POTENTIAL COMMERCIAL USE OF UAVS IN HEALTHCARE AS PART OF CRITICAL INFRASTRUCTURE

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Abstract

Today's times are marked by fast-paced lifestyles, high demands and lots of stress. This is reflected in deteriorating human health and congested roads. Society has reached a point, where everyone wants to have everything instantly and we are adapting to it just to keep our place in it. To cope with all the rigors of everyday life, we are now increasingly being helped by various technologies that are innovating day by day. One of such is an inconspicuous but unmissable device - the unmanned aerial vehicle (UAV).

This paper is aimed at exploring the potential commercial use of UAVs, as an important element in the logistics chain in healthcare. This chain is largely constrained by a number of factors, which may include the congested traffic situation and inadequate infrastructure. In this paper, attention is paid to the analysis of a concrete example of the use of UAVs in real practice.

Keywords: Unmanned Aerial Vehicle, Unmanned Aircraft Systems, Logistic supply chain, Healthcare

1. INTRODUCTION

UAVs have potential commercial applications in **almost every industry**. [1,2,3,4] This paper will focus on their application in healthcare as part of a major logistics chain. The potential of UAVs in healthcare has its merits. Predictions of the future of laboratory healthcare based on various studies and data view UAVs as an important part of the **future healthcare industry**. UAVs could form part of so-called SMART laboratories (Speed Metrics Automation Remote Technologies) as a support for their automation. [5]

The United Nations (hereafter "*UN*") points to continued population growth in its State of the World Population Prospect released in 2019. The **projected population** in 2030 is **8.5 billion** and 10.9 billion at the end of this century. [6] According to the prospect, there are areas where fertility rates are as high as 4.6 live births per 1 mother. But these are also areas with low infrastructure and low health security, such as sub-Saharan Africa. This increases the demands and **needs for health infrastructure**, which is lagging behind in these areas. The high importance of modern technologies to address them is therefore highlighted. [5]

Another worrying statistic is the constantly **ageing population**, which is once again **increasing** the number of **patients** who are **dependent** on a **medical assistance**. The UN reports that in 2018, for the first time, there were more people over 65 than children under 5 in the world. At the same time, by 2050, it is projected that there will be twice as many people over 65 as children under 5 in the world, and more of them than adolescents aged 15 to 24. [6,7]

2. COMMERCIAL USE OF UAV

In this part of the article, the workflow is explained in the first step. This is followed by a description of the selected case study, which is divided into 4 parts (case selection, problem and reasons for the introduction of UAVs, description of the introduction of UAVs, results of the introduction). The last part is the discussion.

2.1 Methodology

The potential commercial use of UAVs is a broad area, so the targeting of the article needs to be narrowed. For the reasons stated in the introduction, the healthcare field was chosen as the specification. The highest level of potential use of UAVs is considered to be the case, where UAVs have already been put into **practice** and the **impact** on healthcare and infrastructure has been **evaluated**. In this paper, we will therefore deal with identifying and describing a specific example.

The initial section is an analysis of the available relevant **literature** with the intention of identifying the use of UAVs in healthcare. Subsequently, the selected specific **example** is **described**. First, the problem and reasons for the use of UAVs in the given context are explained. This will be followed by a description of the actual use of UAVs and last but not least, the effects from the use of UAVs will be evaluated. A **discussion** section is reserved for the evaluation of the use of UAVs in the area. An overall **summary** is provided in the conclusion section.

2.2 Deployment of UAVs in healthcare

Based on the analysis of available and relevant sources, the 4 most frequently mentioned **uses** of UAVs have been identified, namely:

- controlling the number of **mosquitoes** [8,9],
- transport of **samples** and other **medical supplies** [10,11],
- transport of an automatic external **defibrillator** [12,13],
- dealing with **natural disasters** [14]

The transport of **samples** and other **medical supplies** was assessed as the **most developed** and **researched** area, where specific implementations in practice can also be identified. [15,16,17,18,19] Partial implementations can be found within other areas, but several initiatives remain in the exploration and experimentation phase.

In this field, **Zipline Inc.** (hereafter "*Zipline*") stands out [15], with the **longest** use of UAVs in **practice**. The company began in 2014 as a start-up with a noble purpose - to provide every person on the planet with instant access to life-saving medical devices. [20] They partnered with the government in **Rwanda** to create the world's first commercial medical device delivery service via UAV. The transport network mainly provides transportation of blood parcels, vaccines and various medicines. [16]

2.3 The problem and reasons for UAVs in Rwanda

Blood is important in a variety of emergencies, such as massive **hemorrhage** in **childbirth**, which has long been identified as the most common **cause** of **mortality** in women during pregnancy [21], with the highest incidence of cases in central and sub-Saharan Africa. [22] Such death is easily **reversible**. [23]

Another important supply are **vaccines**. For health workers who work in rural areas, storing them at **low temperatures** is a significant problem, as is maintaining the necessary **stock levels**. [16]

Due to its high ruggedness and mountainous **terrain**, Rwanda is a country where it is difficult to build rapid road infrastructure. On the other hand, the country has made significant **progress** in its development, as evidenced by the continuous reduction in poverty or the increase in life expectancy at birth by almost 20 years since 2000. [17, 24] The Government of Rwanda has created a national development plan, **Vision 2020**, based on equity of access to modern health care. [25] The interest was to **rebuild** a quality **health system**, which they achieved by building new facilities or training health workers in each village. However, road communication is slow and health facilities routinely find themselves **short** of various **supplies**, especially blood. In an emergency, blood supply can take several hours, which can have fatal consequences. Rwanda thus became an **ideal candidate** for testing the transport of medical supplies via UAVs due to its extensive wireless connectivity, challenging terrain, low overall land area, and an actively cooperative government. [17]

2.4 Description of UAVs in Rwanda

The logistics of transport is built on 2 bases also serving as warehouses, which they call "**nests**". One of these is the **Muhanga** nest, about 50 kilometers from the capital, where supplies of blood and other blood products are delivered several times a week and then stored by staff in specialized refrigerators. The Nest staff then await **orders** from the hospitals, which can be made via the **telephone network** (SMS, call), but also via the **data network** (website, WhatsApp) with a typical frequency of **20-30 orders per day**. The received order is packed in a red parachute box and placed in the bottom of the UAV. [17]

The **process** of preparing the UAV takes about **6 minutes** in total and involves several steps. These include attaching the wings, inserting the battery, automated pre-flight check via QR code, confirming the flight plan and applying for an air permit. The UAV is launched into the air reaching a speed of approximately **100 km/h** in less than half a second. Due to the predefined flight path, the UAV behaves completely **autonomously** throughout its mission and is monitored by Zipline and the *Rwandan Civil Aviation Authority* in case the flight trajectory needs to be changed or the UAV needs to be withdrawn from the sky to the ground. [18]

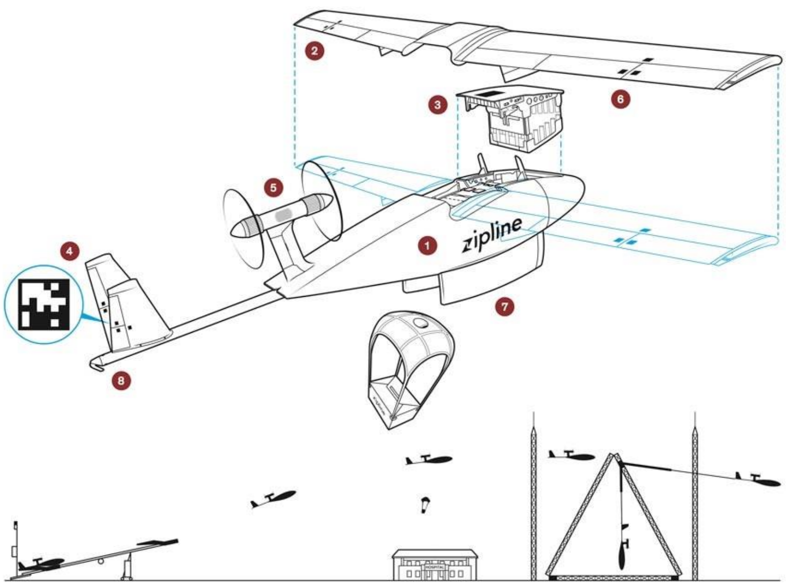

Figure 1 Drawn Zipline UAV and its flight path. [17]

Just before the UAV arrives in the target area, hospital staff will receive **notification** of the impending delivery. Above the dispensing point, the UAV opens the lower part of the fuselage, the order box falls out of it, and the attached **parachute** slows its fall (see **Figure 1**). To **land** the UAV safely, they use a 10-meter-high **tower** composed of 2 arms with a cable between them. [17] The UAV flies between the arms at the height at which the cable is, and the cable is then caught by the tail of the UAV, which simply hangs onto it (see **Figure 2**). It can then be folded, **reset**, and prepared for further use. The **battery** removed from the UAV is connected to a **charging** station where all **flight data** is automatically **downloaded** to server storage during charging. [18]

Figure 2 Fixed-wing UAV from Zipline. [16]

Zipline chose a **fixed-wing** UAV to transport the products (see **Figure 2**). It is characterized by a **higher** flight **speed** compared to propeller types due to its aerodynamics. As a result, it can deliver products even to **remote locations**

(80-kilometer radius). [26] At the same time, the products are placed inside the UAV, thus **protecting** them from environmental influences. It also has the advantage of being **resistant** to different climatic **conditions** and being able to fly even in adverse weather, whether it is heat, rain, or wind. For example, when is windy, the UAV can automatically assess its speed and direction and, when launching the delivery, adjust the time of its release so that it hits the intended location. [17]

The UAV itself is designed to **weigh** as **little** as possible to extend its range. The **GPS** navigation system is **built** into the **battery** and not into the UAV because of the constant connection to satellites. If the GPS were built into the UAV only, before each flight the UAV would have to connect to a satellite after the battery is inserted, which can take up to 10-15 minutes, thus prolonging the pre-flight preparation. [18] The UAV can carry a package with a **maximum** weight of **1.75 kilograms**, which is equivalent to 3 500 milliliter blood bags. In the case of larger requirements, several UAVs are sent to the site at the same time. [16]

2.5 Results of UAVs

Zipline's solution has been actively helping to **reduce** the **death rate** of women in **childbirth** due to hemorrhaging [16] Thanks to Zipline's solution, **vaccines** are stored in **optimal conditions** and are **constantly available** to medical professionals no matter where they are, ensuring they have the necessary number of refrigerated vaccines. [16] Another **country** where Zipline deployed their solution was **Ghana**, where they have been deployed since **2019**. [27] With on-demand storage and distribution of vaccines, they have significantly **reduced** the spread of life-threatening **diseases** in children. UAVs also had a significant role during the COVID-19 pandemic, when vaccine availability was an overall problem. [28]

Zipline declares that approximately **727 children** under the age of 5 were **saved** due to their solution by expanding vaccine availability to 15,000 of them. Other results speak of **reduced duration** of vaccine stock-outs by **30 %**, **reduced** the number of **missed** vaccination **opportunities** by **44 %**, **increased** the number of **vaccinated patients** by **21 %**. [28] Overall, high satisfaction with Zipline's solution can be claimed, especially due to the overall improvement in vaccine accessibility. 96 % of healthcare providers in Ghana declare so. [28]

2.6 Discussion

The potential of UAV for supplementing inadequate healthcare infrastructure can be declared through its favorable outcomes described in the case study article. Further evidence is the overall **expansion** of Zipline into more countries around the world. Specifically, these include **Arkansas** (since 2021), **Utah** (since 2022), **Côte d'Ivoire** (since 2022), **Nigeria** (since 2022), **Kenya** (since 2022) and **Japan** (since 2022). They didn't just stop at the healthcare. Thanks to the redesign of UAVs for **urban** environments, they have also started to look at delivery in gastronomy and agriculture. [27]

A significant part, and many times an **obstacle**, of the use of UAVs is their **safety**. While Zipline's UAV does have GPS, flight plan, and several sensors built in, the risk of accidents or failures should not be underestimated. To ensure safety, Zipline has implemented **duplication** of critical **components**. It also accounts for the situation that **both** the main component and its alternate component **fail**, in which case the UAV will immediately fire its **parachute** and land on the ground. An **emergency landing** can also be initiated by Zipline staff or the Rwandan Civil Aviation Authority. [17]

3. CONCLUSION

This paper provides structured analysis of potential use of UAVs in healthcare. The authors have contributed to the understanding of the possibilities of integration of UAVs into the infrastructure of different countries. Through their research, they have highlighted the problems and implications of the human health and safety issues that developing countries suffer from in the area of road infrastructure, thus pointing out the room for improvement through modern technology.

The workflow of the exploratory activity is structured and provides a way to analyze the introduction of a particular technology into processes. Thus, it provides areas to be addressed during the research. Specifically, the first step involves defining the technology and the context in which it is to be introduced or was introduced. This is followed by an analysis of the current state, focusing on understanding the problems in that context and identifying the reasons why the technology addresses those problems. To demonstrate the appropriateness of the technology deployment, a case study analysis is followed, concluding with an assessment of the real results from the deployment, focusing on the benefits, challenges and risks of the deployment. This approach is generally applicable.

Through this paper, the authors have pointed out that despite concerns about the autonomous operation of UAVs, the technology is a safe, low-cost option with great benefits for improving healthcare in developing countries. This represents a significant finding, as this introduction has also begun to open up opportunities for wider use of UAVs.

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