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Usage and Acceptance of Drone Technology in Healthcare – Exploring Patients and Physicians Perspective

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Abstract

Modern technologies such as virtual reality, robots or drones are getting more and more important for organizations. Accordingly, the question arises in which industries these technologies can make a difference. This paper examines the use of drones in Swiss hospitals. A literature review is conducted outlining the most relevant flied of application for drone usage in healthcare. These use cases are then qualitatively rated by employees and patients of hospitals from different regions in Switzerland. Among others, the analysis revealed that employees and patients have strong concerns about drone usage in the hospital environment in the case drones provide diagnosis capabilities, but show less doubts if drones are used for delivery processes.

1. Introduction

The demographic development of the society, the medical technical progress, and the change of values are faced with limited resources for healthcare. 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*. Central catalyzer of these changes is the setup of incentives in inpatient care by diagnostic related groups (DRGs) in many European countries [1] (p.14). 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 on-going reform efforts in the Swiss health care 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.

When it comes to enhancements of the treatment chain, IT 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 IT thereby has shown a direct effect on the quality of care and patient safety [2] (p.64). This endeavor requires, besides a vast understanding of related medical, nursing, and administrative processes, a proper utilization of given IT resources, the ability to deal with innovation as well as far-sighted alignment of IT issues with hospital objectives.

This calls for effective usage of given technologies. 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 information technology (IT) [3] (p.208).

One technology that has proven its effectiveness in other industries are drones. While developed and initially used by militaries, drones 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].

The development and mass production of the first drones with wireless technology is going back to World War I. Up until the end of the millennium, drones were predominantly used in military. As the technology advanced, drones and their usage started drawing attention from other areas such as the healthcare industry. One of the main advantages of using drones in the healthcare industry is time saving. In an emergency situation, essential vaccines, drugs or blood samples can be transported much quicker compared to regular procedures. The San Francisco (CA) based company Zipline International Inc. is currently working with the Rwandan government to

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deliver blood and vaccines on demand using drone technology. The company plans to expand into Tanzania next year. Furthermore, Matternet Inc., based in Menlo Park (CA), has already run pilot projects in Haiti, Bhutan and Papua New Guinea to prove drone efficiency in inaccessible areas [4].

Other examples of life-saving applications include drones equipped with defibrillators, first aid kits, medical devices or simply transporting water and food to a disaster area.

The subject of the work presented here is the investigation of how drones can be used in the healthcare sector in Switzerland in general and in Swiss hospitals in particular.

The paper is structured as follows: Sections 2 summarizes the problem statement and objectives. Section 3 gives an overview of existing drone technologies. Section 4 investigates literature in the field and outlines relevant uses cases for drone usage in healthcare. Section 5 describes the method of the questionnaire, whereas section 6 analyzes the results of the questionnaire. At the end, section 7 contains the discussion followed by the conclusion.

2. Problem Statement and Objectives

The difficulties to deal with in order to set up the Swiss healthcare system for the future are multi-layered and complex and come from two directions: the Swiss (1) hospital environment and the (2) general challenges of adopting new technologies.

Given an aging society, other challenges to be met by the endeavor toward a fundamental reorganization of the healthcare sector were investigated such as (1) legal restraints caused on Switzerland's federal structure with a complex system of powers and responsibilities [26], (2) the political tradition of direct democracy and governance through consensus [27], (3) closely-meshed organizational and social structures within the hospital and between its stakeholders [30]; [28]; [29], and (4) an underrepresented standing of the IT department characterized by over the years increased heterogeneous IT systems [28]. The functional organization in hospitals is characterized by a hierarchical tripartite division mostly performed according to given jobs or varieties of provided services. Medical care, nursing service, and administration are the prevailing job classifications, which influence to a great extent the organizational design. In practice, the functional organization causes not only physical separation of the departments, but, more often, a *"life of its own"* caused by partial-autonomous decision-making [28]. Most of the clinical divisions have their own divisional director usually staffed by a senior consultant, their own nursing care, and their own administrative staff, along with their own information systems and budget responsibility. Considering the role of IT in the functional organization, it becomes obvious that IT is usually organized around the administration which reports to the director of finance or infrastructure and, thus, is considered a support function as it is not directly represented in the hospital management. The demand for IT integration challenges the traditional organization of the hospital as an entity divided by politics and competences according to medical functions. In the past, this has led to a monolithic information island with a great number of point-to-point connections between vast amounts of specialized applications across the hospital, representing the prevailing fact that hospitals today are still not considered one entity, but rather as a collection of fragmented, mostly autonomous acting entities with departmental targets, budgets, and personnel responsibilities. Given these challenges in the healthcare sector, this calls for clearly defined scenarios, describing how drones technology can be applied in the hospital environment.

Therefore, the following research question (RQ 1) is defined:

RQ1: "How can the adoption of drone technology in hospitals be systematically supported with respect to domain-specific characteristics, particularities, and limitations?"

In order to gain deeper perceptions of related issues, answering the research question encompasses the following accompanying research questions:

RQ 1.1. What kind of fields of application in hospitals can be identified using drone technology?
RQ 1.2. What is the attitude of stakeholders (patients, physicians, nurses) towards the use of drones in hospitals?

In the next section, insights on done technology and available applications are given.

3. 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 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 [31]. 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 [32]. 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 [32]; [33].

While developed and initially used by militaries, drones 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.

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]. In general, the laws concerning the use of drones are divided by purpose of use (commercial, private), weight of the drone, flying within the visual line of sight or flying zone. Therefore, FOCA provides a drone guide containing the different laws and regulations for each specific use case. The main questions in the drone guide are:

- Does the drone have a camera?
- What is the drone's weight?
- In which zone will the drone fly?
- Do you fly inside or outside your line of sight?
- Do you fly near a civil or military landing strip?
- Do you fly above a crowd?

The next section aims at outlining existing scenarios of drone usage in healthcare.

4. Drone Usage in Healthcare: Literature Review

The systematic literature review is based on the approach by [25].
The objective of the systematic literature review is to explore the existing field research taking the usage of drone technology into consideration. It aims at outlining possible uses cases for drones in the hospital environment.

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 2019 [10]. 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 the University of 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 a central laboratory [24].
Table 2 gives a summary of fields of application where drones are currently used in healthcare.

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
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

Given the objectives of this research work, concentrating on the hospital environment, rather on drone usage in the healthcare section (cg. Section 2), the following four use cases are identified for drone usage in hospitals:

1. **Delivery drone** (delivery of blood, medication or vaccines)
2. **Telemedicine drone** (diagnosis capabilities e.g. ultrasound images, cardiac ultrasound)
3. **Emergency drone** (surveillance until first aid arrives, especially in rural areas)
4. **Hospital drone** (transports medicine within the hospital environment, carries blood between hospital buildings)

These four use cases are considered in the further course of this research work. In the next section, the attitude of stakeholders towards the outlined use cases will be analyzed.

5. Study Design

In order to gain deeper perceptions of related issues using drones in the hospital environment, the following sections serves answering the second accompanying research question (RQ1.2) providing insights on the attitude of stakeholders. A quantitative analysis has been conducted consisting of 23 questions. The closed questions contain single-, multiple-choice and yes/no questions. The questionnaire has been divided into the following topics:

- Questions about the person
- Questions about the hospital
- Assessment of the use cases

It is important to mention that both, the questions about the person and about the hospital, include a total of two "filter questions". The first filter question is about a person's place of residence. The analysis is restricted to persons living in Switzerland. The second filter question is about the working place of the employees. The analysis is restricted to employees who work in a hospital which is placed in a German speaking canton of Switzerland.

Furthermore, the questions about the person contain the age and whether the person is working in a hospital or not. The objective is to analyze, if there is a significant difference between employees and patients or their age.

The questions about the hospital contain a subdivision of different groups. The employees were asked about the hospital area (doctors, nursing staff, medical-technical staff, medical-therapeutic staff and other functions), type of hospital (cantonal hospital, university hospital, private hospital and others) and residence of the hospital (for example region of Basel). The subdivision of the hospital area and the type of hospital is oriented on the Federal Statistical Office Switzerland.

Furthermore, the four use cases are integrated in the questionnaire. The opinions on the use cases were measured on a Likert scale with four stages (meaningful, rather meaningful, rather not meaningful, and not meaningful). In addition, the positive and negative arguments are gathered with the use of closed and open questions. In total 172 replies of different stakeholders could be achieved.

6. Results

6.1 Descriptive Analysis

The data gathered from the replies have been transformed as follows. The datasets consist of 172 observations. All samples with missing value have been excluded and all outliers have been deleted (e.g. Age=0 etc.). All samples with habitants from outside of Switzerland or from non-German speaking states have been deleted as well, since the research focuses exclusively on the German speaking part of Switzerland. There were 148 observations left in the dataset. The descriptive analysis considers patients (29) and employees (119).

Table 3. Descriptive analysis

Use Cases	Min.	Max.	Average	Standard Deviation (SD)
Delivery drone	1	4	2.70	.913
Telemedicine drone	1	4	1.71	.864
Emergency drone	1	4	3.02	.911
Hospital drone	1	4	1.56	.766
1=not meaningful, 2=rather not meaningful, 3=rather meaningful, 4=meaningful				

In general, the responses of each use case are different. Some use cases have been rated more meaningful and other use cases have been rated less meaningful. Below, each use case is separately analyzed based on the descriptive analysis (see Table 3)

Case1: Delivery drone

Drones are rated more meaningful for deliveries. However, the standard deviation (0.913) is the highest. The range of these use cases goes from not meaningful (=1) to meaningful (=4). The case is generally rated positive with an average of 2.7. Positive aspects of the use of drones for delivery are seen in their efficiency, economic purposes and innovation. The economic purposes are stated less meaningful compared to the efficiency and the innovation. Some negative aspects of the use of drones for delivery are also stated. The most negative stated aspect is regarding the endangering of safety, followed by privacy protection and the loss of workplaces for humans.

Case 2: Telemedicine drone

The use of drones for telemedicine is rated less meaningful. The standard deviation (SD = 0.864) is low compared to the other standard deviations. This means that the participants have a similar opinion on this case. However, the range of this use case goes from not meaningful (=1) to meaningful (=4). This case is generally rated negative, with an average of 1.71.

For telemedicine, the only noteworthy positive aspect is regarding the innovation. Most of the participants state no positive aspects. Negative aspects are mostly regarding the endangering of safety and privacy protection. Furthermore, there are some negative comments on this use case regarding the lack of social contact and the necessity of a drone for telemedicine.

Case 3: Emergency drone

For emergency situations, the responses are mostly positive, with an average of 3.02. However, the standard deviation of 0.911 is high compared to the other standard deviations. This leads to the statement that there are different opinions on this case. The range of this use case goes from not meaningful (=1) to meaningful (=4). The use of drones in emergency situations isn't seen as positive because of economic, efficiency and innovation reasons. However, there are some positive comments on this case regarding the possibility of saving lives. The negative aspects are mostly regarding the endangering of safety. However, most participants see no negative aspect for this use case.

Case 4: Hospital drone

The use of drones in a hospital is rated less meaningful. Both the responses (with an average of 1.156) and the standard deviation (0.766) are the lowest compared to the other cases. The range of this use case goes from not meaningful (=1) to meaningful (=4).

Based on these results, we can conclude that the participants had similar opinions on this use case, seeing the use of drones in hospitals as not meaningful. Most of the participants state no positive aspects. Again, the negative aspects are mostly regarding the endangering of safety. Other negative aspects are the loss of workplaces for humans, the increase of complexity of a hospital and the noise of a drone. There are also some negative comments regarding the lack and the importance of social contact.

6.2 Statistical Analysis

6.2.1 Analysis between employees and patients. Initially, the ANOVA test is conducted to analyze the differences between patients and employees concerning their attitude towards the use drones in hospitals in Switzerland. The H_0-hypothesis states there is no significant difference between patients and employees towards the attitude to the use of drone for the specific case. The variables case1 to case4 are set as dependent variables. The variable w_hospital (working in a hospital) is set as a dummy variable. The outcome of the ANOVA test after using the sample with 148 observations is as follows: Case1, Case3 and Case4 are not significant. It means that there is no significant difference between the patients' and employees' attitudes regarding the use of drones in hospitals in Switzerland. The ANOVA test for Case2 (Telemedicine drone) is shown in table 4.

Table 4. ANOVA test Case2

Analysis of Variance, response = Case2, treatment = w_hospital:

	Sum of squares	df	Mean square
Treatment	2.58934	1	2.58934
Residual	107.492	146	0.736245
Total	110.081	147	0.748851

F(1, 146) = 2.58934 / 0.736245 = 3.51695 [p-value 0.0627]

Level	n	mean	std. dev
0	119	1.78151	0.90347
1	29	1.44828	0.63168

Grand mean = 1.71622

For Case2, there is a significant difference between patients' and employees' attitudes regarding the use of a telemedicine drone in hospitals in Switzerland on a 10% significance level. It means the H_0-hypothesis can be rejected on a 10% significance level. There is weak evidence that there is a difference between patients and employees. The employees are more positive about the use of telemedicine drones than the patients.

To verify the overall attitude towards the use of drones in hospitals in Switzerland, a new variable CASE is set by computing the mean from the variables case1, case2, case3 and case4. The ANOVA test for CASE variable is shown in table 5.

Table 5. ANOVA test Case

Analysis of Variance, response = CASE, treatment = w_hospital:

	Sum of squares	df	Mean square
Treatment	0.669474	1	0.669474
Residual	43.8926	146	0.300634
Total	44.5621	147	0.303143

F(1, 146) = 0.669474 / 0.300634 = 2.22687 [p-value 0.1378]

Level	n	mean	std. dev
0	119	2.28151	0.56613
1	29	2.11207	0.46573

Grand mean = 2.24831

The p-value is .138. It means the H_0-hypothesis cannot be rejected. There is no significant difference in the overall attitude towards the use of drones in hospitals in Switzerland between patients and employees.

6.2.2 Analysis between employees. Further, an ordered Probit model is used to analyze the attitude of employees towards the use of drones in hospitals in Switzerland. The analysis with the ordered Probit focuses on characteristics from employees in hospitals in Switzerland. Therefore, the observations from the patients will be ignored. The sample without patients has 119 observations. The H_0-hypothesis states there is no significant difference between the independent variable and the dependent variable towards the attitude to the use of drone for the specific case. The variables case1, case2, case3 case4 and CASE are set as dependent variables and the variables hospital, department, leading position, state of workplace and age are set as independent variables. The independent nominal scaled variables hospital, department and state are set as dummy variables. There are only two observations in the variable department=1 (doctors) and four observations for the variable state=6 (central Switzerland). These dummy variables won`t be included in the model.

The ordered Probit model for case1 (delivery drone) is shown in table 6.

Table 6. Ordered Probit model Case1

Function evaluations: 62
Evaluations of gradient: 22

Model 1: Ordered Probit, using observations 1-119
Dependent variable: Case1
QML standard errors

	coefficient	std. error	z	p-value	
leader	−0.398313	0.254344	−1.566	0.1173	
age	0.00789498	0.00980449	0.8052	0.4207	
Dhospital_1	−0.303919	0.321002	−0.9468	0.3438	
Dhospital_2	−0.718688	0.412096	−1.744	0.0812	*
Dhospital_3	−0.0853378	0.462873	−0.1844	0.8537	
Ddepartment_3	1.05048	0.364675	2.881	0.0040	***
Ddepartment_4	0.565852	0.351047	1.612	0.1070	
Ddepartment_5	−0.0932468	0.250553	−0.3722	0.7098	
DState_1	0.0191133	0.347098	0.05507	0.9561	
DState_2	−0.181200	0.390415	−0.4641	0.6426	
DState_3	−0.245472	0.457062	−0.5371	0.5912	
DState_4	−0.406253	0.318876	−1.274	0.2027	
cut1	−1.39220	0.665211	−2.093	0.0364	**
cut2	−0.521015	0.634969	−0.8205	0.4119	
cut3	0.749038	0.614543	1.219	0.2229	

Mean dependent var	2.722689	S.D. dependent var	0.919878
Log-likelihood	−147.0369	Akaike criterion	324.0739
Schwarz criterion	365.7607	Hannan-Quinn	341.0016

Number of cases 'correctly predicted' = 48 (40.3%)
Likelihood ratio test: Chi-square(12) = 10.6848 [0.5561]

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 0.889949
with p-value = 0.640841

The default position, meaning that all dummy variables are equal to 0, is other type of hospital (Dhospital_4), nursing staff (Ddepartment_2) and Zurich (DState_5). The intercept is included in cut1, cut2 and cut3. The dummy variable Ddepartment_3 (medical-technical staff) is highly significant on a 1% significance level. It means employees from Ddepartment_3 are more positive towards the use of delivery drones on a 1% significance level. The dummy variable Dhospital_2 is significant on a 10% significance level. This means that employees from Dhospital_2 (private hospital) are less positive towards the use of delivery drones on a 10% significance level (on the condition that all other dummy variables are equal to zero). The test of normality of residuals is not significant (p-value .640). The H_0-hypothesis states that the residuals are normally distributed. The H_0-hypothesis cannot be rejected. The residuals are normally distributed.

The ordered Probit model for case2 (telemedicine drone) is shown in table 7.

Table 7. Ordered Probit model Case2

Function evaluations: 60
Evaluations of gradient: 24

Model 2: Ordered Probit, using observations 1-119
Dependent variable: Case2
QML standard errors

	coefficient	std. error	z	p-value	
leader	0.0504719	0.249273	0.2025	0.8395	
age	0.00382859	0.0119221	0.3211	0.7481	
Dhospital_1	−0.674747	0.292673	−2.305	0.0211	**
Dhospital_2	−0.508441	0.404204	−1.258	0.2084	
Dhospital_3	−0.750184	0.461857	−1.624	0.1043	
Ddepartment_3	−0.0847095	0.438907	−0.1930	0.8470	
Ddepartment_4	0.768992	0.387589	1.984	0.0473	**
Ddepartment_5	−0.453351	0.249361	−1.818	0.0691	*
DState_1	0.137843	0.402156	0.3428	0.7318	
DState_2	0.0972698	0.406865	0.2391	0.8111	
DState_3	0.696776	0.347492	2.005	0.0449	**
DState_4	0.833895	0.585927	1.423	0.1547	
cut1	−0.456130	0.594180	−0.7677	0.4427	
cut2	0.429540	0.596743	0.7198	0.4716	
cut3	1.33508	0.597366	2.235	0.0254	**

Mean dependent var	1.781513	S.D. dependent var	0.903474
Log-likelihood	−130.2967	Akaike criterion	290.5934
Schwarz criterion	332.2802	Hannan-Quinn	307.5211

Number of cases 'correctly predicted' = 65 (54.6%)
Likelihood ratio test: Chi-square(12) = 15.6218 [0.2092]

Test for normality of residual -
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 6.75477
with p-value = 0.0341366

The dummy variables Dhosptial_1 (cantonal hospital), Ddepartment_4 (medical-therapeutic staff) and DState_3 (Central Switzerland) are significant on a 5% significance level. It means medical-therapeutic staff and the region Central Switzerland are more positive towards the use of telemedicine drones, whereas canton hospitals are less positive towards the use of telemedicine drones on a 5% significance level. The employees from the variable Ddepartment_5 (other types of employees) are less positive towards the use of telemedicine drones on a 10% significance level (on the condition that all other dummy variables are equal to zero). The test of normality of residuals is significant (p-value .034). The H_0-hypothesis states that the residuals are normally distributed. The H_0-hypothesis can be rejected. The residuals are not normally distributed. It means that the application of the Ordered Probit model can be biased in this case.

The ordered Probit model for case3 (emergency drone) is shown in the following table 8. The dummy variables Ddepartment_4 (medical-therapeutic) and DState_3 (Central Switzerland) are significant on a 10% significance level. It means employees from Ddepartment_4 and from the region DState_3 are more positive towards the use of emergency drones on a 10% significance level (on the condition that all other dummy variables are equal to zero). The test of normality of residuals is highly significant (p-value .002). The H_0-hypothesis states that the residuals are normally distributed. The H_0-Hypothesis can be rejected. The residuals are not normally distributed. It means that the application of the ordered Probit model can be biased in this case.

Table 7. Ordered Probit model Case3

Function evaluations: 68
Evaluations of gradient: 23

Model 3: Ordered Probit, using observations 1–119
Dependent variable: Case3
QML standard errors

	coefficient	std. error	z	p-value	
leader	−0.0269754	0.269211	−0.1002	0.9202	
age	−0.0115749	0.0108054	−1.071	0.2841	
Dhospital_1	−0.153036	0.284464	−0.5380	0.5906	
Dhospital_2	−0.0666806	0.575750	−0.1158	0.9078	
Dhospital_3	−0.0547210	0.387224	−0.1413	0.8876	
Ddepartment_3	0.403870	0.418478	0.9651	0.3345	
Ddepartment_4	0.886624	0.479468	1.849	0.0644	*
Ddepartment_5	0.207809	0.239341	0.8683	0.3853	
DState_1	0.0444569	0.344668	0.1290	0.8974	
DState_2	−0.116520	0.365183	−0.3191	0.7497	
DState_3	0.657364	0.383862	1.712	0.0868	*
DState_4	0.958304	0.661090	1.450	0.1472	
cut1	−1.74005	0.494485	−3.519	0.0004	***
cut2	−1.15843	0.498917	−2.322	0.0202	**
cut3	−0.0111167	0.494286	−0.02249	0.9821	

Mean dependent var	3.067227	S.D. dependent var	0.936375
Log-likelihood	−139.2734	Akaike criterion	308.5469
Schwarz criterion	350.2337	Hannan-Quinn	325.4746

Number of cases 'correctly predicted' = 55 (46.2%)
Likelihood ratio test: Chi-square(12) = 10.6544 [0.5587]

Test for normality of residual –
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 12.9274
with p-value = 0.00155903

The ordered Probit model for case4 (hospital drone) is shown in table 9.

Table 8. Ordered Probit model Case4

Function evaluations: 58
Evaluations of gradient: 23

Model 4: Ordered Probit, using observations 1–119
Dependent variable: Case4
QML standard errors

	coefficient	std. error	z	p-value	
leader	0.00964696	0.290029	0.03326	0.9735	
age	−0.0237768	0.0117373	−2.026	0.0428	**
Dhospital_1	−0.519844	0.332063	−1.566	0.1175	
Dhospital_2	−0.606375	0.492442	−1.231	0.2182	
Dhospital_3	−0.875606	0.416624	−2.102	0.0356	**
Ddepartment_3	0.497714	0.482069	1.032	0.3019	
Ddepartment_4	0.506327	0.439321	1.153	0.2491	
Ddepartment_5	0.295906	0.245969	1.203	0.2290	
DState_1	−0.857979	0.636392	−1.348	0.1776	
DState_2	0.528264	0.335652	1.574	0.1155	
DState_3	0.598389	0.436440	1.371	0.1704	
DState_4	0.307129	0.456674	0.6725	0.5012	
cut1	−0.916212	0.599593	−1.528	0.1265	
cut2	0.0672256	0.591168	0.1137	0.9095	
cut3	0.962505	0.613490	1.569	0.1167	

Mean dependent var	1.554622	S.D. dependent var	0.777844
Log-likelihood	−108.9401	Akaike criterion	247.8802
Schwarz criterion	289.5670	Hannan-Quinn	264.8079

Number of cases 'correctly predicted' = 69 (58.0%)
Likelihood ratio test: Chi-square(12) = 17.2517 [0.1404]

Test for normality of residual –
Null hypothesis: error is normally distributed
Test statistic: Chi-square(2) = 0.27193
with p-value = 0.872873

The variables age and medicine-technical staff (Ddepartment_3) are significant on a 5% significance level. It means older employees and employees from the medicine-technical department are less positive towards the use of hospital drones on a 5% significance level (on the condition that all other dummy variables are equal to zero). The test of normality of residuals is not significant (p-value 0.873). The H_0-hypothesis states that the residuals are normally distributed. The H_0-Hypothesis cannot be rejected. The residuals are normally distributed. The ordered Probit model for CASE (overall cases) is shown in table below.

Table 8. Ordered Probit model Case

Model 5: OLS, using observations 1–119
Dependent variable: CASE
Heteroskedasticity-robust standard errors, variant HC1
Omitted due to exact collinearity: Dhospital_4

	coefficient	std. error	t-ratio	p-value	
const	2.62117	0.278923	9.397	1.27e-15	***
leader	−0.0884747	0.120320	−0.7353	0.4638	
age	−0.00288895	0.00479636	−0.6023	0.5482	
Dhospital_1	−0.308828	0.152769	−2.022	0.0457	**
Dhospital_2	−0.393142	0.237996	−1.652	0.1015	
Dhospital_3	−0.300875	0.213516	−1.409	0.1617	
Ddepartment_3	0.378071	0.166295	2.274	0.0250	**
Ddepartment_4	0.528387	0.234624	2.252	0.0264	**
Ddepartment_5	−0.0237640	0.116651	−0.2037	0.8390	
DState_1	−0.00197259	0.128427	−0.01536	0.9878	
DState_2	0.0355774	0.195768	0.1817	0.8561	
DState_3	0.292940	0.221358	1.323	0.1886	
DState_4	0.276030	0.141708	1.948	0.0541	*

Mean dependent var	2.281513	S.D. dependent var	0.566130
Sum squared resid	33.63041	S.E. of regression	0.563265
R-squared	0.110761	Adjusted R-squared	0.010093
F(12, 106)	1.555622	P-value(F)	0.116119
Log-likelihood	−93.66396	Akaike criterion	213.3279
Schwarz criterion	249.4565	Hannan-Quinn	227.9986

Excluding the constant, p-value was highest for variable 31 (DState_1)

For the overall cases, where the dependent variable CASE is built by the mean of the variables cases1, cases2, cases3 and cases4, a multivariate regression analysis is conducted, because the dependent variable (CASE) is no more a discrete variable. The intercept (const.) and the dummy variables Dhospital_1 (canton hospital) Ddepartment_3 (medical-technical staff) and Ddepartment_4 (medical therapeutic staff) are significant on a 5% significance level. While the medical-technical staff and the medical therapeutic staff are more positive towards the overall use of drones in hospitals in Switzerland, the canton hospitals are less positive towards this (on the condition that all other dummy variables are equal to zero). The R-squared is about 11%. It means that about 11% of the variation of the dependent variable can be explained by the independent variables. This outcome is in the accepted range of the field of research. The outcome of the F-test is about 11%. The H_0-hypothesis states that the residuals are normally distributed. The H_0-Hypothesis cannot be rejected. It means that the residuals are normally distributed.

7. Discussion

Considering the attitude from employees and patients towards the use of telemedicine drones, significant differences are identified. Patients rate this case more negative. A possible explanation could be that patients prefer the social contact with an employee. They could be having doubts concerning the treatment quality of the medical staff via telemedicine.

Concerning the type of hospitals where the employees are working, two significant differences are identified. On the one hand, employees from private hospitals rate the delivery drone more negative. Generally, private hospitals are smaller. Therefore, a reason could be that the employees don't see the need for delivery drones. On the other hand, employees from cantonal hospitals generally rate the overall use of drones (mean of all use cases) and specifically the telemedicine drone more negative. An interpretation of this result is difficult without further research.

Two significant differences are identified with regard to the geographic location of the hospitals. The employees working in Berne, Solothurn, Fribourg, Neuchatel and Jura rate case2 (telemedicine drone) and case3 (emergency drone) more positive. An interpretation of this result is difficult without further research.

Considering the employees' working areas, there are many significant differences between the medical-therapeutic and medical-technical staff and the other groups. The medical-therapeutic and medical-technical staff rate the overall use of drones (mean of all use cases) as positive.

Regarding the position of the employees (if they are in a leading position or not), no significant difference is identified. It seemed that the rates of the employees aren't dependent on the scope of the responsibility or competences.

Concerning the age of the participants, a significant difference in one case is identified. Older persons rate the hospital drone as negative. The social contact seemed to be more important for older persons, which could be a result of a higher number of hospitalizations on their part (assuming that older persons were more often in hospitals than younger persons). Another reason could be the doubt regarding the possibilities of a drone.

8. Conclusion

This paper investigates the use of drones in healthcare in general and the acceptance in hospitals in Switzerland in particular. Therefore, different use cases are rated by employees from different hospitals and patients. The results are summarized as follows:

- Delivery and emergency drones are rated as rather meaningful. However, the emergency drone has the most positive resonance. One of its most stated positive aspect is its efficiency. For the delivery drone, the economic reason is additionally seen as positive, whereas for the emergency drone the live saving factor is mostly mentioned as positive.
- The telemedicine and hospital drone are rated as rather not meaningful. Reasons for the negative assessments are particularly the endangering of safety and the lack of social contact.
- There are no significant differences between employees and patients regarding case1, case2, case3, case4 and CASE, except in regard to the drone for telemedicine, where the patients` attitudes are more negative.

The acceptance is given for the delivery (case1) and emergency drone (case3). Therefore, it is recommended to further investigate case1 and case3. For further procedures, pre-studies must be conducted, followed by a pilot project. The pre-studies would contain a stakeholder, cost, requirements and business case analysis. The cost analysis would include a review about funding such projects in Switzerland (in order to find stakeholders for a pilot project). However, if there is a positive business case for the delivery or emergency drone, a funding is not mandatory. Every use case must be considered individually because of its specific requirements.

Before investigating the implementation, further research must be done. Which changes are necessary in order for the use cases to be rated more positive? Are the results of the study representative only for Switzerland or do they also apply to other countries with similar structure? To answer these questions, an extension of the questionnaire from this study (with specific adjustments) would be very interesting.

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