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WHITE PAPER

# UAV PROJECT

## WP3: THE USE OF DRONES IN TRANSPORTING VACCINES FROM THE FACTORY TO THE PATIENT

Use Case: The COVID-19 Pfizer Vaccine's Journey from Belgium to Malawi

NOVEMBER 2022

## TABLE OF CONTENTS

# 1. Executive Summary

With almost half of the globe's population having currently sporadic or even no access to health care and medicine[1], the technology of using drones (UAVs[2]) to increase access, speed and efficiency is more and more evaluated in a logistics ecosystem.

In 2021, Pharma.Aero initiated the UAV Project to explore the use of drones (UAVs) and its potential as part of the Life Science and Medtech logistic chain, thus interconnecting the traditional and modern airfreight worlds. In the final part of the project (WP3), the team investigated an industry case that includes drones in the multimodal process of transporting vaccines with strict cold-chain requirements from the factory in Europe to patients in hard-to-reach areas of Africa. The project's goal is to offer unprecedented insights by mapping the vaccines' journey from factory to patients, and explore modalities of further integrating the drones.

The project team investigated potential directions of optimizing the logistics, thus identifying relevant aspects and factors to be taken into consideration for further research on how and where UAVs are most valuable to the supply chain system.



1 Global maps of travel time to healthcare facilities | Nature Medicine

2 UAV – Uncrewed Aerial Vehicle, commonly known as drone, is an aircraft without any human pilot, crew, or passengers on board. Terms are interchangeable and will be both used in this report.

# 2. Introduction

Emergency health situations caused by natural disasters where populations can be cut from any supply or medical help, war and conflict zones that are impossible to reach by organizations to support the affected population or simply topography and poor infrastructure that slows down and compromises intervention in communities from hard-to-reach areas require smart and sophisticated high technological transport modes, safe in use for and by humans. In today's world, we can no longer look at a linear end-to-end-supply chain, but we need to start looking at a fully integrated logistics eco-system where logistics modes are intertwined.

The figure below underlines the areas that might be of interest in using such modes, especially in the areas where we need more than 5 hours to reach people in the urgent need of medical treatments.

Therefore, it is important to evaluate and learn from use-cases and explore opportunities to build on the progress that has been made by using UAVs as part of the last mile delivery of medicines and vaccines for underserved communities. By creating such a UAV roadmap, we might identify aspects and elements that need further investigation and analysis to achieve the best framework for a wider use and integration of UAVs in pharma logistics.

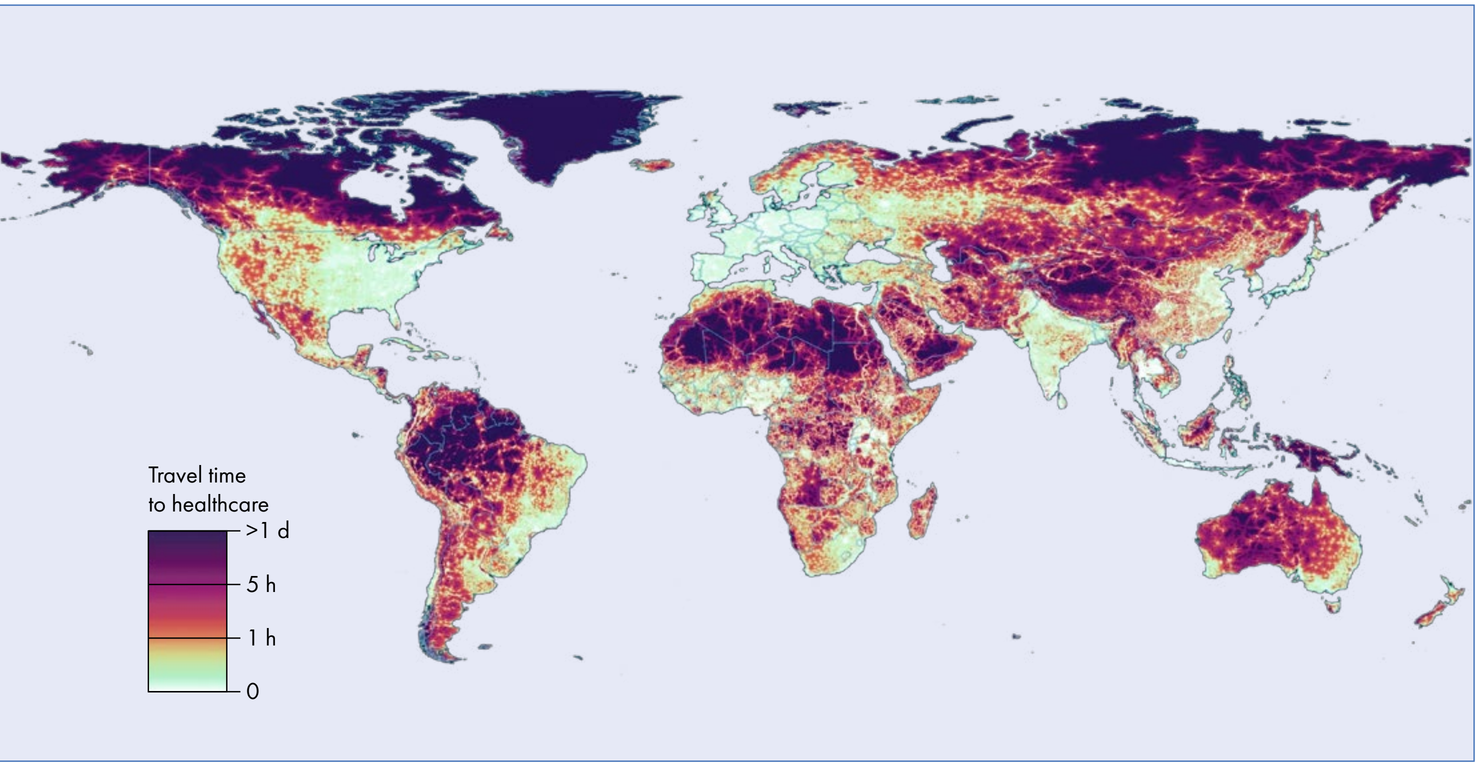


*Figure 1: The global map of optimal travel time to healthcare with access to motorized transport (Nature Medicine, 2020)*

# 3. Methodology

The UAV Project was structured in 3 independent Work Packages with different methodologies, approaches and deliverables:

**WORK PACKAGE 1:**
exploring the competitive positioning of UAV in relation with other transportation modes, the regulatory framework for UAV operations and applications of UAV in the pharma and humanitarian air cargo sector. All findings of WP1 were presented in the White Paper that was shared with the industry, in August 2021.

**WORK PACKAGE 2:**
presenting the technical aspects of the drone systems through a 360° interactive video (drone lab, type of drones, drone operation, etc.). The video is available for Pharma.Aero members and associate partners only.

**WORK PACKAGE 3:**
documenting an industry case to observe the use of drones as part of a multimodal supply chain in real life.

Work Package 3 had the following objectives:

- Map and document the journey of the Pfizer COVID-19 vaccines from the factory in Puurs (Belgium) to the patients in hard-to-reach areas of Southern Malawi
- Identify opportunities to optimize the transport of the Pfizer COVID-19 vaccines or any pharmaceutical product in general

For mapping out and document the end-to-end transport, the project team relied on first-hand information gathered directly from the field and interviewing stakeholders along the supply chain:

- Pfizer manufacturing authorities and logistics partners (transporters, airport authorities, customs) in Belgium
- Local parties (government, UNICEF, WHO, VillageReach, private sectors) involved in ensuring the safe transportation of Pfizer COVID-19 vaccines in Malawi

Based on the information gathered, a video was produced and shared with the industry, illustrating the entire journey of the Pfizer COVID-19 vaccines from the factory in Belgium to the patients in Malawi.

The Technical Report of Work Package 3 was shared with Pharma.Aero Membership in October 2022. The present White Paper will specifically focus on this Phase of the project.

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# 4. Primary Analysis: Roadmap of the Pfizer COVID-19 Vaccines' Journey in Malawi

The Pharma.Aero UAV Project analyses the route and transportation modes used to transfer the Pfizer COVID-19 vaccines manufactured in Puurs, Belgium, to patients in different districts of Malawi.

The transport comprises 4 phases:

**PHASE 1: Factory in Belgium → Airport in Malawi**

**PHASE 2: Airport in Malawi (Lilongwe) → National Warehouse (Lilongwe)**

**PHASE 3: National Warehouse → District Warehouses**

**PHASE 4: District Warehouses → 800+ Health Facilities / Vaccination Centers**

All 4 phases, with modes of transportation and cold chain requirements, are illustrated in the following graphic.

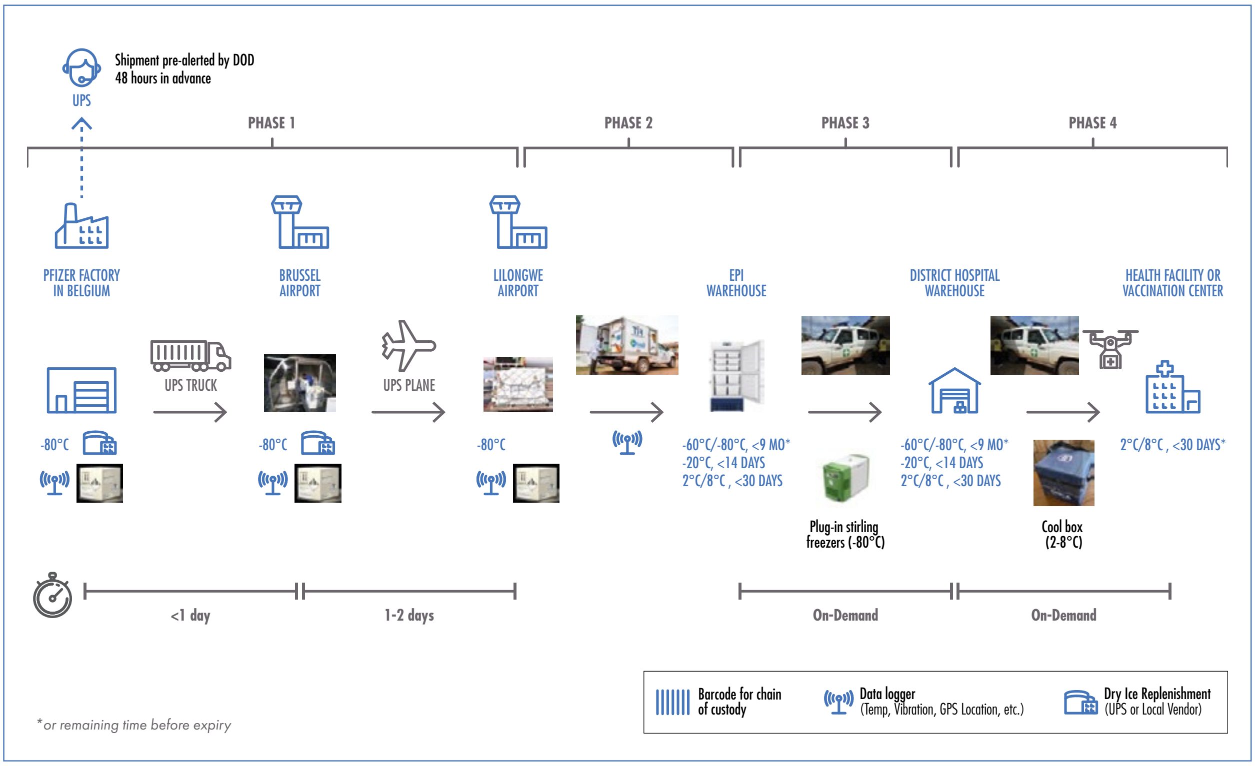



*Figure 2: Pfizer COVID-19 Vaccine's Journey from Factory in Belgium to Health Facilities in Malawi*

**PHASE 1: From the Pfizer Plant in Belgium to Lilongwe Airport in Malawi**

Based on the commercial contract in place, the process is initiated by the Ministry of Health of Malawi which places an order with Pfizer.

The production plant prepares the shipment by adding a tertiary package to the pre-packed secondary plastic container track that holds 195 vials.

The tertiary packaging consists of a Softbox with a real time monitoring device to track the shipment's temperature, location, and light event. The Softbox is filled with dry-ice to maintain the vaccines at a temperature range of -60°C to -80°C for up to 6 days (dry ice lead time).

The shipment is then picked up by the UPS carrier and transported to the airport for the pre-booked flight to Lilongwe (Malawi).

**PHASE 2: From Lilongwe Airport to the National Storage Facility**

Once the UPS plane lands at Lilongwe Airport, the shipment is unloaded and transported by truck to the EPI4 National Vaccine Store in Lilongwe (approx. 30-minute drive). The temperature monitoring device located in each Softbox box is de-activated, which concludes the in-transit monitoring activity. Vaccines are stored in ultra-cold freezers at -60°C to -80°C.

**PHASE 3: From the National to the District Storage Facilities**

Vaccines stored at the EPI National Vaccine Store are to be distributed to the 28 districts of Malawi (Phase 3) and, from there, to the 800+ health facilities around the country (Phase 4).

The transport is ensured by road using traditional land-based modalities and can take days, depending on the district location, road infrastructures and weather conditions. For example, it takes 16 hours to travel to Nsanje district (approx. 600 km by road) and even up to 22 hours to reach Chitipa district (approx. 700 km by road).

Once a district places a request for vaccines, an EPI logistician prepares the order by transferring rack(s) of Pfizer COVID-19 vaccines into portable ultra-cold freezers (-80°C). Once loaded in the truck, the freezer is connected to electrical power through the cigarette lighter outlet to maintain the temperature to -60°C/ -80°C.

**PHASE 4: Integrating the Drone in Delivering the Vaccines to the Local Health Facility**

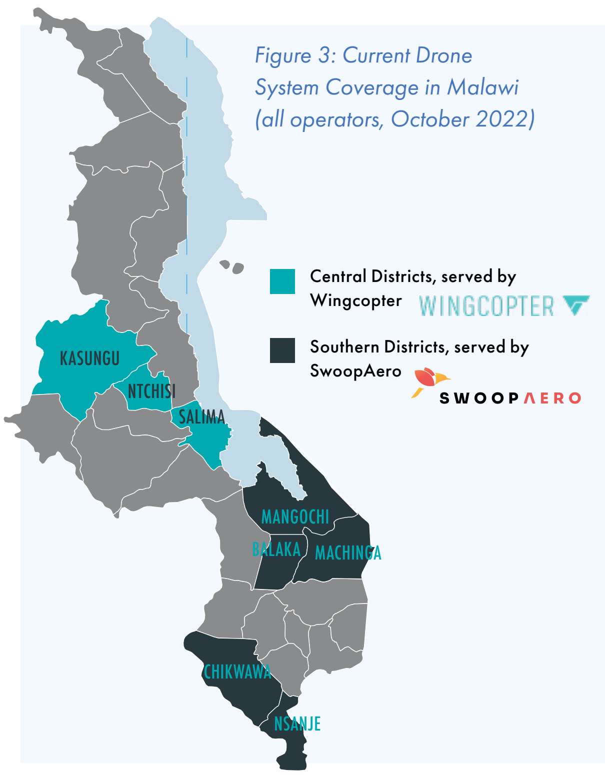
Malawi's national healthcare system comprises over 800 health facilities and vaccination centers, and each of them can place an order for vaccines to its corresponding district warehouse.

The delivery to local health facilities is done by using various types of carriers (truck, ambulance, motorcycle, bicycle, UAV, and even by foot), depending on the infrastructure's condition, availability of vehicles and size of the shipment. Drones are used only as an additional mode of transportation, either in an emergency or when roads are flooded and become impracticable sometimes in the rainy season.

In 2022, a health facility in Southern Malawi was completely isolated for over 5 months, due to road damages. Not even the ambulance could be sent for emergencies. From December 2021 to the end of May 2022. the facility was heavily reliant on UAV operations for emergency supplies (Oxytocin, antibiotics, laboratory samples to be urgently analyzed, vaccines and other medical supplies).

Even in such extra-ordinary circumstances, the use of drones is limited to only 8 of the 28 districts, where drone systems are in place (see figure 3 Today, Malawi has two drone systems (served by two operators) that covers hard-to-reach areas in 8 of the 28 districts of Malawi (see figure 3). The Government of Malawi has decided to scale up the integration of UAVs to more districts, for better coverage nationwide.).

*Figure 3: Current Drone System Coverage in Malawi (all operators, October 2022)*




The scheduled monthly distribution uses vehicles like ambulances or trucks from the district for round trips to health facilities. The emergency resupplies between the monthly rounds are done by motorcycles, but health facilities have competing needs and distribution is challenging. Even more, in some cases, the staff from the health facilities needs to leave the clinics to travel and fetch the products themselves.

This is where the UAV has become a readily available resource: it reaches the health facility faster and requires very little intervention from the health facility staff. Additionally, the current UAVs in use (with a payload of 2.5 kg and a volume of 5.5 l) are able to make multiple rounds to a health facility while carrying bulkier or heavier payload.

In some districts of Malawi, drones shorten the delivery time significantly, from 3-hour (by boat) to 12 minutes by UAV, from 90-minute by truck ride to 9 minutes by UAV. This valuable time can make a difference in saving the life of a person and this is why drones are primordially used in emergency situations.

The Pharma.Aero UAV Project team monitored the process of delivering COVID-19 vaccines by bi-directional drones that have a vertical take-off and landing, which resulted in 4 major aspects.

**Infrastructure**

The service does not require heavy ground infrastructure to set it up or to operate. All that is required is the drone, a laptop, a charger, and a clear space for landing.

**Human resources**

The human resources required to manage daily operations at each UAV hub (district) are pilot, hub supervisor, hub operations manager and pod swap manager.

**Usability**

The bi-directional type of UAV is used for on-demand transport in both directions, delivering medicines, vaccines or supplies to hard-to-reach health facilities, but also picking-up lab samples or reports for the district authorities (reverse logistics).

**Regulations**

The UAV routes need pre-authorization from the Malawi Department of Civil Aviation (DCA). Malawi was the first country in Africa to open a UAV testing corridor in mid-2017 in collaboration with UNICEF. The process for obtaining authorization to fly from the DCA evolved over time. Initially, it required demonstration of safe operations in addition an assessment of the take-off and landing sites. In the second phase, approvals for additional districts were given only after conducting the site assessments in the specific areas.

# 5. Secondary Analysis: Optimization of the Pfizer COVID-19 Vaccine Supply Chain

Pharma.Aero's Project Team identified and explored potential ways of optimizing the supply chain by further integrating the drones in the transport of Pfizer COVID-19 vaccine (or other healthcare products in general).

One important investigation is the use of drones in earlier phases of the supply chain.

## 5.1. Integrating the Drones in Phase 3 (Middle Mile segment)

In the present, vaccines are transported from national to district level only by traditional modes. What if the drones would be integrated in this phase of the transportation?

A "middle mile" UAV capable to carry larger payloads (> 50 kg) and/or travel longer distances (> 100 km), would significantly reduce the transportation lead time. A 24-hour drive would take only 8 hours by air, allowing a fast response to disease outbreaks or any kind of emergency.

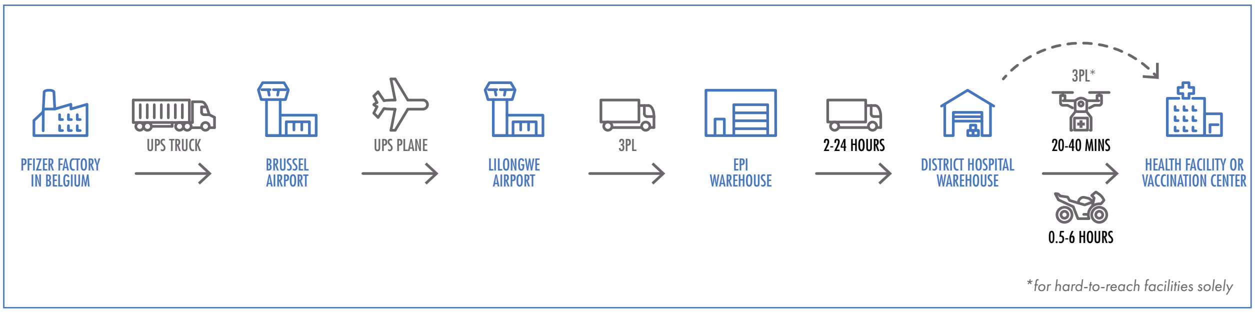



*Figure 4: Current Supply Chain*

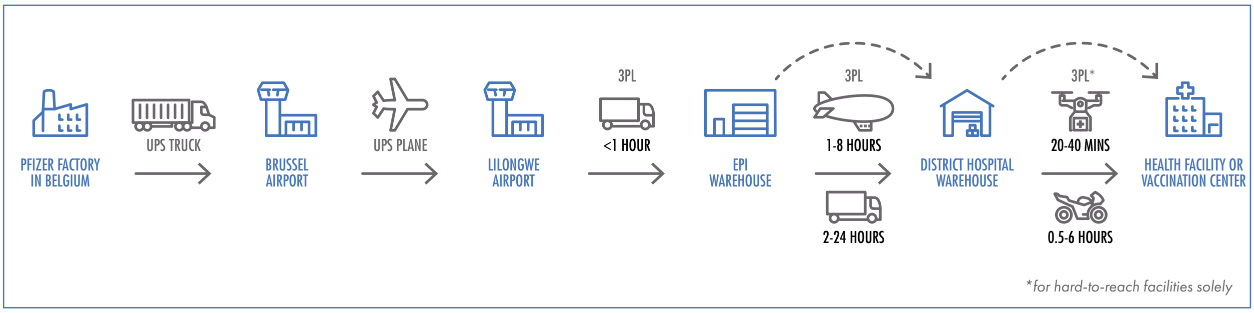



*Figure 5: Optimized Phase 3 Logistics*

## Feasibility and requirements

### Technology

With no proven middle mile UAV technology yet, the integration of middle mile UAVs into supply chains poses a series of challenges. The development of middle mile UAV technology (VTOL[3], fixed wing or LTA[4]) is still at an early stage. However, the industry is growing fast, and some platforms are almost ready to fly.

### Regulations

Additional challenges include, but are not limited to, the lack of rigorous flight regulations and authorization processes, both national and international, for larger size UAV aircrafts, as well as the need of an adapted supply chain management process (i.e., governance, supply planning, inventory & requisition process, etc.).

### Sustainability

Furthermore, is it sustainable, from economic point of view, to use drones (as complementary modes) in the middle mile phase of healthcare products, especially in low- and middle-income countries?

One way to overcome the financial challenges could be to extend the use of UAVs to multiple health programs that will share the fixed costs associated with the UAV transport networks. The government of Malawi is starting to explore the consolidation of the various vertical health supply chains (i.e., vaccines; essential medicines; HIV, Tuberculosis, Malaria programs, etc.). Since these vertical supply chains sometimes follow different paths, some include regional medical stores while other go directly to district warehouse, the integration of middle mile UAVs will face additional network design considerations and collaboration between different potential users, to align with the health supply chain consolidation strategic decision.

## 5.2. Integrating the Drones in Phase 2: Connecting Import Hubs Directly to UAV (In-country segment)

The Pharma.Aero UAV Project is exploring even further the use of UAVs in earlier phases of the process. What if the in-country transport of vaccines could start directly at the Lilongwe Airport? Using an airport as a starting direct distribution point to the Point of Use (POU) represents the ultimate streamlined supply chain with a direct link between the international airfreight carriers and local UAV transport services.

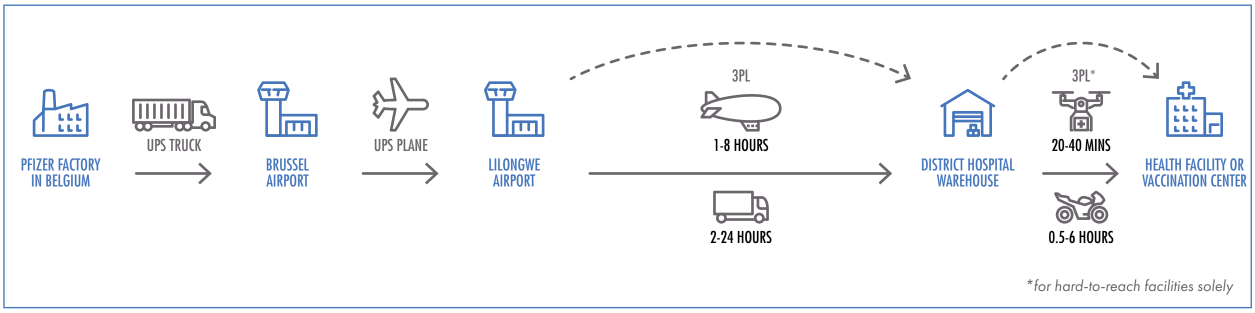



*Figure 6: Optimized Phase 2 Logistics*

Shortening the supply chain clearly improves lead times and reduces handovers, thus dramatically reducing risks on temperature excursions, damages and loss of the product. The financial gain would be significant. However, it should be put in balance with the "affordability" exercise when the cost versus final return on investment should be thoroughly evaluated.

3 Vertical Take Off and Landing
4 Lighter Than Air (aka airship)

Picture by SwoopAero

## Challenges

While using only drones for the entire in-country distribution is the end game of all supply chain optimization effort, in practice, its implementation would face numerous challenges. "Level Jumping" the EPI National Vaccine Store would require significant policies & strategies (i.e., Health Sector Strategic Plan), managerial, operational, and financial adjustments.

Other challenges include the need for an airport process to follow GDP/GMP (Good Distribution Practice/ Good Manufacturing Practice) practices, or the lack of regulations for UAV integration into the airport airspace. As demonstrated in a previous Pharma.Aero Project, Lean Logistics for Vaccines in Uruguay, the use of an airport as a direct distribution point does not simply limit to using the airport as a logistics operator, by providing infrastructure and services, but requires the participation of multiple decision factors at all levels (airport experts and authorities, transport and health authorities at national and local levels, cyber specialists etc.) and a high degree of coordination and interconnectivity to implement and operate an efficient distribution system. It is comparable with current e-commerce services where large bulk shipments arrive at airport hubs and are on package level divided and distributed.

If considering re-locating the start of in-country supply chain at the first point of entry into Malawi, the national governmental authorities need to adapt relevant strategies, policies, and procedures to enable managerial, operational, and financial integration of drone transport. Since UAVs complement traditional land-based transport modalities, operational procedures need to be further adapted to guide decisions on what products goes where, when, by what mode of transportations, etc.

## 5.3. Pre-packaging of COVID-19 Vaccines According to POU's Orders

The Pfizer COVID-19 vaccines are manufactured and delivered in pre-packed racks containing 195 vials (of 6 vaccine doses each). Before leaving the factory in Belgium for being transported to Malawi, the pre-packed racks are placed in special containers (tertiary packaging) equipped with real-time temperature monitoring device and dry ice.

It is only after the Phase 2 of the transportation (at the EPI National Vaccine Store) that the tertiary packaging is opened for the first time. The racks with 195 vials are kept in ultra-low temperature freezers in the original factory packaging.

Only after Phase 3, at the district level, is the secondary packaging removed to prepare on-demand orders for the local health facilities around the country.

### Pre-packaged Customized Vaccine Orders, at the Manufacturing Facility or at the National Vaccine Store?

In the supply chain world, one end-to-end form across the supply chain is often associated with increased convenience, reduced packaging waste, cost savings associated with limited handling while in transit, and other advantages. In the case of global supply chains with end beneficiaries located in low- and middle-income countries (LMICs) such as Malawi, decisions must be weighed up carefully.

Theorizing, when considering moving the end-customer-based packaging earlier in the supply chain.

First, one must know if prioritizing "cost to market" or "speed to market". Less handling/repackaging at any points of the supply chain will promote speed to reach destination no matter the cost. But the questions remain: "What is the most expensive location to do the re-packaging? Is it logical to do it that early in the supply chain? Who is paying for the repackaging during transit?"

When shipping orders in bulk, there are higher side costs associated with storage, handling, or repackaging during the transit, or even associated delay to deliver the products at the destinations.

Also, the nature of the cargo will influence the location of the repackaging. For cargo requiring special storage/transport conditions or handling procedures, like the Pfizer COVID-19 Vaccine, the re-packaging process should be done if/where cold-chain resources are available, in the early phases of the supply chain. It is important to note that since logistic UAVs have been introduced into supply chains, the design and location of cold chain in LMICs has often been altered as UAV technology allows to leapfrog the cold chain and transfer its associated burden higher in the supply chain where resources exist.

Furthermore, the packaging characteristics are a key element in the evaluation of changing the repackaging location.

For the use case presented in this project, the packaging used at the manufacturing point is too big, or, if it fits, it leaves no room for insolation and cooler to maintain quality of the shipment.

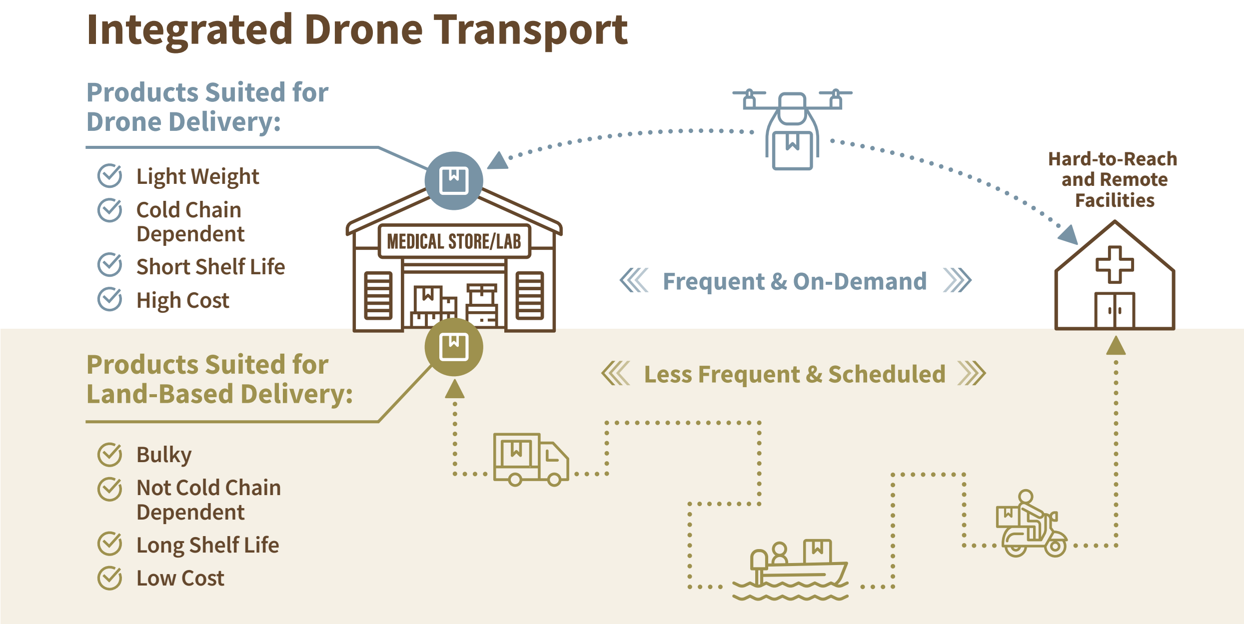
Therefore, it is essential to include pharmaceutical companies in the design of a holistic supply chain solution with the end-customers, in our case, Malawi Government Health logisticians and health care workers.

# 6. Conclusions

As it becomes clear that UAVs have a place in the pharma & humanitarian supply chains of the future, the need for further research on where fit for purpose UAVs offer the most value to an existing supply chain system is certain. UAV transport has primally been seen as stand-alone solution (as opposed to integrated into an existing system) replacing a land base transport modality.

Today, a growing body of evidence suggests that UAVs do not replace traditional modes of transportation[5]. In many cases, trucks, airplane, boats, and motorcycles enable efficient and high-performance supply chains. It is where land-based transportation modalities fail to support supply chains — due to the environment context or the specificity of the transport needs — that UAVs are most useful. As it stands, UAVs are effective for reaching remote areas of low-income countries. In addition, it is equally imperative to explore the use of UAVs in metropolitan cities. We believe that with UAVs, it is facile to achieve sustainability and efficiency in such areas.

But above all, the integration of UAV technology into an existing supply chain system must be considered with affordability being a priority, especially in context of resource-limited settings. So far, the benefits, cost and cost-effectiveness of UAV transport are mainly measured for vertical segments (emergency, on-demand, or routine transport) in the public health market and are measured for small/medium-scale operations. While early data on supply chain benefits is promising[6], the cost of UAV services is still perceived as too high to be financially sustainable for resource-limited health systems.




The current market penetration strategy for UAV logistics focuses on the public health market. That narrow strategy has resulted in a lack of depth of understanding of how and if UAV transport can reach a price point that makes it more compelling across various markets (postal, ecommerce, etc.) as a core integrated service in supply chains, or a supplementary augmentation with an important, but smaller niche role.

A different market penetration strategy, one that is based on entering various vertical markets simultaneously, combined with various commercial subsidization and localization strategies, is essential to determine the shape and future of the UAV logistics industry and the breadth of its adoption. Economic analysis and further research need to be done on wider scale, also evaluating the scalability and the wider impact on saving lives through speed operations, economical and humanitarian impact. And last, but not least, the environmental impact should be considered: the long-term use of UAVs significantly reduces the fuel consumption and, thus, pollution. Pharma.Aero is already planning a follow up project (Work Package 4) where middle mile transportation innovation, like UAV or LTA, will be introduced to not only enable a more equitable access to life-saving products, but also invest in an environmentally sustainable transport mode that requires no additional roads, embraces green spaces, and brings massive reductions in carbon emissions.

5 https://www.villagereach.org/wp-content/uploads/2022/09/Integrating-Drones-SC-Whitepaper-2.pdf
6 https://www.updwg.org/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