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Uses of Drone & UAV Technology in Accessing Healthcare: The Case of Madagascar

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Abstract

In the field of health logistics, drone technology has increasingly become used in delivering medical materials including blood bags, plasma, and critical pharmaceutical products to save patient lives. Among countries where existing transportation infrastructure is insufficient for the needs of hospitals and other healthcare actors, drone delivery can provide a swift and reliable solution in situations where time is of the essence. However, the present literature regarding the feasibility of UAS-supplemented healthcare logistics programs in specific nations is limited, and often restricted to wealthy and developed nations. Through a qualitative thematic analysis of factors including geography, drone capabilities, transportation regulations, and government financing, this paper finds implementing a wide-spread UAS-supplemented healthcare logistics program in Madagascar at present to be extremely difficult, largely due to stringent regulations and limited government funding. Despite these challenges, future implementation is not impossible, as some steps can be taken towards resolving them, given that government interest in the uses of drone technology grows overtime.

Key words: UAV, UAS, Drone Health Logistics, Madagascar, Feasibility

Key Terms and Distinctions

Drone - A commonly used term to describe any unmanned aerial vehicle which can travel autonomously or beyond a visual line of sight, including those that can travel in water or on land.

UAV - Abbreviation for Unmanned Aerial Vehicle. It refers to drones that travel through the air, specifically, the traveling vehicle component. All UAVs are drones, but not all drones are UAVs. However, for this paper, the two terms will often be used interchangeably.

UAS - Abbreviation for Unmanned Aerial System. It refers to all the parts which enable UAVs to function properly, including the ground control unit (the *controller/remote), GPS, and the UAV itself.*

Introduction

Aim

This research paper aims to investigate factors affecting the implementation of a UAS-supplemented healthcare logistics program in rural Madagascar and provide recommendations for its creation through a themed analysis. It must be noted that this paper is limited and best understood as an introductory analysis into a complex area. This paper does not explore in-depth the financial feasibility of such an operation, but rather, broadly explores the multitude of components affecting possible implementation.

Objectives:

1. Identify and summarize existing relevant literature on drone usage for medical & logistical purposes and best practices in the field
2. Distinguish tangible benefits, disadvantages, and critical factors necessary to determine the feasibility of such a drone healthcare logistics program

3. Investigate the needs and priorities of Madagascar's healthcare system, as well as the capacity of Madagascar to implement such a program.
4. Provide a list of the next steps administrative bodies in Madagascar may take to make the implementation of such a program easier.

Background

Globally, the usage and applications of drone and unmanned aerial vehicle technologies have substantially grown over the past two decades. At present, there is a growing demand and market for drone technology in the delivery of medical products including vaccines, blood supplies, and general pharmaceutical products (Euchi, 2021). According to Global Market Insights (2019), in 2018, the entirety of the medical drone market was valued at USD 88.2 million and is projected to grow to about USD 399 million by 2025. Proponents of UAV technology in medical logistics often cite cost-savings, versatility, and swift delivery speeds as benefits to its implementation in health systems.

Under the COVID-19 pandemic, interest and exploration in this field's potential have grown significantly from health providers and private corporations alike. With successful UAV-logistics companies like Zipline operating in Rwanda, various local and national governments in sub-Saharan Africa have identified this technology as a potential area of development in their respective health systems.

In addition, the growth of medical logistic industries in all forms aids in attaining the 3rd and 17th United Nations Sustainable Development Goals regarding "Good Health & Well-Being" and "Partnership for the Goals" (United Nations, 2015):

3.8 Achieve universal health coverage, including financial risk protection, access to quality essential health-care services and access to safe, effective, quality and affordable essential medicines and vaccines for all.

3.3: By 2030, end the epidemics of AIDS, tuberculosis, malaria and neglected tropical diseases and combat hepatitis, water-borne diseases and other communicable diseases.

17.17: encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships

Madagascar is an African island country located in the Indian Ocean, off the southeastern coast of the African mainland. With a population nearing 27 million people as of 2019 and a land area of 567,000km², Madagascar has a GDP of $14 billion and is classified as a 'low-income country' by the World Bank (2021; n.d.). Under the United Nations Human Development Index (HDI) rating system, Madagascar ranks 164th out of 189 nations with a 0.528 rating, which is both lower and growing slower than its southeast African counterparts (Kenya - 0.601, Zimbabwe - 0.571) (UN, 2020).

The top health priorities of Madagascar are related to infectious diseases, malnutrition, human resources deficiency, limited funding, and limited access to healthcare (Barmania, 2015). In 2018, there were 233 incidences of tuberculosis per 100,000 people and 76.1 incidences of malaria per 1,000 people at risk (World Health Organization [WHO], n.d.).

Methodology

The methodology used for this project primarily involves a literature review through sources such as academic papers & journals, news articles, and relevant Madagascan legislation found through databases such as JSTOR, Google queries, and official government websites. Although the drone industry's fast-paced development has led certain information to become outdated fairly quickly, I found date-restricting certain queries for topics such as medical drone delivery literature in Madagascar greatly limited both the quantity and quality of research I could obtain on the topic. However, the vast majority of referenced sources are still relevant and created within the past five years.

Some keywords used in my queries include 'medical drone delivery', 'Madagascar drone regulations', 'UAS', 'UAV', and 'Health Logistics'. To guide the direction of my research, I had also conducted two informal unstructured interviews with experts in the field of drone technology, one of whom is Mr. Lei Zhang, founder, and CEO of the drone-logistics company Antwork Technology based in Hangzhou, China. To a considerable extent, this paper takes a qualitative approach, using thematic analysis to identify critical factors and form conclusions.

Discussion

Public Health - Accessibility

From high Karst-landscape plateaus running down the middle of the island to thick tropical forests lining the coast, Madagascar contains many biomes and varying topographic features (World Wide Life, n.d.). Unfortunately, the roads in this varied, vast, and rough terrain are "scarce or of poor quality." For certain rural areas, even with access to vehicular transportation, arranging a trip would be costly and difficult. Movement across this terrain "requires creativity and innovative partnerships, often with those in other sectors, such as conservationists" (Barmania, 2015).

A significant portion of Madagascar's population lives in what their national statistics bureau classifies as rural areas, and in 2019, the percentage of people living in rural areas in the country accounted for 62% of its total population (Macrotrends, n.d.). With 16 million Madagascans living 5 kilometers or further from a health center (USAID, n.d.), and the only widely available public transportation being bush taxis or taxi-bes (taxi cars or vans used for both short and long-distance travel) between relatively large Madagascan cities or towns, transportation options are limited for those living in more remote or hard-to-reach areas (Hoffman, 2014). In addition, the cost of transportation can be a significant and often unconsidered barrier to healthcare access (Shrime et al., 2017). This is one reason why healthcare utilization in Madagascar remains low, with a rate of only 30% of the population seeking government-funded healthcare services for fever (Marks et al, 2016). Moreover, a severe shortage and geographic inequality of trained medical professionals exists between rural and urban areas. Technical specialist Felix Andrianjaranasolo explains how at most, a town in Antananarivo would have "12 doctors but in more remote areas, there is often only one health-care professional and often not even a doctor, maybe just a midwife" (Barmania, 2015).

Drones can bypass the constraints imposed by the physical geography and limited infrastructure by simply flying over them. In the event of a natural disaster, where geographic features are significantly altered, drones appear to be a natural solution to moving vital equipment and essential medical goods on-site rapidly. In areas with little access to the road network or rural communities with few trained medical professionals, drones can deliver all the same and encourage the development of alternative digital solutions to physically visiting a doctor. Drones could also reduce the cost of logistics, as multiple drones can be piloted by one pilot or control center simultaneously.

Public Health - Healthcare Costs and Funding

Healthcare is mostly free of charge in Madagascar, with some expenses being paid for out-of-pocket by patients. Although healthcare is provided by the government, the sector is funded from a mix of sources, with public tax only funding 47.7% of the total expenditure in 2016 (WHO, 2016).

A quarter of Madagascar's total health expenditure is paid for by external sources such as non-governmental health organizations, programs like USAID, or donation programs. However, this heavy reliance on foreign aid has proven to be a vulnerability in the country's ability to fund its healthcare program.

In 2009, a political crisis led to a coup of the national government by the then-mayor of Antananarivo, Andry Rajoelina. Governmental

instability severely affected Madagascar's ability to fund its healthcare:

The 2009 political crisis had a substantial impact on the country's health sector, from budget cuts to donor withdrawal. Jean-Claude Mubalama, a health specialist at UNICEF, said: 'It's clear that since the crisis, the budget allocated to the health sector has decreased.' This shortfall, he explained, had a bearing on the ground with the departure from rural areas of many health-care workers who had not been paid. Some left to work for non-governmental organizations, others headed to the capital Antananarivo in search of work (Barmania, 2015).

Due to the fallout of the 2009 crisis on the healthcare sector, healthcare had turned into a national priority for all governments since. It must be acknowledged that the quote cited above comes from an article written in 2015, and since then, the budget allocation has started to increase again.

The 2020 Madagascan budget for healthcare saw an increase of 26% from the previous year, jumping from Ar 546.8 billion (USD 144 million) to Ar 688.9 billion (USD 181 million) (UNICEF, 2020). The upwards trend in Madagascar's health budget allows more potential funding for the creation of a drone logistics pilot program. However, until such a program reaches maturity and widespread application, instability in the nation's governmental institutions could cause foreign donors to once again withdraw their aid and limit funding for lower-priority and experimental healthcare initiatives.

Technology - Technical Limitations

There are three critical aspects when considering drones purposed for delivery. They are range, load, and speed. Differentiating between custom-designed and commercially available drones is also crucial.

The undisputed global industry leader in drone manufacturing is the Shenzhen DJI Technology Corporation, holding a solid 76% market share in the US alone, despite trade-war tariffs specifically targeting Chinese drone companies (Schroth, 2021). Their longest range commercially available drone is the Mavic Air 2, "with a transmission distance of up to 10 km" (DJI, 2020).

While conventional drones often use four blades connecting to a central frame, certain companies like Zipline have designed drones similar in appearance and function to gliders to maximize range. Zipline's winged drones have "a top speed of 128 km/hr, and a round trip range of 160 km, carrying up to 1.75 kg of cargo" (McCall, 2019).

In Australia's Northern Territory, which covers a vast terrain, researchers from Charles Darwin University and iMOVE (a leading applied research center in Australia) are hoping to develop drones with a range of 250 km in all weather conditions (IMOVE, n.d.).

Traditionally, progress in the drone logistics industry has been hampered by technical limitations and insufficient capabilities. Increasingly, however, innovative advancements in the three critical aspects are progressing exponentially. With sufficient funding and by learning from these advancements, more companies, organizations, and governments can create drones capable of conducting long-distance deliveries.

Technology - Weather

Drone operations may be particularly ill-suited for Madagascar's east coast weather during the rainy season. Throughout the year, tropical cyclones formed from the trade winds of the Indian Ocean slam into the Island's east coast, partially causing the high average annual precipitation of coastal regions, which vary" from 2,030 mm to 3,250 mm" (World Weather & Climate Information, n.d.). On average, Madagascar faces 1.5 cyclones annually (UN OCHA, 2019).

Madagascar enjoys a tropical and temperate climate, with most regions including Antananarivo having minimum temperatures of around 10°C in the coldest months, and highs of around 30°C in the warmest months (Yu Media Group, n.d.).

While Madagascar's temperature would not pose a problem for drone operations, as most drones feature a temperature operating range between

0°C and 40°C, the strong winds and heavy rain could affect operations during hurricanes and the rainy season in coastal areas of the country (Spires, 2019).

National Regulations and Laws

National laws on drone usage remain stringent and inflexible. Madagascar does not differentiate between commercial and personal drone usage and will not allow anyone to fly a drone outdoors without a specialized permit (Dronemade, n.d.; Jones, 2017). From 2016-2018, the State University of New York (SUNY) at Stony Brook operated "the 'DrOTS: Drones Observed Therapy System in Remote Madagascar' project [as] a proof-of-concept" in "deploy[ing] healthcare in remote settings". One of the biggest problems they encountered related to regulations: "the lack of drone-specific flight regulations led to delayed flight permit approval and required frequent renewals thereof" (Knoblauch et al, 2019).

After reading the relevant laws, it becomes evident that there are severe limitations in one's ability to operate a drone and a significant number of bureaucratic processes required to obtain the special permit.

In Madagascan legislation, under Article 3 of the section, 'Relative aux conditions d'exploitation des aéronefs télépilotés' (Relating to the operating conditions of remotely piloted aircraft), drones are not allowed to fly through clouds and fog; less than 30 meters away from vehicles, buildings, boats, or people for drones weighing 4 kilograms or less; more than 50 meters above the ground for drones weighing more than 4 kilograms; and cannot surpass a speed of 80km/hour at full power—to name a few restrictions (Aviation Civile de Madagascar [ACM], 2015a).

The permits given to fly drones are also on a case-by-case basis and only valid given a pre-approved flight plan, meaning it will only be useful for one flight. Up to 20 additional documents are required to apply for the permit alone (ACM, 2015b).

The current controls on drone operation in Madagascar largely negate the potential benefits of drones as a logistics tool. Namely, access, flexibility, and speed. For private drone technology corporations looking for business opportunities in the country, the regulations are very clearly red tape obstacles that could discourage investment and access into the market. The requirement for a pre-approved flight plan restricts flexibility and limits sudden changes to the scheduled route due to weather or problems arising from the ground. The limitations on UAV speed and the lengthy bureaucratic process required to receive a permit take away the benefit of quick delivery in both emergency and non-emergency situations. As of the present, the largest obstacle to implementing a drone logistics program for any industry or field in Madagascar would be its uncompromising legal framework.

Case Studies - Antwork Technology

Antwork Technology is a drone delivery logistics company headquartered in Hangzhou, China. It was the first company in China to receive a license from the Civil Aviation Administration of China (CAAC) for urban drone deliveries and has carried out 50,000+ drone flights since its inception in 2015 (UAS Vision, 2019; LinkedIn, n.d.). Through an informal interview over the internet with the company's CEO & Founder Mr. Zhang, several critical considerations were brought up regarding the roles both national governments and intergovernmental organizations play in creating balanced regulations which ensure civil safety and encourage economic development.

Mr. Zhang explains that China is a member state of the Joint Authorities for Rulemaking on Unmanned Systems (JARUS), a "group of experts gathering regulatory expertise from all around the world" with "63 countries and the European Aviation Safety Agency (EASA) and EUROCONTROL [contributing] to the development of JARUS work products (JARUS, n.d.)". He says the CAAC created new standardized regulations based on the Specific Operations Risk Assessment (SORA)

methodology developed by JARUS, taking advantage of the already present expertise in the field and applying it in specific UAV and UAS applications. SORA is a 10-step process that holistically assesses the risks of drone operations in detail.

He also mentions how in response to Antwork being licensed for urban drone delivery, the Hangzhou municipal government set up a pilot zone for unmanned aviation in coordination with the CAAC (Zhejiang Government Site, 2020). This provided a space for real-world testing, finetuning urban drone delivery, and learning about any unexpected challenges resulting from such operations.

While Hangzhou's pilot program is primarily designed for testing urban UAV flights, there is also no shortage of examples where pilot zones have been opened in rural settings in sub-Saharan Africa as well, starting with UNICEF's Malawian drone corridor set up in 2017 (UNICEF, 2017).

At present, Madagascar is not a member of JARUS and has not taken the initiative to create a designated area for UAV technology testing outside of a case-by-case basis with a select few research institutions.

Case Studies - Rwanda & Zipline

Perhaps the most successful and well-known example of a drone logistics company operating in sub-Saharan Africa is Zipline. As of early 2021, Zipline had already flown 4 million miles, making over 400,000 vaccine, plasma, and blood deliveries across countries like Rwanda, Ghana, and the United States under contract with both national and local governments (Boudway, 2021). By 2019, the company was delivering "more than 65 percent of Rwanda's blood supply outside of the capital, Kigali" and "[increased] the use of rare and specialized blood products by 175 percent and reducing waste and spoilage by over 95 percent" in the country as compared to 2016 figures (McNabb, 2019).

This example in particular also highlights the benefits UAV technology has over the physical terrains of nations. Rwanda is known as the 'land of 1000 hills,' and "[the] maintenance costs of the country's roads are very high as the roads get destroyed due to heavy rainfall and landslides. Even if they try to maintain the roads, their budget does not allow them to do so" (Gangwal et al., 2019). UAVs, however, can bypass the logistical challenges of rough hills, blocked roads, and traffic conditions.

While Zipline's commercial success is remarkable, in Rwanda's case, its government had enlisted more than just Zipline in its bid to become the technological and financial hub of Africa. In 2020, the government hosted the first African Drone Forum in Kigali, inviting international regulators and companies alike to learn from and participate in a series of UAS delivery competitions on Lake Kivu (African Drone Forum, 2020). By hosting the first forum of its type in the region, Rwanda established itself as a leader for technological innovation and business in Africa. Rwanda is also one of only four African members in JARUS (JARUS, n.d.).

The public-private partnership between Zipline and Rwanda tangibly illustrates a successful example in Africa which Madagascar could seek to emulate, should their aviation regulators choose to pursue future drone and UAV logistic operations in the medical field.

Conclusions

This research aimed to identify and determine factors that may affect the success of implementing a medical drone logistics program in rural Madagascar. Based on the broad analysis of topics in public health, technology, and regulations, any large-scale UAV operations in Madagascar within the near future will be unlikely and difficult.

The technological and public health discussion provides both the means and the reasons to implement a UAV program, and case studies have shown successful examples of real-world applications in environments similar to rural Madagascar's. However, strict regulations and

bureaucratic redundancies remain as large obstacles to all extensive drone operations.

Nonetheless, there still are several clear steps Madagascar can take to improve the likelihood of future development in its drone industry. Most critically, amendments to the current legislation regarding drone laws will be required. While balancing the interests of corporations and both environmental & personal safety can be difficult, an easy step towards resolving this issue would be to join JARUS and seek advice from other experienced aviation regulators and adopt the SORA methodology to streamline and standardize risk assessment procedures. As every nation has different circumstances, the solutions every nation requires will be different. Therefore, pilot programs or testing areas could provide valuable practical information about cost and operational feasibility for the optimal solution for Madagascar.

To make comprehensive and necessary changes to current laws, input from more than just the local aviation administration will be required. Of the most relevant governmental bodies to this topic, the Ministère de la Santé Publique (Ministry of Public Health), Ministère des Transports, du Tourisme et de la Météorologie (Ministry of Transport, Tourism, and Meteorology) and the Aviation Civile de Madagascar (Madagascar Civil Aviation Administration) could form an interministerial committee to resolve concerns about regulations from all angles.

The drone industry is rapidly developing in various fields on every continent. Though Madagascar lacks the necessary framework to handle larger drone operations, I am confident that as time passes, the benefits of UAV technology and its applications will be better understood and valued by the country's government and prompt action for its use.

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