A Work Project, presented as part of the requirements for the Award of a Master's degree in Management from the Nova School of Business and Economics.

STATUS QUO AND POTENTIAL DRIVERS AND HURDLES OF URBAN AIR MOBILITY WITH A FOCUS ON THE GERMAN MARKET

AN EMPIRICAL ANALYSIS OF ENVIRONMENTAL & COMMUNITY- RELATED SUCCESS FACTORS

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17-12-2021

Abstract

Status quo and potential drivers and hurdles of Urban Air Mobility with a focus on the German market

An empirical analysis of environmental and community-related success factors

Urban Air Mobility (UAM) aims to solve mobility problems in urban areas by using electric vertical take-off and landing vehicles (eVTOLs) for passenger and goods transportation, moving transportation networks into the air. Despite the growing interest, there is limited comprehensive literature on the relevance and interdependencies of the industry's success factors. Thus, this paper analyses the environmental and community-related success factors public acceptance, regulatory, and environmental impact. The findings of semi-structured interviews and an online survey indicate safety and noise as the most crucial adoption factors, whereas safety concerns are related to regulations as stricter regulations lead to more safety and thus, higher social acceptance.

Keywords

Technology Adoption; Innovation; Technological Innovation; Business Model; Digital Transformation; Technology; Technology Strategy; New Product Development; Advanced Air Mobility; Urban Air Mobility; Drones; Air Taxi; User Adoption

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1 Introduction

In 1940, Henry Ford said, *"Mark my word: A combination airplane and motorcar is coming. You may smile, but it will come."* Almost 80 years later, Ford's vision can become a reality. The convergence of new technologies makes it possible to add transport networks to the third dimension - the sky. As a result, what has long been in the realm of science fiction is now attracting global interest. The expectations are enormous, as investors and players assume there will be flying passenger and delivery drones in the sky by the middle of this decade. The increased interest from prominent investors fosters Urban Air Mobility (UAM) companies as investment sums continuously exceed previously established thresholds (Thornhill 2021). Global trends, such as growing population and urbanization, raise the need for new mobility solutions (United Nations 2018). Thus, innovative developments such as shared mobility services and autonomous vehicles providing safe and comfortable transportation have been emerging. The need to reinvent mobility led to research interest beyond mobility solutions on the ground. Accordingly, a new perspective on moving mobility up in the air has ascended (Al Haddad et al. 2020). Emerging start-ups in the drone industry are currently racing for market power, reaching valuations of billions of dollars even before the first commercial flight has taken place. However, for successful implementation of UAM, drones must not only be technologically and commercially viable but also socially acceptable. Therefore, drone companies face significant challenges yet to be overcome (Thornhill 2021).

This paper aims to provide an overview of the different relevant areas of UAM research. Since UAM is a relatively unexplored and exciting topic, only a little exhaustive overview of the main drivers and potential hurdles of UAM has been provided. This paper aims to fill this gap by analyzing these success factors according to their relevance and interdependency and thus, intends to constitute an implementation compass for industry stakeholders. Hereby, particular focus is placed on Germany as a potential market for UAM operations, as the country holds some of the strongest players in this uprising sector.

The thesis is divided into six chapters. After these introductory words, chapter 2 first provides a literature review on the topic of Urban Air Mobility. Chapter 2.1 discusses the theoretical background, while chapter 2.1.1 defines the term Urban Air Mobility and chapter 2.1.2 classifies drone applications. This is followed by a presentation of passenger drones (2.1.3) and delivery drones (2.1.4). Finally, the relevant success factors for implementing UAM are presented (2.2), and the innovation scene in Germany is introduced (2.3). The foundation of the third chapter is a previously conducted empirical study and expert interviews on the success factors of UAM. The approach and methodology are presented in section 3.1, followed by a description of the participants (3.2). The third chapter focuses on delivering the results, where the industry challenges and hurdles are divided into two main sections. First, the industry setting-related success factors in chapter 3.3.1. Second, a discussion of the environmental and community-related success factors in chapter 3.3.2. This is followed by a brief discussion (4) and a presentation of the study's limitations (5). A conclusion and a brief outlook conclude this work in chapter 6.

2 Literature Review

The following chapter comprises an extensive literature review of the UAM sector. First, the theoretical background is presented, followed by a brief presentation of relevant success factors, and finally, an overview of the innovation scene in Germany is given.

2.1 Theoretical Background

2.1.1 Definition of Urban Air Mobility

Advanced Air Mobility (AAM) is a concept that provides consumers with access to on-demand air mobility, commodity delivery, and emergency medical services using an interconnected and integrated multimodal transportation network (Goyal et al. 2021). One term that is often used within the AAM approach is Urban Air Mobility (UAM). This emerging concept foresees safe and efficient air transportation in the low-altitude airspace in urban and suburban areas. The idea of UAM has been around since the 1960s when several companies used aircraft to provide point-to-point shuttle services in megacities such as New York and Chicago. However, operations had to be significantly curtailed due to public acceptance issues and financial problems that continue to impede the development of UAM today (Wu and Zhang 2021).

As a result, a new UAM concept has emerged in recent years based on a new type of electric aircraft that can take off and land vertically, called eVTOL (electric vertical take-off and landing vehicle). These aircraft types are equipped with autonomous and electric propulsion technologies enabling safe, quiet, and efficient air transportation in low altitude flight. Therefore, it can transform the way people move in and around cities by reducing their commute times, circumventing ground traffic jams, and providing point-to-point flights in cities (NASA 2018). In addition, though, these eVTOLs are not solely limited to passenger transportation but also include delivery drones, which is discussed in more detail in sections 2.1.3 and 2.1.4.

As stated in the literature, recent advancements in UAM have opened up entirely new possibilities, especially for small unmanned aerial vehicles. This is primarily possible due to improved power electronics, sensor technology and data analysis, in conjunction with the significant cost reductions resulting from the availability of high-performance, commercially available components (Straubinger et al. 2020). Moreover, ambitious net-zero emission targets set by numerous nations drive R&D investments as the need for infrastructural adaptations is emerging (Gerasimova et al. 2021).

Thus, forecasts for this industry are optimistic, with a potential annual market of nearly $2.5 billion for passenger drones during the first operating years. This bullish outlook is attributed to low service prices that can be well controlled through economies of scale, thus potentially leading to high adoption (Wu and Zhang 2021). Furthermore, industry research conducted by Roland Berger (2018) indicates a total of 100,000 passenger drones, also referred to as air taxis, could be in the air by 2050. By then, around 100 cities worldwide might offer drone services, with 1000 passenger drones operating in each city. Nevertheless, the number of drones in the cities will initially vary greatly. While in small metropolitan regions, on average, only 60 drones will firstly operate, up to 6000 drones could already be used in megacities. As for passenger drones, Roland Berger (2018) expects them to be mainly utilized as airport shuttles in the first few years, while over time, they potentially might operate mainly as point-to-point air taxis. Regarding delivery drones, a study by Doole, Ellerbroek, and Hoekstra (2020) expects an even faster adaption rate as there is already rising demand and interest in the field of autonomous unmanned aerial vehicles for last-mile delivery. Hence, the market value is projected to be higher, with a total of $4.4 billion by 2025 at a CAGR of 45.1% (The Business Research Company 2021).

Due to this immense market potential, several stakeholders from different industries are already initiating diverse activities to make this vision a reality. These activities include, in particular, the design and development of a suitable aircraft (Shamiyeh, Rothfeld and Hornung 2018, Lineberger et al. 2018).

Despite the enthusiastic industry outlook, several factors introduce uncertainty about the potential success for UAM. These include social acceptance, infrastructure accessibility, service quality, and cost, which will be further analysed in section 3 of this paper (Wu and Zhang 2021, Al Haddad et al. 2020, EASA 2021a). Notwithstanding several factors that may negatively impact the future adoption of UAM, studies (EASA 2021a) predict that UAM will provide an alternative form of transportation that offers significantly improved mobility by extending UAM into the third dimension: air (Roland Berger, 2018).

2.1.2 Classification of drone applications

Besides the above-mentioned passenger and goods delivery, there are other potential use cases for drones. Moreover, the demand for flying drones with different capabilities for diverse applications is continuously growing. Thus, there is great interest in developing new drones that can fly autonomously in different environments and locations and perform various tasks. The following aims to give a brief overview of other applications of drones next to passenger and delivery drones. Here, the three main categories (a) civil (b) environment (c) military are referred to (see appendix A), following extensive literature approaches by Singhal, Bansod and Mathew (2018), Hassanalian and Abdelkefi (2017) as well as Watts, Ambrosia, and Hinkley (2012).

a) Civil

In recent years, drones have been a widely discussed topic worldwide due to their remarkable advances, encompassing technology, safety issues, rules, and regulations (Singhal, Bansod and Mathew 2018). Particular focus has been placed on passenger and delivery drones, which represent the central part of this work and, thus, will be discussed in more detail in the following chapters.

Regarding agriculture, unmanned aerial vehicles (UAVs) are not yet integrated into the mainstream agriculture space. However, drones and GPS technologies in agriculture allow workflows to be optimized using robust data analytics. Among other things, this can facilitate crop monitoring through more efficient planning and execution. It also enables more intensive farming methods, allowing farmers to improve fertilizer application and detect diseases early. Thus, drones have become more relevant during past years as they lead to more sustainable agriculture (Pinguet 2021).

Drones in the construction industry ensure maximum efficiency whilst reducing the waste of materials (Verma 2021). This is due to drones in construction sites offering fast and on-demand high solution image acquisition and providing accurate measures of distances and surfaces. Furthermore, UAVs significantly reduce the time-intensive data capturing and the accompanying labour costs (Wingtra 2021).

Next to the construction industry, drones in mining are used to foster monitoring and operation planning, optimize transportation routes, and particularly explore mines that are difficult to navigate on foot (Position Partners 2021).

In the case of disaster management, there is no doubt about the efficiency of drones in emergency management. For special rescue teams, UAVs can be helpful in quickly finding a location with enough space for victims to survive (Maharana 2017).

Since drones are equipped with onboard cameras, they are often used in photography and videography (Maharana 2017). Thus, UAVs are often used in ground traffic surveillance and infrastructure monitoring and inspection. During this operation, a group of drones equipped with special sensors and cameras monitor various objects on the ground (Savkin and Huang 2019). Lastly, the sales of civilian drones used for hobbies and sporting events are constantly rising as well as the use for non-ordinary missions like gutter cleaning (Hassanalian and Abdelkefi 2017).

b) Environment

In addition to drones in the civil sector, they are increasingly used for environmental measures. In this context, they are applied, for example, in the management of national parks and agricultural land and the monitoring of wildlife in various areas. Furthermore, climate change impacts and biodiversity monitoring of multiple ecosystems can be better observed (Hassanalian and Abdelkefi 2017). Moreover, drones can help keep an area mainly under observation during floods and detect wildfires (Restas 2015).

c) Military

The actual origin of UAVs can be found in the military field, and only later were they introduced for civil and environmental applications. The original goal was to perform war missions such as reconnaissance, spying, surveillance and border control. Moreover, military usage of drones has become one of the most crucial applications for bomb-dropping and ensuring warzone supply (Business Insider 2021).

2.1.3 Definition passenger drones

A passenger drone can be defined as an electric or hybrid-electric Multicopter, a rotorcraft with more than two rotors, that is utilized to move people between both established and on-demand start and destination sites. These vehicles can be piloted manually, steered remotely, or run fully autonomous. These types of drones, also recognized as flying cars, do not need runways and can accommodate three to five passengers (Lineberger et al. 2018, Chibuogu Nneji et al. 2017). The capability of vertical take-off, hovering and landing, as well as comprehensive infrastructure and operational requirements, such as helipads, or respectively vertiports, highlight similarities towards familiar airborne objects, such as helicopters (Datta 2018).
Vertiports subsist as tailored helipads that facilitate passenger drones' landings and take-offs and serve as sites for embarking and disembarking. As mentioned above, short to medium-range distances ranging from 100 to 300 kilometres and travel speed create differentiation to a helicopter. A higher energy efficiency, increased preciseness, and significant noise reduction even constitutes passenger drones as a credible substitute option for specific application areas (Lineberger et al. 2018).
Another critical difference in air taxi usage is the typical embedment into longer multimodal journeys. Thus, passengers will reach an origin vertiport through any type of transportation model, board their urban flight, and finish their journey by departing the destinations vertiport (Bennaceur, Delmas and Hamadi 2021).

The world's first passenger drone was introduced by Ehang in 2016. The UAV was presented as completely autonomous, relying on sensors and computers to navigate from take-off to landing (Gruber 2016). Furthermore, several companies have publicized strategies to launch passenger UAM services using VTOL and other novel aircraft designs in this nascent industry. Various prototypes for manned flights were thus manufactured in recent years by players such as Airbus, Boeing, Lilium, Kitty Hawk and Volocopter. However, the first serial production of manned, autonomous flights was successfully established by EHang with the launch of their EH216 and EH116 models (EHang 2020).

As of March 2020, twelve app- and web-based, on-demand manned UAM providers worldwide were in operation, with transportation network companies such as Uber or Lyft also entering the marketplace (Goyal et al. 2021). Based on a recently conducted study by John Salib and Gregor Grandl for Porsche Consulting (2021), more than 100 companies intend to bring an eVTOL to market by 2025. Out of which, not more than five to ten ventures are expected to become economically successful. Consequentially, increased market volatility and intensified competitive surroundings are likely to shape the industry.

Riedel and Kloss (2021) appoint six main use cases for passenger drone usage, touching upon different activities: Commuting to and from work, errands, business travel, short-distance leisure travel, long-distance leisure travel, and trips to and from the airport as part of a longer journey. In addition, recent studies show that airport shuttle services could be most suitable for early UAM implementation (Desai, Al Haddad and Antoniou 2021).

Opposing publications state that even use cases with sufficient demand, such as airport shuttle services, lack suitability due to a so-far preliminary critical analysis of the entire operating environment (Straubinger, Michelmann and Biehle 2021). As mentioned above, safety is one of the major concerns for society. It thus establishes a need for aircraft designers to ensure a feeling of security in all design aspects, including the built form, material used, and cabin space

(Rajendran and Srinivas 2020). From an operator point of view, intercity connections persist as another promising use case as the founder of Lilium, a leading German UAM start-up, Daniel Wiegand, stated: "Air taxis will connect all big German cities with one another" (Wiegand 2021).

Regardless of specific use case applications, a physical asset infrastructure must be established to ensure seamless UAM operations. Charging stations, integrated into landing- and take-off zones, are thus crucial elements, as well as receiving vessels that are especially relevant to package delivery use cases (Duvall et al. 2019). Therefore, when planning vertiports and estimating the passenger frequency required, a thorough trade-off between the negative impacts of more extensive ground infrastructure and larger vertiports to achieve a higher passenger frequency is unavoidable (Straubinger, Verhoef and De Groot 2021).

Multiple publications further appoint unmanned traffic management (UTM) software systems as operational requirements. These systems contain radar, flight-management services, and communication systems, collaborating with servers that coordinate, organize, and manage all traffic in the airspace and are elementary for seamless UAM advancement (Acubed 2021, Verma et al. 2020). Hitherto, there are numerous services proposed for UTM, with most players developing their own systems. Nonetheless, the first types of partnerships can be observed to emerge between UTM system providers and air traffic control operators, such as Unifly and DFS in Germany (Roland Berger 2021). It can be expected that UTM technologies are likely to mature and be systematically integrated to deliver a cooperative service with high-reliability levels, which will be adequate to passenger-carrying operations, either manned or fully autonomous (Hader and Baur 2021a).

The duration of the trips offered additionally plays a significant role for all operators. Accordingly, each eVTOL has both fixed costs per departure, such as landing infrastructure, maintenance costs or booking fees and variable costs, such as energy. While fixed costs are spread over the entire trip, it can be assumed that shorter trips tend to have higher unit costs and revenues (Gerasimova 2021). Therefore, players need to deliberately consider this effect when planning operations.

While road congestion does occur in vehicular traffic while vehicles are in motion, this issue is not likely to appear in the UAM area. This is because eVTOLs will most likely not receive take-off clearance if the airspace is already occupied. However, a vertiport can be assumed to be considered delay prone with its embarking and disembarking zones since punctual take-off and landing depends on several external factors (Straubinger, Verhoef and De Groot 2021). As reliability and availability play a significant role in securing customer retention and broad-scale adoption of air taxis, these factors are inevitable for players to consider in their operational planning. Some reliability enhancement strategies used in public transportation, such as a guaranteed ride home, can thus be helpful for UAM applications. For example, if the UAM service cannot take-off, passengers would be prioritized, and a trip on a ground transportation mode, such as ride-hailing at a similar or reduced price, would be offered. All these factors reveal a decision dilemma between system performance and system cost, i.e., by ensuring that additional aircraft are available in the fleet to serve peak periods, operators will face enormous expenses (Garrow, German and Leonard 2021).

As mentioned above, passenger drones can be categorized according to their use case-specific implementation area. A classification can be withdrawn based on providers' varying concepts and strategic focus areas, dividing the industry into providers who are more drawn to providing short-range flights and providers focusing on offering longer-range flights. The most reasonable distance to cover with vertical mobility is between 20 and 400 kilometres, with 20 to 50 kilometres being the sweet spot for intercity routes and 100 to 400 kilometres for city-to-city connections. When it comes to city-to-city routes, passenger drones will most likely compete with cars, long-distance buses, and trains (Garrow, German and Leonard 2021).

2.1.4 Definition delivery drones

Delivery drones are commonly used in the last-mile delivery in urban freight transport (He 2021). According to Lohn (2017), these services have the potential to become widespread over the next five to ten years, particularly for what is known as the "last-mile" logistics of small, light items. A study published by Brar et al. (2015) appointed three factors in which drone delivery can increase value: cost reduction, increased delivery speed, and convenience.

While considering commercialization and competitor driven challenges, the main influential drivers of drone delivery adoption are different distribution channels. A case study conducted by Doole, Ellerbroek, and Hoekstra (2020) analyses the on-air traffic in low-altitude airspaces and projects air traffic density in Paris. As a result, they approximated that the metropolis could manage more than 63,000 drone-based deliveries of fast-food meals and small parcels by 2035, highlighting the enormous potential of this type of delivery.

The most common use cases for drone delivery include food, beverage, and small item delivery as they have been prone to early adopt autonomous goods delivery to consumers (Wurst and Graf 2021, Baloch and Gzara 2020). But as mentioned in section 2.1.2, several sectors beyond retail and delivery depict potential implementation areas.

The exploration of drone delivery use-cases for low- and middle-income countries further concluded that combining multiple use-cases will enhance the cost-effectiveness of Unmanned Aerial Systems (UAS) by increasing the number of flights the UAV will be used for (Wright et al. 2018). For example, unmanned aerial vehicles (UAVs) and precise analytics have great potential to challenge and solve some of the most relevant issues the agriculture industry is facing due to a lack of access to actionable real-time quality data. Sylvester (2018) presented a study that predicts that the agriculture sector will be the second-largest user of drones in the world in the next five years.

The health care industry further constitutes a pertinent area of use for delivery drones, as fast and reliable medical deliveries can be steered independently from existing road infrastructures. This advantage does not only apply to developing countries with insufficient infrastructures (Wright et al. 2018). Moreover, it yields potential for developed countries in hazardous situations (e.g., natural disasters such as floods). According to Scott and Scott (2017) and Boyle (2020), drone applications in healthcare include delivery of medicine, defibrillators, blood samples, long-tail products (small quantity, unpredictable demand products), and vaccines (Schierbeck et al. 2021). Further medical-related use cases have been deliberated in a whitepaper by the JSI Research & Training Institute for the Bill & Melinda Gates Foundation (Wright et al. 2018). For example, for safe blood transfusions, small drones can offer both cost and speed benefits overland transport to deliver rare blood types and support-products on-demand. These diverse implementation areas highlight the manifold of potential use case concentrations for providers.

A broad scope of drone delivery aircraft operators is foreseeing high adaption rates once the post-pilot phase of this nascent industry has been passed. Major funded delivery drone market players are Amazon.com, Zipline, Boeing, Google Wing, Matternet, Wingcopter and Flytrex (see appendix C) (Culus, Schellekens and Smeets 2018). Representatives of Zipline, a medical goods drone-delivery company, consider themselves essential stakeholders to support the industry in moving beyond its pilot phase and reaching the potential of large-scale commercial operations. The company will potentially be able to reach about 90% of homes in the Salt Lake City metropolitan area with its drones, which navigate autonomously by satellite and drop payloads of up to four pounds on parachutes (Boudway 2021).

Moreover, the CEO of Google Wing, James Ryan Burgess, envisions a "future where delivery drones will be able to serve the community whenever somebody feels the need to receive a package or send a package" (Burgess 2021, Austin 2021). With the first pilot flights in 2017, Wing operates in Queensland, Australia, Christiansburg, Virginia, and Helsinki, Finland. The order process can be classified as convenient and identically to current food delivery services, a location in the front- or backyard of the customer needs to be chosen. It can be assumed that a delivery typically takes 10-15 minutes, with flight time accounting for two to three minutes. If food is being shipped, it will thus arrive very fresh, with an average speed of 110 kilometres per hour (Koetsier 2021). During the corona pandemic, prescription medication was delivered to people in quarantine, depicting the positive impact of drone delivery usage. Thus, the pandemic further accelerated drone delivery companies as they created a connection between stores or restaurants and the community (Banker 2020).

But the industry has not only been experiencing enthusiastic highs in the past years. In 2016, Amazon envisioned their prime air vehicles to be someday as normal as seeing mail trucks on the road but discontinued operations (Maes 2016). One major issue the drone delivery industry faces is a lack of profitability for the end consumer delivery (Fuest 2021). In addition, the design of urban airspace for drones will depend on critical design metrics such as drone traffic densities, traffic distribution patterns, the distance between origin-destination, and the number of distribution centres (Doole, Ellerbroek and Hoekstra 2020).

Estimation of viable market potential and access to citizens across European cities concluded that the potential drone coverage across Europe could be very heterogeneous due to the differences in population and land-use patterns. Further, the UK, Germany, Italy, and France appear to be the most likely countries where drone-vertiports may have the most efficient development (Aurambout, Gkoumas and Ciuffo 2019).

2.2 Introduction of relevant success factors

As outlined in the sections above, the hype around UAM is not diminishing, which is also due to numerous advances putting the implementation of UAM within reach. For example, the electric propulsion of eVTOLs will represent a cost advantage compared to standard technologies once the product reaches maturity and battery costs are already dropping due to the ongoing investments in the automotive sector. In addition, several stakeholders are conducting intensive research into autonomous flight technologies to reduce the operating costs per flight. Lastly, the expansion of the 5G network also enables substantial technological progress, as 5G represents significantly more precise navigation compared to GPS satellite reception. This development is particularly important in densely populated megacities. However, this disruptive development cannot be implemented abruptly, even though these factors can accelerate the integration time (Roland Berger 2018).

Moreover, it is crucial to understand the key drivers and potential hurdles for successfully implementing UAM. Based on the literature review conducted for this paper (e.g., Grandl, Salib and Kirsch 2021, Al Haddad et al. 2020), several issues for UAM adoption were identified. To analyse these issues sufficiently, this paper will focus only on the most critical factors. These will be divided into two categories: industry setting related success factors and the environmental and community-related success factors. The former includes technology, infrastructure, provider, and funding, whereas the latter comprises public acceptance, safety and regulatory, and environmental impact. Additionally, this paper analyses the success factors for the German market to assess the future viability of UAM in Germany. The remainder of this section aims to briefly introduce each factor, laying the ground for the empirical analysis in chapter 3.

In the extensive literature reviews conducted over the past years, the technology underlying the vehicle construction is analysed in great depth (Bacchini and Cestino 2019, Lufthansa Innovation Hub 2021, Brown and Harris 2020). Besides technology, research on infrastructure explores how UAM solutions can add value to a city's existing infrastructure and what additional infrastructure is needed. For example, studies focus on the design and location of vertiports and drone hubs necessary for vertical take-off and landing. In addition, digital infrastructure solutions used in the development and management of smart cities are being sought (Airbus 2019). Finally, the number of players and thus the funding is of great importance for the development of UAM. A slight slowdown can currently be observed when looking at deal activity by business phase, and seed deals have declined over the years. In contrast, early and late-stage deals are gaining more importance. This trend suggests that few new companies are entering the market, and investors are focusing on well-known candidates. In addition, existing players make it more difficult for new entrants, especially in terms of upfront R&D costs and technical expertise (Lufthansa Innovation Hub 2021, Duvall et al. 2019).

Numerous studies have investigated public acceptance regarding the environmental and community-related success factors to better understand the potential users' choice behaviour and overcome the resulting hurdles (EASA 2021a). Herewith, safety concerns are analysed in great depth as they represent one of the biggest challenges for UAM adoption. Lastly, the two success factors, regulatory and legal framework, and environmental impact, examined in this paper have not been the centre of attention in recent studies, whereas this paper tries to close this gap.

2.3 UAM Innovation scene in Germany

As this thesis also investigates specifics of the German market, an overview of the current UAM innovation landscape in the country is being provided. As the largest economy in the European Union, Germany has, like many other nations, experienced a downfall in innovation within the last years (Naudé and Nagler 2021). In the preceding years, Germany's positioning in terms of scientific output regarding air taxi development has been at the lower end, with only 6% of all research papers deriving from Germany compared to 34% from the U.S. (Lufthansa Innovation Hub 2021). However, based on a recent increase in political interest, this share is likely to change.

Another hurdle for the German market is the smaller number of investments compared to the American market. Since the German investment market has historically not been technology-prone, lower investment sums below €100 million are usually disbursed. However, especially with high hardware expenditures, tech companies require larger sums. This finding supposes that investors are more substantial overseas and potentially slow down German progression in the field (Wiegand 2021). Nevertheless, increased funding from German governmental initiatives indicates a growing awareness of the UAM technology. The German Federal Ministry of Education and Digital Infrastructure (BMVI) envisions Germany to become the lead market for drone innovations, further depicting the governmental vision for the country (Bundesministerium für Verkehr und digitale Infrastruktur 2021).

In contrast to passenger drones, commercial drone usage is growing significantly faster in Germany. As of March 2021, the commercial drone market accounted for €738 million (€404 million in 2019) in revenue (Keller 2021). The results of a study conducted with the German BMVI clearly show that the attitudes of the German population toward drones are multi-layered and complex. Still, categorical rejection or unconditional approval were rarely expressed (Fischer et al. 2019), highlighting this technology adaption's highly intricate and uncertain future in Germany.

3 Empirical Analysis

The seven success factors for UAM presented in the previous chapter will be empirically examined in the following. To this end, qualitative semi-structured expert interviews were conducted and compared with secondary data from existing literature. In addition, an online survey was conducted to investigate social acceptance to examine the potential usage in the German market. The remainder of this paper provides a brief description of the methodology (section 3.1), followed by a presentation of the interviewees and survey participants (section 3.2), to then present the results (section 3.3).

3.1 Methodology

At this point, only a small number of empirical studies examine the success factors of UAM with a focus on the German market. However, as the industry is rapidly evolving and the number of recent academic and non-academic literature is increasing, a comprehensive overview of the success factors of the UAM industry is needed. In addition, most of the existing literature deals with either passenger or freight transportation, so this thesis examines the success factors for both transportation sectors. To present the success factors in the UAM industry, we use qualitative, primary data from semi-structured interviews and secondary data from existing literature. This holistic approach allows us to complement the extensive research in the UAM sector with insights from industry experts. The overall goal of the interviews was to analyse each of the industry settings related success factors as well as the environmental and community-related success factors. Furthermore, the conducted online survey creates additional inside knowledge into the social acceptance and environmental impact of drones in Germany.

In total, we conducted five interviews with industry experts in the field of UAM. The interviews were held in German and took the form of 30- to 60-minute conversations on MS Teams and Zoom.

An interview guide (see appendix F) was used to conduct the interviews, with introductory questions first, followed by detailed questions on the relevant success factors. Then, as Aberbach and Rockman (2002) suggest, we mainly used open-ended questions and individual follow-up questions during the interview to examine some topics in particular depth.

Moreover, we conducted the interviews with two interviewers as it is suggested by Fifić and Gigerenzer (2014) while one person took the leading role in the interviews, and the other person was responsible for detailed note-taking.

In addition to conducting interviews, we used quantitative data from our online survey to especially analyse the social acceptance of UAM, particularly in the German market. We used the online tool Qualtrics in creating the questionnaire, which enables an efficient overview and initial evaluation of the data. Finally, previously published studies were used to guide a well-founded selection of potential user acceptance factors (e.g., Al Haddad et al. 2020, EASA 2021a). In appendix E, the questionnaire is deposited with comments on the sources used. After a short introduction to the survey topic, questions with a single-item scale were initially chosen for the start of the survey, as they lead to a lower dropout rate, according to Kuß, Wildner, and Kreis (2017). Furthermore, we used short closed-ended questions in designing the questionnaire, meaning that participants could choose from predetermined answer categories. Thus, it is easier for the participants to answer the questions, which leads to a higher response rate (Kuß, Wildner and Kreis 2017). However, closed-ended questions can lead to inconsequential response behaviour through the thoughtless ticking of individual headings. Therefore, for selected questions, participants had the opportunity to add their own answers in addition to the given answer options. In this way, original answers that were not considered when the survey was created could also be included in the survey (Kuß, Wildner and Kreis 2017). To perform a detailed statistical evaluation, the participants were asked to rate individual questions on a five-point Likert scale. An uneven scale was deliberately chosen to avoid a restriction of freedom in which subjects would not have the chance to select the middle position consciously (Porst 2014).

Finally, the participants' demographic data relevant to the statistical study were collected. These questions were deliberately placed at the end of the questionnaire since they quickly lead to listlessness on the respondents, and in some cases, such as information on age or income, they are answered reluctantly. Therefore, this part should only be answered after the most significant part of the questionnaire had already been completed (Porst 2014).

3.2 Participants

For our five expert interviews, we selected people from leading German start-ups, the Department of Airports and Air Transport Institute of Transport Sciences at RWTH Aachen University, the Sustainable Aero Lab, Bauhaus Luftfahrt e.V., a non-profit association founded by three aerospace companies Airbus Group, and academic institutions. Our interviewees hold positions as strategic managers, senior managers, co-founders, and research analysts.

Regarding our online survey, a total of 203 people took part in the questionnaire. However, only 154 were included in the analysis, as the remaining 49 questionnaires could not be considered due to incompleteness. The distribution was carried out through social media channels, e-mail distribution lists, and word of mouth. Since this paper aims to analyse relevant success factors, especially in the German market, the study was only distributed to German speakers. The gender distribution of the 154 participants is relatively balanced, with 45.9% male and 52.7% female respondents, and only 1.4% indicated third/non-binary gender. Finally, a comprehensive overview of participant demographics is provided in appendix E.

3.3 Success factor analysis

3.3.2 Environmental & community-related success factors

Besides industry setting related success factors, the implementation of UAM operations strongly depends on environmental and community-related success factors. Thus, the following chapter examines these factors using interviews, a conducted survey, and existing literature for the analysis.

3.3.2.1 Public acceptance

Status Quo & Outlook

Several studies show that public acceptance is one of the most crucial factors for the success of UAM (e.g., EASA 2021a, Lufthansa Innovation Hub 2021, Grandl, Salib and Kirsch 2021). For example, a study conducted by the EASA (2021a) investigates potential users' attitudes, expectations, and concerns. The analysis shows that most EU citizens express a positive attitude towards UAM and associate a new and innovative mode of transport. As mentioned in section 3.3.1.3, the attitude towards use cases for the general public, such as medical and emergency transport, is more favourable than just satisfying individual needs. Additionally, the participants perceive drones as a faster and more environmentally friendly mode of transportation than existing vehicles.

However, there are some primary holdbacks regarding the use of passenger and cargo drones. First, most participants expressed the safety aspect as one of their main concerns, followed by noise as a potential factor of disturbance. Here, however, the degree of annoyance depends on the familiarity of the noise (EASA 2021a). As Anna Straubinger mentioned during the interview, an employee of Airbus emphasized that it is not about vehicles being quieter but people finding the noise pleasant. Building on that, Eva Feldhoff and Gonçalo Soares Roque see noise as a potential hurdle for implementing eVTOLs as the sound of drones is so far unknown and could seem threatening, thus, complicating the implementation.

Besides safety and noise, privacy concerns, job security, affordability, and willingness to pay could negatively influence the adoption of UAM (NASA 2019). Regarding privacy, people are mainly concerned that drones fly above or too close to their residence and may not fully understand how the camera technology works (EASA 2021a, NASA 2019). Additionally, literature shows that job losses are associated with UAM since logistics and taxi services could become obsolete (EASA 2021a). However, this fear is somewhat unsubstantiated as our interviewee Anna Straubinger expects drones to be more of an add-on to the current transportation market rather than a substitution. Furthermore, she states that passenger drones' implementation is highly complicated, thus less of a threat to existing transportation services.

It needs to be considered that building public trust should continue to be vigorously pursued by all stakeholders, as just one fatal incident has the power to ruin trust in the already controversial UAM industry (Schunck and Osborne 2021).

Situation in Germany

As mentioned above, Germany is home to top players in the drone market. Thus, we find it particularly interesting where Germany is positioned in terms of public acceptance and whether it is attractive for becoming one of the entry markets for drones.

The interviewee Anna Straubinger attributes significantly more importance to Germany's social acceptance factor than other countries such as China and Dubai, where other cultural drivers and legislation outweigh the factor of social acceptance. Additionally, one of our interviewees from a German drone start-up identified noise, safety, costs, and range of drones as key social acceptance factors. Though, to achieve a higher acceptance of the population through a higher range, a more complicated technical implementation is necessary, which leads to an elaborate approval process. Besides, our interviewee from a German drone start-up named some ideas on how the industry can educate the public to alleviate the especially in Germany highly ranked safety concerns. On the one hand, drone companies need to create awareness by performing test flights and press releases. On the other hand, reputable partnerships lead to more trust among the population.

A study conducted by the EASA (2021a) indicates that the likelihood of trying out air taxis or delivery drones was similar among various European cities. However, participants from Germany demonstrated a slightly less positive attitude towards UAM than other European countries. Moreover, Ploetner et al. (2020) investigates UAM's application potential in Munich, Germany, and indicates that safety, travel time and costs play a significant role in adopting drones. Furthermore, the results show that the adoption of drone transportation is more likely among younger people and people with a higher income.

Our survey results are partly in line with literature research and our interviews. The respondents consider drones an exciting innovation with many possible benefits while, on the other side, citing potential severe hurdles for UAM that should not be overlooked. The participants name safety, costs, and noise as central concerns for passenger drone usage – in descending order (see appendix E). Regarding delivery drones, they are mainly concerned about noise, visual pollution, costs, and the environmental impact – in descending order (see appendix E). Still, the survey respondents also see possible benefits of passenger drones in being independent of road traffic (26.0%), saving time in traffic jams (24.2%), and having an exciting experience (20.2%). In total, almost half (47.3%) of the participants rate the likelihood of using a passenger drone as likely or very likely. While only 15.8% of survey respondents feel that passenger drones will become part of their daily lives, about 53.4% of all participants believe this could be the case for delivery drones. This is in line with the result that scepticism (26.0%), curiosity (25.4%), and fear (14.5%) are the top three emotions associated with passenger drones. In the delivery drone sector, only positive emotions are listed among the top three associations: Curiosity (29.3%), anticipation (19.3%), and enthusiasm (18.6%).

The survey was also designed to investigate differences in the social acceptance between autonomous and manned drones. Here, it is not surprising that the likelihood of using autonomous drones is lower compared to manned drones. Additionally, about half of the participants (50.3%) rate the likelihood of feeling safe on the streets while unmanned drones are flying in the air as either very unlikely or unlikely. Only a tiny percentage (4.8%) of survey recipients assume they would feel safe.

In conclusion, the interviewees, the survey results, and the extensive literature review identify public acceptance as an essential success factor for the implementation of UAM in Germany, whereas the safety aspect presents the biggest concern. Thus, players need to emphasize alleviating this fear.

3.3.2.2 Legal and regulatory landscape

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Literature review shows that safety concerns are related to regulations, meaning stricter regulations lead to higher social acceptance. Respondents to an EASA study (2021a) say they have confidence in the current level of safety regulations in aviation and call for the same level to apply to UAM. In addition, special attention must also be paid to cybersecurity regulations. Protective measures must be taken against jamming, spoofing, and other potential security vulnerabilities (NASA 2019).

To enable a smooth design of the systems, the regulatory aviation authorities worldwide need to set standards for the certification of the hardware and operation. Furthermore, they need to define the procedures and requirements for the infrastructure to ensure safe air operations (Grandl, Salib and Kirsch 2021). International laws from ICAO globally regulate current traditional air transport, so authorities are working closely together. The U.S. Department of Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) dominate here, following the so-called step-by-step authorization approach. In vertical mobility, on the other hand, regional or local mobility networks are now being introduced to which provincial legislation applies. Therefore, it is expected that different authorities will take diverging approaches to regulations. Consequently, there will be specific hardware, software, and infrastructure requirements in different regions. It must be noted here that government authorities, as political decision-makers, must also represent the interests of society. Therefore, a good balance must be struck between promoting innovation and the demand for safety and security (Grandl, Salib and Kirsch 2021). There are two different regulatory approaches for passenger and delivery drones: The traditional step-by-step approach and the multistep approach. As mentioned above, the FAA and EASA follow the step-by-step approach. In contrast, other authorities like the Civil Aviation Administration of China (CAAC) follow the multistep process certifying more than one innovation at a time. By using this approach, the CAAC could make numerous technologies possible simultaneously. However, this imposes higher risks and a lack of safety and security (Grandl, Salib and Kirsch 2021).

One of the most significant regulatory challenges is dealing with emergencies. Since eVTOLs can be expected to have failure rates similar to commercial air vehicles, the same guidelines should apply (Grandl, Salib and Kirsch 2021). Thus, Anna Straubinger points out that the current system reliability factor of 10^{-9} which estimates the likelihood of a system failure should also be applied for eVTOLs.

Roland Berger (2018) points out that aviation authorities like the EASA and FAA are already working closely with drone manufacturers and other industry players to establish and execute workable regulations. For example, on the player side, Airbus Urban Mobility works with aviation authorities and private stakeholders to create regulatory frameworks that maximise society's value (Airbus 2021a). As mentioned above, our interviewee from a leading German drone start-up emphasized that start-ups face the challenge of a more complicated approval process by developing a more complex technology. In conclusion, the regulatory environment is critical to the launch timing and successful implementation of eVTOLs. For example, regulations for delivery drones can be expected within the next two to five years. In contrast, regulatory for scalable passenger drone operations is not expected for at least another ten years. (NASA 2019).

Situation in Germany

As mentioned in the section above, Anna Straubinger expects different regulations for different countries. Nevertheless, Eva Feldhoff and Gonçalo Soares Roque said during the interview that the EASA primarily sets the guidelines for the drone market in Germany. Therefore, the aviation authorities in Germany, such as the BMVI, must incorporate these rules. Recently, the BMWI has signed a memorandum on cooperation with German Urban Air Mobility regions to make Germany the lead market for drone innovations. The goal of the collaboration between German UAM model regions and the BMVI is to overcome the challenge of deploying the corresponding technologies, the necessary regulations, suitable infrastructure and, finally, the acceptance of the population. Among other things, the network is trying to develop legal solutions, for example, for vertiports or the charging and communication infrastructure. These can be used as blueprints to help cities and municipalities set up the infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur 2021).

In addition, our interviewee from a German automotive consulting firm assumes that municipal authorities in Germany are working closely with eVTOL companies that want to secure exclusive rights for aerial routes. It is the task of the aviation authorities to ensure that monopolies are not created. For drone companies, approval of certificates could also depend on the authorities' recognition. It would be possible for certification to occur more quickly if the trust had been built up beforehand.

Nonetheless, Eva and Gonzales rate the political commitment of the German authorities as relatively low compared to other countries. As mentioned in section 3.3.1.2, this could be due to the low necessity of Germany's already well-developed inter-and innercity route network.

3.3.2.3 Environmental impact

Status Quo & Outlook

Besides public acceptance and the regulatory framework, the environmental impact of eVTOLs is crucial for the adoption of UAM. In recent years, there has been a steady effort to improve vehicle technologies to achieve the necessary environmental goals. Nevertheless, the number of rides and the length of routes are constantly increasing, so exhaust emissions continue to rise. This has adverse effects on air quality and leads to soil and water pollution. In addition, noise pollution is also rising as a result. Considering these environmental concerns, the impact of eVTOLs on transportation-related emissions needs to be explored (Pukhova 2019). The major advantage of eVTOLs is their electric propulsion. Since CO_2 emissions from transportation in megacities contribute to 25% of the world's CO_2 emissions, the new sustainable transportation option with eVTOLs is an attractive way to reduce emissions (European Environment Agency 2013). The apparent advantage is electric propulsion, which offers zero emissions, but beyond that, the demand for green energy could also increase (Pukhova 2019).

Nevertheless, it is crucial to understand that zero-emission is not the same as zero pollution, as it depends on whether the energy used comes from a green energy source (Verhovek 2021). Thus, the promise of delivery or passenger drone companies to produce zero-emission vehicles (Lilium 2021, Volocopter 2021b) does not automatically correlate with a positive environmental impact. As of today, there are almost no studies that prove that eVTOLs have a positive effect on CO_2 emission (Pukhova 2019). Hence, Pukhova (2019) studied the impact of UAM on daily emission rates in Munich, Germany. However, the results show no significant effect on emission rates. Nevertheless, if the electricity is generated from 100% renewable resources, eVTOLs can reduce the total daily CO_2 gases by 0.06% (O'Mahony et al. 2002).

Besides the effect on emission rates, the noise of flying drones impacts the environment. As stated in section 3.3.2.1 above, noise represents a major concern of society and, thus, influences the potential user acceptance. Nonetheless, as identified in a study conducted by the EASA (2021a), participants associate a positive environmental impact with UAM. They assume that traffic in urban areas can be reduced and air quality improved. Still, they have concerns about how noise associated with UAM might affect wildlife. Therefore, companies like Lilium try to address these concerns and promise low noise emissions (Wiegand 2021). The Ducted Electric Vectored Thrust (DEVT) technology used in the jets ensures that much of the noise from the ventilators are trapped by acoustic liners. Lilium has already conducted tests showing that the perceived noise level is equivalent to the sound of a dishwasher 100 meters away. Once the jet is in the air, the noise level decreases even more sharply. Besides affecting community acceptance, the noise level is also crucial to accessing the desired take-off and landing spots in the urban environment. For comparison, helicopters can already take off and land vertically, but the fact that they are very noisy and negatively impact the environment makes them unsuitable for broad passenger transport. This shows that the success of the UAM industry is highly dependent on solving these problems (Wiegand 2021).

In addition, weather conditions represent a critical factor for the UAM industry. It affects components such as operations, supply, comfort, traffic control, infrastructure, and social acceptance (Reiche et al. 2019). The study conducted by Reiche et al. (2019) investigates how different weather conditions influence UAM operations. Overall, most western cities have favourable weather conditions for UAM services. However, areas with high temperatures or temperatures below zero, strong winds and thunderstorms, or low ceilings may negatively impact the implementation of UAM.

Lastly, the impact of UAM operations on wildlife is discussed in literature and surveys on the user acceptance of delivery drones and passenger air taxis. As shown in section 3.3.2.1, people indicate the environmental effect as the second greatest concern. A study of the EASA (2021a) shows that negative impact on wildlife (e.g., birds disturbed by noise or bats bothered by lights) is the most significant environmental concern even before noise pollution and emission. Here, no difference was seen between passenger and delivery drones. To protect wildlife, wildlife sanctuaries could be established with overflight prohibitions, and special lighting equipment might be installed on the jets. Furthermore, bird avoidance systems could also be implemented. However, these measures imply longer flight routes and higher costs (EASA 2021a).

Situation in Germany

As of today, there is very little literature on the environmental impact of the use of drones in Germany. Reports on the drone market are less concerned with individual aspects of the topic and more with the fact that the importance of drones will increase. Nevertheless, noise or CO_2

pollution factors are highlighted as essential aspects of drone operation that can cause adverse reactions among affected individuals (Becker et al. 2021).

Thus, it must be said that due to the existing uncertainties in the specification of noise emissions for drones of a specific size and the uncertainties in the calculation methodology, substantiated quantitative statements are currently only possible to a very limited extent. Therefore, as of today, there is no specific data on noise pollution from using eVTOLs specifically for Germany (Becker et al. 2021). Nevertheless, when looking at the effect of noise on society, results from our survey show deep concerns regarding noise pollution caused by eVOTLs. More than half of the participants (55.6%) rated the noise concerns as high or very high. Only 25.5% have very low or low concerns, whereas the remaining is indifferent. Furthermore, in the open-ended question part, numerous participants expressed concerns about a possible interference with the bird's airspace. To date, there is no precise information on how passenger and delivery drones are integrated into Germany's bird airspace. Still, it is not expected that the noise of an isolated operation at altitudes above 100m will significantly disturb the population living there, especially birds. Furthermore, compared to the current practice of carrying out any necessary inspection flights with helicopters, the use of drones would even lead to relief, as the drones are much quieter. Finally, it can be assumed that adapted laws will also apply to passenger and delivery drones (Becker et al. 2021). Regarding lowering air pollution in Germany, German authorities are already actively trying to find solutions for commuter traffic, commercial traffic, and the challenges in rural areas. More people are moving from rural areas to cities, so mobility needs to change for a better quality of life, climate protection and environmental protection (Becker et al. 2021). Although work is already underway on attractive models for electromobility for a better CO_2 value, the balance so far is not good. Wind and sun still generate so little energy in Germany that coal and gas provide high shares of electricity. Especially in the cold spring, there is little wind and sun, so more electricity is generated in Germany from fossil fuels (Viehmann 2021). Fortunately, the share of renewable electricity generation in Germany has been increasing for years, and in 2019 it already reached 42% (Kämper, Helms and Biemann 2020). As described above, the availability of green electricity is essential for the life cycle assessment of eVTOLs. Otherwise, they may fly emission-free, but this cannot be equated with zero pollution. Even though drone companies promote the fact that their service is sustainable and environmentally friendly (Lilium 2021, Volocopter 2021c), a study conducted by Finkeldei, Feldhoff, and Roque (2020) concludes that air taxis will not have a significant impact on traffic in Germany and thus will not lower traffic-related pollution.

4 Discussion

In the following section, the previously presented success factors will be subject to discussion to understand their relevance when set in relation to each other. Further, the distinct role of Germany will be discussed, which we are aiming to investigate within this work.

Overall, it is evident that stakeholders of the UAM field, especially aspiring hardware operators, need to focus on gaining public acceptance and providing proof of concept to succeed long-term. These aspects were mainly agreed upon throughout our comprehensive literature research, a conducted online survey, and interviews as they constitute the most relevant success factors. Without the societal disposition to use UAM, the industry will most likely fail. The same applies to providers with concepts that do not meet usage demand, resulting in a downfall in a fiercely competitive environment.

Regarding the player's choice of choosing the ideal market entry strategy, it is discussed controversially whether the formula for success lies in approaching the segment as a first mover versus choosing the fast follower approach. It is apparent that first movers such as Lilium or Volocopter mainly communicate the advantage of their positionings, such as faster certification or established partnerships with relevant stakeholders (e.g., airports and governments). On the other hand, research or independent consulting representatives strongly emphasize potential hardships and resulting risks in developing a highly intricate technology and holistic ecosystem from scratch. Therefore, it cannot be deducted whether one or the other strategy is more prone to success. However, bypassing early-stage challenges and accessing the market slightly later seems to be a common strategy for traditional OEMs such as Airbus as they have substantial financial and network resources. For start-ups, a strong partnership network including stakeholders with sufficient know-how in UAM supply chain management and potentially former OEM employees with fundamental industry expertise mitigate risks and ease complex certification processes.

Based on the complexity of the UAM industry, an increased competitive convergence can be expected, leading to a downsizing of the overall market towards an expected maximum of 10 relevant players (Grandl, Salib and Kirsch 2021). The current funding landscape already hints towards this development as somewhat disproportionate funding allocation can be observed among industry players (see appendix C). Thus, only a few companies have received significant sums, highlighting funding as a substantial "rise or fall" determinant for players. This becomes especially evident for the German market as international investors are known to allocate higher sums than the relatively conservative amounts invested in Germany. For instance, innovation hubs such as Silicon Valley assign high investment sums needed for this magnitude of innovative disruption (Wiegand 2021).

Consequently, German players, such as Lilium, are more and more drawn to the international stage, which was highlighted by their deliberately preferred American IPO versus a German one. Thus, one hypothesis for this development is that American or Chinese markets will eventually be more likely to actively shape this industry than Germany (Wiegand 2021).

But not only the funding attitude in Germany will have a significant impact on the country`s overall status towards potential UAM adoption. With two top domestic players: Volocopter and

Lilium, Germany is strongly represented in the UAM scene. Nonetheless, this paper indicates it is not likely that this country will be an early adaptor of this technology.

Our broad distribution of interviewees from active start-up representatives to researchers and consultants demonstrated an apparent discrepancy between both stakeholders in terms of industry assessment. Overall, this paper concludes that the player who demonstrates the fastest and most sustainable benefit will prevail. Generating public approval for UAM is thus only achievable if the industry provides a true societal advantage. While engaged players expect the industry take-off during the early to mid-2020s, side-line observers anticipate that the first operational UAM application will be employed in the late 2020s (Pitchbook 2021). Thus, it is more realistic that Germany starts the UAM application once other markets have proved concepts, especially regarding safety.

Even though these players also have big visions for the industry in their home country, research reveals that due to excellent public infrastructure, cities with distances below 20 kilometres, and the lack of significant congestion issues, the need for another dimension of mobility is outright weaker than in other nations such as the U.S.

As mentioned before, gaining public acceptance is commonly agreed upon as a key gateway for the UAM industry. Our online survey further revealed that the most common holdbacks, such as safety, are significantly higher for passenger drones than delivery drones. Additionally, gaining public acceptance in Germany is particularly difficult, especially compared to other nations. It can be discussed that this is for once reasoned in the country's cultural and societal background but amplified by the previously identified unseen need (Süddeutsche Zeitung 2017). Therefore, for passenger drone use cases, it is almost inevitable that medical and police-related operations are more likely to be implemented for subsequent years as their social adoption rate is assumed to be higher. Since the public acceptance is significantly greater for autonomous goods versus autonomous passenger transportation, a focus on delivery drones also facilitates early market access for players.

Nevertheless, within the existing research literature and our conducted interviews, it was agreed upon that safety constitutes an overriding concern, pressuring the players to engineer superior solutions and showcase them. The fact that safety concerns play a particularly relevant role for potential German users was further confirmed during our survey. Especially the thought of autonomous passenger drones appears to be menacing for many. Accordingly, players are pressured to develop ways to mitigate safety concerns. One of these measures could enable the passenger to intervene if an emergency occurs, providing a sense of control (Deloitte 2017).

In contemplation of the industry's immense dependence on regulatory decision-making by authorities such as FAA or EASA, regulators will play a critical role in setting comprehensive guidelines for vehicle requirements and airspace management. Since higher restrictions lead to increased public acceptance while at the same time hindering fast progression for operations, this success factor has the power to set the industry's pace.

Within existing literature and discussions revolving around UAM, infrastructure has been a topic receiving less awareness than regulation or technological specifics of relevant players. This is reasoned by the fact that UAM concepts are technically very multifaceted, and the application areas are so captivating that they tend to receive the most attention (Duvall et al. 2019). Players usually remark that little infrastructure is needed, but it is very complex in reality. Thus, infrastructure providers will gain relevance once more, and more technical questions of the aircraft have been answered, and concrete operation plans are being presented.

Concerning technological concepts, it is consensus that two dominant design categories will persist. On the one hand, rotary-wing for efficient short-haul flights and on the other fixed-wing aircraft for proficient long-haul flights. Subsequently, players will need to decide on which segment to serve or whether to develop technologies sufficient for both use cases. Currently, either a rotary-wing strategy (Volocopter) or a fixed-wing strategy (Lilium) is being pursued. However, due to environmental factors such as noise pollution, innercity routes are not likely to be implemented first in Germany. Therefore, fixed-wing providers such as Lilium have an advantage, as long-haul and intercity connections are more likely to be established first. This is because positive environmental impacts cannot be confirmed compared to popular alternatives, such as biking or walking.

However, Airbus is concentrating on both technologies. Our interviews have revealed that this strategy is only conceivable for established companies, such as existing OEMs, as they can raise higher expenditures needed for dual product development. Therefore, it will be noteworthy to observe to what extent these well-established companies will disrupt the scene, even if they arrive later to market.

The analysis of these success factors reveals the extend of interrelation and interdependencies between them and identifies public acceptance, regulatory, and players as the main drivers for UAM's success in the near future. For instance, the regulatory framework is fundamental for players to develop their aircraft and plan their operations. But beyond that, regulations are also significantly influencing public acceptance, as a stricter certification might lead to increased trust within society. Societal preferences simultaneously influence players' decision-making to focus on specific use cases. Thus, to do justice to the complexity of this industry, future in-depth investigations concerning the interplay and impact of these success factors are required.

5 Limitations

The following paragraph addresses the limitations of the empirical analysis. First, acquiring potential interview partners was challenging as out of 30 contacts, only five people agreed to be interviewed. This could be mainly because drone start-ups and stakeholders have strict non-disclosure agreements and only disclose little information via their press releases. Thus, it was difficult to get detailed information on all success factors, especially in the field of regulation, the interviewees had only little insight. Furthermore, due to the limited number of pages in this paper, it was impossible to examine the individual success factors in more detailed aspects. Moreover, as stated in section 2.1, this paper only focuses on the most crucial adoption factors while more factors are affecting the success of UAM.

Regarding the survey, care was taken to generate a representative group of participants. Nevertheless, people from the lower educational class are underrepresented, while the 21-29-year-olds are overrepresented in this study. In addition, almost a quarter of all respondents have a very high household income of over €100,000. This could distort the results, as the willingness to pay might differ from people with lower income. For this reason, an investigation of the public acceptance of these sociodemographic groups is recommended, analysing in more detail how they differ from the younger or better-educated population. Finally, multiple questions with many different response options were used in the survey. Thereby, the order of the answer choices could influence the behaviour of the respondents, which could lead to a limited validity of the results (Raab-Steiner and Benesch 2018).

6 Conclusion

This thesis aims to present the status quo of the emerging UAM industry and identify the critical factors for a successful implementation. The analysis is based on findings from semi-structured interviews, an online survey and existing academic and non-academic literature to determine the relevant implications for players in the UAM industry. We limited our analysis to two categories: industry setting-related success factors and environmental and community-related success factors. Here, the focus is on technology, infrastructure, players and funding as well as public acceptance, legal and regulatory landscape, and environmental impact.

While the application fields of drones are constantly expanding, this report focuses on two primary use cases: delivery and passenger drones. First, delivery drones are currently deployed to deliver medical goods, food, beverages and other retail items. Second, passenger drones will enable the aerial transportation of people in the inner- and intercity areas. This is of great importance because, by 2050, 70% of the world's population is expected to live in urban areas, so new mobility concepts will have to be developed (United Nations 2018). However, even though UAM can make an essential impact and transform the way people travel, air taxis are still far from commercialization.

While it seems a logical progression to use airspace for urban mobility, there are many challenges in implementing UAM. First, specific technological requirements have to be met regarding speed, range and, most crucially, safety. By developing the best possible design and technology, pioneers can secure a technology edge. As a result, a more competitive environment and increased market volatility will shape the industry. To prevail against the competition, extensive capital investments are elementary. Beyond that, not only the amount of the funding but also the reputation of the partnership networks as well as the creation of a true societal benefit is decisive to secure a competitive advantage. Lastly, passenger and delivery drones require a specified infrastructure to operate correctly, whereas delivery drones can operate via drone hubs, which are less complex in size and technological features.

Looking at the environmental and community-related success factors, the most critical enabler for UAM solutions is public acceptance. While there is an overall positive attitude towards UAM operations, the main concerns are safety, noise, costs, privacy, visual pollution, and job security. To address these anxieties, aviation authorities such as the FAA and EASA play a crucial role, as they must set standards for hardware and operational certification. Here, a good balance must be found between promoting innovation and requiring safety.

While there are domestic solid top players in Germany, the country will most likely not be a leading first mover market for drone innovation. This is mainly because the need is lower due to good infrastructure. Further, public acceptance will be difficult to achieve due to comparatively deeper concerns about safety, visual pollution, noise, and environmental impact.

In the context of this work, some questions remain unanswered, which represent starting points for further research. Due to the complexity of the topic, this work could not elaborate on all aspects that are crucial for the development of UAM. Consequently, it could be interesting to analyse the individual success factors in more detail to derive well-founded recommendations for action for the industry players.

In conclusion, the hype around UAM will probably not diminish over the next few years, but several hurdles yet need to be overcome. Thus, it remains uncertain if Ford's vision of a *"combination airplane and motorcar"*can become a reality.

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Appendices

Appendix A: List of abbreviations

Table 1: List of abbreviations

Abbreviation	*Definition*
AAM	Advacned Air Mobility
ATC	Air Traffic Control
ATM	Air Traffic Management
EASA	European Aviation Safety Agency
eVTOL	Electrical Vertical Take-off and Land
FAA	Federal Aviation Administration
TOLA	Take-off and Landing Area
UAM	Urban Air Mobility
UAS	Unmanned Aircraft System
UAV	Unmanned Aerial Vehicle
UTM	UAS Traffic Management
VTOL	Vertical Take-off and Land

Appendix B: Overview and classification of drones

Table 2: Overview and classification of drones (Source: Singhal, Bansod, & Mathew, 2018)

Civil	Environment	Military
• **Passenger and goods delivery** • Agriculture • Construction/ Mining • Disaster management • Photography • Surveillance mapping • Sports and hobby	• Wildlife • Climate change • Biodiversity • Natural disaster management	• Combat aircraft • Warzone supply • Spying • Bomb dropping • Surveillance and border control

Appendix C: Funding overview of Drone Start-ups

Table 3: Status Quo - Funding of Passenger Drone Start-ups (Source: Pitchbook 2021, TNMT 2021)

Company	Funding in million USD	Country of Origin
Joby Aviation	1,628	
Lilium	1,222	
Archer Aviation	919	
Xpeng	500	
Vertical Aerospace	429	
Volocopter	377	
Ehang	132	
Kitty Hawk	75	

Table 4: Status Quo - Funding of Delivery Drone Start-ups (Sources: Crunchbase, 2021, Tracxn, 2021)

Company	Funding in million USD	Country of Origin
Zipline	501	
Elroy Air	61	
Manna	41	
Matternet	34	
Wingcopter	22	
Flytrex	20	
Volansi	20	
Flirtey	16	

Appendix D: Drone certification announcements

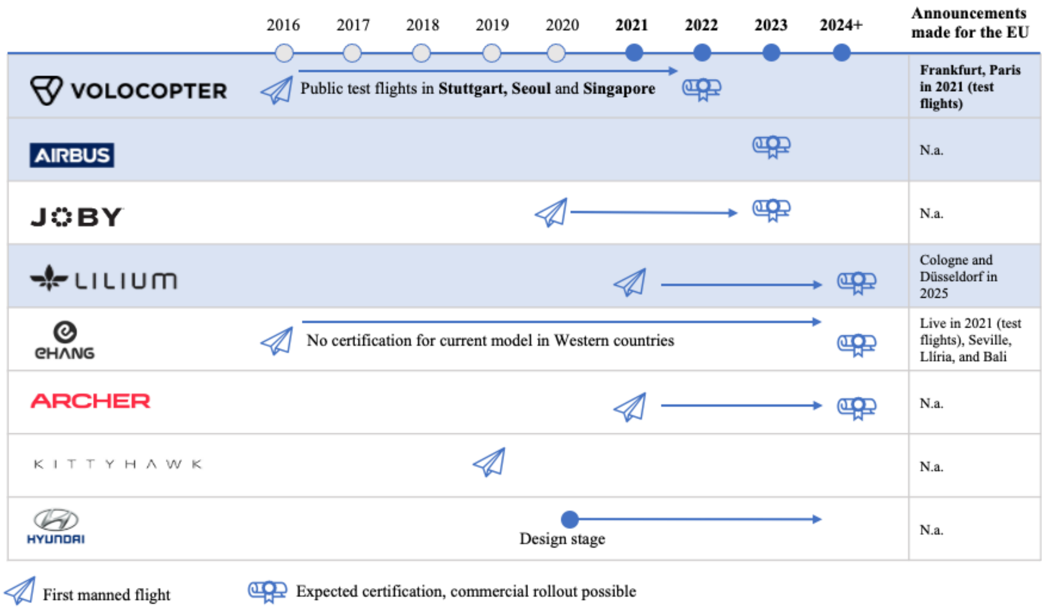

Figure 1: Passenger drone certification announcements (Source: EASA 2021a)

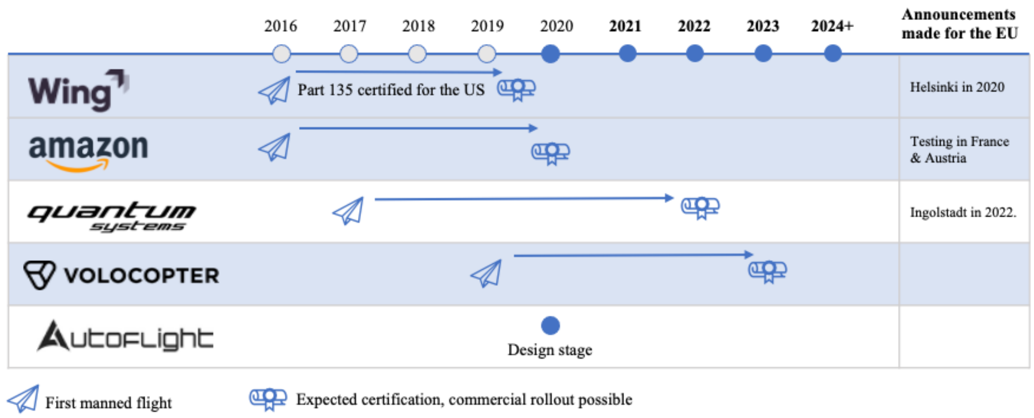

Figure 2: Delivery drone certification announcements (Source: EASA 2021a)

Appendix E: Online survey results

The online questionnaire was designed based on existing questionnaires from EASA (2021b), Thomsen (2018) and Riedel and Kloss (2021). The following parts have been translated into English as the survey was initially distributed in German.

Introduction
Dear Participant, *the following survey is part of our master thesis at the Nova School of Business and Economics and deals with the topic of Urban Air Mobility.* *This survey aims to investigate the willingness to use manned and unmanned drones.* *For a better understanding, a short explanation of the most important terminology of this topic follows in the next section.* *The survey is anonymous and will take approximately 5 minutes to complete.* *Thank you for your participation!* *Urban Air Mobility is the emergence of new air transportation technologies for transporting people and goods in new flying objects.* *An autonomous passenger drone is an air taxi that transports passengers without the use of a human pilot.*

Q1. How do you feel about getting into a passenger drone?
(Multiple answers possible)

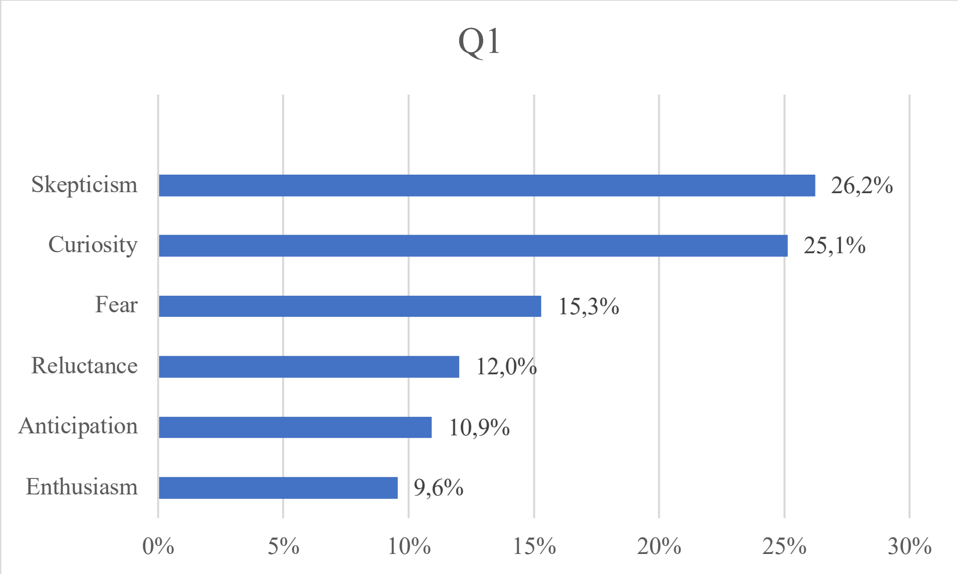

Figure 3: Question 1 results

Q2. What advantages would travelling with a drone have for you?
(Multiple answers possible)

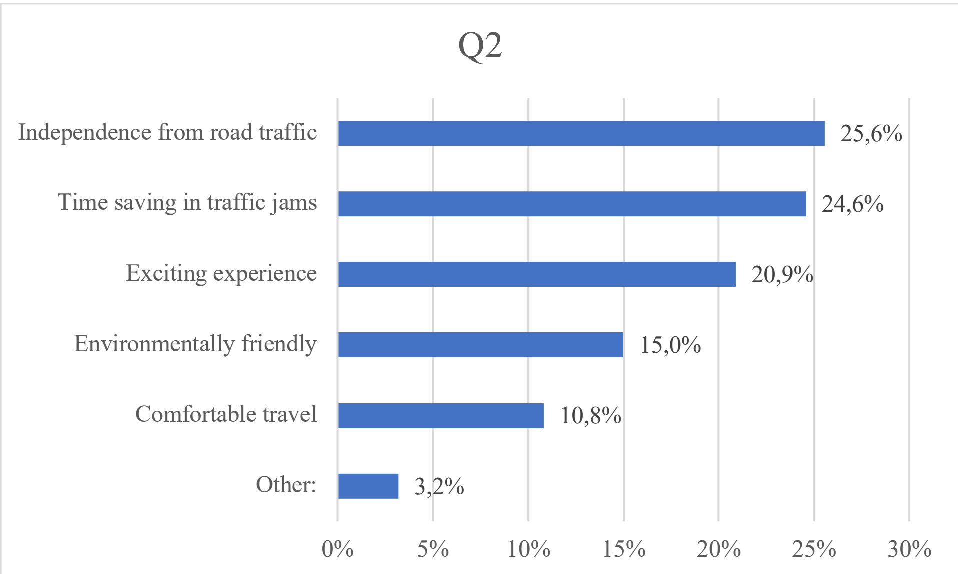

Figure 4: Question 2 results

Q3. Please rate the following statements on a scale of 1 - 5.
(1 = I strongly disagree to 5 = I strongly agree)
Why would you choose to use a passenger drone?

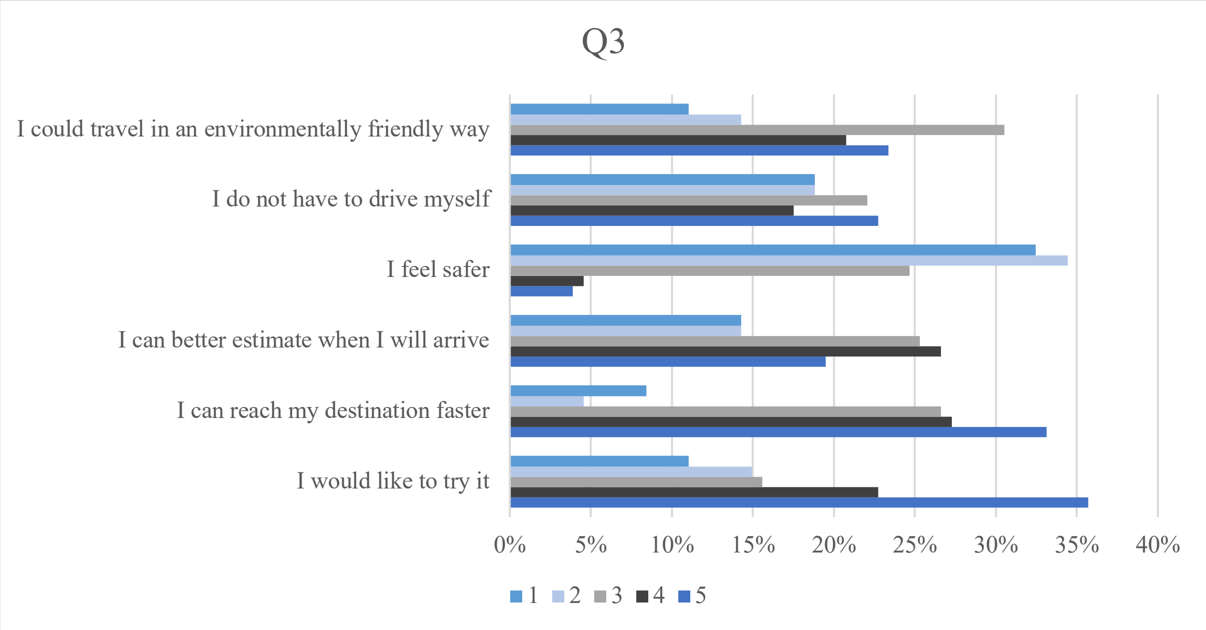

Figure 5: Question 3 results

Table 5: Statistical evaluation question 3

For the following questions, please rate the answers on a scale from 1 - 5. 1 = strongly disagree 2 = disagree 3 = moderately 4 = agree 5 = strongly agree				
Q3. Why would you choose to use a passenger drone?				
	Minimum	*Maximum*	*Mean*	*Standard deviation*
I would like to try it	*1*	*5*	*3.57*	*1.39*
I can reach my destination faster	*1*	*5*	*3.72*	*1.21*
I can better estimate when I will arrive	*1*	*5*	*3.23*	*1.31*
I feel safer	*1*	*5*	*2.13*	*1.04*
I do not have to drive myself	*1*	*5*	*3.06*	*1.42*
I could travel in an environmentally friendly way	*1*	*5*	*3.31*	*1.28*

Q4. Please rate the following statements on a scale of 1 - 5.
(1 = I have no concerns at all 5 = I have very great concerns)
About what factors regarding passenger drones do you have concerns?

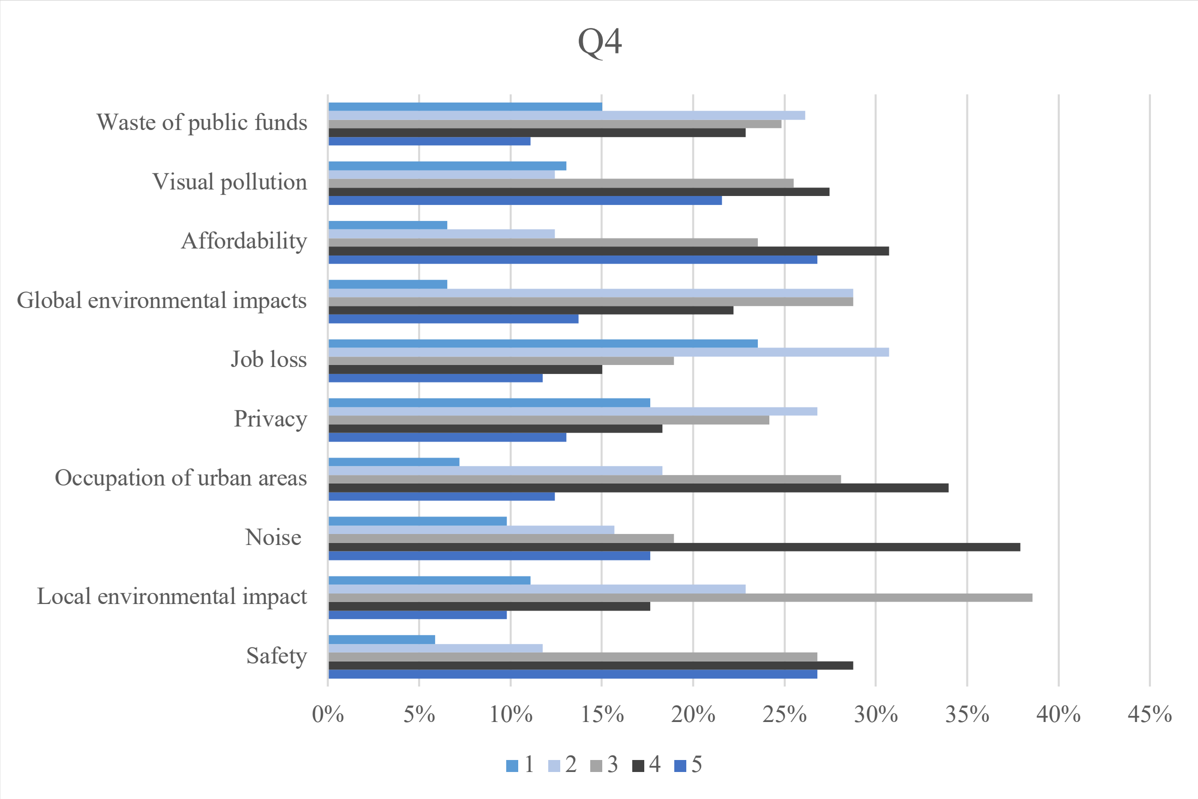

Figure 6: Question 4 results

Table 6: Statistical evaluation question 4

For the following questions, please rate the answers on a scale from 1 - 5. 1 = strongly disagree 2 = disagree 3 = moderately 4 = agree 5 = strongly agree				
Q4. About what factors regarding passenger drones do you have concerns?				
	Minimum	*Maximum*	*Mean*	*Standard deviation*
Safety	*1*	*5*	*3.59*	*1.17*
Local environmental impact	*1*	*5*	*2.92*	*1.11*
Noise	*1*	*5*	*3.38*	*1.22*
Occupation of urban areas	*1*	*5*	*3.26*	*1.11*
Privacy	*1*	*5*	*2.82*	*1.28*
Job loss	*1*	*5*	*2.61*	*1.31*

Global environmental impacts	*1*	*5*	*3.08*	*1.15*
Affordability	*1*	*5*	*3.59*	*1.19*
Visual pollution	*1*	*5*	*3.32*	*1.30*
Waste of public funds	*1*	*5*	*2.89*	*1.23*

Q5. What emotions do you feel about drones being used to deliver goods in the future? *(Multiple answers possible)*

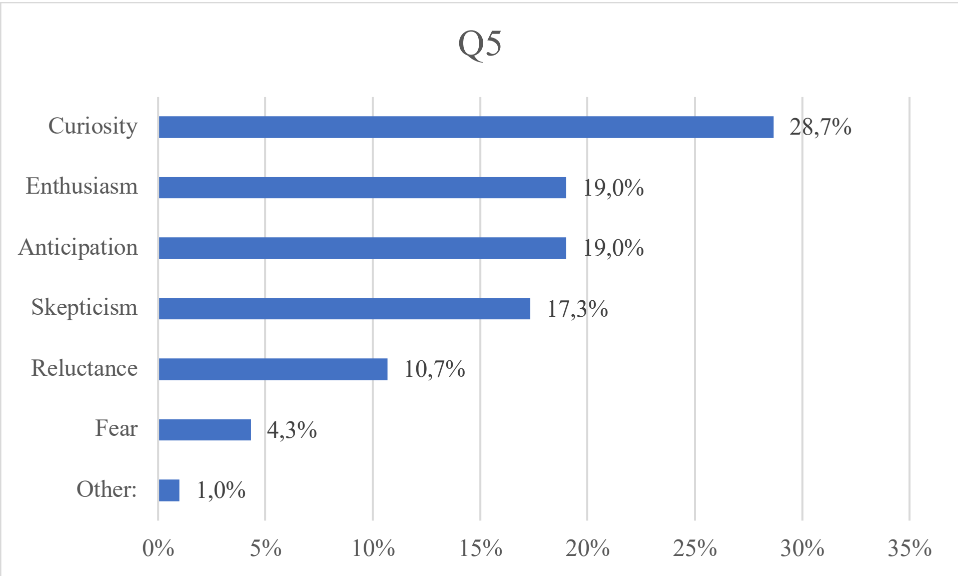

Figure 7: Question 5 results

Q6. What associations do you have when thinking about a delivery drone? *(Multiple answers possible)*

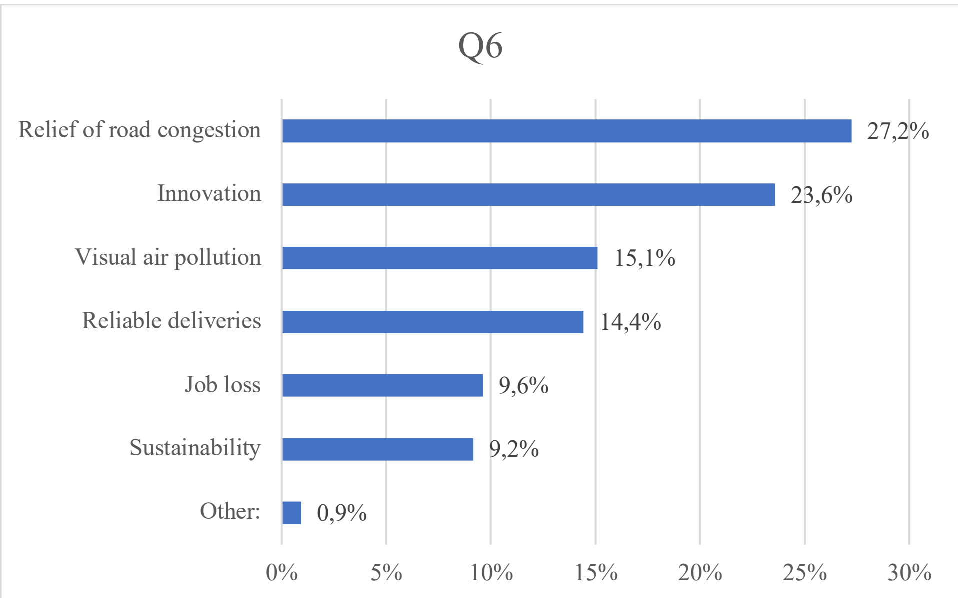

Figure 8: Question 6 results

Q7. Please rate the following statements on a scale of 1 - 5.
(1 = I have no concerns at all 5 = I have very great concerns)
About what factors in the delivery drone field do you have concerns?

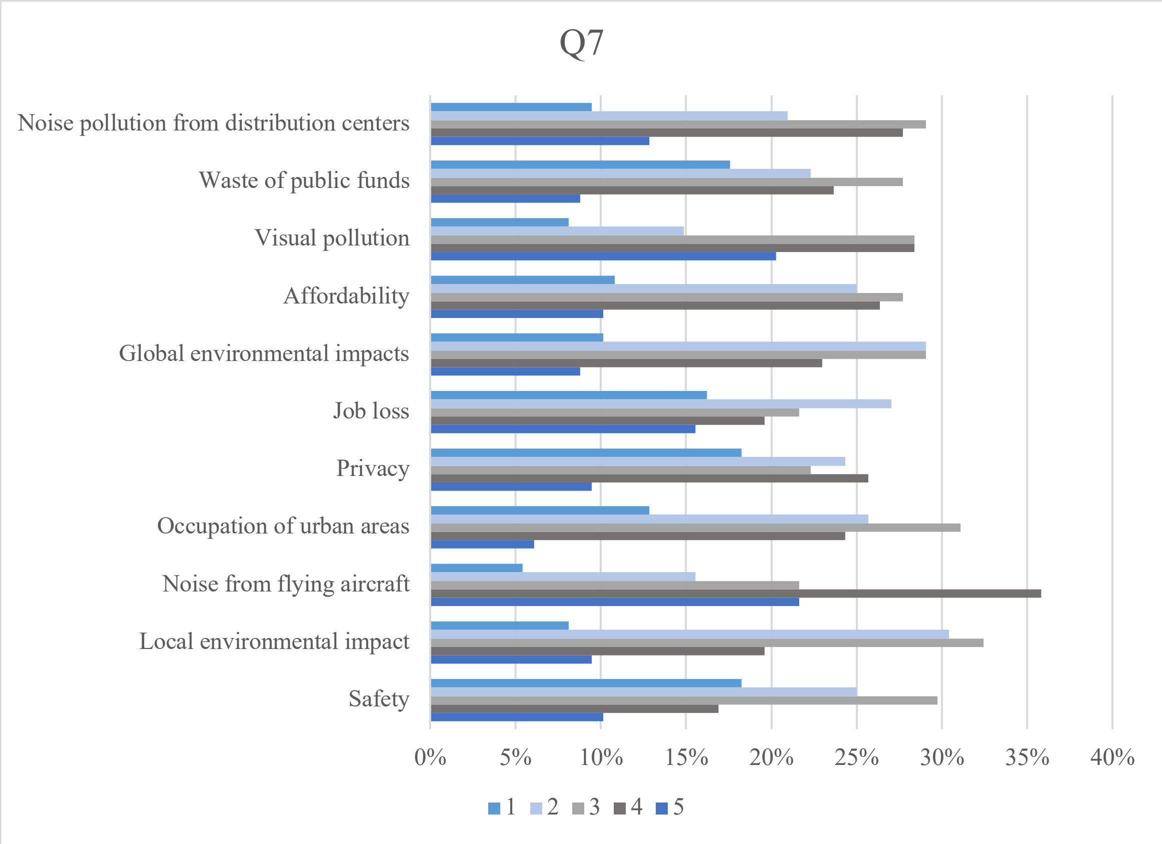

Figure 9: Question 7 results

Table 7: Statistical evaluation question 7

For the following questions, please rate the answers on a scale from 1 - 5. 1 = strongly disagree 2 = disagree 3 = moderately 4 = agree 5 = strongly agree				
Q7. About what factors in the delivery drone field do you have concerns?				
	Minimum	*Maximum*	*Mean*	*Standard deviation*
Safety	*1*	*5*	*2.76*	*1.22*
Local environmental impact	*1*	*5*	*2.92*	*1.09*
Noise from flying aircraft	*1*	*5*	*3.53*	*1.15*
Occupation of urban areas	*1*	*5*	*2.85*	*1.11*
Privacy	*1*	*5*	*2.84*	*1.26*
Job loss	*1*	*5*	*2.91*	*1.31*

Global environmental impacts	*1*	*5*	*2.91*	*1.13*
Affordability	*1*	*5*	*3.00*	*1.16*
Visual pollution	*1*	*5*	*3.38*	*1.19*
Waste of public funds	*1*	*5*	*2.84*	*1.22*
Noise pollution from distriubution centres	*1*	*5*	*3.14*	*1.17*

Q8. Please rate the likelihood of each of the following statements on a scale of 1 - 5. *(1 = not at all to 5 = most definitely)*

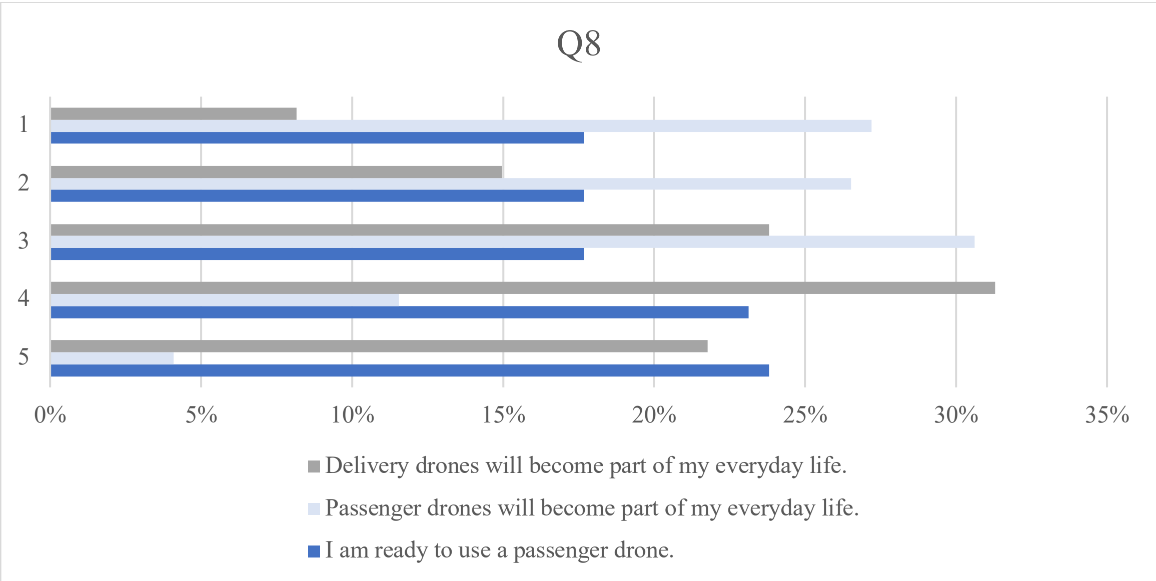

Figure 10: Question 8 results

Table 8: Statistical evaluation question 8

For the following questions, please rate the likelihood on a scale from 1 - 5. *1 = not at all 2 = slightly 3 = moderately 4 = very 5 = most definitely*				
	Minimum	*Maximum*	*Mean*	*Standard deviation*
Delivery drones will become part of my everyday life.	*1*	*5*	*3.44*	*1.21*
Passenger drones will become part of my everyday life.	*1*	*5*	*2.39*	*1.12*
I am ready to use a passenger drone.	*1*	*5*	*3.18*	*1.43*

Q9. Please rate the following statements on a scale of 1 - 5.
(1 = I strongly disagree to 5 = I strongly agree)

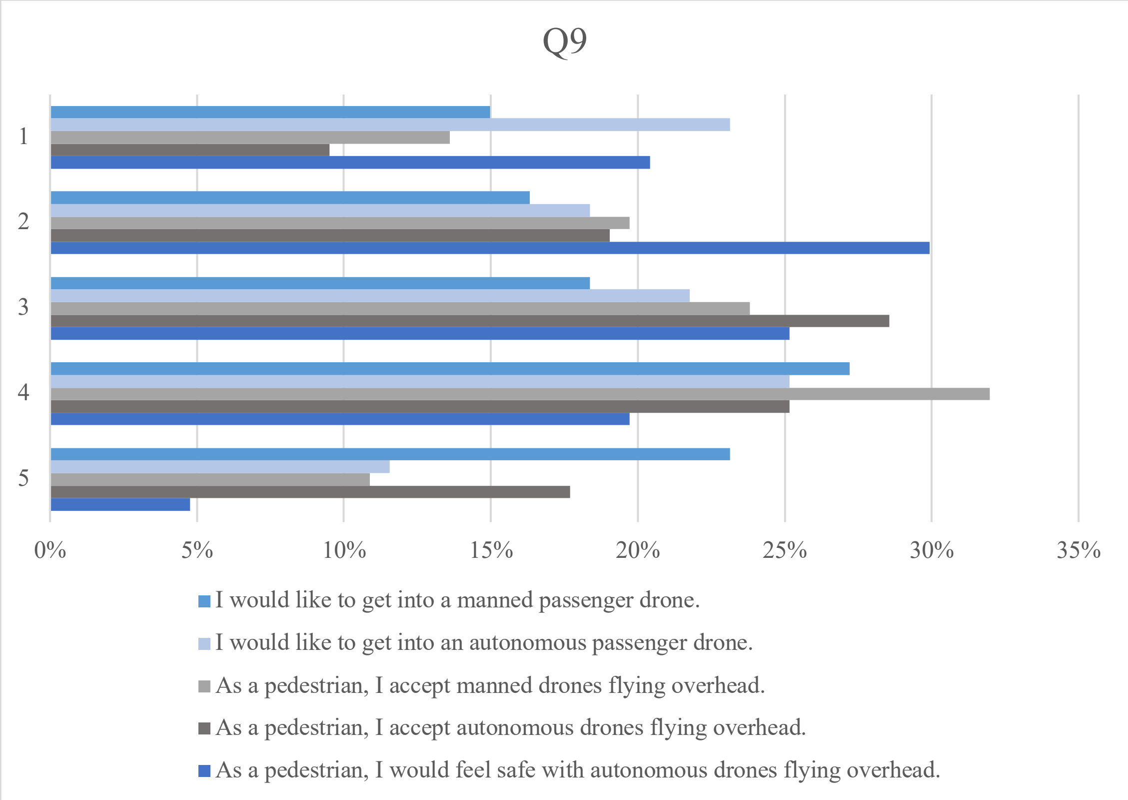

Figure 11: Question 9 results

Table 9: Statistical evaluation question 9

For the following questions, please rate the likelihood on a scale from 1 - 5. 1 = not at all 2 = slightly 3 = moderately 4 = very 5 = most definitely				
	Minimum	*Maximum*	*Mean*	*Standard deviation*
As a pedestrian, I would feel safe with autonomous drones flying overhead.	*1*	*5*	*2.59*	*1.15*
As a pedestrian, I accept autonomous drones flying overhead.	*1*	*5*	*3.22*	*1.22*
As a pedestrian, I accept manned drones flying overhead.	*1*	*5*	*3.07*	*1.22*
I would like to get into an autonomous passenger drone.	*1*	*5*	*2.84*	*1.34*

I would like to get into a manned passenger drone.	*1*	*5*	*3.27*	*1.37*

Table 10: Summary of open-ended questions survey results

Open-ended questions *	
Are there any other factors in the passenger drone field that you have concerns about? If so, please list them briefly.	*1. People are losing awareness of the amount of energy required for individual mobility.* *2. When are these things supposed to be a general means of transportation? I still lack creativity.* *3. Congestion in airways and front of landing fields* *4. Disturbance of airspace and birds* *5. Affordable only for the rich. Deterioration of the social fabric.* *6. Why is it assumed that they would be environmentally friendly? How are they powered? Who controls them? What about in case of severe storms? At what altitude do they move? How are they coordinated against/with each other? Is there a maximum limit in terms of numbers in the airspace? Collision hazards? (Power poles/wind turbines/other flying objects etc.) , manufacturing? Disposal? Maintenance? Safety briefing? Autopilot? "Drone driver's license"?*
Are there any other factors in the delivery drone field that you have concerns about? If so, please list them briefly.	*1. Crash hazard/collision hazard/coordination* *2. Deliverability in inner-city areas (safe unloading facilities).* *3. Fall hazard* *4. Fear of new, ask for safety* *5. A risk to the environment. Even more irritation for birds*

** Due to overlaps in content, answers have been partially summarized.*

Table 11: Summary of sample and subsample characteristics

		Total sample (N= 154)
Gender	Female	53.7%
	Male	45.9%
	Non-binary/ Third gender	1.4%
Age	0-17	1.4%
	18-20	2.7%
	21-29	58.2%
	30-39	6.2%
	40-49	6.2%
	50-59	21.2%
	> 60	4.1%
Education	Lower education	4.1%
	High School	14.4%
	Studies without degree	6.9%
	Bachelor	34.9%
	Master	37.0%
	Doctorate	2.7%
Household income (Gross)	0 – 9,999 €	15.1%
	10,000 – 19,999 €	7.5%
	20,000 – 29,999 €	2.7%
	30,000 – 39,999 €	4.8%
	40,000 – 49,999 €	8.9%
	50,000 – 59,999 €	4.8%
	60,000 – 69,999 €	8.2%
	70,000 – 79,999 €	8.9%
	80,000 – 89,999 €	8.2%
	90,000 – 99,999 €	5.5%
	> 100,000 €	25.3%
Geographic area	Rural	21.2%
	Sub-urban	55.5%
	Urban	23.3%

Appendix F: Interview catalogue

The interview catalogue was designed based on existing catalogues from Hader and Baur (2021b) and Hader and Baur (2020).

Starting Questions:

1. In which direction is the entire UAM industry developing, in your opinion. How can your work (e.g., publication, report, product) influence this development?
2. We consider "public acceptance" the most important factor for successfully implementing UAM. What do you think are the most important factors and why?

Industry setting related questions:

Technology

3. Do you believe that incremental innovations such as improved energy storage through optimized battery charging will shape the technological development of UAM? Or do you rather expect disruptive changes that will significantly influence the sector? (e.g., new propulsion technologies).
4. Will dominant design concepts most likely take over the landscape of the sector? (e.g., wing specifications more suitable for airport shuttles, etc.)
5. Do you consider the number of patents or the quality of patents relevant to success? (Hypothesis: There is no correlation between the number of patents and attractiveness to the market as Lilium is highly funded but only owns four patents).

Infrastructure

6. How can UAM as new, unknown technology be optimally integrated into a city's infrastructure? What steps need to be followed? What is the approximate duration of an elaborate project as such?
7. Who will be responsible for integrating UAM into the existing city infrastructure? Privatization or government-owned?
8. What factors need to be communicated (by players) to facilitate a city's readiness to integrate this new technology?
9. How would you rate the feasibility of establishing vertiports as landing and take-off zones in (German) cities?
10. For car transport, congestion occurs en-route, while for UAM, we would not expect to see delays while aircrafts are in the air. It can thus be assumed that vertiports are the

bottleneck for UAM congestion and not airspace. What specific risks can you identify for take-off and landing congestion?

Players & Funding

11. How do you assess the current competitive environment? Are young start-ups competing with large OEMs as the industry progresses? (David versus Goliath)
12. Do you think companies have a significant advantage in being the first to achieve public acceptance by creating a direct association between themselves (the brand itself) and the AAM industry? (First Mover Advantage) Or do you think other competitive factors are more relevant?
13. Do you think the current landscape of market players will evolve towards a more fragmented or concentrated market?

Environment & community-related questions

Public acceptance

14. Do you expect players to position themselves in certain niches depending on their specifics? (e.g., Joby Aviation as an urban airline compared to other brands) Or do you foresee more of a regional consolidation?
15. In your opinion, what are the most important factors for acceptance among the population? (e.g., ease of use, safety).
16. Which of these factors can be influenced by companies providing drone services?
17. Should the government influence society to support the trend toward UAM?
18. How do you think industry stakeholders (players, investors etc.) can educate the public about the advantage of this new technology?

Legal and regulatory landscape

19. An EASA study shows that safety concerns are one of the main barriers to UAM adoption. How can EASA address these concerns through regulation without interfering with the innovation process?
20. How can we leverage regulations for autonomous cars (or other technologies that have been integrated into society) to develop a robust UAM regulatory framework?
21. What regulatory issues need to be addressed first to make drone innovation a reality?
22. How is EASA working with the German ministry (e.g., BMVI)?
23. How does the German ministry or executing agencies such as airports, etc., contribute to making Germany the lead market for drone innovation?

Environmental impact

24. Do you think that UAM companies are leading the progress in developing innovative low-carbon technologies, or are these companies more dependent on the general development of these technologies?
25. To what extent could noise pollution be a significant barrier to successful integration?

Other

26. What do you think is needed, especially in Germany, to get the necessary political support for widespread AAM implementation?
27. Would you consider Germany an attractive or unattractive market for early UAM implementation? Why?
28. How do you think urban air mobility will develop in the next 20-30 years? What is your vision for this sector?