Cure for Health Care? Using Drone Technology in Hospital Processes—An Explorative Analysis

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Abstract While developed and initially used by militaries, the technology of unmanned aerial vehicles (UAVs), commonly known as drones, has already proven 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. The paper at hand aims at outlining the potential and possible fields of application using drone technology inside the Swiss hospital environment. The research problem is analyzed from two main perspectives: (1) the hospital environment with its domain-specific conditions, particularities, and constraints, and (2) the field of drones, including its range of best practices, regulations, standards, and available technology. As part of a survey, face-to-face interviews with CIOs and IT executives of four Swiss hospitals were conducted on the status quo of drone technology in the Swiss hospital environment providing valuable insights into the current situation and the possible fields of application. Exploring the reasons for the skeptical attitude toward drone technology in hospitals, the study revealed that different priorities, lack of motivation, and budget constraints were mentioned as the three major obstacles to improving the situation.

Keywords Health care · Switzerland · Drone

1 Introduction

The demographic development of the society, the medical–technical progress, and the change of values are faced with limited resources for health care. Legislative reform efforts, for that reason primarily aim at the increase of productivity within health care, while ensuring the quality of care, however, the therein justified changed conditions issue continually a challenge to actors in the hospital market, which make it highly dependent on the political priority of the day.

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The Swiss healthcare system ranks among the best healthcare systems in the world but is, at the same time, one of the most expensive. This conclusion comes from the review on health care by the Organization for Economic Cooperation and Development (OECD) and the World Health Organization (WHO) [1]. Like many developed countries, Switzerland is facing increasing costs for its healthcare system: 11.4% of the Swiss gross domestic product (GDP) in 2009 was spent on health care, whereas the OECD average was 9.6%.

Since 2009, hospitals in Switzerland have been transitioning to a new remuneration approach providing case-based payments. The *"SwissDRG"* is being introduced in 2012 and is becoming the dominant payment mechanism for hospitals in Switzerland. Motivated by ongoing reform efforts in the Swiss healthcare sector, for the affected hospitals, it is necessary to develop concepts to work more efficiently and have control over their medical, nursing, and administrative processes. Hospitals in Switzerland are constantly searching for possibilities to save costs and improve processes.

As shown in other developed countries, reforms beginning at the hospitals inside show a tremendous potential for improvement, promising optimization effects by transforming existing (organizational) structures, consolidating provided services (specialization) and a more efficient use of technology [2] (p. 208).

When it comes to enhancements of the treatment chain, technology has proven to be a driver for improving process quality such as patient records were collected and communicated more easily across admitting physicians or medical and nursing staff was relieved from compulsory documenting tasks. The efficient use of technology thereby has shown a direct effect on the quality of care and patient safety [3] (p. 64).

While developed and initially used by militaries, the technology of unmanned aerial vehicles (UAVs), commonly known as "drones," have already proven 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 [4–6].

The paper at hand aims at outlining the potential and possible fields of application using drone technology inside the Swiss hospital environment.

Section two summaries the problem statement of the study. The third section provides insights on the research approach and methodology applied. The fourth section summarizes the main finding of the study. The paper closed with a conclusion and some final remarks.

2 Problem Statement

Although the research work at hand focusses on the Swiss healthcare system and its hospitals, it may be applicable to different countries that share the same kinds of problems. The challenges facing the Swiss healthcare system for the future are multi-layered and complex. The research problem is therefore analyzed from two main perspectives: (1) the hospital environment with its domain-specific conditions,

particularities, and constraints and (2) the field of drones, including its range of best practices, regulations, standards, and available technology.

Challenges facing the endeavor to achieve a fundamental reorganization of the Swiss healthcare sector and the therein implied approach to optimized processes through the usage of drones include: (1) legal restraints caused by Switzerland's federal structure with its complex system of powers and responsibilities, (2) the political tradition of direct democracy and governance through consensus, (3) closely meshed organizational and social structures within the hospital and among its stakeholders, and (4) an under-represented role of IT characterized by years of increased heterogeneous IT systems. These are just a few aspects making the healthcare sector a sensible field for the management of technology [2] (p. 218).

Since the beginning of the 1990s, hospitals have evolved from self-regulating, autonomous systems into externally regulated modern enterprises. Despite this long period of time, this transition is still incomplete and related topics such as entrepreneurial thinking, interdisciplinary cooperation, or even process-oriented workflows are still open issues for most hospitals today [7] (p. 218).

The necessary meshing of processes is all too often hampered by a three-lane organization of healthcare services, represented through medical care, nursing service, and administration.

Although numerous contributions can be found for dealing with approaches for a more comprehensive, inter-professional, and interdisciplinary consideration of workflows according to clinical pathways [2], until today, hospitals have had difficulties restructuring existing organizational structures into a more process- and patient-oriented manner [7] (p. 148).

On the other hand, the idea of autonomous flying already promises significant improvements for the healthcare sector [8]. Drone manufacturers have already started experimenting with ambulance drones that deliver defibrillators in remote locations that lack adequate roads [9]. UAV commonly known as "drones" is vehicles that fly unmanned. Alternative terms include remotely piloted aircraft (RPA) or unmanned aircraft system (UAS). Drones are available in numerous sizes and configurations. They can operate under distant control by a human or autonomously by onboard computers [10]. 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 the usage of global positioning systems (GPS), mobile applications, onboard camera(s), and other composite materials [9, 10].

Although their usage promises significant life- and cost-saving innovations, drones also have to overcome regulations and concerns related to safety, security, criminal acts, and invasion of privacy [11]. This includes concerns about taking unauthorized photos of objects or areas using drones, packages being stolen, for instance, through shooting down drones, flying over private grounds, and the risk of collision with other aircraft.

The USA are one of the countries with the most restrictive drone regulation, while developing countries such as Rwanda are less restrictive since the UAVs have the potential of saving lives especially in areas where traditional transportation reaches it

limits [12]. In Switzerland, a Federal Office of Civil Aviation (FOCA) issued license is required for drones weighing more than 30 kilograms (kg). For drones under 30 kg, license is only required for flights over masses or without direct eye contact [13].

Some of the leading drone manufacturers are currently conducting experiments to enable drone use in health care, e.g., for delivering medicine, blood, vaccines, and organs [14]. In 2017, Matternet, Swiss Post, and the Lugano Regional Hospital (EOC) launched a project to use drones to transport laboratory samples autonomously between two hospitals in the canton of Ticino/Switzerland. In early 2017, test flights were completed successfully using M2 quadcopters, the very last technology from Matternet. Once the drone meets all the stringent criteria, independent drone flights will become ordinary, which is expected to occur in 2018 [8]. Matternet's M2 quadcopter can carry up to 2 kg and has a speed of 36 km per hour (km/h) and a maximum range of 20 kilometer (km) with only one 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 [15, 16].

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 [17].

In 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 [18].

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 min. Zipline and UPS are intending to remain partners to implement this idea in other countries [19, 20]. The drones can carry 1.5 kg and have a speed of 100 km per hour. They do not land on these missions but rather drop cargo using paper parachutes [21].

A prototype ambulance drone was created at the Delft University of Technology (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 doctor arrives [22]. While traditional services need 10 min 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 [9, 22].

Table 1. Fields of application and key features of drones used in health care

Drone specification	Payload (kg)	Speed	Range	Flied of application in health care
Matternet M2 [14, 16]	2	36 km/h	20 km	Delivery of diagnostics or production samples from point of collection to laboratory
Flirtey [17, 32, 33]	2.5	20 km/h	30 km	Delivery of medical supplies including food, water, first aid kit
Ehang184 [34]	100	60 km/h	N/A	Organ delivery
Zipline [19–21]	1.5	100 km/h	70 km	Delivery of vaccines, blood, medical supply
TU Delft Ambulance Drone [22]	4	100 km/h	12 km	Delivery of defibrillators
Google Drone [23, 35]	2.3	N/A	N/A	Delivery of medical supplies with instructions on how to use
Vayu Drone [24]	2	N/A	60 km	Blood samples

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 is able to reach the patient prior to the emergency services [23].

Another example from Madagascar proved that drones are able to transport blood samples to a central laboratory [24].

Table 1 gives a summary of application areas in health care and some key features of drones.

The outlined research problem revealed that a few drone implementation scenarios can be found in health care in general. However, the investigation revealed that the fields of application using drone technology in Swiss hospitals have not yet been thoroughly examined. Existing approaches are lacking scenarios covering processes inside the hospital environment facing the endeavor to achieve a fundamental reorganization of the Swiss healthcare sector and the therein implied approach to optimized processes.

The next section provides an insight into the research approach taken.

3 Research Approach and Study Design

The previously described research motivation and subsequent research problem, however, allow at least the formulation of a preliminary research question in terms of a "general focus research question" [25] (p. 31).

Based on the research motivation and the knowledge-oriented objective of this research work, the following research question is addressed:

> What fields of application of drone technology are applicable inside the Swiss hospital environment with respect to its domain-specific characteristics, particularities, and limitations?

The following sections seek to empirically verify the gained insights from the previous chapters, outlining the hospital as complex and sensitive environment for the adoption of drone technology. With a focus on the demand for a hospital-specific approach for the adoption of drone technology, the challenges of its implementation in the Swiss hospital environment is discussed.

The author of this paper conducted a survey on the status quo of drone technology in the Swiss hospital environment providing valuable insights into the current situation and the possible fields of application. The purpose of the research was to reach members of the IT management to determine their priorities and actions taken relative to drone technology, as well as their need for methods to help ensure its effectiveness [26, 27].

Hence, the objective of the survey was

- to analyze the degree to which the principles of drone technology and their usage are recognized, established, and accepted by CIOs and IT executives of Swiss hospitals,
- to determine what level of drone technology and related process management expertise exists and which technologies and fields of application are known and are (or will be) adopted and, finally,
- to examine possible implementation scenarios in the Swiss hospital environment.

Following the approach by Denzin, data triangulation is applied to this research work enhancing validity, reliability, and richness of the research results [28]. In doing so, the involvement of different hospitals in terms of their ownership (i.e., public and fully private hospitals) and scope of work (i.e., centralized care level 1 and 2) from the Swiss healthcare sector is planned. Based on the approach by the Swiss Federal Office of Public Health (FOPH), four healthcare institutions are selected [29]. With the selection of healthcare organizations from various categories, different scenarios can be investigated and integrated, allowing for a critical discussion of different perspectives and contributing to the depth and importance of the study. Table 2 summarizes the configuration of the selected hospitals participating in the study. The related information including level of care, ownership, number of employees, and beds is held in confidence at the request of the hospitals.

The semi-structured interviews were carried out in four cantons, covering two geographic regions within Switzerland (i.e., German and Rhaeto Romance region).

Table 2. Information about anonymous hospitals participating in the study

	Hospital A	Hospital B	Hospital C	Hospital D
Level of care	Centralized care level 1	Centralized care level 2	Centralized care level 2	Centralized care level 2
Ownership	Public	Public	Private	Public
Number of employees	7000	2700	4800	5800
Number of beds	920	530	1400	830
Number of inpatients (outpatients)	37,000 (273,000)	25,000 (105,000)	80,000 (N/A)	36,000 (244,000)
Role of participant	CIO	IT manager	CIO	IT manager
Organizational structure	Functional organization	Matrix organization	Affiliated doctors	Functional organization
Organization of IT department	Centralized	Centralized	Hybrid	Outsourced

As part of the survey, face-to-face interviews with CIOs and IT executives of four Swiss hospitals were conducted from March 2017 until May 2017 in order to identify the lessons learned in implementing and embedding drone technology. The survey covered nearly 21% of all beds according to the latest annual report by the Federal Statistical Office in Switzerland [29]. The interview questions have been defined based on the outcome of the literature research (problem statement).

The outcomes of the interviews are summarized in the following sections.

4 Findings

It turned out that all four hospitals have already thought about the possibility of using drones as part of their processes. For instance, Hospital A has an associated pharmacy delivering medications, which can take more than half an hour by car or public transportation. In this situation, drones could be used to support the delivery, providing an enormous potential to save time and coordinate the deliveries. All hospitals agreed that there is the potential of using drones on the hospital campus—meaning, that from point A to point B different utilities, medication or blood samples can be transported. Hospitals B and C stressed that they are currently using pneumatic tube system for carrying small objects (e.g., laboratory sample, patient records, and orders). These systems are expensive and difficult to be implemented in the aftermath and sensitive to errors. Hospital D emphasized that their hospital campus includes various heritage buildings, where the implementation of pneumatic tube systems is not allowed.

Hospitals A and B thought about the use of drones in emergencies and rescues. Drones could be equipped with a live camera allowing a physician to react on a situation by communicating and suggesting what to do. The interview partner from Hospital A has written a concept in which he described how a drone could be used in a hospital. The focus was on drone delivery between different hospitals which are approximately 30 km apart. In his concept, he described different challenges such as approvals and budgets. Hospital D talked about the use of drones in transport of light goods weighting approximately 15 kg.

It turns out that the usage of drones in hospital mainly focuses on transportation according to the supply chain between different departments.

All interview partners emphasized that differences exist managing ambitions implementing new technologies. Approaches that can be found in Swiss hospitals dealing with the involvement of technology at the management level are performed on a case-by-case basis, representing disorganized issues rather than standardized and well-established processes. Differentiating these findings in more detail, it has become obvious that private hospitals, in comparison to public hospitals, have increasingly recognized the strategic importance of technology, since all of the private hospitals surveyed had technology strategy committees in place, which either report directly to the hospital board of directors or to the CEO.

The study revealed that IT in Hospitals A and B is all too often considered a fire brigade being responsible for the implementation of any kind of hard- or software that has been procured by the different organizational units. In addition, management's involvement is needed in order to establish accepted policies that allow for the consolidation, structuring, and planning and, at the same time, address business concerns. Emphasizing the use of established methods, it can be assumed that the IT manager relies on best practices and existing concepts rather than experimenting with unconfirmed approaches. These hospitals see themselves not as first mover. They wait for others to take the first step. In Hospital A, 44 clinics deliver their ideas to the business-service responsible in each medical sector. The business-service responsible collects all ideas, a committee then reviews and prioritizes them and, finally, defines if and when they will be implemented.

There are also differences of the time horizons the hospital consider it would take for a project to be implemented. Hospitals C and D mentioned 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 would be 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 cantonal or national approval. With these kinds of approvals, it can take up to three to five years until the hospital can implement the project. Even projects that do not exceed the sum listed above require about two years to be launched.

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

Table 3. Fields of application of drones in hospitals

Area	Purpose
Logistics	Delivery of drugs and other utilities from hospital to hospital. Deliveries from pharmacies to hospitals
Emergencies	First aid using a camera

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. One interview partner said that it is sometimes difficult to implement innovative technologies due to regulation (Hospital A). Toward the end of the interviews, all partners indicated that a pilot project is necessary before such a technology would be fully accepted.

Exploring the reasons for the skeptical attitude toward drone technology in hospitals, the study revealed that different priorities, lack of motivation, and budget constraints were mentioned as the three major obstacles to improving the situation.

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 Swiss 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 [30]. 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 successfully. For example, Amazon started drone delivery trials in the UK in December 2016. The first delivery took 13 min after being told to take off to reach the destination. 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 [31]. 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 (Table 3).

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.

5 Conclusion and Final Remarks

Our results prove that many hospitals are willing to think about new technologies and some of them have already started with early research.

An area for future research could be the implementation of drones in hospital logistics using a concrete example. A road map should be created outlining the necessary steps to be taken for implementing drone technology.

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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