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**UAV last-mile delivery in the humanitarian aid context –  
a qualitative analysis of the implementations in the health  
supply chain**

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**0 Abstract**

Drones as innovative transportation mode for medical supplies have the potential to contribute significantly to humanitarian aid. Building on three key case studies and five in-depth interviews, this work project developed a conceptual framework illustrating the success drivers and factors of UAV delivery in the health supply chain. The four identified main categories of the project environment, namely project operators, UAV environment, regulatory environment and public, are influenced by local conditions and specifications of the cargo. The focus on and understanding of all interdependent dimensions is crucial for a project's success. However, to allow for scalable operations, technological features and regulatory environments require further development.

*Keywords: UAV delivery, drone delivery, humanitarian aid, health supply chain*

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**List of Abbreviations**

BLOS            Beyond line-of-sight  
DAA             Detect and avoid  
EASA            European Aviation Safety Agency  
FAA             Federal Aviation Administration  
GPS             Global positioning system  
NGO            Non-governmental organization  
PR              Public relations  
UAS             Unmanned aerial system  
UAV             Unmanned aerial vehicle  
UTM            Unmanned aircraft traffic management  
VTOL           Vertical take-off and landing

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# 1 Introduction

Logistics deliveries will be modified significantly as new technologies are emerging constantly. Although the use of unmanned aerial vehicles (UAVs) in the humanitarian aid and healthcare industry is relatively new, practical applications have been growing over the last years accompanied by increasing media attention. This new mode of transportation aims to address some of the most common health logistics challenges by circumventing inadequate infrastructure on the ground, accelerating delivery processes, and enhancing supply chain efficiencies. Industry experts assign significant potential to UAVs to transform healthcare and medicine in the 21<sup>st</sup> century. Global Market Insights Inc. (2019) estimates the compound annual growth rate of the medical drone market to around 25% within a time frame of five years, exceeding USD 399 million by 2025. According to the latest survey by Unmanned Airspace (2019), 45 countries are now implementing or planning to launch drone delivery services.

Although drones are seen as a disruptive force in the field of transportation with humanitarian and even lifesaving potential, only a limited number of respective delivery projects has been successfully implemented until now. Most use cases are being carried out over a limited time frame and primary concern the trial of technology. It seems that long-term implementations of projects fail due to a lack of considerations that are critical for success, insufficient knowledge about prevalent challenges as well as lack of resources and capabilities to address them. Hence, this thesis contributes to filling the gap by answering the following research question:

*RQ: What are the success drivers of UAV last-mile delivery, and how do they influence successful implementation in the humanitarian aid and health supply chain?*

The first chapter aims to provide sufficient background knowledge of humanitarian aid, the last mile in the health supply chain as well as state-of-the-art research and relevant practical applications of UAVs. The subsequent part explains the methodology behind the qualitative research method using three key use cases and five semi-structured in-depth interviews. Next,

the results from case studies and interviews lead to a conceptual framework illustrating identified success drivers and influenced factors defining successful UAV delivery implementation. Lastly, the discussion concludes with a future outlook, limitations and future avenues for research as well as managerial implications.

Providing a comprehensive foundation of relevant background knowledge for decision-making supports and accelerates research efforts of involved organizations and may facilitate the implementation process; thereby inspiring and encouraging further projects to exploit the humanitarian potential of UAV deliveries in the health supply chain. Such framework may be of interest to (1) decision makers in the healthcare industry including business developers within pharmaceutical organizations, hospitals or pharmacies as well as linked delivery companies to optimize supply and patient care; (2) decision makers within humanitarian organizations who aim to alleviate suffering and to protect human life and health globally; (3) decision makers within the drone industry including drone developers who are interested in advancing their service and growing the business to implement drone delivery at scale in a variety of industries; and (4) local governments that focus on interventions that advance development goals of the country as well as the security and enhancement of public health.

## **2 Background**

This section provides an overview of the relevant terms in the field of humanitarian aid and the health supply chain, as well as the current state of research on drone delivery.

### **2.1 Humanitarian aid and the health supply chain**

#### **2.1.1 Definition of humanitarian aid**

Humanitarian aid as area of focus faces a broad variety of terms that differ in context and in scope of application. Considering a variety of relevant terms and explanations (Appendix 1), a definition was elaborated that meets the purpose of this work:

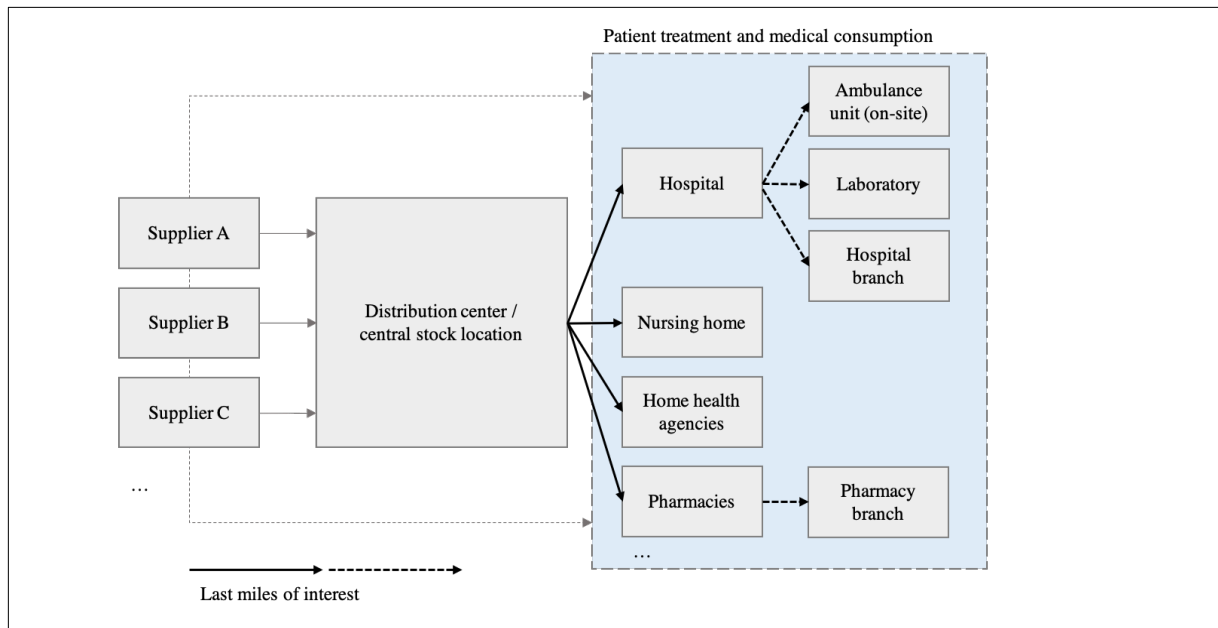
Humanitarian aid aims to maintain and restore physical and emotional health as well as well-being of all populations; thus, aid is not restricted to emergency situations and the

development context. Respective measures deliver healthcare solutions to a broad set of health needs of the target population.

### **2.1.2 The health supply chain – a focus on last-mile delivery**

Nations design and develop medical services in accordance with their resources and the populations' needs. Therefore, a broad variety of health systems with numerous histories and organizational structures can be identified around the world. The term of last mile, however, is generally defined as the supply chain stage of products and services reaching the final delivery destination, hence, the patient as end-consumer considering the humanitarian aid context (McCoy 2013). This step may be performed in a variety of ways: (1) patient treatment via doctors and caregivers in hospitals and health centers, as well as on-site rescue operations carried out by paramedics; (2) medical collection from pharmacies; or (3) home delivery via courier services.

The final delivery destination for this research is defined as any kind of intermediate facility that subsequently passes medical supplies to patients. Considering the current state of practice as well as status quo of technological progress and regulatory environments, safe UAV home delivery of any product is not yet standardly available. Thus, the typical last mile of latest use cases is consistent with the focus of this work project. A simplified health supply process and last miles of interest are depicted in Figure 1. Hospitals, nursing homes, home health agencies as well as pharmacies are intermediate facilities that receive medical supplies from a point of access, i.e. a distribution center or a central stock location. Healthcare supplies are then directly distributed to patients in form of medications for medical care, vaccines for immunization or blood transfusions for use during surgery. Hospitals, in addition, supply on-site operating ambulance units with emergency equipment. Samples for laboratory tests are sent to co-located laboratories when required. Also, medical supplies may be transported between different branches of hospital groups or pharmacy chains. Inter-organizational delivery may become necessary if one branch experiences medical stock-out or shortage in its blood bank.



**Figure 1: Simplified health supply chain process and identified last miles of interest (own presentation)**




In most countries, conventional trucks and vans deliver supply in ordered quantities from centralized drop-off locations to intermediate facilities and beyond. Due to a lack of proper road network and often difficult terrain, motorbikes and all-terrain vehicles are frequently utilized to serve remote areas in developing regions. Delivery efficiency is influenced by the number and local distribution of people in need of medical care, location of facilities, travel distances, road speed, fleet size and associated costs among other considerations (Haidari et al. 2016).

## **2.2 Brief introduction into unmanned aerial vehicles (UAVs)**

### **2.2.1 Definition of terms - UAV Types and Technology**

Although historically developed and primary used for military operations since the late 1800s, drone technology finds increasing application for civilian purposes (Department for Transport 2016; Shaw 2014). Being a matter of debate in academic, military and legislative circles, drones are associated with a broad set of alternative terms. In the delivery context, literature generally refers to unmanned aerial vehicles (UAVs) as components of unmanned aerial systems (UASs) (Gupta, Ghonge, and Jawandhiya 2013). Therefore, both terms ‘drone’ and ‘UAV’ are used synonymously throughout this work project.

UAVs are pilotless aircrafts that are driven by engines and aerodynamic forces. Operating autonomously or being remotely controlled, drones are capable of sustained flight as well as carrying a payload (Scott and Scott 2018; USDoD 2011). Categorizations are made using various criteria. Drone sizes range from long-range aircraft-sized UAVs dominating the military domain to nano and micro drones (Pathak et al., 2019; Rosser et al., 2018). Delivery drones are generally small or medium sized devices, weighting between five and 15 kilos (USAID 2017). The degree of autonomy can vary as either remote human operators or on-board computers control the flight (Pathak et al. 2019). Besides sizing and weight, regulatory categorizations focus on performance including a drone’s flight range, power capacity and battery size. Propulsion design composition as well as application-specific configurations are further distinction criteria. The most common categorization, however, is made by a drone’s hardware design into fixed-wing, rotary-wing and hybrid designs as displayed in Table 1.

	Fixed wing	Rotary wing (multirotor)	Hybrid designs (tilting wing)
			
<b>Range</b>	Up to 150/160km	Up to 20km	About 80-100km
<b>Speed</b>	Up to 100km/h	Up to 60km/h	Up to 150km/h
<b>Payload ability</b>	1.5 - 4.5kg	Up to 5kg	Up to 5kg
<b>Take-off; landing</b>	Catapult; runways or tailored collection platforms (e.g. via wire)	Vertical take-off and landing (VTOL)	VTOL
<b>Advantages</b>	Long service range, heavier payload, high flight stability and engine efficiency, backed by sophisticated aerospace engineering	High mobility and maneuverability, possibility to float, vertical take-off and landing, generally cheaper, in-air delivery possible	Combined advantages: VTOL, service radius comparable to fixed wing, higher flexibility of VTOL sites, heavier payloads than multirotor
<b>Disadvantages</b>	Requires landing strip of open space or alternative landing establishments, difficulty to control emergency landings, limited maneuverability	Shorter service radius and flight capacity, transport lower cargo limit, experienced staff and know-how required due to complex design	More expensive, more limited service radius than fixed-wing, and maneuverability compared to rotary wing
<b>Use case examples</b>	Zipline in Rwanda	Matternet in Switzerland	Wingcopter in Vanuatu

**Table 1: Categorization of UAV design (own presentation based on Balasingam, 2017; Martin & Kadura, 2019; Pathak et al., 2019; USAID, 2017)**

Drone design depends on several considerations including environmental conditions, regulatory frameworks, organizational needs, associated cost, the supporting infrastructure as well as the specific use-case application (USAID 2017). All three UAV designs are used for delivery.

### **2.2.2 UAV Regulations and Authorities**

The nature of regulatory authorities as well as the scope of legislative frameworks differ from country to country and even within countries. For instance, the Federal Aviation Administration (FAA) is the main governmental body of the United States that regulates all aspects of civil aviation within the country, including drones. The European Aviation Safety Agency (EASA) presents the respective regulatory authority for Europe. Numerous national aviation agencies are being triggered by the establishment of regulations of main governmental bodies; others lack a drone-specific legal environment all together. Authorities determine basic guidelines and measures for technological, safety and security, privacy as well as administrative issues, and closely monitor and support operations (Balasingam 2017).

### **2.3 UAVs as an innovative transportation mode in the health supply chain**

The last mile is often characterized by inefficiencies, slow and delayed deliveries, being the most expensive part of the supply chain, and thus presenting the most promising segment for delivery drones (Doole et al., 2018; McKinsey & Company, 2016). The potential of UAVs in the health supply chain is being tested all over the world. Drone service providers partner up with logistics and supply chain experts, humanitarian organizations and local governments. Blood is transported from blood banks to surgery sites, specimens from hard-to-reach areas to central laboratories or medicine from pharmacies to remote branches.

The following section demonstrates the potential of UAVs to reinforce the importance of this research. In addition, an overview of related challenges is provided that have to be addressed and explored further to successfully launch UAV delivery projects.

### 2.3.1 UAV potential and benefits

By complementing existing health supply chains, UAVs have the potential to optimize logistics and contribute significantly to humanitarian value (Rosser et al. 2018). Five key benefits have been identified and will be introduced in the following.

Many areas, primary in the developing context, are characterized by isolation and remoteness. Lack of adequate road infrastructure, difficult topography, geographical dispersion of island states or the sudden inaccessibility due to severe weather conditions, natural disasters or city congestion pose transportation barriers to conventional delivery modes (Güner et al., 2017; Scott & Scott, 2018). By circumventing otherwise impassible terrain, drones present an effective option to improve **access** to affected locations. Taking the beeline further allows to **decrease travel time**, thereby accelerating logistics processes, increasing efficiency and maybe even leading to just-in-time lifesaving medical supply (Scott and Scott 2018). Although there is only limited data available to run precise cost analyses, several sources expect drones to be a **cost-effective** alternative to ground transportation (Sudbury and Hutchinson 2016; Hotz 2017). When comparing to helicopters and full-sized aircrafts, cost-efficiencies are identified with respect to initial investment and operating costs (U.S. Department of Transportation 2013). However, cost-advantages depend on a broad set of influencing factors including flight frequency, minimum purchase contracts or overall project duration. Moreover, studies by Figliozzi (2017), and Goodchild & Toy (2018) compared the CO<sub>2</sub> emission of UAV deliveries with conventional transportation modes. These studies conclude that UAVs are a **CO<sub>2</sub>-efficient** mode for the delivery of small payloads as well as for operations in regions characterized by scattered population and a limited number of required stops. Lastly, UAVs have the potential to contribute positively to the delivered **quality and supply of products**. High quality of medical supplies upon delivery is crucial. Any compromise would lead to serious adverse consequences to the health and well-being of patients (Hotz 2017; Balasingam 2017). Although there are doubts about the clinical integrity of products requiring special handling (e.g. cold-

chain products like vaccines), studies show that drone flights under regular conditions do not adversely affect product quality and the accuracy of laboratory results (Amukele et al. 2015, 2016, 2017; Hii et al., 2019; Hotz, 2017). In addition, investing in centralized drone distribution centers may address the problem of low reliability standards of many health facilities in developing countries. Timely delivery via drones may decrease dependence on uncertain facility conditions and local capabilities to carefully handle, transport and store medical products as well as circumventing the problem of local stockouts in emergency situations (USAID 2017).

### **2.3.2 UAV challenges and limitations**

New technologies, however, entail challenges that have to be addressed in order to successfully implement respective UAV delivery projects and to exploit associated humanitarian value.

The **regulatory environment** is said to limit the full potential of UAV applications. The lack of sophisticated drone-specific frameworks results in time-intensive authorization processes as responsibilities and liabilities have to be defined and project-specific risks must be assessed continuously. Drone developers seem to be discouraged considering relatively rapid technology advances (Balasingam 2017). Further, efficiency may be limited as the compliance to no-fly zones as well as the flights that are required to be conducted in visible altitude do not guarantee the fastest routes in emergency situations (Balasingam 2017). The scalability of UAV deliveries is limited due to the lack of sophisticated airspace integration initiatives. UAV technology is under continuous evaluation and improvement to address **technological challenges**. For instance, the current state of battery efficiency and operating time set boundaries to payload capacity as well as the maximum coverable distance (Roca-Riu and Menendez 2019; Scott and Scott 2018). Also, drone projects face high collision rates exposing the public and the drone itself to increased risk. The capability to securely handle difficult topography under all weather conditions requires advances in ‘Detect and Avoid’ (DAA) technologies. Moreover, new technologies require **expert know-how** as complex software and

hardware is involved. Trained staff is essential on site throughout the entire operation to safely launch, monitor and maintain the drone. This may limit the sustainable operational success of a drone service providers' co-located projects. Although not directly involved into the operation of UAVs, **public concerns** may decelerate the implementation process or even limit the full potential of UAV projects as drones mostly operate in public space and in visual line of sight. Such issues may include privacy and safety concerns, UAV noise complaints, misconceptions due to historically shaped military associations as well as general change-resistance and skepticism facing new technologies (Scott & Scott, 2018; Yoo et al., 2018).

### **3 Methodology**

The aim of the work project is to identify the drivers of successful UAV delivery projects in the humanitarian aid and health supply chain as well as analyzing their direct impact on success. An exploratory research using qualitative data analysis was chosen as the topic under investigation presents a complex concept involving various stakeholders and interdependent influencing factors. In order to develop a respective conceptual framework, a two-state approach was applied using both use case analyses and in-depth interviews. Appendix 2 illustrates the methodology approach in detail.

#### **3.1 Use case analysis**

In a first step, 12 use cases of relevant UAV field deployments have been identified. All highlight the recurring theme of UAV delivery projects conducted for a general humanitarian purpose and cover a broad range of project locations and strategies. Too basic projects such as prototype testing and demos in test environments have not been included as this research focuses on a future business operational view. The use cases have been analyzed with regard to the positive impact of drones as well as prevailing challenges throughout the operation. Drawn key learnings helped to identify the degree and reasons for project success or failure. Identified use cases as well as respective findings are displayed in Appendix 3.

The insights allowed to classify use cases into three different types: (1) Unsuccessful projects, i.e. projects that failed during operation, therefore being discontinued. Failure may refer to technical malfunctions or other operational deficiencies; (2) Successful pilot projects with an initially envisaged limited time frame and successful completion; (3) Successful permanent implementation, meaning the establishment and continuous operation of a long-term drone delivery network. Classifying use cases by degree of successful outcome was perceived as an appropriate step aiming to identify a UAV project’s success drivers.

### 3.2 Key case analysis

To provide a detailed and multifaceted view on relevant success drivers within the scope of this work, one key case study for each identified use case type was chosen. All selected projects allow for a reasonable degree of insights given data access. Data was obtained using both secondary sources as well as primary sources when available. Sources for secondary data included published company reports and case studies, press releases, journal articles and newspaper articles. Primary data collection will be described in the following section.

Key case studies serve as representative example for each type as gained insights broadly cover and summarize the main findings of all 12 concerned case studies. In-depth analyses of sources for and management of failure and success allow to determine the nature and direct impact of success drivers on a project’s outcome. All three selected key case studies will be introduced briefly in Table 2 and the following paragraph. A more detailed summary of each study can be found in Appendix 4.

Case Type	Synonym	Year	Project operators	Location	UAV technology
1	C1	2017 - 2019	Swiss Post, Matternet	Switzerland	Multirotor (quadcopter)
2	C2	2018	Wingcopter, UNICEF, local Ministry of Health	Vanuatu (Oceania)	Hybrid design, winch mechanism for delivery
3	C3	2016 - present	Zipline, Rwanda Ministry of Health and ICT	Rwanda	Fixed wing, parachute drops

**Table 2: Overview of selected key case studies (own presentation)**

**Type 1, C1.** From 2017 until 2019, the national logistics service Swiss Post delivered laboratory samples in three regions of Switzerland, cooperating with drone manufacturer Matternet. Over 3,000 successful deliveries were executed to date. The sub-project in Zurich was envisaged to last one year but repeating failure of safety mechanisms led to the suspension of the program.

**Type 2, C2.** In 2018, German startup Wingcopter performed a successful two-month pilot project on the Pacific island state Vanuatu. 91 beyond line-of-sight (BLOS) vaccine deliveries have been performed from one main distribution facility to multiple locations on remote islands.

**Type 3, C3.** Starting in 2016, drone manufacturer Zipline established the world's first long-term full-scale UAV delivery network in Sub-Saharan Rwanda. More than 14,000 successful deliveries have been performed up to date. Drones serve remote hospitals and health centers of the entire nation with a variety of medications, blood, oxygen, laboratory samples and vaccines.

In addition to representing each use case type, a broad overview is achieved as key case studies differ in project location, utilized drone design as well as actual delivery technology.

### **3.3 In-depth interviews and a proposed conceptual framework**

Primary data, provided by relevant informants, supplemented gained insights from secondary sources and offered additional details about state-of-the-art practical applications and future perspectives. Interview partners have been selected to present a broad variety of stakeholders considering previous UAV project and relevant industry experiences (Table 3). Although the focus of research is on UAV application in the humanitarian aid and health supply chain, experts from other commercial areas were considered relevant when providing transferable insights.

Semi-structured in-depth interviews with open-ended questions have been conducted to ensure nonbiased responses. The general direction was guided, albeit, directions could change as enough flexibility was preserved. This approach facilitated posing clarifying questions, and thus helped to tap into the full potential of the interviewees' information and knowledge. Appendix 5 displays the general interview guideline for respondents. Each questionnaire has been slightly modified to address the individual experiences and areas of expertise of the

interview partner. Questions have been classified into a general topic category and further subcategories to allow for modification of the question order during an interview and to seamlessly guide through topics of interest.

Five interviews have been conducted in German, then translated by the author for the relevance of the thesis. The length of interviews ranged from 00:25h to 1:15h. Interview transcripts are displayed in Appendix 6. Due to the high sensitivity of research into future mobility solutions, two interview partners and three involved companies had to be anonymized.

Synonym	Name	Position	Company	Industry	Relevance
I1	Derrer, C.	Specialist for Drones	Swiss Post	Logistics and Supply Chain	Involved into UAV delivery pilot-project of medication in Switzerland
I2	Illbertz, D.	Specialist for Drones	n/a	Forestry, Drone Development	Involved into various UAV applications, incl. delivery of defibrillators
I3	Norman, A.	Global Networks Operation Lead	Matternet Inc	Aviation and Aerospace, Drone Development	Responsible for global flight operations; involved into medical UAV delivery projects in Switzerland and the U.S.
I4	n/a	Future Transportation Manager	n/a	Automotive	Involved into previous implementations of UAV pilot-projects using hybrid system
I5	n/a	Project Manager Urban Air Mobility	n/a	Automotive and Consulting	Extensive background in urban air mobility

**Table 3: Overview of interview partners (own presentation)**

To evaluate primary data, the coding procedure introduced by Strauss & Corbin (1990) was applied. In the first step, open coding was used to analyze the raw data and to select, categorize and label direct statements (first-order codes). This allowed to compare and conceptualize responses. Secondly, axial coding served to compound and cluster codes into more theoretical second-order codes. Lastly, through selective coding, main categories were determined by identifying semantic relationships between categories. Every interview served as its own analytical unit. Multiple iteration steps of reviewing and comparing qualitative data allowed the emerging model to replicate, contrast or extend (Eisenhardt 1989). The coding process is depicted in Appendix 7. One should note that the coding and interpretation of the interviewees'

responses is a subjective step and may differ among authors (Gioia et al., 2013). Integrating the insights obtained from both secondary and primary data sources allowed to propose a conceptual framework that provides an overview of the success drivers of UAV last-mile delivery as well as their hypothesized influence on success. After the model development phase all five experts were contacted once again and asked to challenge, modify or approve the proposed conceptual model, thus contributing to the development of a validated UAV framework as comprehensive basis for decision-making focused on humanitarian purpose.

## **4 Results**

The structure of the conceptual framework as well as the identified dimensions will be described in the following.

### **4.1 Conceptual framework of successful humanitarian UAV last-mile delivery**

The elaborated and validated conceptual framework is illustrated in a quadripartite model in Figure 2 and answers the research question ‘*What are the success drivers of UAV last-mile delivery, and how do they influence successful implementation in the humanitarian aid and health supply chain?*’. First, qualitative data analysis of interview responses allowed to cluster the UAV last-mile delivery project environment into four main categories, namely ‘Project operators’, ‘UAV environment’, ‘Regulatory environment’, and ‘Public’. This classification broadly covers and allows to independently examine the interrelated main dimensions involved in UAV delivery. Respective success drivers of each category as well as their direct influence on success have been identified. Success drivers are defined as the key elements that drive operational and financial results, and therefore require critical consideration. The way of effectively managing these dimensions defines to what degree they contribute to the achievement of an organization’s goal. Project success is composed of a variety of key success factors that are required to claim a project’s success. The emergence and degree of success factors depends on leveraging related success drivers effectively.

‘Local conditions’ and ‘Cargo type’ have been identified as the two dimensions influencing the entire project environment of UAV last-mile delivery. Both influencing factors will be described taking the perspective of UAV delivery projects in the health supply chain.

All experts emphasize the interdependence of the identified dimensions. The depicted conceptual framework must therefore be understood as relational model as a project’s success depends on the effective interaction of the success drivers of all identified categories (see Appendix 8).

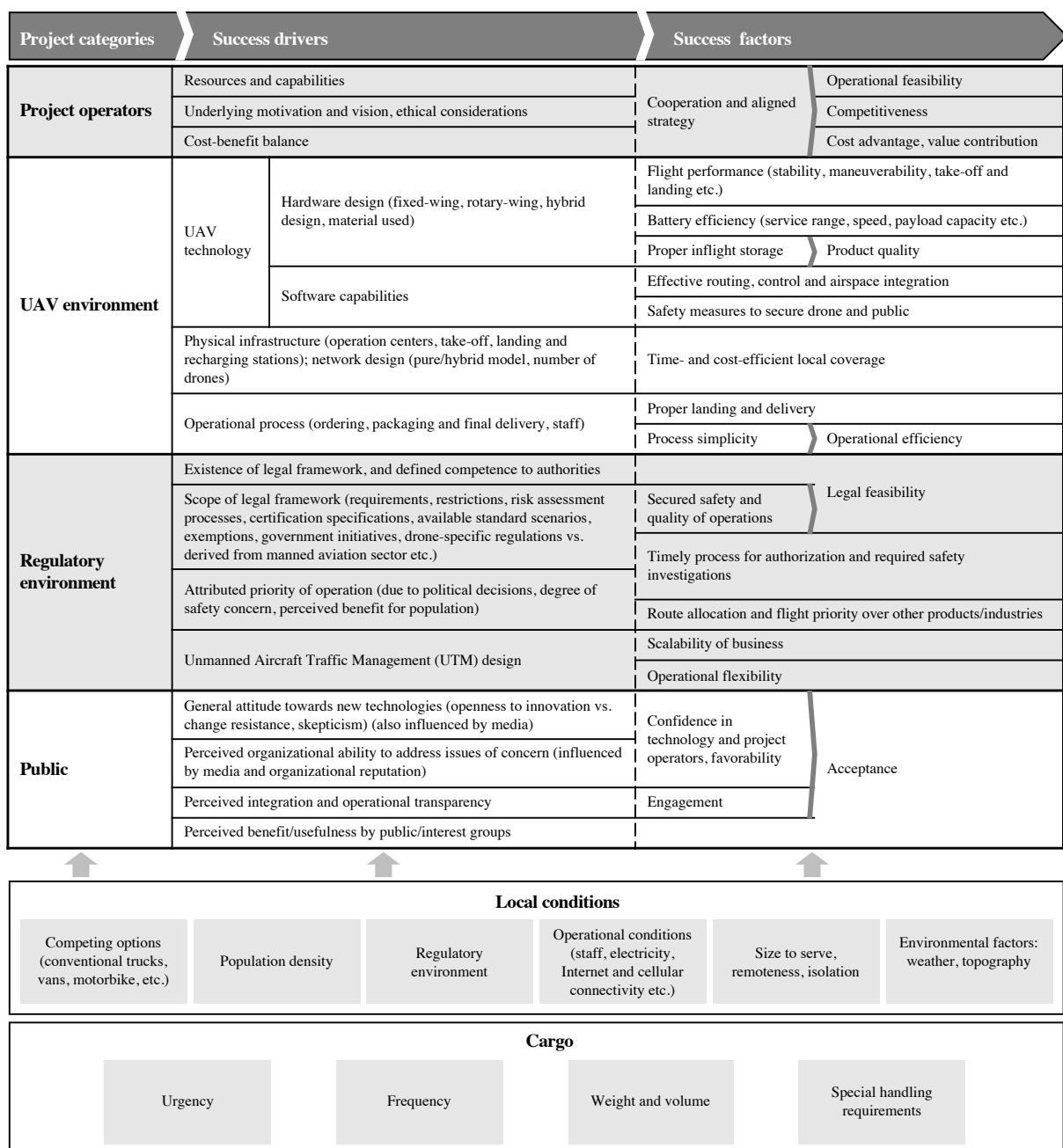


Figure 2: Validated conceptual framework of successful UAV last-mile delivery (own presentation)

## **4.2 Identified success drivers and success factors**

Considering the scope of this work project, the dimensions and relations of main relevance and significance to humanitarian aspects are prioritized and will be examined in more detail.

### **4.2.1 Project operators**

Close cooperation and an aligned strategy of involved parties allows to complement an organization's internal limited technological, operational and financial capabilities by combining expertise and resources from all relevant fields (I1). Partnerships are built based on strategic fit (I4). Cutting edge last-mile delivery technology, deep public health knowledge and the understanding of local markets and airspace, among other, are critical for a project's strategy and operational feasibility. Looking at key case studies, it can be identified that project operators share underlying motivations and visions. For instance, all considered drone developers focus on life-saving UAV applications by aiming to revolutionize medical access in underserved states and areas (C1; C2; C3). Also, Swiss Post is continuously prioritizing the healthcare and life science logistics segment as UAVs provide added value to doctors, caregivers and patients (C1). Related ethical considerations may also influence the decision for partnerships. I2 emphasizes the case of some NGOs actively refusing to cooperate with large drone manufactures as aerospace operations often extend into the military sector.

Cost-benefit analyses are influenced by a variety of factors. Such may include the number of clients to serve in a determined area, the minimum purchase quantity or the required frequency of flights, performance and efficiency drivers of a drone as well as initial investments into the establishment of a proper UAV environment (I1; I2; I5). In order to make UAV delivery a competitive alternative to conventional modes of transportation, available budget must be balanced with required investments, monetary return as well as the non-monetary contribution to humanitarian value. Health-related outcome indicators may include an increased vaccination coverage as well as decreased morbidity and mortality rates.

#### **4.2.2 UAV environment: technology, physical infrastructure and operational processes**

As introduced in Chapter 2.2.1, a drone's design influences its flight performance and battery efficiency. Energy consumption in turn has an effect on the range a drone can serve as well as its speed and payload capacity. The selected key case studies represent all three drone designs. Wingcopter developed a hybrid drone design that combines advantages of both fixed-wing and rotary-wing technologies. Subsequent to rotor-enabled vertical take-off, the drone transitions into more efficient forward flight once air-borne (C2).

Although there are already advanced levels of autonomy with regard to routing software and control systems, UAV control and airspace management are mainly conducted manually by skilled flight operators. Embedded GPS systems and predetermined flight paths facilitate the navigation process. Safety mechanisms are agreed on as the top priority for all interviewed parties. Measures prior to implementation are used to reduce risk for the population from the very start. Wingcopter and Matternet, for instance, route their delivery drones over water and over uninhabited areas whenever possible to minimize so-called ground risk (C2; I3). Automated collision avoidance systems or DAA technologies must ensure secure operations throughout the entire flight (I1; I2; I3). Safety pilots have the option to manually control the drone in case of emergency and are constantly present on site (I1; C1; C2; C3). Beyond that, Matternet drones possess an integrated emergency parachute for controlled descent (I1; I4; C1). In order to resume medical UAV delivery, Swiss Post established a board of independent experts and stakeholders who will provide advice and guidance for risk and safety management for all aspects of drone operation in the future (I1; C1).

To utilize UAVs for delivery, the establishment of an appropriate physical infrastructure is required including the strategic placement of operation centers and the respective design of take-off and landing stations. Whereas the latter depends on the hardware design, the location of operation centers should be focused on maximizing speed and availability. In Rwanda, two Zipline bases have been launched in accessible distance to the majority of hospitals, currently

serving 25 health facilities within 30 minutes delivery time (C3). Defining the UAV network design considers, among other, decisions about the degree of UAV involvement and dependency. Although all key case studies exclusively utilize drones for delivery, future mobility expert I4 emphasizes the advantages of a hybrid model by complementing the existing supply chain system with drones. First, vans may serve as mobile and safe landing platforms for multirotor drones in cities where proper landing options are rare. Second, a higher delivery coverage is possible as vans allow for multiple landing options across the intended service region. The required route can then be activated out of a set of predetermined routes.

In order to successfully perform a delivery by drone, the entire operational process and all related factors must be in place. First, the availability and presence of trained engineers and flight operators is crucial to allow for safety throughout the operation (I2). Key case studies emphasize the importance of simplicity of all up and downstream processes of delivery. In Rwanda, hospitals can place orders in numerous ways using email, text message or phone call (C3). The actual delivery processes are also focused on reducing complexity. Zipline and Wingcopter innovated the process by focusing on minimum effort with regard to infrastructure and training (C2; C3). Zipline drones drop the cargo a few hundred feet over the pre-determined landing spot; an attached parachute slows the fall. Similarly, Wingcopter uses a winch mechanism to precisely and gently deliver the package via cable. These delivery technologies do not require any additional energy infrastructure, no co-located take-off and landing platforms or battery charging systems. Qualified staff for pre-take-off checks is only required at central operation centers. In addition, single-use cargo boxes eliminate the need for recollection.

### **4.2.3 Regulatory environment**

Regulatory safety and quality requirements have to be met to make projects legally feasible. As introduced in chapter 2.2.2, regulatory authorities and the existence and scope of drone-specific guidelines differ around the world. In most cases, first engagement with legal authorities is a time-intensive process. Liability and safety solutions must be determined for any possible

scenario (I2; I4). Successful precedents are likely to result in smoother processes for follow-up projects. Although humanitarian applications are assumed to have higher chances for certification specifications and exemptions, the lack of an established legal infrastructure that enables and safely manages the widespread use of low-altitude airspace limits UAV operations at scale (I1; I5). Experts agree, an automated and centrally operated Unmanned Aircraft Traffic Management (UTM) system that coordinates and integrates all drone operations is essential to enable a scalable, dynamic and safe UAV delivery environment (I3; I4; I5). However, final responsible parties are still undefined. Aviation safety authorities, government-related bodies as well as private companies such as emerging startups are under consideration (I4; I5).

#### **4.2.4 Public and community**

The success of UAVs as innovative solution for last-mile delivery is considerably influenced by public acceptance. In general, some populations seem more open, less resistant and less skeptical towards innovation than others (C1-3; I1-5). However, each technology entails its own risks. Challenges specific to UAV delivery and the community involved have been introduced in chapter 2.3.2. The perceived organizational ability to address and resolve these issues of concern influences the public's confidence towards the technology itself as well as towards project operators. Expert interviews allowed to retrieve managerial implications to enhance public acceptance. First, all relevant interest groups have to be identified to effectively address issues of concern. Taking the perspective of involved parties allows to find solutions to identified issues prior to implementation. Take-off and landing sites as well as flight routes should be pre-planned considering areas of low population density (C1; C2; I1; I3). Personal conversations with all relevant residents are highlighted to inform about the project's purpose as well as the relevant technical specifications that ensure safety and privacy of the public (C1; I1; I4). Wingcopter's project in Vanuatu focused on local integration by providing professional trainings and workshops open to the public (C2). Mutual knowledge transfer strengthened confidence and built curiosity. In addition to educational work, transparency should be

emphasized throughout the entire operation. Swiss Post and Matternet, for instance, published the failure reports to integrate the public into all issues of interest (I1; I3; C1). Future Mobility expert I4 suggests informing public authorities like police stations along the flight route to build multiple contact points and information sources for concerned and curious residents. Further communication efforts may build upon the benefits of medical UAV delivery for the public.

### **4.3 Overarching influencing factors of the UAV project environment**

‘Local conditions’ and ‘Cargo’ have been identified as the two factors influencing the entire project environment of UAV last-mile delivery including respective success drivers and relational success factors.

#### **4.3.1 Local conditions**

Dimensions characterizing a project’s location differ widely and influence all project categories under consideration. First, the benefits of UAVs must be compared to the potential of conventional transportation modes operating under existing infrastructural conditions. Drones are a competitive delivery alternative if the balance between costs and the contribution to humanitarian or monetary value are of higher efficacy. In addition, the degree of remoteness and isolation of local populations defines the general need for an alternative transportation mode. The safety hazard of UAV delivery in densely populated areas is increased, thus, privacy and security issues are of a larger concern to the public as well as to regulators (C1; I1). As previously stated, regulative authorities and respective guidelines are specific to a country or regions within a country. In general, the presence of ground experience and knowledge influences the need for investment into local expert training to safely operate the drone fleet and ensure clinical integrity of products. The hardware design of a drone as well as the delivery process technology is dependent on the local feasibility of designing a proper landing infrastructure. Level of flight performance and efficiency, resulting from chosen design, must be sufficient to serve the aimed size range. Environmental factors like severe weather conditions and wind speed might demand more stable fixed-wing drones.

Some locations seem more suitable than others. Mainly unpopulated areas, a flat topography, stable weather conditions and little air traffic present beneficial local conditions for the implementation of UAV delivery. Nevertheless, future mobility expert I4 emphasizes a focus on customer needs. Project operators should establish UAV networks if drones present an innovative way to benefit people regardless of the location.

#### **4.3.2 Cargo**

Health-related cargo differentiates humanitarian UAV deliveries from projects in other industries. The specified cargo type influences related sub-characteristics. For instance, the urgency and frequency of delivery is dependent on whether medication for regular patient care or emergency supplies such as defibrillators or blood bags for transfusion are being transported. Both mentioned aspects may influence public's acceptance among other. Experts agree, the contribution of medical UAVs to public health is perceived more favorably than other supplies with limited humanitarian purpose (I1; I3; I4). In addition, regulators may assign a high-priority status to urgent humanitarian UAV deliveries, thus, being more responsive when approving respective flight routes (I3). Also, cargo type determines if special handling of products is required. Vaccines, for instance, are cold-chain products, hence, operational processes including packaging must be aligned to ensure clinical integrity throughout the entire process (I1; C2; C3). Further, the product's weight and volume influence required payload capacity and affect overall UAV battery efficiency and flight performance. In general, the potential of UAV delivery of medical supplies stems from its suitability for transport due to high individual and humanitarian value merged into light weight products and small package size.

## 5 Discussion

### 5.1 Future outlook – the scalability of humanitarian UAV last-mile delivery

As accurate information about the future potential of UAV deliveries does not exist, expert judgment in the form of personal opinions and estimations allowed to gain respective insights in addition to findings from literature. The extent of and reasons for agreement as well as disagreement helped to propose the following outlook.

Recently, drones are experiencing a huge hype within all fields of application as projects all over the world receive increasing media attention. However, whereas some parties skeptically classify it to be a PR topic, experts agree on the future reality of drone delivery. According to future mobility expert I4, drones will take a part in the cityscape in the medium to long-term future to complement traditional parcel delivery. Besides general time and cost efficiencies, primary developing nations will be impacted at large scale. As establishing proper road networks is very costly, some nations may leapfrog stages of development adopting UAV transportation technology, thus enabling access across countries with relatively low investment (I1; Dieterich, 2019). However, to estimate the actual potential of drone delivery, further cost analyses are required that build upon local context as well as taking into account project specifications including frequency, size and weight of payload and operational cost (I2). Zipline plans global expansion across Africa, Asia and the Americas to serve 700 million people within the upcoming five years, thereby scaling up its technology cost-effectively (Kolodny 2019).

Technological and regulatory deficiencies have been identified as the two focus areas that require further exploration and development to establish UAV delivery as scalable business solution. The drone operations lead I3 emphasizes the lack of technological evidence of UAVs to be an effective delivery alternative that creates a reliable business model. Innovation and research efforts into UAV hardware and software capabilities are essential to guarantee safe, efficient and acceptable operations under all conditions. UAV noise level, as one of the major obstacles to public acceptance, may be addressed by incorporating larger rotor diameters,

designing larger drones in general or by refining used materials (I1). Limits with regard to flight distance and payload capacity may be overcome by advances in battery technology and the establishment of a proper charging infrastructure. Such may be characterized by solar-powered drones and integrated battery rechargers, or autonomous battery exchanges as drones dock at charging stations along a predefined route (I1; USAID, 2017). The increased focus on automation reduces the costs for the human factor involved and eliminates the need for on-site expert staff that continuously monitors every vehicle (I1; I2). Research into software capabilities is also focused on automation. Next to navigation and routing software, sophisticated DAA technologies are required to reliably avoid collision with unplanned obstacles, people and other vehicles in real time (I3; Bäckman et al., 2018; Pathak et al., 2019). All experts agree on sophisticated UTM design being the key success driver for scaling technological advanced UAV delivery projects. A safe and efficient integration of UAV operations into air traffic must be automated. Air highways that reflect a similar network as street networks, as well as automated concepts that aim to immediately respond to flight requests are solutions under discussion (FOCA, 2019; NASA, 2019; I1; I3). Drone specialist I1 emphasizes the potential of UAV drone delivery within the next two years as the launch of the U-space concept by the European commission will induce national regulatory authorities to evolve the UAV environment gradually, starting in summer 2020. Besides a positive impact on operational scalability, effective airspace integration may present a big step towards UAV door-to-door delivery considering the number of independent, geographically scattered patients (I3).

To conclude, safety and efficiency through automation have been identified as the factors enabling scalable long-term success. However, further exploration into UAV technology, regulatory processing and airspace integration is required to launch UAV delivery networks in target destinations.

All above mentioned future perspectives may be applied to UAV deliveries with a humanitarian purpose as well as other industries. However, regulators may assign a higher

priority to healthcare projects with respect to efficient route allocation and rank order of parallel requested flight clearances once the business model is scalable (I1; I2; I3; I5).

## **5.2 Limitations and further research**

As with most qualitative studies, the above-mentioned results need to be interpreted while considering some limitations. First, suitable key case studies have been identified to serve as exemplary use cases summarizing general repetitive main drivers of all initially identified projects. However, as data access is limited and project design is adapted to the specific environment, findings may not be representative for all humanitarian UAV delivery projects. Second, interview partners have been sampled theoretically based on their suitability to contribute to the development of the conceptual model. No generalization of statements is possible due to limited heterogeneity of interview partners as well as an insufficient quantity of interviews conducted. Insights have been generated from single representatives with certain industry background and thus might be prone to biases which led to the distortion of results. However, this thesis' objective was to gain an understanding of the general drivers and facets of success and implies an aggregated perspective which was only derivable by interviewees with a different area of focus. Further, the sample is geographically limited to experts mainly operating in the German and Swiss market, thus the model requires further testing of the applicability to other geographical contexts. In addition, integrating findings from both secondary and primary sources allowed to assume direct relationships between success drivers and success factors. Nevertheless, the actual influence and interdependence of identified drivers and a UAV project's success is a matter to empirical testing. Moreover, to not exceed the scope of this project, the last mile of the health supply chain was defined to focus on intermediate delivery destinations representing predominant practical applications. Examining the differences in identified dimensions and hypothesized relationships considering UAV home delivery may also be of great interest.

### **5.3 Managerial implications and conclusion**

UAVs are a disruptive force with the potential to optimize logistics of humanitarian aid and healthcare. By building on three key case studies and five interviews with relevant experts, this work project discusses the drivers and factors of successful implementation of UAV delivery projects. Taking into account state-of-the-art research, current practical applications as well as future potential, five general managerial implications can be drawn that are of critical importance to all decision-makers involved in the implementation. First, the potential benefits of drones as innovative mode for transportation should be understood; not only from a firm's monetary perspective but also considering non-monetary humanitarian value in the form of beneficial contribution to public health. Future developments of the legal and technological UAV environment allow to exploit the identified potential of drones as a competitive alternative to conventional modes in urban and remote areas. Second, the developed conceptual framework serves as a comprehensive overview; exceeding the individual focus area of decision-makers involved. One must understand that all identified and interdependent business drivers have to be effectively managed and coordinated to allow for the emergence of success factors that ultimately lead to integrated project success. The model stimulates to take on such overall perspective. Third, prevailing challenges must be identified and addressed effectively to allow for sustainable success. Especially the public, as one of the main stakeholders, can be influenced directly by project operators. A focus on operational transparency, side-by-side project development and collaboration with communities involved will allow to overcome barriers to public acceptance. Fourth, throughout the entire planning, implementation and subsequent evaluation of UAV delivery projects, technological and regulatory development should be examined to continuously improve the operational approach and to take adaptive measures supporting sustainable success. Last but not least, as technological advances focus primary on automation, organizations have to focus on recruiting and training employees to obtain technical competencies that are crucial in a developing automated environment.

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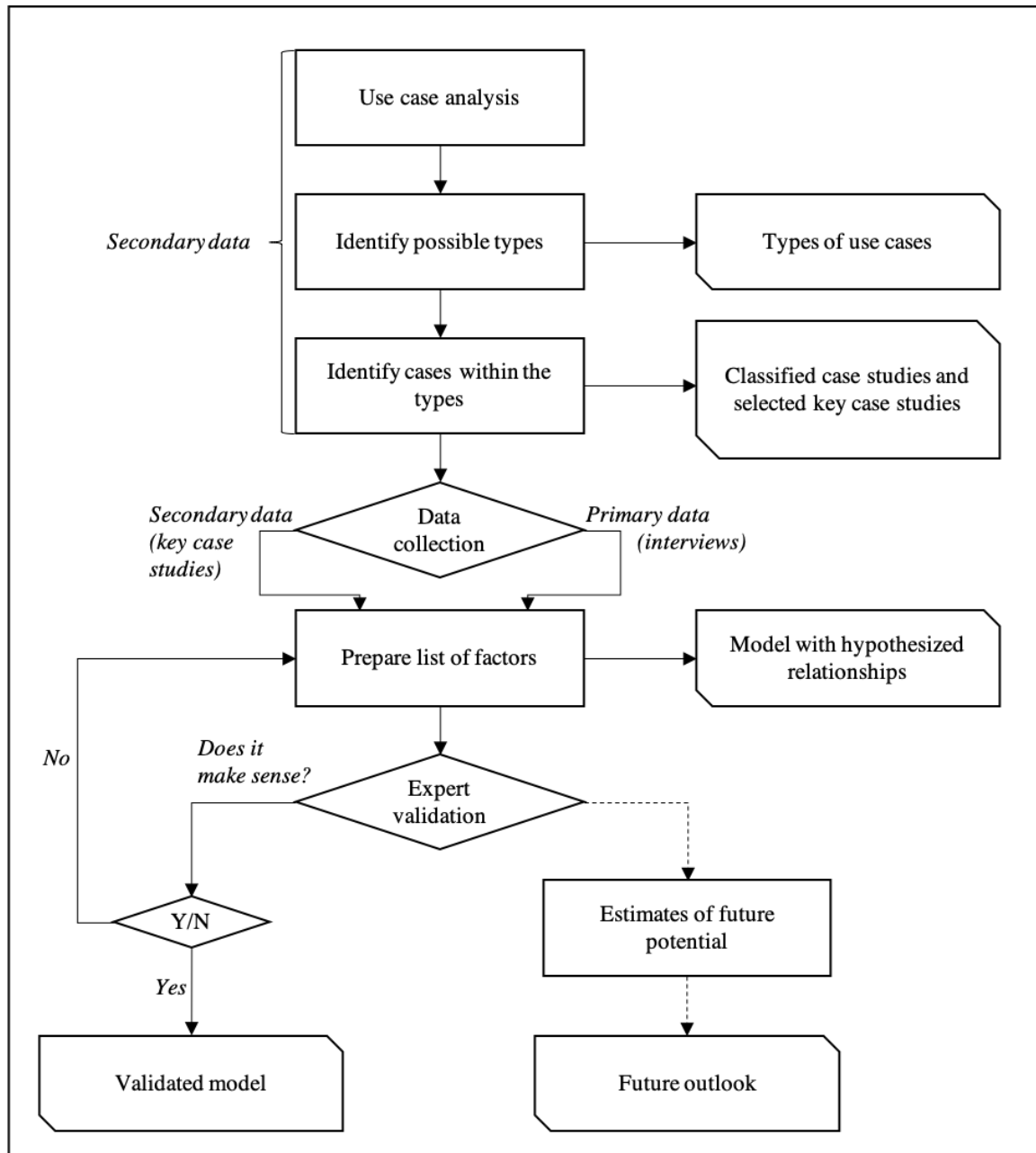
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## Appendices

### Appendix 1: Relevant definitions in the context of humanitarian aid and healthcare

<b>Term</b>	<b>Definition</b>	<b>Source</b>
<b>Healthcare</b>	Efforts made to maintain or restore physical, mental, or emotional well-being [...].	Merriam-Webster, n.d.
<b>Humanitarian aid</b>	[...] designed to save lives and alleviate suffering during and in the immediate aftermath of emergencies.	Humanitarian Coalition, 2019
<b>Humanitarian missions</b>	Missions conducted to relieve human suffering, especially in circumstances where responsible authorities in the area are unable or unwilling to provide adequate service support to civilian populations.	NATO, 1997
<b>Humanitarian action</b>	Assistance, protection and advocacy actions undertaken on an impartial basis in response to human needs resulting from complex political emergencies and natural hazards.	UNOCHA, 2015
<b>Humanitarian actions</b>	Humanitarian action includes [...] the provision of [...] health services [...] for the benefit of affected people and to facilitate the return to normal lives and livelihoods.	Auswärtiges Amt, 2003 (Germany)
<b>Humanitarian assistance</b>	Aid that seeks to save lives and alleviate suffering of a crisis-affected population.	UNOCHA, 2017
<b>Development aid</b>	[...] responds to ongoing structural issues, particularly systematic poverty, that may hinder economic, institutional and social development in any given society, and assists in building capacity to ensure resilient communities and sustainable livelihoods.	Humanitarian Coalition, 2019
<b>Emergency Relief</b>	The immediate survival assistance to the victims of crisis and violent conflict.	UNHCR, n.d.

**Appendix 2:** Illustrated methodology and workflow of the work project (own presentation)



### Appendix 3: Use cases under consideration (selected key case studies are highlighted)

Year	Project operator	Cargo /Payload	Location	Benefits	Challenges	Key takeaways	Source	Type
2013-2016	DHL Parcel	blood samples, medications and other urgently needed materials	Bonn, Just, Reit im Winkel and Winkmoosalm (Germany)	cost-savings, increased speed of delivery (8 minutes compared to 30 minute road trip in winter in Bavaria)	initial regulatory challenges	hybrid system: drone delivery package on island where DHL courier performs last-mile delivery; competitive alternative over water	Scott and Scott (2018)	2
2014	Médecins Sans Frontières (MSF) + Matternet	laboratory samples for tuberculosis testing	Papua New Guinea	access to hard-to-reach areas, reduction in delivery time (55 minutes vs. four hours by car),	technological challenges: battery lifetime, service constraint of 20km (minimum distance to be covered of 43km)	focus on ease of use, and local knowledge and skills for sustainable success	Meier and Soeiso (2016); USAID (2017)	2
2015	Flirtey + National Aeronautics and Space Administration (NASA) + Virginia Tech University + local healthcare organizations	medications for asthma, high blood pressure and diabetes	Virginia, Nevada	delivery time reduction from 90 minutes by road to less than 30 minutes by drone	n/a	first government-approved drone medical delivery in the U.S.; focus on partnerships	Scott and Scott (2018); DeAnnis (2015)	2
2016	United Nations Children's Fund (UNICEF) + Matternet	HIV testing kits	Malawi	overcome transport challenges (poor infrastructure and limited distribution schedules) and associated delays, cost-effective alternative	time consuming process of getting permission for trial period due to local authorities	partnership with local government is key to accelerate implementation process; cost analysis by VillageReach concludes that although exact guesses cannot be estimated, an optimal system takes advantage of both transportation modes (motorbike/car and drone) to minimize costs and transportation time	Reuters (2016); UNICEF (2016); USAID (2017); VillageReach (2016)	2
2016	Zipline + Rwanda Ministry of Health + Rwanda Ministry of ICT	blood, medications, oxygen, samples for laboratory tests, and vaccines	Rwanda	cost-effective solution compared to delivery by motorbike; faster and safer delivery	n/a	first permanent installed national drone transport service of the world; close cooperation with local authorities; Civil Aviation Authority and Ministry of Health; placement of operation center focuses on speed and availability; sophisticated delivery process focusing on ease of use	USAID (2017); de Leon (2019); Wenderover Productions (2019)	3
2016	United Nations Population Fund and Dutch government	contraceptives and other gynecological supplies	Ghana (women's health clinics)	increase women's health and family planning (decrease rate of unintended pregnancies and prevent deaths from unsafe abortions); access; decreased delivery time (30 minutes compared to two days)	terrain issues, uncertain cost-advantage	focus on preventing community association of medical drones with military drones	Cousins (2016)	2
2016	Vayu (funds from government, healthcare organizations and NGOs)	blood samples for TB testing and treatment	Madagascar	access to underserved communities due to difficult weather conditions, transport modes and restrictive family traditions	regulatory challenges for BLOS flights; time-intensive research phase into take-off and landing process	focus on user-friendliness to integrate technology into local community; extended service offering of delivering a tablet including video construction to enable untrained individuals to administer treatment; empowerment of small communities	Perry (2016)	2
2017-2019	Swiss Post + Matternet	blood and pathology specimens	Lugano, Berne, Zurich (Switzerland)	increased flexibility; eco-friendliness; less dependency on traffic; time decrease from an entire process time of around 45 minutes by car to 10 minutes via drone, thereof 3 minutes flight time (in Zurich)	repeating failure of drone safety mechanisms led to a forced suspension from delivery program	safety as top priority (internal decision to suspend program; immediate and long-term oriented safety measures); continuous evaluation of progress and technology adoption; company reputation influences public's confidence	Swiss Post (2018); Derrer (2019)	1

## Appendix 3 (continued): Use cases under consideration

Year	Project operator	Cargo / Payload	Location	Benefits	Challenges	Key takeaways	Source	Type
2018	UNICEF + Wingcopter/Swoop Aero + local Ministry of Health	vaccine	Pentecost Island (Vanuatu)	effective alternative to overcome inadequate road network, and unreliability of existing boat fleet; decrease time required to reach rural health facilities (30 min drone vs. several hours per boat or two hours by car); decreased costs associated with transportation.; decreased travel risks	temperature effects on delivery mechanism; communication with local nurses; cancellations and rescheduling; challenging topography	hybrid drone design as core innovation; specific cargo lowering mechanism was developed to adapt to local terrain, and to provide safety and simplicity; focus on educating and inspiring community about potential social impact	Martin and Kadura (2019)	2
2018	DHL Parcel + Wingcopter + Deutsche Gesellschaft für internationale Zusammenarbeit (giz)	medications, blood samples	Mwanza/Ukerewe island (Tanzania)	decreased delivery time (6 hours by road vs. 40 minutes by drone), enable access and supply in emergency situations	n/a	applied key learnings from previous DHL projects; continuous advances in drone design and technology; test advantages of BLOS flights	Deutsche Post DHL Group (2018, Pressemitteilung)	2
2018	UPS, Mattemet	blood samples	Raleigh, North Carolina (USA)	increased transportation efficiency for blood samples that account for 70% of courier deliveries (up to 30 minutes vs. 3 minute); expansion of logistics service by offering same-day and on-demand delivery; operational savings	n/a	First initiative to develop a solid solution for urban and metropolitan area, focus on partnering local governments with private sector companies to understand how to integrate emerging technology into day-to-day operations with a strong emphasis on safety and usefulness; focus on reliability, safety, and control requirements of the FAA; won federal approval to expand operations in October 2019	Mattemet (2019); Uria (2019); UPS (2019a)	2
2019	Zipline Ghana Limited + Ghana's Ministry of Health (some sub-projects conducted with Novartis + Sickle Cell Foundation)	vaccines, blood and life-saving medications	Ghana	24/7 operation; serve 12 million people across the country	n/a	largest long-term delivery drone network of the world -> see Zipline in Rwanda; hire fully local teams	Riley de Leon (2019)	3

Identified use case types:

(1) Unsuccessful projects; (2) Successful pilot projects; (3) Successful permanent implementation.

## Appendix 4: Key case studies – detailed project description

### Type 1, C1 – Switzerland (Lugano, Berne, Zurich), Swiss Post & Matternet

UAV factsheet, C1 (Swiss Post 2019)		
<b>Technical details</b>	Developer	Matternet
	Model	M2V9, quadrocopter (multirotor)
	Propulsion	electric
	Weight	13.2 kg
	Size	w/o rotor blades: 80 x 80 x 26 cm, w/ rotor blades: 128 x 128 x 26 cm
<b>Technology</b>	Launch and landing	VTOL
	Security	Emergency parachute; geo-fence-3D multi-points; FLARM (collision and avoidance technology)
<b>Performance</b>	Service radius	Max. 20 (15) km with 1 (2) kg payload
	Payload	Up to 2 kg; 4-liter volume; 23 x 15 x 12 cm
	Flight altitude	110 m above the ground
	Top speed	72 km per hour
	Delivery process	Direct pick-up when landing

**Background / Overview:** From 2017 until 2019, the national logistics service Swiss Post delivered special healthcare supplies in various regions of Switzerland with the help of multirotor drones, more precisely quadcopters, drones with four rotors (Swiss Post, 2018; I1). In cooperation with the drone manufacturer Matternet and various partners from the healthcare sector, Swiss Post was the first company that received authorization for full operations of a drone logistics networks over densely populated Switzerland (Matternet 2019). Over 3,000 successful deliveries of time-sensitive medical laboratory samples have been executed to date. The project pioneered the sample delivery system in Lugano in 2017 with autonomous and commercial drones. Further initiative followed in Berne and operations were expanded to the country's capital in December 2018. The main motivation behind all projects was to speed up delivery time through less dependency on traffic congestion, and thus increased flexibility. The project in Zurich was envisaged to last one year but repeating failure of safety mechanisms led to the internal company decision to suspend the delivery program. Although projects were decided to be discontinued, Swiss Post realized several advantages by utilizing drones. Main benefits include the decrease of delivery time from an entire process time of around 45 minutes

by car to ten minutes via drone, thereof three minutes flight time (2,5 km) in Zurich as well as a positive environmental impact by decreased usage of traditional fuel-operated delivery vehicles (I1).

**Evaluation & key learnings:** The goal of valuable contribution to patient care as well as guaranteeing safe operations have always been the top priorities for all parties involved. The shared interest and understanding of safety are displayed in continuous evaluation efforts of progress and adaption of technology. In order to continue UAV efforts in the future, Swiss Post and partners immediately implemented safety measures including emergency parachute improvements as well as setting additional safety margins with regard to wind limits for flight operations (Wertheimer, 2019; I1). Moreover, an established board of independent experts and stakeholders will provide advice and guidance regarding risk and safety management for all aspects of UAV operation in the future (Wertheimer 2019). Swiss Post will continue to prioritize the healthcare and life science logistics segment as UAVs provide high operational availability by offering doctors, caregivers and patients added value.

### Type 2, C2 – Vanuatu, Wingcopter

UAV factsheet, C2 (Martin and Kadura 2019; Wingcopter n.d.)		
<b>Technical details</b>	Developer	Wingcopter
	Model	Wingcopter 178 Heavy Lift
	Propulsion	electric
	Weight	6 kg
	Size	178 x 132 x 52 cm
<b>Technology</b>	Launch and landing	VTOL
	Flight	Tiltrotor Technology
	Security	Telemetry (continuous flight control); return to launch (RTL) command
<b>Performance</b>	Service radius	Up to 100 km (fixed-wing mode)
	Payload	Up to 10 kg; 3.3 kg project average; maximum take-off capacity of 16 kg
	Flight altitude	Max. 5000 m; BVLOS (beyond visual line of sight)
	Top speed	50 km per hour (multicopter mode); 130 km per hour (fixed-wing mode)
	Delivery process	Delivery via cable enabled by winch mechanism

**Background / Overview:** The German startup Wingcopter focuses on life-saving UAV applications and performed a successful seven-week pilot project in 2018 on the Pacific island

country Vanuatu (Martin and Kadura 2019). In cooperation with the national Ministry of Health and the United Nations Children’s Fund (UNICEF) the startup was backed with financial and technical support to deliver vaccines from one main distribution facility to multiple locations on the remote islands. The aim of the project was to test the suitability of UAVs as new mode of transportation to be included into the national Expanded Program on Immunization (EPI) as well as to test technical feasibility and local feedback and acceptance. The country is composed of around 80 small islands and faces several logistics challenges. Lack of adequate road network, impassible terrains following excessive rainfall, remoteness of numerous population groups, or unreliable existing boat fleets result in excessive time and costs to reach rural health facilities as well as a high risk of travel. Wingcopter developed a hybrid drone design that integrates VTOL and fixed-wing technology, meaning that subsequent to rotor-enabled vertical take-off, the drone transitions into more efficient forward flight once air-borne. Although the entire project was continuously challenged by adverse temperature effects on payload, miscommunication and cumbersome coordination with local partners as well as difficult topography characterized by mountains and lush vegetation, Wingcopter was able to successfully perform 91 BLOS flights, covering a distance over 3664km. Substantial benefits of UAV delivery have been identified regarding time as a two-hour drive on difficult terrain plus a several hour boat trip around the island could be replaced by a 30- minute drone flight with an average of 90 km/h cruising speed.

**Evaluation & Key Learnings:** Great payload capacity and stable flight behavior even in challenging weather conditions was achieved by Wingcopter’s core innovation of a hybrid drone design. The delivery process developed in accordance with local conditions presents the second key enabler. A use case-tailored winch mechanism allowed to precisely and gently deliver goods via cable. As there was no need for fenced-off landing areas, the drone was not exposed to any risk of interference by humans or animals. In addition, no remote pre-take-off checks or physical assessments were required. Additional safety measures include the constant

presence of a safety pilot during take-off and landing at the distribution center who had the option to manually control the drone in case of emergency as well as determining the flight routes mainly over water as well as inhabited areas reducing risk from the very start. Lastly, the project operators focused on local integration by providing professional trainings and workshops open to the public. This allowed to transfer knowledge mutually leading to a better understanding of local challenges as well as building confidence and curiosity, and thus a higher acceptance of local community towards the new technology. The company’s focus on safety, operational simplicity and local integration makes it a suitable example for the second type of identified use cases. Moreover, taking a sustainability focus, Wingcopter aims to develop and use 100% biodegradable single-use delivery box to reduce its environmental footprint.

**Type 3, C3 – Rwanda, Zipline (2016)**

UAV factsheet, C3 (Dieterich 2019; Zipline 2018)		
<b>Technical details</b>	Developer	Zipline
	Model	Zip (fixed-wing drone)
	Propulsion	electric
	Weight	10 kg
	Size	3.3 meters span
<b>Technology</b>	Launch and landing	Catapulted into air and caught by electronic rope mechanism when returning
	Security	3D-space communication of location with radio receivers; back-up motors and actuators; emergency parachute
<b>Performance</b>	Service radius	Up to 160 km
	Payload	Up to 1.5 kg
	Flight altitude	Up to 150 m above the ground
	Top speed	128 km per hour
	Delivery process	Delivery via parachute

**Background / Overview:** Rwanda, the small and densely populated Sub-Saharan African country established a long-term UAV cargo delivery network that almost covers the entire nation (USAID 2017). Starting in October 2016, drone developer Zipline International Inc., a silicon-valley company, revolutionized medical access in the underserved state. In the beginning, delivery focused mainly on blood supplies, however, the delivery assortment soon

expanded to medications, oxygen, vaccines and samples for laboratory tests to hospitals, health centers and remote regions. The initial transportation challenges Zipline aimed to address are concerned with traffic congestion faced by cars and motorbikes, unfavorable weather conditions especially during rainy season, and obscurity leading to time-consuming and unreliable delivery of often urgently needed medical supplies. In addition, uncertain conditions of health facilities and on-site capabilities to carefully handle, transport and store medical products do not guarantee product quality and availability in emergency situation. With timely and appropriate treatment, Zipline aims to prevent many deaths and incurable conditions (e.g. Malaria, infant deaths or mothers dying in childbirth). More explicitly, the objective of this long-term project is to serve 11 million citizens with essential medical products by establishing a UAV network that puts every potential recipient within a 30 minutes delivery zone (USAID 2017; Balasingam 2017) Currently, Zipline is serving 25 health facilities including transfusion facilities and hospitals across Rwanda (de Leon 2019).

The first Zipline base for launch and landing was established in Muhanga in 2016, followed by the second distribution center in eastern Rwanda. Engineers, operations and supply chain specialists as well as air traffic control responsables are operating onsite following clearly defined task and simple processes. The drones fly autonomously but without decision-making authority, following preset flight paths (Wendover Productions 2019). As drones fly beyond the visual line of sight, no obstacle avoidance ability is required. However, drones are able to enter a pre-set holding pattern, return to the starting base, or apply a parachute for emergency landing. When arriving at the destination, the drone drops the package from inside the drone body a few hundred feet over pre-determined landing spot; a parachute slows the fall. As packaging focuses on cargo integrity blood supplies are ready for transfusion upon delivery. With multiple UAVs in parallel operation, Zipline carried out more than 14,000 successful flights up do date that add up to more than one million kilometers.

**Evaluation & Key Learnings:** The full-scale and nearly country-wide UAV delivery network in Rwanda presents the first UAV transport service installed for permanent operation. Operation centers are placed close to public medical warehouses and hospitals ensuring timely response. Supplies are received within 30 minutes compared to five hours by car or motorbike. By enabling timely access and reliable supply to remote areas of a country characterized by high mountains and difficult terrain UAVs demonstrate lifesaving benefit (USAID 2017). For example, vaccine delivered by Zipline drones allowed to prevent infections by the Ebola virus which is prevailing in the neighboring state Congo.

Several key learnings can be drawn that lead to the continuous success of the UAV project. First, drones have been designed incorporating expertise from former Nasa and Boeing engineers (Dieterich 2019). Drones are wheel-less in order to eliminate unnecessary weight and complexity as well as the establishment of runways for launching and landing. Moreover, light-weight material (polystyrene) is used to utilize battery capacity more efficiently and increase service radius. The fixed-wing design allows for higher speed and longer distances, and the parachute delivery technology does not require energy infrastructure, no co-located take-off and landing platforms and battery charging systems. Second, simplicity is the focus of all processes (Wendover Productions 2019). For example, orders are submitted via email, text message, WhatsApp or phone. Products are packed into single-use boxes assembled from cardboard, bubble wrap and tape and being delivered by parachute made from paper. Third, cooperations with several parties have been critical to Zipline to establish the long-term delivery service (USAID 2017). The universal healthcare system of Rwanda grants access to hospitals at an affordable or no cost to its entire population, presenting one of the best healthcare systems in Africa. In addition to the humanitarian focus of the government, openness to innovation cleared the path for smooth operations and to the establishment of a favorable regulatory environment towards unprecedented drone initiatives. Further cooperations with the Civil Aviation Authority and the Ministry of Health allowed to understand the air traffic environment

and to design tailored flight routes as well as to guarantee a minimum number of deliveries per month to ensure long-term cost coverage.

In April 2019, Zipline expanded to Ghana and built the world's largest autonomous medical drone delivery service, serving nearly 22 million people. Zipline has been valued to a billion-dollar business and presents the most funded cargo drone delivery company at present (Kolodny 2019). Following its expansion efforts, the drone manufacturer aims to spread its operations to other countries, including the U.S., accompanied by continuous technological and operational progress (Ling and Draghic 2019).

**Appendix 5:** General overarching interview guideline for expert interviews

#	Topic	Question Topic	Question
1	'Warm-up'	Role of interviewee	What is your position within the firm?
2		Relevance	How are you involved in the area of drone delivery?
3	Project overview	Conducted projects	Please explain briefly what projects your firm already conducted (focus on humanitarian aid context within the health supply chain).
4			What kind of stakeholders were taking some kind of role when implementing the project?
5			With what partners did you work together? Why did you decide for this specific partner?
6		Motivation	What has been your primary motivation to start these projects?
7			What initial challenges were you addressing and trying to overcome with this initiative?
8		Success factors	Why have projects been successful or have failed?
9			What have been your main challenges (pre, during and post project; also internal)?
10	Humanitarian aid and healthcare industry	Difference	In your opinion, what are the main differences of UAV delivery projects in the health supply chain compared to other industries (e.g. e-commerce, groceries)? What aspects require particular attention? (e.g. type of cargo, special handling requirements)
11		Cargo	What kind of cargo is considered suitable for drone delivery? Why?
12			Did you experience any adverse effects on the quality of cargo caused by delivery by drone?
13	UAV journey	Drone technology	What drone features and technological capabilities do you consider most important for successful operation?
14			What characteristics distinguish sophisticated drones from drone technology that lags behind?
15		Safety	How do you ensure safety of the public throughout the journey?
16			How do you ensure safety of the drone and its cargo throughout the journey?
17	Acceptance	Public acceptance	In your opinion, how is this technology perceived by the public? Is there a difference between urban and remote areas?
18			In your opinion, how can organizations gain favorable opinion from the public? (e.g. communication, incentives)

19		Governmental acceptance	What are your main challenges or efforts when complying with regulatory requirements?
20			In your opinion, how can organizations gain favorable opinion from local governments? (e.g. communication, incentives)
21	Location	Destination	What locations/destinations do you consider most suitable for implementing a UAV delivery project? Why (characteristics)?
22		Long-term success	In your opinion, how can you ensure long-term operation and success in a country with limited drone expertise? (if relevant)
23	Future Outlook	General	Does your organization continue to invest into UAV delivery projects (if not main business)?
24			Does drone delivery have the potential to be implemented at scale in the near future? If yes, in how many years? If yes, will other transportation modes get superfluous? If yes, how to ensure sustainable success?
25			What technological advances would be beneficial to see in the future?
26		Limitations	What challenges need further exploration in the future? How can these challenges be addressed and overcome?
27	End	Closing questions	What have been your key learnings? Which factors and conditions are of crucial importance when considering launching a UAV delivery project?
28		Other aspects	Are there any other aspects you would like to mention?

## Appendix 6: Expert interview transcripts

Expert Interview #1	
Name / Synonym:	<b>Christoph Derrer / II</b>
Position:	Specialist for Drones
Company:	Swiss Post
Industry:	Logistics and Supply Chain
Relevance:	Involved into UAV delivery pilot-project of medication in Switzerland
Interview date and time:	11.11.2019, 9:30 am
Interview length:	00:50 h
<p>I studied aviation with a specialization in operational management and specialized in drones in my last year. I also wrote my bachelor's thesis about it. I then came to the Federal Office of Civil Aviation with my permanent position after my studies, where I dealt with flight operations for helicopters and also the Innovation Management Office with applications for drone flights. The legal situation in Switzerland at the moment is such that all drone flights outside the pilot's range of vision require a permit from the Federal Office for Civil Aviation. I was able to examine all the applications there. There are quite a few of them in Switzerland, because we still allow things from the legal framework that other countries often say no to from the beginning. Here there is a playing field or a framework that makes such things possible. I then moved to Matternet, a manufacturer of drones that also cooperates with the Post. I have also done risk assessments for the flight routes which were now partly in use, now also for the permanent deployment in Bern and Zurich and since last December I am responsible here at Swiss Post as a specialist for drones, also for operations with customers, whether they are interested in using drones as a delivery option, how realistic that is, what is the requirement profile. Partly there is another solution. Our goal is simply to use the drones as another possibility to transport goods in the future. We are specialized in logistics; that would be another means of transport.</p> <p>Everything started a little earlier with the drones. This had already been done in 2015 as a proof of concept, together with Matternet, who presented the predecessor model of the drone at that time. That was about a rented airfield already out of sight but over unpopulated area and the challenge was then to get the permit to perform such flights in the city or in densely populated area. At that time this was closely accompanied by the people from the Federal Office of Civil Aviation. Thus it was possible that in March 2017 we received the first permit for flights out of sight and over densely populated areas worldwide here in Lugano to Switzerland. At that time we tested to introduce a permanent operation in Lugano in spring for three weeks and in autumn 2017. There are two hospitals in a relatively small area -</p>	

Lugano is not a giant city - and both have an emergency ward as prescribed. At one hospital it is not worth leaving the laboratory open at late hours. The emergency room is open until 11 am. Before we arrived, it was handled in such a way that if someone came to the emergency room and the laboratory was already closed, a taxi was called. The taxi went to the hospital, took the sample, fought its way through the traffic and left it at the other hospital in the laboratory. That sometimes took 30 to 45 minutes if you consider the whole process time. If you use the drone for the transport, there is always one person on site. If this person receives the message that there is something to test, they fetch it from the emergency room and fly it with the drone to the other hospital within three minutes. The drone flies outside the opening hours, starts at 2 pm in the afternoon and flies until 22/23 pm.

The process time has been significantly reduced. In total, it will be about ten minutes; flight time three minutes. This is also much more ecological if you consider that an electrically powered drone can fly such a small blood tube instead of a car weighing tons.

The idea for the project came in collaboration with the CEO of the hospital group in Lugano. We had the delivery drones and didn't know what to transport with them at the beginning. He came with the suggestion, because he had it with the taxi and it sometimes takes a long time. He asked if we would like to try to transport the blood sample. We analyzed this and found out that the requirements in the air as well as on the ground are well documented. This is also a very good use case in terms of public acceptance, if you can say that you also contribute something to health.

There were alternative partners. Back in 2015, four years ago, there were other manufacturers in the race. These are all start-ups that produce such delivery drones. And Matternet was the only one who could deliver what he promised. This was confirmed in 2017 when we started with the permanent flights. They simply have the personnel, the know-how, the relationships that make this possible.

Since May 9th, there's actually a nationwide stop. The first proof of concept was in 2015 and the first permanent network was in 2017 in Lugano. Then in spring 2018 there was a two-week pilot project in Bern; then a two-week pilot in Zurich and in December 2018 we put two new networks into operation in Zurich. There was one incident on 25 January. One drone had a short-circuit in the satellite navigation system over Lake Zurich and therefore its situation for the flight computer was no longer clear. And there the security mechanism regulates that the parachute has triggered. All this worked wonderfully. The stupid thing was that the lake was underneath, and the drone was not floating, so it sank. This incident was also investigated by the Swiss safety investigation authority. The report is also available online. We started again after the final report was published in April. And then, unfortunately, on 9 May there was another incident over the forest in Zurich, where the emergency parachute was also triggered and which was then torn down and the drone fell into the forest. This investigation is still ongoing. The Federal Office of Civil Aviation never actually withdrew the permit. It is an internal political decision that we have said that we are temporarily stopping the whole thing, and that we have set up an expert council of safety experts from manned aviation. Over the past few months, they have examined all the processes, operations and manuals and will shortly be submitting a report. Parts of it will then also be made public.

After the second incident, the outcry from the media was all the greater and our management is also completely new; since April we have had a new CEO at Swiss Post. He immediately declared it to be a matter for the boss and he wanted it to be completely reexamined by an independent body. The entire process has already been reviewed by the Federal Office of

Civil Aviation. Now we still have an independent opinion on it, which we can also use at a new start to communicate it in this way.

There have been many inquiries from clients which had to be clarified how serious they mean this; is this just a showcase for them that they can put the innovation stamp on them, or do they really want to have goods delivered by drones? Then you also have to clarify whether the quantity is sufficient. If it's just one flight a day, the effort is simply too great in advance to get the permit and even during operation. The flight is autonomous, but the whole loading, the flight checks on the drone, and the battery change still has to be done by one person. At every location where a drone takes off and lands, one person is employed for eight hours a day, five days a week. It costs a lot to fly a drone a day, from a purely economic point of view you have to offset these costs. The permits are issued by the Federal Office of Civil Aviation. This is the only authority that can do this in Switzerland. The processing time was between half a year and a whole year. It is partly very complex, because many documents are needed to prove how secure the whole system is etc. Also in every city the stakeholders have to be identified anew. It is certainly much more complex and costly than over unpopulated areas somewhere above the sea or a large forest where you don't bother anyone. Especially in the city there are a lot of interest groups.

There was a pilot project in Zurich with a small operations center in a courtyard. We had the drone launch site approved just like that. But right next to it was a residential building and because the houses and the walls reflected the noise it became very noisy especially during the landing. The neighborhood said on the first day that they would resist. Although everything was approved, we decided to move the landing place. Simply to avoid the problems from the beginning. We found a new launch site near a road where the noise of the drone goes down by the tram and other traffic.

We did very good preparatory work, because we were able to filter out all the addresses from the routes we have; who lives along the route. The whole population was informed in advance that Swiss Post was doing this - of course one of the best-known companies in Switzerland - and that they knew that the drone had no camera on board, so you don't have to worry about being monitored. Only a few negative feedbacks came from opponents of new technologies who suggested that you should hire bike couriers, as they are much faster and more ecological anyway. There was no very positive feedback at all. Nobody writes an e-mail or calls and says he thinks it's great what we do. Usually it's people who have something to complain about.

I was always looking for a conversation with the people - that was maybe a handful - I visited them, we looked at the routes again and partly changed something again. But when planning the route, we made sure that we didn't fly over schools, kindergartens or the university campus. So that we are sure that if a drone does come down, it won't fly over this area right from the start.

The manufacturers have installed a rescue parachute and a flight alarm system. This is a system that can communicate with other aircrafts. And if it discovered a collision risk in 30 seconds in the future, it would warn the other aircraft. So, people on the ground, but also other airspace participants, are better protected.

The concerns were there at the beginning. The difference in pressure, or vibrations, which can damage the samples. New technologies are a bit more critical - for example, there was no concern from a courier driver who had vibration in his car. The dangers have been checked

and the temperature requirements are met at all times. Of the 3000 flights we have made so far, no sample has been spoiled or the quality suffered.

If it is really necessary in midsummer, you can add ice packs to the box. The flight with three minutes is also very short. The box is stored and packed in a warm room at 22/23 degrees; it takes a relatively long time until the inside temperature changes and reaches a dangerous level.

The permit is related to the drone and does not take into account what is being transported. Also, a commercial flight operator gets the license to fly and who he transports with it is another issue.

In Switzerland, you can fly any drone up to 30 kilograms without a permit. That is not a problem. Everything about that is regulated, as well as flights out of sight. But there are so few of them. At the moment, the regulator still has everything in sight. The correct no-fly zone in Switzerland is actually only areas declared by the Federal Office for the Environment, such as hunting areas or protected areas for waterfowl and migratory birds.

In Africa, road infrastructure is partly non-existent. In case of big thunderstorms, the roads are washed away and the transport on the road becomes very difficult. Therefore, it makes sense to carry out transports in the air and thereby reduce the risk compared to other airspace participants or for people on the ground. There are many startups in Africa trying to do the first proof-of-concepts. In the city it is interesting because of the traffic congestion and thus the transport on the ground is made more difficult. In addition, we find many potential customers from hospitals, pharmacies, joint practices that a drone can reach quickly in a relatively small space. Or, in the case of Zurich, the drone can cross the lake and save time driving around.

We continue to firmly believe that drone logistics will continue to establish itself. Since we have been talking to hospitals, we have been learning more and more what is transported between stations and between locations. It can also be assumed that in the future we will transport blood samples as well as other products such as medicines or over longer distances. In the future, we will also be pursuing short-haul and long-haul flights between different cities.

I have the feeling it has real potential as the whole environment for drones is created over time. On the one hand there are the delivery drones, but other companies need drones to carry out inspections, make measurements. For all this airspace - unmanned aerial vehicles - a system is now being developed that can coordinate everything much better. That it may also be possible to obtain a permit within seconds in the future. It will become even more interesting as soon as the U-space is developed and functioning. Nowadays, people are still charging the drone and changing the batteries. It is the idea that this will be automated in the future. The manufacturer of the drones we use is currently developing a logistics station that has a robot arm inside that can do all the work. Then in the future it will be possible for everyone to push a transport box into a station that we load automatically, and the drone can start automatically. To be able to use the system as a whole, you don't have to be trained.

U-Space will become active in individual areas of Switzerland in June 2020. The logistics station will be presented at about the same time. In June 2020 will come from the European Union specifications to operate drones, and also for this U-Space. All authorities are currently

preparing themselves, so that from this point on it will be possible to issue permits with this set of rules. Soon, these rules will be better defined and then you know what to stick to.

On the other hand, technical progress is needed to cover greater distances. The volume of the drone must also be approved by the public. I think it is difficult to make it quieter, but a different sound would be more pleasant. Aerodynamics always makes noise. No one can promise silence. The high buzzing annoys a lot of people. Larger propeller diameter, an overall larger drone will produce a deeper sound and is acoustically more comfortable for most people. Newer propellers have already been used in manned aviation on aircraft that were not quieter, but made a more pleasant sound, so they were perceived as less annoying.

Drone deliveries are very demanding. Every city and every canton has something new. Stakeholders must be identified in order to build cooperation. Once the project has started and is working, it will actually be very positively received by the majority of those involved and we still see potential to expand it further.

Expert Interview #2	
Name / Synonym:	<b>David Illbertz / I2</b>
Position:	Specialist for drones
Company:	n/a
Industry:	Forestry and Drone Development
Relevance:	Involved into various UAV applications, incl. delivery of defibrillators
Interview date and time:	14.11.2019, 4:00 pm
Interview length:	00:40 h

I will shortly introduce the two last projects I worked on. The first project was concerned with testing semi-automatic flight systems for a rescue service in the Netherlands and Germany. It was designed to supply defibrillators built into the drone (such as the University of Delft). Secondly, we used fixed wings for forest evaluation. Those projects have been conducted in collaboration with a large NGO and a private company.

Operators within the medical field that deliver medicines, blood and organs are often motivated by cost advantages and efficiency reasons. Projects are often conducted in areas that are either remote or in cities where ground paths are too complex, and where airspace simplifies. In comparison, deliveries by helicopter cost about 600-1000€ per flight hour; with such smaller devices, one can work much cheaper.

Madagascar also supplies medicines to its smaller islands as they have no airports. There has been a successful project that started in 2015 and since 2017 the project is halfway functional and nowadays it's said to be very successful.

The technology of the drone and also the size depends essentially on the specific application. For example, if you compare the urban space with remote areas completely different technology and completely different security systems are used.

Challenges and problems prior and during implementation include three main types: legal, social and technical. Most of the time there is only a limited regulatory framework, especially in Germany. Also, an important question is how this technology is accepted by the public. With regard to technical issues, security systems have to be in place in case of flight failure. Manual takeover by a human operator is essential to guarantee safe performance.

The actors within the drone environment can be classified into three types. First, the classical drone manufacturers who already have experience in the aviation sector. Then, large tech companies that recognize a new market (e.g. Amazon), and start-ups. Some of them stem from the military area and use respective knowledge and expertise. Humanitarian organizations cooperate with large NGOs and other partners, as they have no money for their own development. They use already existing and finished concepts for their own projects. If own capacities and abilities are not sufficient, appropriate partnerships and collaborations are formed.

When choosing a partner, also ethical principles apply. For example, that is why some NGOs do not cooperate with companies such as Airbus. Because such large airlines also operate in the military sector. Cooperations are also built country dependent. Technologies of some manufacturers partly fall under arm weapons and are thus viewed critically. For example, navigation systems are sometimes similar to those used for missiles.

The last mile is the most expensive in the entire delivery system and is usually taken over by the complex delivery system of e.g. the post office. Tech giants hope that the drone will take over this task instead of a delivery couriers, as it is a much cheaper alternative in the long run. There is also already intensive research on mobility technology. Air taxis from Airbus or Uber will be a cheaper option than helicopters.

One must differentiate between three types of drones: fixed-wing, hybrid drones, and classic helicopter-like drones. There is also a difference between UAV and UAS. UAS are for example zeppelin systems that are very interesting for the future of the medical delivery sector. It resembles a mother ship where payload goes in, and can be further processed with other smaller delivery drones.

Technological features a drone must possess include navigation and control systems. Battery systems nowadays still have many technical limitations. Efficiency always is the main focus of technological drone design. All aspects are also interesting in the military sector. The fixed-wing and hybrid drones are very interesting, because once in the air they consume relatively little energy by gliding.

There are legal guidelines regarding weight and type of delivery. Government in Madagascar, Africa, for example, is much more open to such technologies as they recognize the opportunity and added value for the country. Prevailing infrastructural problems such as non-existent or bad roads can be overcome by air.

Areas that benefit from such technologies are rural area with poor infrastructure but also urban areas. For example, Uber in Brussels is working on an autonomous air taxi to shorten the way from the airport to the city.

Questions that have to be solved from a regulatory perspective include the definition of no fly-zones (for example around high buildings and hospitals). Or, how is a potential crash integrated into normal air traffic? What happens if the drone crashes? A safe recovery of the drone is essential, especially in rural areas.

These projects always include various interest groups. Residents and urban population fear security aspects, privacy and espionage and are as well concerned with noise nuisance. Also drone delivery leads to the extension of the city by an additional level and can be used as class argument (who can afford transport or delivery by drone?). Such problems can be tackled with educational work which is especially carried out by larger companies. That includes informing the public about the technology and purpose of the drone. Also, the ethical design of the technology is critical. It should be technical impossible to invade the privacy of the public. It should be only possible to turn on the security camera if an error message is received by the drone during operation. Ethical decisions have to be taken at the beginning of implementation and development.

The potential of drone delivery depends on region and application. The legal situation is often not very attractive. However, drone technology will become established in niche markets. For example, for authorities such as police, fire brigade and rescue service, perhaps also for hospitals. I am skeptical about parcel delivery as there is no state monopoly. Regulations always have to be taken into account. But also, the type of delivery as there might be a special status for certain deliveries granted. A possible consequence would be the lifting of the ban on night flights for the named authorities, and this is also very interesting for the private sector. For the future, cost-benefit analyses are very important. There are already many possibilities for the last mile such as bicycle and car. I see high potential in semi-urban areas, such as suburbs, where population density is not so high.

Challenges arise from a combination of all areas: public acceptance and turmoil, uncertainty of safety guarantees, existence of no-fly zones, lack of suitable landing sites, as well as numerous technical challenges. The hype of the drone as a miracle cure and all-purpose tool is over. Cost-benefit analyses are made to recognize real advantage and investment needed.

Three factors must be examined critically to lead to a project's success. Technical aspects include control systems (autopilots, crash avoidance etc.), efficiency (how can I transport as much as possible with the most efficient engines and good battery charging?). Regulatory aspects decide on whether I am allowed to do that at all. Social aspects include general acceptance, and the openness for such technologies should be recognized before implementation. New technologies cannot be assessed by people. Many companies recognize the importance of involving the population. For example, a project in Stuttgart was only implemented as soon as all population groups and suburbs involved had given their consent. It's a new field for everyone. As a pilot it's very difficult to get licenses, because even authorities don't know how this area develops. Questions like 'who is liable for the drone if it crashes into a car', or 'who is liable if a drone triggers a forest fire when flying over a forest' must be clarified. These questions are being discussed. As you can see, all these factors are interdependent.

Looking at the long-term, it can be said that the human factor is very expensive in the long run compared to a robot. Efficiency presents the long-term success factor (e.g. frequency of drone, how often it flies, how often it can be used before it is worn out). At the moment, human pilots, operators and monitors work together. After the automation of the entire process there are only technicians left and needed who take care of maintenance and technical problems. The human factor will be reduced to a minimum.

Expert Interview #3	
Name / Synonym:	<b>Alexander Norman / I3</b>
Position:	Global Networks Operation Lead
Company:	Matternet Inc
Industry:	Aviation and Aerospace, Drone Development
Relevance:	Responsible for global flight operations; involved into medical UAV delivery projects in Switzerland and the U.S.
Interview date and time:	28.11.2019, 9:00 am
Interview length:	1:15 h

My background is airspace engineering. I used to work at Airbus and then at another drone startup in Switzerland. A little over two years ago I started working for Matternet. At that time we were probably about 20 people worldwide; we created the first drone network in Lugano; that was at the end of 2017.

And that was in cooperation with Swiss Post. But it started a little earlier. The first test flights were carried out in Switzerland in spring 2017 and at the end of 2016 respectively. From the network in Lugano in 2018, we then expanded to Zurich and then significantly expanded our team. In Switzerland we are about twelve people and worldwide we are around 60. Our HQ is in California. My responsibility concerns the entire flight operation worldwide. I am also very involved in the new projects that we have now and all Regulatory concerns and also in the partnership with UPS.

Besides the HQ we have a subsidiary in Zurich: Matternet Operations GmbH. These are the two hubs. In Switzerland we still have a route in Lugano that we operate and in the USA, we currently have a route in North Carolina that we operate in Raleigh. And then we have some projects worldwide that we are currently managing.

The challenges here in Switzerland are definitely different from anywhere else in the world. This is mainly because the regulatory environment here in Switzerland is very liberal. We have a very good relationship with FOCA, the Federal Office of Civil Aviation. The Federal Office of Civil Aviation is very innovative when it comes to drones. They are not only active within Switzerland, but the BAZL has contributed significantly to the fact that worldwide drones have a certain framework to be approved at all.

The JARUS Group (Join Authorities for Rulemaking on Unmanned Systems) has pushed this forward and has developed a methodology that was originally known in Switzerland as GALLO, then internationally as SORA. That is why we are in Switzerland at all and why the Regulatory Environment is better than anywhere else. The latest EU regulations have also recognized this SORA process as an Acceptable Mean of Compliance, which is yet another big step and also shows once again that these methodologies, which were developed in Switzerland, are also applied internationally. This whole ecosystem allows us in Switzerland to carry out these flights as we do. Other countries do not yet really have a framework for this.

In Germany there is no federal office, but this is regulated per federal state. There are own state aviation authorities. That is a problem of its own. But there it is mostly so that they say: We do not even have the framework to approve a flight. They lack a legal basis. The law states that neither the population nor air traffic may be exposed to an increased risk.

The responsibility itself is actually clear. The Federal Ministry of Transport and the Interior is the responsible body and it is also in charge of making legislation so that the industry can develop further. At the moment, however, this is not actually the case. There is so much that could be done in Germany with drones, but at the moment this is simply not possible because the BMVI does not push it. Some aspects of the aviation laws in Germany are very old. Also it depends very much on the individuals, who co-operate that and in what respect they are innovative. And then another layer comes over it. Namely the entire politics and what has just priority. In Germany, especially with the scandals we had in the south with the car manufacturers, a great deal was invested in climate and climate protection. The priorities were then also set so that a Federal Ministry could allocate resources accordingly.

The challenges that we usually see here in Switzerland have to do mainly with public opinion. We are in a niche where many people think they understand something about it, but it is actually very complex. And it's actually an aviation issue. For example, the incident in Zurich: The drone worked exactly as it should. And also, the SORA (specific operational risk assessment) that lies above it. It was no coincidence that the drone fell into the lake. In commercial aviation, the approach is to use a certified aircraft. This was designed according to certain standards, then built and maintained according to certain standards. There are very strict regulations that prescribe exactly how an aircraft may be built. The problem, however, is that these standards and regulations do not exist in the drone world. This is called a certification specification. They don't exist for drones at the moment; at least not in the class we normally operate in or talk about now. Accordingly, a non-certified aircraft can't fly over people, for example, because that is of course an increased risk. Neither are you allowed to transport people with a drone that is not certified. Because it is not guaranteed that it is safe. The problem that arises is that even if you wanted to make a specification, it would have to be as extensive because the drone sector is not as manageable as that of an aircraft. For example, an airplane must always have two wings and it must always have at least one engine, and from there you can build. But a drone can be fixed-wing or rotary-wing. It can take any

other form. Accordingly, one asked oneself: How can we ensure that where drones fly and also the drone that flies is a safe operation? The approach that was then chosen is risk assessment. Risk assessment takes everything into account. This includes who flies the drone, how the drone is equipped, how the drone was built, where the drone flies. All this adds up to this Specific Operational Risk Assessment (SORA).

In our case, the route was chosen exactly so that it flies as much as possible over the lake. That we do not, or fly as little as possible over inhabited areas (unsheltered people) in order to minimize ground risk.

In this particular case, the drone did not have a GPS anymore and triggered the parachute by not being able to ensure where it was. And then it fell into the lake with a parachute.

Everything, from beginning to end, worked as it should. The only thing was that the GPS sensor gave up. But all the population can see is that a drone fell into the lake. That's a big problem. Then come other "drone specialists" who claim that it would be easy to fix it and so on and so forth. Many people think they know what they are talking about.

What made the whole thing even more difficult in this case was that because we fell into the lake and the drone was a total loss, the safety investigation authority for transport in Switzerland classified this incident as a flight accident. If an aircraft is a total loss, then it is assumed to be a flight accident. A total loss is of course something quite different for a drone than it is for a manned aircraft. If you have a total loss on an aircraft, then you can be pretty sure that people have also been injured. This is simply not the case with a drone. In addition, the cost of a drone is substantially less than that of a manned aircraft. The problem here was that this incident was classified as a flight accident. Accordingly, we were the first to deal with the SUST. This was then further investigated as a flight accident.

Now one must also know that for such flight accidents that are investigated by the SUST, it can take up to a year or longer until an investigation report is available. The reason for this is that these things in manned aviation are usually extremely complex. The aim of these investigations is to make air transport safer in general. In other words, if an airplane falls out of the sky, we want to make sure it doesn't happen again. The investigations are very thorough. It goes from what happened to why it happened. This can involve looking at the whole organization behind it, the company, up to the CEO of the company, all the decisions behind it and investigating whether there might be a risk behavior somewhere that ultimately led to this accident. Or a behavior that could lead to an accident in the future.

These investigations are very thorough and take a long time. Of course, the SUST does not only have to treat one accident, but mostly several at the same time. Our drone accident is of course not a priority, because no people have been injured. And because you can also say that this is a relatively isolated incident or that it does not affect the whole of Swiss aviation but only us.

These factors also played a major role in the second incident. In the first incident, we were able to persuade the SUST to publish a report relatively quickly. The problem with SUST is that they do not necessarily have the necessary expertise to investigate an accident at all, because they are more used to manned aviation than unmanned aviation. There are already some things that are different, e.g. the software is much more detailed.

It is important to understand that we operate in an environment that is on the threshold of manned aviation. This means that we have to comply with certain regulations that actually apply to manned aviation. In Switzerland it's still relatively okay. But especially with the flight accidents that we have had, all these laws have also become effective for us.

It is much more extreme in the USA. In the USA, in principle, we have to comply with the same regulations as an airline. It's almost absurd sometimes because, for example, an update or the replacement of a charger is treated as if you were changing an engine on an airliner. You have to go through similar processes, you have to have similar qualifications and you have to keep similar documentation; that means the Maintenance Record, Maintenance Program and Training. Many additional requirements that must be met in order to fly at all.

This affects the duration of the process and, unfortunately, public perception. Because if someone like the SUST writes that a drone fell into the forest right next to children, it's like a plane almost killing children. This is very problematic. Above all because it is not true and because the population no longer makes a difference between an airplane and a drone.

The initiative we launched was the Safety Panel. The problem was that the SUST said from the outset that they needed at least one year for this report. But we cannot wait a year until we fly again. In the eyes of the public, this is a criminal investigation, in other words a police investigation, but it does not take place in this way. This is a safety investigation. If there were any reason to suspend our operations, the Federal Office of Civil Aviation would have to withdraw our permit. But that never happened. So theoretically we could have continued flying immediately after the incident. That would have been legally okay. That had to do purely with Public Perception and with our customers that we did not fly. Internally we took this very seriously and grounded our drones immediately after the incident. But we understood relatively quickly what the problem was and how it came about. We fixed it and from our side it would have been okay to start again.

Also, from the Federal Office for Civil Aviation it would have been okay to take off again. But the fear was that the population would not accept that if we take off again. And it turns out that the investigation report is not yet available. The population is not familiar with manned aviation. This is a perfectly normal process. Such a safety investigation can take years. If there is no direct Safety Concern, then this is not necessarily urgent. For this reason, it was decided not to start because one was afraid that it might have an impact on the public. In the first accident of the 737 Max more than 200 people died. Even then the Max wasn't grounded, just to make a comparison of what is needed to ground a fleet and say you can't fly anymore. We weren't grounded either, but it was an internal decision that was made to manage the Public Perception.

The problem, however, is that we now haven't flown for a very long time, so that the population will ask why we didn't fly even though everything is claimed to be safe.

The plans are clear. The Safety Panel was founded. The task is to screen our operations for industry standards. This safety panel consists of high-ranking experts from manned aviation. This means that you know what the industry standard of manned aviation is. And if they find the operation with our drone for safe, then we will take off again. It will not be too long before that happens.

That we transport medical goods is of course something completely different than a BigMac or an iPhone. And that also goes back to public acceptance. If you transport medical goods,

then we fly from a known Point A to a known Point B. But when you transport Big Macs, you fly from point A to somewhere. You don't know where to go because you probably always have different customers. That's an enormous challenge, because each time a new route is flown. This route must be approved by the Federal Office of Civil Aviation not only in Switzerland but also in other areas. Accordingly, it is still relatively unrealistic at the moment that such a door-to-door delivery has a business model at all. At the moment not only the regulatory framework is missing to implement such a model, but also the technical possibilities to implement it in such a way that it is also safe. If you fly somewhere else every time, then you have to be able to dynamically determine the risk in the air and on the ground every time.

I believe that in the distant future, the end customer will also get delivered home. However, it is likely that you will need a prescription drug more often. This means that it would perhaps make sense to create a route to this house. So, unlike other industries, the likelihood of regularity is more likely.

I think it will generally take some time, medical or otherwise, before we can really fly to individual homes. Although we have demonstrated that in the USA. But it is one thing to demonstrate that in an individual case, and it is quite another to really make a business out of it.

We have to say that at the moment we are in a phase where the focus is not necessarily on the business, because we are still in a phase where the technology still has to prove itself and we still don't know very much. We don't know how certain factors behave that could create a truly reliable business model.

The weight plays a big role. Weight and volume. Medical goods are usually high-value in small volumes and with a low weight. What is also very interesting is that the good is usually not valuable for third parties. So if we look at blood samples, for example. For an individual it is of very high value. But for a third person it is absolutely worthless. That makes it very interesting from a security point of view. In Switzerland we won't have the problem so much. But if we transport Prescription Drugs in America and this is publicly known, then I could imagine that we will have one or two incidents where someone tries to get these drugs.

The drugs then also often have a positive influence on public acceptance. This is probably the main factor; the public acceptance is quite different when transporting blood samples compared to other products.

The drone has a certain noise footprint. We have also had complaints and will continue to do so. In addition, because the drone is something new, people will always be skeptical. If your answer can be that you don't have to worry and also that blood samples are transported, then it's different from saying: 'yes, we know it's loud, but we transport something to eat.'

At the moment the regulation is completely independent of the product that is delivered. In fact, the regulator is not allowed to make a distinction. In principle, everyone should be equal in front of the law. That means it should make no difference from the regulatory point of view what you transport. That does not mean that it will be the same everywhere. That does not mean that everything will be accepted, especially when it comes to innovative technologies and an increased risk for the population. Then not only the Federal Office of Civil Aviation is involved, but also other stakeholders, such as the city of Zurich, which can

also veto and thus exert an influence. In principle, the regulator is not allowed to make a distinction.

What will play a role at some point is that a drone that transports drugs or blood samples will probably have priority over other drones.

Politics, of course, always plays a role. It is not only about regulations, but these are real projects that will be set up. These are projects that aim to create certain standard scenarios and to present certain criteria that make approval easier. A lot can be achieved through standard scenarios. For example, the EU recently published a certain number of standard scenarios. For example, there is a standard scenario for surveying flights in order to get a quick authorization with the fulfillment of certain criteria. It may well be that standard scenarios are also created for medical care. A standard scenario can only be created on the complexity of the mission, not on the goods we transport. So, when we fly from A to B, there is a certain risk. But if you fly from A to XYZ, that has a certain other risk. Accordingly, it needs a different risk assessment and would fall under a different scenario accordingly. What you're transporting shouldn't really matter, though. It's more about the type of operation. And what is still superior to the whole is a permit whether you are allowed to fly in the country at all. There can be a political decision about the aviation authority.

**Validation:** I find this an interesting approach. That makes sense. I think it's a good framework. It's very extensive, very detailed.

I start from our company and we already have a relatively well-developed product; that means I don't have to worry too much about our software capabilities or hardware design. If you don't address that of course, then you don't have to worry about public acceptance.

Regulatory Environment could be expanded. That is still a little vague here.

So as said the Regulators shouldn't make a distinction. I am pretty sure that drones are applied much more in Rwanda or other African countries. But you don't necessarily know that. For example, I can imagine that many more flights are made for surveying. So, there are some raw material quarries that have to be surveyed or that have to be explored in the first place. Healthcare is simply a sector that is not well promoted in the Third World or developing world or where there is simply no turnover. That's why these projects are created there.

All these challenges there exist only because your benefit for them is directly available and because it is an incentive for European companies to bring technology into the country and further develop it there, but then also a win-win arises directly where the company can further develop itself but also brings a benefit for the population at the same time. A surveying flight has an extreme benefit for the company that is based there or tries to mine some raw materials there. They are also willing to pay for this technology and maybe buy it. That's why in general you don't know so much about this kind of use of drones.

I wouldn't say there's a benefit for the authorities. On the contrary, I would say that the more different the dimensions are, the better for the regulator. This is the only way for the regulator to create laws that really make sense, i.e. to cover as many operation spectra as possible and to get the best picture of what is necessary to allow drone flights in the future.

Perceived benefit plays a more important role in public perception. The regulator may approve the project but cannot or should not set priorities. Even on the contrary, blood or,

depending on what you are transporting, an increased risk, i.e. a dangerous good. And it has to be treated accordingly.

With regard to the drone there would be another big factor: Detect and Avoid. The ability of the drone to integrate into the airspace. This can be software as well as hardware, and also on-board or off-board.

Expert Interview #4	
Name / Synonym:	n/a / I4
Position:	Future Transportation Manager
Company:	n/a
Industry:	Automotive
Relevance:	Involved into previous implementations of UAV pilot-projects using hybrid system
Interview date and time:	19.11.2019, 12.30 pm
Interview length:	00:30 h
<p>I am currently responsible for the Solution and Sharing Strategy in the Future Transportation division at {Company X}. Our division's goal is to develop innovative products and projects that go beyond our core business of vans. As part of this, the {Project X} was launched, for which I was responsible for some time. Vans were combined with drones and thus combined with the advantages of the individual means of transport.</p> <p>We initially deprioritized this project, which means that we actively decided not to carry out any further pilot tests this year, but to wait and see how the regulatory landscape develops: How fast is the drone legislation progressing, what are the competitors doing, what will the legislation look like in Germany? The second major topic besides legislation is UTM, i.e. Unmanned Aircraft Traffic Management Systems. How do drones that are in the air manage to orchestrate in such a way that safety is guaranteed, and dynamic flight route determination is possible? We would like to wait and see how these two areas develop.</p> <p>The safety of our drones is our top priority. We have safeguarded this through various tests and markets. The question is how to organize the air transport system for drones. Air traffic management systems: how can person A get his or her specific flight route cleared if he or she wants to fly to a specific destination at a specific time? How does it work that all drones in the air recognize each other or are assigned specific flight routes from a central location so that no collisions occur in the air?</p>	

It is not yet entirely clear who the final responsible parties are, this can be the aviation safety authority, as well as a government-related organization, but also private companies. There are very different strands as to who sets up this air traffic system. As things stand today, this responsibility has not yet been clarified.

{Company X} has invested in the Matternet company. Matternet is a drone manufacturer based in Silicon Valley, USA. On the one hand we made this investment and on the other hand we decided to carry out the strategic cooperation with {Project X} and to cooperate beyond the investment. Unfortunately, I can't say anything about the exact details of how we decide to invest in projects. It was of course the combination of their product and ours, the strategic fit that was there. Another important criterion was that the product was safe. Those were the main motivating factors.

The motivation behind this project can be answered quite well with the order from the Future Transportation division, we are trying to look beyond our core product. We try to combine innovative technologies with our classic products. This develops either in the area of mobility of people or the transport of goods. Combining vans with drones was part of this. Various transport options and solutions were looked at. For example, experiments with small delivery robots were carried out in-house. We tried to add an innovative technology to our core product.

The subject of security is very diverse. It starts with the actual drone technology, but then goes beyond that to humanitarian factors. The people who fly these drones need to be well trained. One safety feature we always had with the Matternet drones was that there was a parachute that would automatically open to take the drone to a controlled descent.

The combination of range, carrying capacity, safety as top priority, energy consumption (combined with range), autonomy level (fully autonomous, automated flying) is important when choosing partners. Also, the purpose and application of the drone, whether for delivery, for installed cameras or passenger transport (air taxis) is essential for the choice of drone technology.

We started our project in Switzerland. Switzerland is very open to German projects. At the time, we were very close in exchange with FOCA, the Federal Office of Civil Aviation, for a project of this kind that had never existed before. Then, of course, all participants must be brought together at one table and must have the confidence to accompany such a project. Switzerland was very open and cooperative. We found safety solutions or options for all possible scenarios, so that all participants started the project with a good feeling. Nevertheless, there are still a few aspects missing until drone flights can be scaled up and used everywhere.

We tried to make the whole project very transparent. We informed all residents at the locations where there were departure areas and also all police stations along the flight route, in the event that residents report to the police and request information, these authorities know about it. That worked very well. We were welcomed with open arms and had many interested visits. To approach the subject with transparency was exactly right. The feedback was predominantly positive. However, the limited time phase of the pilot project was clear from the start.

We wanted to show that it is possible to carry out these flights at all. These were automated flights, i.e. semi-autonomous flights over inhabited areas in Zurich in Switzerland. There

were four different flight routes and this type of project had never existed before in the world. We wanted to show that it is possible to do something like this. For us it was also important to show the technological processes behind it. It was clear from the start that the project would be limited in time. After the project, we went back to {City X} and evaluated the key learnings. It was clear from the beginning that we would not continue to operate on a day-to-day basis in Zurich. Whether it's a two-week pilot program or a scaled solution, the public's opinion will of course also be influenced. I find it difficult to assess what the population's opinion of a long-term project would be.

We focus on the customer and the use case. In our project, i.e. the combination of van and drone and innovation on the last mile as well as the time efficiency of parcel delivery, mainly people in urban areas are affected. It may be easier to fly drones in an unpopulated area, but that was not the approach we took. The risk is, of course, much lower if the drone flies over unmanned territory. There are probably other countries that do not have such high standards. We deliberately wanted to carry out this pilot project in an urban area.

There are various initiatives within the company. For us, the main focus was on expanding and combining our products with new technologies. The combination is very exciting. If you look at the inner-city flight, the take-off and landing area of the drone is always a problem. You always have to make sure that neither people nor animals are in the vicinity. As a rule, people in large cities do not have sufficient green areas or terraces where the drone could land without problems. If the drone lands on the van roof, the height of the roof alone makes it a safe landing place where no one can injure themselves. Also, the roof is always free for the drone landing. We have also found that it is very complex to choose completely flexible flight routes. Because the integration and management of the airspace is not established. Our solution had the advantage that different landing points in the city were distributed over the vans. From there, you can then say exactly which flight route is to be released. With predefined flight routes, you can get a regulatory grip on this and you always have a safe landing site. The number of vans used depends on the required number of landing points of a certain district. The delivery is then brought to the end customer by the parcel driver, who may already be on his tour anyway.

Basically, I see potential in many industries. Overall, the concrete development of this sector is difficult to assess. I can imagine that drones will be part of the cityscape in the medium to long-term future. I believe that the two issues of regulatory affairs and the Air Traffic Management System need to be clarified and then a lot of things will clarify by themselves. You can get a grip on the subject of technology and on the subject of the public, because you can also offer them new opportunities through new technologies. The drone is particularly suitable for small and light products. In the medium to long term it will initially not be possible to deliver all products transported by vans by drone.

The drone landscape is very different and should be classified according to the use case or application (inspection, delivery, transport drone in larger dimensions). Many of the factors mentioned depend on this.

Expert Interview #5	
Name / Synonym:	n/a / I5
Position:	Project Manager Urban Air Mobility
Company:	n/a
Industry:	Automotive and Consulting
Relevance:	Extensive background in urban air mobility
Interview date and time:	20.11.2019, 4:30 pm
Interview length:	0:25 h
<p>Until a quarter of a year ago, I led the Automotive Strategy Department at {Company X} and spent two years working intensively on the topic of Urban Air Mobility. I've been with {Company Y} for six months now working in the Urban Air Mobility division with a focus on passenger transport. However, drone delivery is an adjacent area with similar challenges.</p> <p>The regulatory perspective is crucial when it comes to scaling the first business models, be it in the area of last-mile delivery or in passenger transport. There are still no fixed aviation regulations in this area. The biggest challenge is certainly the management of the airspace and the automated registration with traffic management, which must be given in order for the whole business to be scalable. Technically speaking, the drone must be designed to enable stable flight so that it can be used. The topic of noise level is also important, as social acceptance is largely triggered by the extent to which a drone is perceived as annoying or not.</p> <p>There are three major authorities worldwide that control and regulate the entire airspace: 1) EASA for Europe, 2) FAA for North America and 3) CAAC in China. These three main authorities trigger the national aviation authorities. Non-European agencies are also connected to EASA, e.g. Singapore has quite similar adaptation behavior to European aviation law, just as Australia and New Zealand. Brazil or Dubai are rather triggered towards FAA. An own regulation set was already established for small drones up to 25kg, EASA gives regulations as far as possible which are then developed further, with regard to FAA the topic is advanced by organizations.</p> <p>Basically, there are always a lot of regulations when it comes to air transport, goods and people. The small delivery of drones is already much more regulated than passenger transport. It is relatively new that one can use private drones, and if one looks at the development times of the regulations, and also the current state in comparison with past regulations which were predominant 10-40 years ago, the last five or three years the EASA needed to publish a standard work for drones is relatively fast. However, the technology is of course developing much faster than the regulatory level; it is also clear that the players feel slowed down by this. But this step is extremely time-consuming, and at the end of the</p>	

day the safety of the regulations is crucial, since the safety of the entire population depends on it. Therefore, it is justified to take this time.

Looking to the future, it can be said that the potential will be application-related. In the medical care field, it will be easier to argue with regard to the social aspect, because this is needed. And transport between hospitals in hard-to-reach areas will benefit greatly. I believe that once it goes into commercial operation and you have a larger load transport than today, there will be application dependent cases.

If traditional delivery methods will still be needed or completely replaced depends on the application. The transport of organs could be carried out more efficiently using drones, and the lower frequency of such transport also makes it suitable. With regard to the delivery of medicines, it is also necessary to differentiate whether the medicine is extensively available, whether it can be transported by road, or how urgently it needs to be transported to its destination.

With regard to cooperation, a typical case would be to sign a public-private partnership. Support structures of a state nature are required and are actually always present in the health sector. Private companies manufacture the drone and secure the operations.

In terms of technology, the drone must be equipped with a certain probability of failure. If operational engines fail, the drone must be intercepted. In general, there are various failure probabilities in aviation that can be derived. Furthermore, it must be considered whether there is a coupling to Air Traffic Management that ensures interaction between the individual flying objects in a safety-critical area.

The Federal Ministry of Transport is responsible for this Air Traffic Management. In Germany it has been handed over to the German air traffic control. The task is air traffic control. German air navigation services are integrated into the European air navigation services system. To this day, all this is monitored by humans, by radio and GPS. This is difficult with small flying objects. There are now several start-ups, including Droniq, started by Deutsche Telekom and German air navigation services. They equip the drones with SIM cards and thereby coordinate them. There are very different approaches and technologies. In the future, an automated system that captures every single drone and coordinates everything will be indispensable so that everything can be carried out safely. How exactly this will happen in the future is relatively open. Today this is not yet regulated to that extent. I have to register my drone with a certain weight; if it exceeds a certain limit, I have to register a flight and also define the altitude and destination. In my opinion, the whole drone business will only be realized when the whole process is automated, i.e. the drones are automatically routed according to the destination.

In densely populated areas it is of course also a visual theme, as the population does not want the drone to fly past the window and over my property. Depending on the technology, it may also be necessary to take pictures to control the drone. This is certainly an issue that influences acceptance.

The noise of the drone is a difficult topic, because it is hardly possible to not make it recognizable. As far as safety is concerned, the drone must never come down unsecured and injure people. If such an incident occurs, it can have an impact on the whole business. The reliability must be extremely high and the noise level extremely low. And route planning must be so clever that as few people as possible feel affected.

Passenger air traffic in Frankfurt, for example, is based on highway routes, as noise pollution is already relatively high there and buildings are not very dense. This is more difficult in the city. Villages where the need is larger than the disruptive factor are better suited for such projects. This is of course more often the case in developing countries. The medical care sector is predestined to use this technology. I believe that in the developed countries, especially in Europe, this issue will be extremely difficult to implement.

The extent to which this can be achieved cost-effectively is also an important point.

**Appendix 7: Coding of interview responses**

<b>First-order codes</b>	<b>Second-order codes</b>	<b>Overarching dimensions</b>
Public detailed reports	Transparency	Public as relevant interest group
Independent expert council		
Informing residents in advance		
Well-known, trusted company	Reputation	
Positive associations		
Internal political decision to stop project		
Negative media attention		
Contribution to health		
Pre-planned route	Perspective-taking, communication	
Personal conversations and problem solving		
Many interest groups involved		
Learning from clients		
No cameras	Ethics and Privacy	
Espionage		
Extension by another society level		
Noise nuisance	Challenges, issues	
Resistance of local residents		
Mistrust		
New technology-opponents		
Influenced by and focus on negative media publicity		
Personnel	Human resources	Partnerships
Know-how		
Relationships	Cooperation	
Local partnerships		
Governmental support		
Ethical values		
Win-win situations for firm and population		
Public-Private-Partnerships		
Drones manufacturers with experience in the aviation sector	Parties involved	
Start-ups		
Tech-giants		
Humanitarian organizations and NGOs		
Number of potential clients	Cost-benefit	Contract and client
Frequency		
Minimum purchase, quantity		
Operational costs		

Required staff on site		
Product quality concerns	Client management	
Seriousness, intention		
Suitability		
Cities and densely populated areas, inhabited areas	Population	Location
Unpopulated areas		
Poor, washed out roads	Infrastructure	
Lack of adequate infrastructure		
Flying over lake		
No prior experience	Staff	
Expert knowledge required		
Weather	Environmental conditions	
Strong winds		
Rainy season		
Well documented ground conditions	Topography	
Distance between destinations		
Size of service range		
Local restrictions	Regulations	
Regulations per country and federal state		
Emergency landing	Safety features	Drone technology
Security mechanisms (e.g. collision avoidance)		
Detect and avoid capability		
Minimize ground risk		
Pre-planned route	Prior safety measures	
Fly over unmanned areas whenever possible		
Service radius	Technological capabilities	
Speed		
Manual battery exchange		
Test environment	Proof-of-concept	
Trial phase		
Pilot project		
Enhanced safety, navigation and control systems	Future outlook	
Focus on training technicians		
Modify drone sound		
Efficiency		
Approval by Federal Office of Civil Aviation	Legislative infrastructure	Regulations and legal processing
Liberal country		
No existing regulatory framework and drone-specific legal basis		

Strict regulations and restrictions		
Liability, responsibility		
Airspace integration and dynamical risk assessment		
Long processing time for authorization and safety investigations	Management and regulatory collaboration	
Risk assessment to issue certifications		
Priority of topic		
Close collaboration, transparency		
Difference in pressure, vibrations and temperature	Quality	Cargo
No documented adverse effects on products		
Transportation of variety of products		
Product quality of utmost importance		
More regular deliveries of medical supplies	Specifications of medical cargo type	
High individual value, low value to third parties		
Weight and volume		
Regulations are independent of the transported product		
Effective airspace integration crucial	Airspace management	Scalability of UAV delivery
UTM design		
U-space		
Authorities are preparing themselves	Regulatory developments	
Better defined regulations		
Sophisticated detect and avoid capabilities	Technological advances, automation	
Combination of technologies and drone systems		
Increased battery lifetime, longer distances		
Heavier payload transportable		
Autonomous battery exchange		
Automated loading and launch		

**Appendix 8:** Relational model of identified UAV project dimensions (own presentation)

