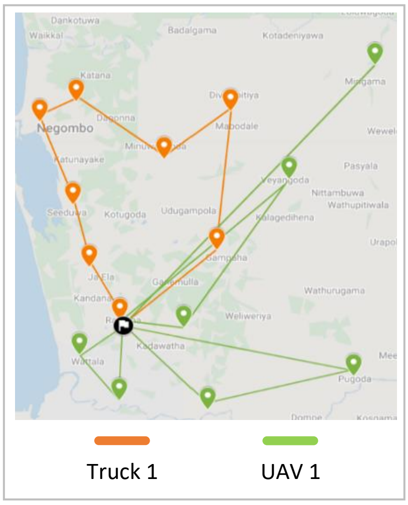

Figure 2. Heterogeneous fleet delivery solution

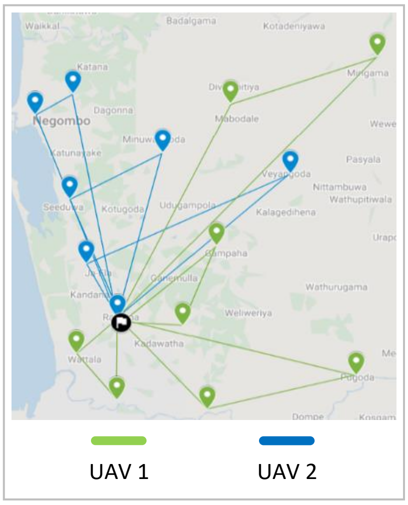

Figure 3. Homogeneous fleet delivery solution

The UAV utilized in the solutions is a small, electric vertical takeoff and landing (VTOL) drone, and the truck is a medium-sized lorry powered by fuel. It was also assumed that the UAV and truck maintain an average speed throughout the trips at 100km/h and 35km/h respectively. Further, the UAV has payload, range, and driving time limitations per trip at 5kg, 75km, and 1 hour respectively.

4.2 Comparative Analysis of the KPI

Figure 4 depicts the KPI comparisons between the optimized current plan and UAV inclusive solutions.

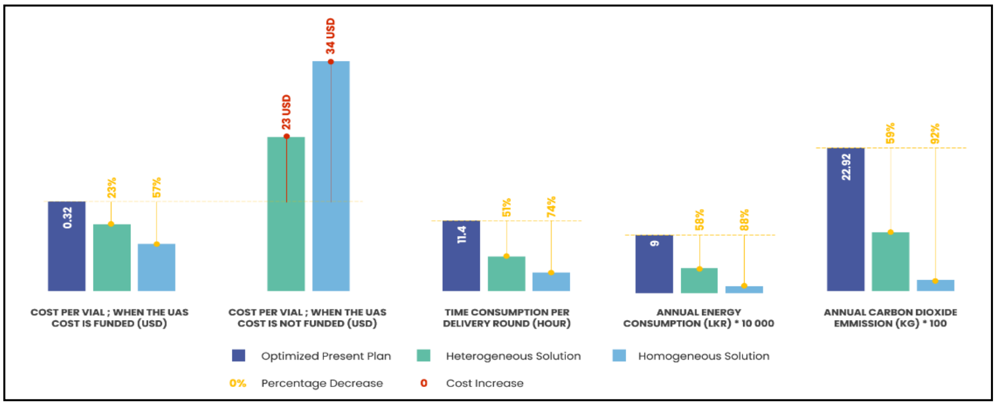

Figure 4. KPI Comparisons between the Optimized Current Plan and UAV Solutions

5. CONCLUSION

Implementing a UAV delivery solution is more efficient and environmentally friendly due to the reduction in time consumed and carbon dioxide emission. On the hindside, due to the limited number of flights per year, the operational cost of vaccine distribution can be reduced only if the initial UAS cost is funded. If it is not, the infrastructure cost overrides the operational cost savings resulting in a higher cost per vial than the status quo. It could be overcome by increasing the number of flights across different healthcare use cases, expanding the savings enough to cover the initial setup cost. Nevertheless, when the initial infrastructure cost is covered either by funds or an increased number of flights, UAVs are a promising solution to overcome the inadequacies in the local vaccine supply chain. Furthermore, it was identified that the homogeneous solution produces better savings than the heterogeneous solution. However, considering the high preliminary resources required, it is suggested to initially apply the heterogeneous plan and gradually shift to a homogeneous plan in the future years. This enables frictionless adoption of UAVs into the healthcare system as well.

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