Drones in Healthcare: Application in Swiss Hospitals

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Abstract

The drone age has arrived and autonomous flying is being applied in several areas. Accordingly, the question arises in which industries this technology can make a difference. This paper examines the use of drones in Swiss hospitals. First, a literature review was conducted followed by interviews with selected hospitals. The literature research revealed that academic research on drone use in healthcare is limited. This paper contributes to the literature by showing in which areas of Swiss hospitals drones can be implemented to create cost saving as well as process optimization possibilities in order to manage increasing cost pressure and technological progress.

Our study is summarized in two papers one of which is this current paper, which aims to outline the possible areas of drone use while the second paper examines the implementation of this impressive technology in these detected areas.

1. Introduction

Like many modern technologies, drones have the potential to disrupt existing traditional industries. The drone age has arrived and autonomous flying is being applied in several areas such as gaming and sports, police and defense, arts and entertainment as well as logistics. Another key area this impressive modern technology can significantly improve is the healthcare sector, where it has already started to be implemented. Thus, drone manufacturers are conducting experiments to enable drone use in healthcare areas such as medicine, blood, vaccines and organs, e.g. ambulance drones also deliver defibrillators. [1]

This is a significant step as Swiss hospitals need to expand their IT and search for modern technologies in order to manage the regulatory framework and increasing cost pressure. In order to do so, they must create cost saving and process optimization possibilities. Also, delivering medicine, blood, vaccines and organs in-time to destinations where they

are urgently needed is critical and can save a considerable number of lives. Drone technology can also make a considerable difference in areas where access to urgently needed materials is limited or difficult because of traffic, weather or other circumstances.

The results of our systematic literature research show that academic research on drone use in healthcare is very limited. Our contribution with this paper is to show possible areas in Swiss hospitals where drones can be used and can accordingly create cost saving and process optimization potential.

The second chapter provides a background on drone technology. It explains what the newest drones can do and gives an overview of drone applications in general. The third chapter provides an overview of specific examples of drones currently being used in healthcare by outlining their key features, application areas and countries in which they are already being used.

The forth section summarizes the processes in Swiss hospitals with focus on key processes. It is important to understand which processes exist in order to figure out processes which can be optimized through drone use. These first four chapters are the result of a systematic and extensive literature review and are the basis for the definition of the next method, namely the interviews.

Chapter 5 outlines why literature research and interview were selected as research methods and what concrete steps were taken to implement them and how the concrete interview partners were selected.

Chapters six and seven contain the outcomes of the interviews and our suggestions to hospitals considering drone use.

The last chapter includes the concluding remarks and the outlook to future research.

2. Background on drone technology

Unmanned Aerial Vehicles (UAV), commonly known as "Drones", are vehicles that fly without a human on board. Alternative terms include Remotely Piloted Aircraft (RPA) - the term preferred by the military

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authorities - as well as Unmanned Aircraft (UA), Remotely Piloted Vehicle (RPV) and Remotely Operated Aircraft (ROA). Unmanned Aircraft System (UAS) is the system including a UAV, a controller on the ground as well as a communication system between these two components. [2] In this paper, we use the terms Drone, UAV and UAS interchangeably. Drones are available in numerous sizes and configurations. They can operate under distant control by a human or autonomously by onboard computers. [3] They are powered by electricity, gas, turbines or hybrid power while lithium batteries are continuously improving to enable longer flights with one single charge. Efficiency and communication is empowered by usage of global positioning systems (GPS), mobile applications, onboard camera(s) and other composite materials. [3, 4]

While developed and initially used by militaries, UAVs have the potential to disrupt several industries ranging from gaming and sports to police and defense, as well as arts and entertainment, logistics, search and rescue and healthcare. [5, 6] Drone applications in the latter are relatively young but research and development and test flights are rapidly expanding. The next section provides a review of the most recent examples of drone use in the healthcare sector.

Although their use promises significant life- and cost-saving innovations, drones also have to overcome regulations and concerns related to safety, security, criminal use and privacy misuse [7]. This includes concerns about photographing using drones and packages being stolen, for instance through the shooting down of drones, flight over private ground and risk of collision in the air. The United States is one of the countries with the most restrictive drone regulation, while developing countries such as Rwanda are less restrictive as the UAVs have the potential to be of significant use in saving lives especially in areas where traditional transportation reaches it limits. [8] In Switzerland, a Federal Office of Civil Aviation (FOCA) issued license is required for over 30kg while under 30kg, a drone license is only required for flights over masses or without direct eye contact [9].

3. Review of drone usage in healthcare

The leading drone manufacturers are conducting experiments to enable drone use in healthcare delivery such as medicine, blood, vaccines and organs. Ambulance drones also deliver defibrillators. [1]
In mid-March 2017, Matternet, Swiss Post and the Ticino EOC hospital group launched a project to use drones to regularly transport laboratory samples autonomously between two hospitals in Lugano. The

Federal Office for Civil Aviation (FOCA) has approved the project. In early 2017 test flights were completed successfully using M2 quadcopters, the very latest technology from Matternet. Further testing will be performed in summer 2017. Once the drone meets all the stringent criteria, independent drone flights will become ordinary, which is expected to occur in 2018. [10, 1] Matternet's M2 quadcopter can carry up to two kilograms, has a speed of 36 kilometers per hour and a maximum range of 20 kilometers with one kilogram on a single battery charge. Safety is ensured by the installed duplicates of the autopilot and other key sensors. A parachute will automatically deploy in the event of an emergency. The technology is certified by principal aviation authorities around the world such as National Aeronautics and Space Administration (NASA) and FOCA. [11, 12]

Nevada based UAV start-up Flirtey performed the first Federal Aviation Administration (FAA)-sanctioned drone delivery of medical supplies to a health clinic in rural Virginia, with the help of its partner, the University of Nevada at Reno. This delivery raises hopes that drones can transport supplies without issues, even in inhabited places. Flirtey drones have also transported items in the Nevada, Australia and New Zealand. [13]

In May 2016, Ehang and Lung Biotechnology PBC agreed to collaborate for fifteen years to optimize the Ehang 184, the first autonomous human transporting drone in the world, for organ deliveries. Every year, thousands of people die while waiting for organ transplants. This remarkable innovation in organ transport could save tens of thousands of lives. [14]

Zipline, a San Francisco based Drone start-up, and UPS are cooperating to create an autonomous drone network in Rwanda to deliver vaccines, blood and medical supplies to clinics in remote places. This project enables delivery of items to 12 million people in 30 minutes. Zipline and UPS are intending to remain partners to implement this idea in other countries. [15, 16] The drones can carry 3 pounds and have a speed of 100 km per hour. They do not land on these missions but rather drop cargo using paper parachutes. [17]

Table 1 outlines the key features of drones currently used in healthcare.

Table 1. Key features of drones in healthcare

Drone	Key features
Matternet M2 [12, 1]	Payload 2 kg, speed 36km/h, range 20km
Flirtey [13, 18, 19]	Payload 2.5kg, speed 2km in less than 5minutes, range 30km
Ehang184 [20]	Payload 100kg, speed 60km/h, duration above sea level 25min, 100% with green technology,

	powered by electricity only
Zipline [15, 16, 17]	Payload 1.5kg, speed 100km/h, range 70km
TU Delft ambulance drone [21]	Payload 4kg, speed100km/h, range 12km
Google Drones [22, 23]	Payload 2.3kg,
Vayu Drones [24]	Payload 2kg, range 60km

A prototype ambulance drone was created at TU Delft in the Netherlands, with a defibrillator and integrated video capability. In the event of an emergency, the drone should reach the emergency spot and the person close to the patient would get instructions on how to act until the emergency stuff reach the person in need. [21] While traditional services need 10 minutes for 4.6 square miles, this technology can fly the same distance in only one minute. This innovation therefore has significant potential to increase survival rate of cardiac arrest patients, with 80% versus 8% with traditional services. [21, 4]. A similar approach is used by Google, which has obtained a patent for a drone to provide medical supply to persons in need. The drone would also reach the patient prior to the emergency services. [22] In Madagascar, Vayu drones transported testing blood samples to the central laboratory. [24]
Table 2 gives a summary of application areas where drones are used in healthcare and in which countries.

Table 2. Application of drones in healthcare

Drone	Application in Healthcare	Country of application
Matternet M2 [12, 1]	Delivery of diagnostics or production samples from point of collection to laboratory	Haiti Bhutan the Dominican Republic Papua New Guinea Switzerland
Flirtey [13, 18, 19]	Delivery of medical supplies including food, water, first aid kit	Virginia Nevada New Zealand Australia
Ehang184 [20]	Organ delivery	United Arab Emirates
Zipline [15, 16, 17]	Delivery of Vaccines, blood, medical supply	Rwanda
TU Delft ambulance drone [21]	Delivery of defibrillators	Netherlands
Google Drones [22, 23]	Delivery of medical supplies with instructions on how to use	only patent obtained yet
Vayu Drones [24]	blood	Madagascar

The next section provides an insight into the hospital processes in Switzerland with a special focus on the key processes.

4. Processes in Swiss hospitals with a focus on the key processes

First, it is important to know who the process owners in a hospital are. Usually a chief process officer (CPO) is responsible for the process management of a company. Still there are many companies without a CPO so the role of managing a process is spread between people. The organizational structure in health care can be complex, with doctors, management and nurses needing to cooperate. Thus, it is difficult to define the distinct roles of a process management officer in a hospital. In every process, respective process owners/managers take a few responsibilities. Thus, the process manager or process owner has a vital role to play. They are responsible for the operational control of the processes. In a hospital, this person is most likely the senior doctor. S/he is responsible for a particular station and for the operative processes. There is also the ward physician who is liable for the operational process execution and monitoring. [25]
In process management it is important to distinguish between three kinds of processes. First, there is a leadership process. This includes processes in planning, strategy and controlling. These are mostly defined by the top management who are in charge. Next, there are many core processes in a hospital. One of the first core processes is patient admission. This also includes sub processes like appointment and admission. The second core process is nursing. The sub processes here are nursing admission, patient care and kitchen. Furthermore there is a medical treatment that is also defined as core process. Sub processes here include medical admission, conversation, diagnosis and therapy. Another important process is technical medical treatment, which can include laboratory, electrocardiography (ECG), x-ray and cardiograph. These processes all involve the patient. Therefore, these processes are very important for the hospital and must be perfectly organized. There are two more core processes such as service settlement and dismissal. In service settlement, a sub process is cooperation between the hospital and health insurance funds. The dismissal of a patient includes sub processes such as

settlement of additional services and registration. These core processes do not work on their own. Every process should have sub processes and every sub process is to some extent different from the other. The last type of processes are supporting processes. These processes have a low value for the added value and are not usually competition-critical processes. One of their main jobs is to cooperate with the core processes so that they can be done better. In hospitals, there are supporting processes such as procurement, accounting, HR management, IT and facility management. They also contain their respective sub processes. In procurement, this would be buying and distributing material and other services. The IT is another important supporting process that has a lot of influence on the standardization of most processes in hospitals. [25]

The different types of processes show that it is a complex job to manage, control and monitor all processes of a hospital. In addition, the roles in hospitals are not always clear so it makes it more difficult to manage processes. However, one cannot deny that optimizing processes can and will improve the benefit of any company. [25]

5. Approach description

This section describes the approach we took in the current study. It provides a complete overview of our research questions, methods and selection of interview partners.

5.1 Study research questions

Our structured and extensive literature research as summarized above revealed that implementation possibilities of drones in Swiss hospitals has not yet been thoroughly examined. The aim of this study is to close this gap by focusing on the following research question:

- Which drone implementation possibilities apply for Swiss hospitals?

This main question is to be answered in two papers one of which is the current one while the second one will follow. The sub-questions for the current paper are as follows:

- What is the current state of the art with regards to drones?
- To what extent is drone technology already in use today?
- Which challenges are to be considered during the implementation?
- Which regulatory constraints are to be considered?

- What are the requirements for implementation?
- Which are the challenges in terms of the topic hospitals?
- Which processes in hospitals have potential for drone implementation?

5.2 Methodology

To ensure triangulation in the qualitative analysis, a method mix of literature research and explorative expert interviews was implemented. First, a two-step literature research was conducted. The first step was to obtain an overview of the state of the art on drone technology and the second to understand the main hospital processes. A respective predefined literature strategy was implemented for each step to ensure a structured, systematic and efficient review with a transparent method. After having obtained a comprehensive understanding of the state of the art on drone technology and hospital processes, explorative expert interviews were conducted with experts in four selected Swiss hospitals. The aim of the interviews was on the one hand to complement the knowledge obtained through the literature strategy on the other hand to find out possible implementation scenarios for drones in Swiss hospitals. The interviews were conducted personally instead of through written questionnaires, in order to allow open questions and to cover all of the questions precisely [29,30]. Given the nature of the questions to be answered, we believe that this method is the most suitable.

5.3 Selection of interview partner and questions

After the selection of the research method, one of the most important steps was to select the most suitable hospitals and the right expert within the hospitals.

We started with the big picture by drawing a map of the Swiss hospital system. This shows the two main types of hospitals: special clinics and general hospitals. See Figure 1: Typology of hospitals in Switzerland. [26]
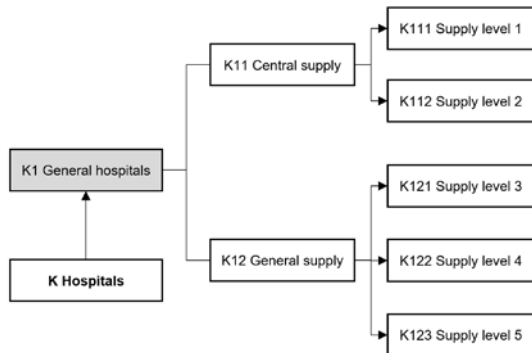
Figure 1. Typology of hospitals in Switzerland

Within general hospitals there are 5 different supply levels (K111, K112, K121, K122, K123). Special clinics were eliminated as our aim was to reach an outcome applicable to all Swiss hospitals. As special clinics are specialized in only certain areas such as psychiatry, pediatrics, etc. a study outcome focused on those would not necessarily result in an outcome that could be generalized.

We first decided to interview at least one hospital of each level of the general hospitals. However, our research revealed that regional hospitals and special hospitals did not have their own IT and therefore are not be able to autonomously implement drone technology. We therefore decided to focus on university (K111) and canton hospitals (K112), which have their own IT and are in principle able to implement such a drone technology project. After making this decision we contacted all university hospitals and the biggest canton hospitals and conducted interviews with the ones open to a drone project. This resulted in following interview partners:

- Canton hospital Aarau
- Canton hospital Luzern
- University hospital Zurich
- Canton hospital Graubünden

Another crucial point is to select the right interview questions. We defined the questions based on the outcome of the literature research with a focus on the defined research questions. The outcomes of the interviews are analyzed and summarized in the following chapters.

6. Interviews: Main findings

As we already described, we did four interviews with hospitals in Switzerland. Our focus was to find out how and where we could implement the usage of drones. This helped us discover many areas in which drones could be used.

6.1 Introduction to the interviews

In the introduction of the interview, we asked questions about the interviewee's department and if the IT is mainly in-house or outsourced.

The four responsible people from the different hospitals were mostly head of IT or head of an area that collaborates strongly with IT. University hospital Zurich and Canton hospital Luzern do everything in-house, which can be an advantage if you have enough resources. The Canton hospital Aarau uses a different approach, outsourcing its whole IT-operation. This also has its pros and cons. The IT in Swiss hospitals is also divided into different fields. These include medical application and services. Then there are fields such as logistics and administration. Furthermore, there are areas like first-level-support, systems engineering and IT-controlling. Some of the interview partners also talked about drones before we started asking questions about them, which was very interesting as it indicated that drones are not new and are already being talked about by different experts.

After a brief introduction, the interview moved forward to the main part: The usage of drones.

6.2 Drone technology and the use of drones in hospitals

The focus in the main part of the interview is the use of drones. First, the interviewees talked about their own experiences with drones. One of them already uses drones at home for private use, mainly for taking pictures and just flying around.

The use of drones in hospitals was also discussed. It turned out to be a focus area for all the interview partners. For instance, the university hospital in Zurich has a pharmacy in Schlieren which delivers medications, which can take more than half an hour by car or with public transport to arrive. In this situation, drones could be used as delivery tools. There is an enormous potential to save time and coordinate the deliveries of important medicines better. There is also the potential of use on the campus of hospitals. This means that from point A to point B you have a route and can transport different utilities, medication and other objects. Though it depends on the type of drone, it is a possible process, which could be optimized. One of the interview partners thought about the use of drones in emergencies and in rescues. In addition, he focused on the capacity of drones to make deliveries, even though the Canton hospital Luzern has a pneumatic tube system. Nevertheless, they would think about implementing drones to optimize their logistics chain. Additionally, the use in emergencies was also

being talked about. Drones could have a live camera implemented and then be sent out in emergencies. A doctor could then actively react to the situation and help by communicating and suggesting what to do. Another interview partner had written a concept in which he described how a drone could be used in a hospital. The focus was on drone deliveries between different hospitals which are approximately 30 kilometers apart. In his concept, he described different challenges such as approvals and budgets. One partner talked about the use of drones in transport of light goods weighting approximately 15 kilograms.

It turns out that the use of drones in hospital could be mainly focused on delivery and transport. Thus, it improves the logistics chain and optimizes processes.

6.3 Management of projects and challenges of drone usage in Swiss hospitals

In Swiss hospitals, there are differences regarding project management, especially in terms of drones and other modern technologies. One interview partner is the logistics manager and is responsible for such projects. In cooperation with the executive board, he initiates projects including innovative technologies such as drones. In another hospital, a project board decides if the idea is good enough. Then they present it to the CIO or CEO. There are also hospitals that are not the first mover and do not initiate such projects. They wait for others to take the first step and then adapt fast. In the university hospital in Zurich it is not easy to implement drone projects. 44 clinics deliver their ideas to the business-service responsible in each medical sector. The business-service responsible then collects all ideas together. Then a committee reviews all ideas, prioritizes them, and defines when they will be implemented.

There are also differences between the amount of time the hospitals considered it would take for a project to be implemented. Some hospitals said that it could take about 6 months to start with a pilot project. Depending on numerous factors like budget, organization and regulations, it could also take up to three years until a project including drones is implemented. A few hospitals have special regulations regarding project like this. If the sum of the project exceeds 250,000 Swiss Francs they must seek national or cantonal approval. With these kind of approvals it can take up to three to five years until the hospital can implement them. Even projects that do not exceed the sum listed above require about two years to be launched. Various factors influence how and when a project can be implemented.

So, what do we need for the acceptance of such a project? A main aspect several hospitals agreed on was

economic viability. This means that the project must create value and operating efficiency. It also needs to deliver a benefit that the hospital can take advantage of and use to create better processes. Furthermore, some interview partners also indicated that their customers must accept the recent technology. The main customers in a hospital are humans who are sick or injured. Another point that was discussed is that there needs to be some sort of a use case or business case so that the value and the economic viability can be estimated. It is also always a battle between technology and regulation. One interview partner said that it is sometimes difficult to implement innovative technologies due to regulation. Towards the end of the interviews, all partners indicated that a pilot project is necessary before such a technology would be fully accepted. All interviewees stated they would like to use drones in their hospitals. This paragraph shows that it is important to understand the technology itself and later analyze every aspect that is necessary for the use of drones. Then it will be possible to initiate a project.

7. Suggestions for use of drones in Swiss hospitals

The interviews show that there are a few aspects and one big area that drones can be used for. We suggest that the hospitals focus the use of drones in logistics, or more specifically in delivery. There is also an ongoing project with the post and the hospital association of Ticino. This case could be used as an example case and be further analyzed. Some Swiss hospitals must wait for the others to take the first step and others need to be one of the first to analyze and adapt such a new technology. In Ticino it is used for the delivery of specimens between two hospitals. This is an important milestone for other hospitals. [27] As it stands now, it will be a few years until drones can be used in many different areas of our lives. Solely focusing on drones in healthcare would be wrong. To get a broad understanding of drones and their technology it is important for hospitals to analyze other areas such as the military and companies like UPS or Amazon which are already using this technology. For example, Amazon started drone delivery trials in the UK in December 2016. The first delivery took 13 minutes after being told to take off to reach their owner. These tests are still ongoing and Amazon has authorization from the Civil Aviation Authority. This technology will speed up delivery time and could be used as a business case for hospitals in Switzerland that want to start drone deliveries between two or more hospitals. [28] There are many more cases that could help Swiss hospitals to learn and adapt. The following table shows

areas that drones could be used. There is also a case study in which drones are used in humanitarian action. This case offers useful insights for the area of emergencies in which drones will aid as the first help in a difficult situation. The following tables show areas to focus on for Swiss hospitals with regards to drones.

Table 3. Areas of hospitals to use a drone

Area	Purpose
Logistics	Delivery of drugs and other utilities from hospital to hospital. Also for deliveries from pharmacies to hospitals. Very important for medications which are used for cancer and other complex diseases with a low pharmacological half-life.
Emergencies	First aid with a camera. Drones can also help with catastrophes such as avalanches and earthquakes.

It is understood that drones could also be used for the deliveries of utilities like tools for physicians but we would recommend keeping the focus on a few areas so that projects can be initiated.

8. Concluding remarks and future research

This research shows a "new" technology that can be used in different ways and in different areas of our lives. Not only is it important to understand a variety of processes which are connected to each other but also to have an overall view. Through our research we conducted several methods and had several milestones to achieve. The literature research in which drones and hospitals' processes were analyzed was one of the milestones that took a considerable time of our research. We collected literature, magazines and other research. We also analyzed the websites of a number of companies that produce drones. This helped to pave the way for the interviews. It was significant to understand the technology itself and the processes of Swiss hospitals. Only then could we prepare meaningful questions for our interview partners at the four hospitals. An issue we had was that it was difficult to find interview partners. We contacted several team leaders from different Swiss hospitals by phone and by mail. After that we realized that hospitals are categorized based on many factors. Thus, we created a list of hospitals, we contacted them and at the end, we could only do an interview with four people. However, it helped us to understand the processes of a hospital. In addition, we identified several areas for

drones to be used in a hospital. The areas are mainly in the range of logistics, mainly in the delivery of tools, medicines, and specimens. This was not surprising for us because in our literature research we realized the potential of drone usage in deliveries for hospitals. The confirmation of this through interviews was satisfying and made everything clearer.

Drones can support the logistics of hospitals in a way that has never been seen before. Our results show that many hospitals are willing to think about it and some of them have already started with early research.

For future research, it is important to start with the results of this paper. An area for future research could be the implementation of drones in hospital logistics using a concrete example. We will create a road map in which the drone implantation is explained based on a hospital. This will be conducted in the next paper and will help Swiss hospitals to analyze and understand the value of drone usage.

Another area for future research could be a professional use of drones in-house. This means that drones are implemented in the infrastructure of the buildings and can conduct automated deliveries in house. There are still many issues to consider. An implementation needs the support of board members, project managers and those responsible for infrastructure. After assessing the economic value there will be room for creating a use case and starting a pilot project. Finally, drones can be used for the delivery of drugs between hospitals, laboratories, and pharmacies. Hospitals however need to be aware that the whole process from the beginning to end will be ambitious.

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