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Examining legal requirements for a ground infrastructure at airfields as part of an automated, emission-free airfreight transport chain

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Abstract

As traffic volume has been increasing in Germany due to passenger and freight transport growth, time critical delivery services are facing new challenges. A possible solution arises from the technical progress in air transport research within the last years enabling the use of automated, light aircraft, which can operate in a more flexible manner and do not produce air pollutants. In order to establish an innovative airfreight chain, airfields have to meet the applying infrastructural requirements. The aim of this work is therefore to identify an according legal framework. We examined existing, progressing and missing regulations in order to assess the technical feasibility and point out further demand for legal assurance. The investigation shows that most applying regulations are technically feasible for the proposed airfreight transport, but a regulatory framework is not yet clarified for drone aerodrome design as well as unmanned aircraft systems operations at aerodromes.

Keywords: airfreight; express freight; UAS; airfield design; urban and regional mobility

1. Introduction

The growing demand for mobility and the effect of urbanization have led to higher traffic loads in urban areas within recent years. This overload of the ground transportation system reduces the reliability and the speed of package delivery, which are both important characteristics for express delivery services. At the same time, the express delivery market has been constantly growing over the last decade. The German Aviation Association (2019) states that, in 2017, the number of express deliveries to, within, and out of Germany summed to 3.35 billion,

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doubling since 2008. Additionally, the German Parcel and Express Logistics Association (BIEK, 2019) expects a further expansion of 3.3% per year within the years 2018 and 2023. The significant market development towards e-commerce is considered one of the most important drivers in this progress. This development likewise occurs in airfreight business, as airfreight volume in Germany has increased by 3.8% per year between 2015 and 2018 reflecting the worldwide growth of airfreight volume (German Aviation Association, 2019). Companies and private customers experience decreasing delivery times and are willing to pay accordingly for this service. Thus, delivery services need to seek for new solutions in order to provide time critical express deliveries as a high quality service product. To ensure a quick and reliable delivery, a possible solution might be relocating the transport chain into the third dimension by using small airplanes and drones as means of transport. Along with the overload of urban street networks, emissions in cities have become a serious issue. In order to improve air quality, new limits have been defined and research is now focusing on locally emission-free means of transport, with air traffic related efforts being a significant part of it. Regarding light aircraft or heavy lift drones with electric or hybrid propulsion technologies and innovative fuel systems, significant technological progress has been achieved within recent years.

This paper examines the regulatory framework for these light aircraft, which is mostly not clarified yet, as these vehicles are planned to operate unmanned in the unregulated airspace. In comparison to the topic of the vehicle development, investigating the required infrastructure for these aircraft has been of secondary importance. The requirements to an according ground infrastructure are not yet defined, which forms one of the main challenges when creating the concept of an automated, airborne delivery chain. This paper consequently focuses on the airfield infrastructural requirements resulting from the existing and progressing regulatory framework, and investigates the roles of the regulations as well as the responsible authorities.

The paper is structured as follows. Section 2 provides an overview to the state of the art concerning new light aircraft concepts and illustrates the present research strategy. After that, Section 3 introduces the already established as well as the newly developed legal framework and examines relevant resulting requirements on the airfield. Section 4 presents and discusses the key findings of the analysis of legal framework. Finally, Section 5 indicates the main conclusions and gives an outlook for potential future research on the subject.

2. Research demand

2.1. State of the art

Concerning light-weighted aircraft such as small fixed-wing aircraft or vertical take-off and landing (VTOL) aircraft, various new concepts have been developed in recent years. In particular, hydrogen powered aircraft are estimated to be a promising solution to realize air transport without any pollutant emissions. Sürer and Arat (2018) and Baroutaji et al. (2019) point out that many concepts combine the use of hydrogen with a fuel cell propulsion system to generate electrical energy. The research field of vertical mobility enabled by VTOL aircraft constitutes another focus in air transport research. It specially targets the congestion of urban and suburban street networks, since the capability of VTOL enables new locations and transport routes in urban areas. Studies conducted by Porsche Consulting (2018) and Horváth & Partners (2019) consider the delivery of goods to be one of the major use cases of vertical mobility, besides the functions of passenger transport and inspection services. Focusing on heavy lift drones for passenger or freight transport use, a comprehensive overview is given by technical websites like The Electric VTOL News (2020) and TransportUP (2020). At the same time, air transport research is aiming for unmanned operations. This aim brings up challenges for the aircraft system and its environment of air space and aerodromes, for example for detecting and avoiding other aircraft within the air space or performing take-off and landing procedures.

2.2. Research strategy

Express deliveries mainly consist of parcel-sized goods like electrical equipment or health and biotech products (Oxford Economics, 2011). This kind of freight often requires intercontinental routes of transport being realized by express cargo airlines. When arriving at an international express cargo airport, the express freight is typically sorted in a cargo facility and afterwards is transported further by trucking. In order to be independent of congested street

infrastructure and to improve delivery speed, the idea of this research is to create an airborne delivery chain, which connects the international cargo airport to urban city hubs.

The proposal of this new type of delivery chain is presented in Fig. 1. Within this delivery chain, a light airplane starting at the international airport overcomes most of the distance to the destination city. This airplane will be powered by an innovative propulsion system, which does not produce any air pollutants. In this context, one of the earlier proposed propulsion technologies as hydrogen or electrical power has to be applied. The necessary infrastructure for suburban destinations of the airplane already exists in most parts of Germany, as 960 aerodromes are located within its area, with 25 of them being major airports and nearly 390 of them being general airfields (Berster et al., 2018). When arriving at the airfield, the freight is transshipped to heavy lift drones, which transport the express freight to city hub locations within the destination city. The heavy lift drones should be designed with an electrical powered engine. Finally, the last mile is completed by electrical vans or freight bikes. Overall, the envisaged delivery chain combines several newly developed means of ground transportation and aircraft. As these are powered by pollutant emission-free propulsion systems, we create an environmental friendly delivery chain until the end-customers' door. Furthermore, by using unmanned aircraft systems, we can take advantage of the ongoing legal development in innovative urban and regional air transport.

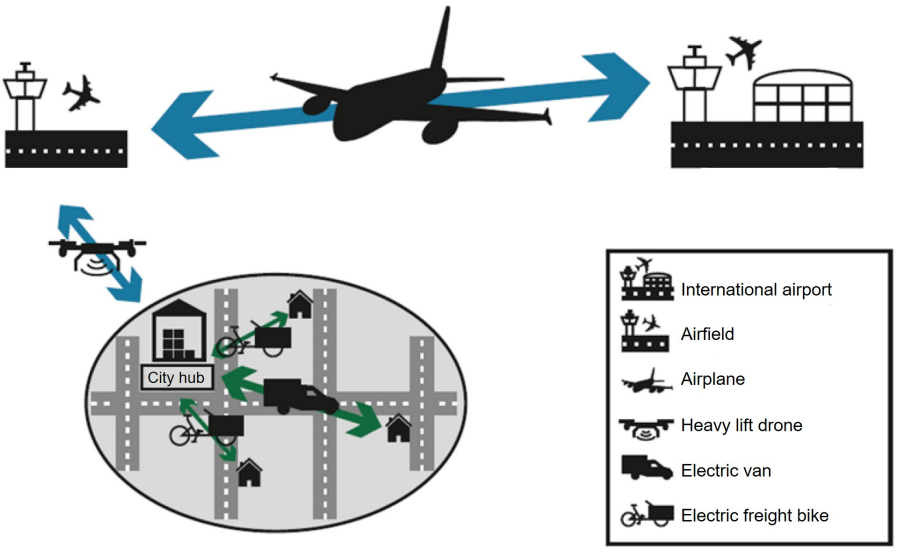

Fig. 1. The proposed airborne freight delivery chain

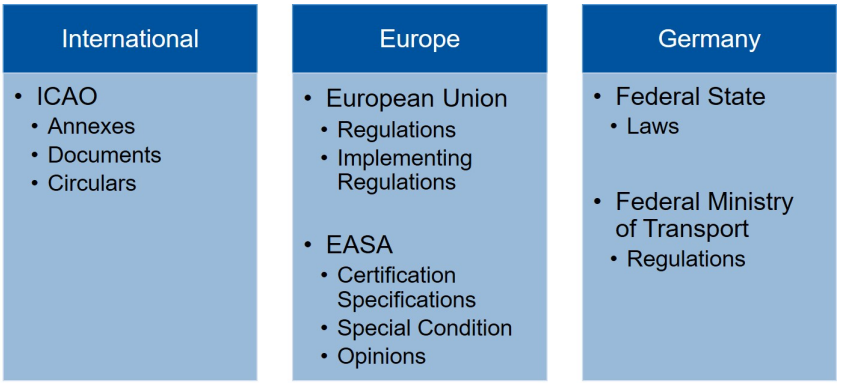

Fig. 2. Aviation authorities

3. Legal requirements

This section presents the legal framework and the corresponding authorities for the airfield infrastructure within the proposed delivery chain. The authorities and legal documents discussed in this section can be assigned to the geographic levels shown in Fig. 2. As a basis for international legal matters, the International Civil Aviation Organization (ICAO) was founded by the Chicago Convention in 1944. Their standards and recommendations constitute the foundation for all subsequent authorities. The ICAO also publishes additional documents such as manuals, and circulars. Accordingly, their specifications are transferred into European law by means of Regulations, which are passed by the European Parliament and the Council, and subsequent Implementing Regulations, which are published by the Commission. Furthermore, the European Council founded the European Union Aviation Safety Agency (EASA) by the Regulation (EC) No 1592/2002 in order to harmonize European civil aviation. They define Certification Specifications and publish opinions during the process of developing new specifications. Germany as an example of a member state of these institutions transfers international and European regulations into national law.

The legal requirements regarding the focused airfield infrastructure result from various subject areas. First, an existing set of rules defines the established business of airfreight handling. Additionally, there are fundamental requirements regarding the design of aerodromes, which mainly depend on the operating aircraft. Besides these general design requirements of the airfield, the ground infrastructure has to meet additional requirements due to the objective of unmanned flight operations. This section will focus on every of these subject areas in order to point out according legal requirements and finally discuss the legal feasibility of an airfield as a transshipment point within the described airfreight delivery chain.

3.1. Airfreight handling

Considering airfreight handling and security regulations, the ICAO (2017) gives primary regulations published in “Annex 17, Security”. On the European level, the European Commission implements these rules within the Regulation (EC) No 300/2008 as well as the Implementing Regulations (EU) 2015/1998 and (EU) 2019/103. For the example of Germany, the Luftsicherheitsgesetz (LuftSiG, 2005) integrates these into national law. The key requirements for airfreight handling can be summarized from the Regulation (EC) No 300/2008 as following:

- *“All cargo and mail shall be subjected to security controls prior to being loaded on an aircraft. An air carrier shall not accept cargo or mail for carriage on an aircraft unless it has applied such controls itself or their application has been confirmed and accounted for by a regulated agent, a known consignor or an account consignor.”*
- *“Cargo and mail to be carried on an aircraft shall be protected from unauthorized interference from the point at which security controls are applied until the departure of the aircraft on which it is to be carried.”*
- *“Cargo and mail that are not adequately protected from unauthorized interference after security controls have been applied shall be screened.”*

In order to ensure a quick delivery, processing within a restricted area is of advantage compared to additional security controls. The restricted area may only be entered by approved staff that was subjected to a background check. This check ensures that a person is suitable *“for unescorted access to security restricted areas”* (EC No 300/2008).

3.2. Aerodrome design

The requirements regarding the design of aerodromes depend on the intended operating aircraft. In this use case, we have to consider several aircraft. Small airplanes in the category of light aircraft are intended to conduct the transport between the international cargo airport and the suburban airfields. These airplanes represent a common aircraft type for airfields. Additionally, heavy lift drones as VTOL aircraft shall connect the airfield with city hubs. For airplanes, the ICAO (2018) gives primary definitions on the design of aerodromes by the “Annex 14, Aerodromes – Volume I, Aerodrome Design and Operations”, which corresponds on European level to the

EASA (2015) "Certification Specifications and Guidance Material (CS-ADR-DSN)". In these regulations, we find requirements regarding the design of the runway including stopways, clearways, safety areas, and further aspects. Moreover, it states necessary taxiway and apron infrastructure. Besides the physical infrastructure, Annex 14 also defines requirements regarding obstacle clearance and visual aids for navigation. All of these requirements depend on the type of flight operation: visual flight rules as opposite to instrumental flight rules. At this moment, the majority of airfields in Germany operate at visual flight rules, since they form no critical infrastructure and the application of a landing system is very cost-intensive. The considered airplane connecting the international cargo airport with suburban airfields will have the dimensions of a common fixed-wing aircraft in the category of light aircraft. For example, a Cessna 172, which is the most-built aircraft worldwide and a popular vehicle within light aircraft, has a wingspan of 11 m. This corresponds to an aerodrome reference code of 1A, which is the minimum reference code (ICAO, 2018). Although the airplane considered for this use case will have a different propulsion concept providing emission-free transport, we assume that it will have a similar size and take-off and landing performance compared to the engine powered reference airplane. We can therefore expect that the physical ground infrastructure and the obstacle clearance for the aircraft operation is already available at existing airfields. The requirements concerning visual aids at the airfield highly depend on the operating aircraft flight guidance and navigation as well as the existence of a landing system at the airfield. Thus, the investigation of required visual aids needs to be carried out for each specific combination of airfield and aircraft.

Besides the fixed-wing aircraft, the heavy lift drone will also operate at the airfield. The drone connects the airfield with several city hub locations. To this moment, heavy lift drones are still under development. From the regulatory point of view, a legal framework to the specific infrastructure for VTOL or drone operations as well as regulations on the certification of an according cargo aircraft are not published yet. Regarding the example of passenger transport, a milestone was achieved when the EASA (2019b) published a Special Condition for small-category VTOL aircraft. In order to examine infrastructural requirements at this stage, we must consider other, already existing regulations. The aircraft that is most similar to a heavy lift drone and already operating within regulatory boundaries is the helicopter. We assume that upcoming VTOL aircraft will have an equivalent or even more precise flight performance than helicopters. Thus, applying the infrastructure required for helicopter operations is considered sufficient for a heavy lift drone as well. Infrastructural requirements derive from the regulations published by the ICAO (1995; 2013): the "Annex 14 – Volume II, Heliports" and the "Heliport Manual" are the legal foundation on international level. The EASA (2019a) integrates these legal requirements into the "Certification Specifications and Guidance Material (CS-HPT-DSN)", which are also transferred into German law by an according administrative regulation (BMVBS, 2005). The framework of these rules points out the following aspects:

- Heliports require different design parameters depending on their location (surface-level, elevated, or helideck).
- Heliports require different design parameters depending on the operating helicopters' performance class.
- Every heliport consists of at least one final approach and take-off area (FATO) and one touchdown and lift-off area (TLOF), which may be located within the FATO. Their dimensions depend on the largest dimension of the largest drone planned for operation.
- A FATO is surrounded by a safety area and complemented by a clearway.
- For simultaneous operations, a FATO minimum separation distance towards a runway or taxiway is required.
- Taxiways and taxi-routes may be realized in the air or on the ground.
- There are requirements regarding obstacle clearance and visual aids for navigation.

Since helidecks are not envisaged for this use case and elevated locations require equal or stricter design characteristics than on surface-level, we examine the design parameters for an elevated heliport. Furthermore, we assume the drone's performance to be equivalent to a helicopter's performance class 1, given that the drone will be powered by several rotors and retains airworthiness even in the case of rotor failure.

3.3. Unmanned aircraft systems (UAS)

In the past years, the focus of air transport research has shifted towards the aim of operating unmanned aircraft systems. The regulatory frame for this new kind of aviation is continuously developing, and relevant regulations

have been published within the last decade. The ICAO (2011) gives foundational rules by the Circular 328 "Unmanned Aircraft Systems (UAS)". This document aims to investigate the difference between manned and unmanned aviation, which will finally lead to a safe and harmonized air transport system, with unmanned aircraft operations integrated into the existing air transport system. The circular therefore describes existing legal matters, operational procedures, and further aspects, and examines their applicability for UAS. Regarding aerodromes, it states that remotely-piloted aircraft "must be able to work within existing aerodrome parameters. Aerodrome standards should not be significantly changed" (ICAO, 2011). Thus, we can conclude so far that UAS operations may not lead to additional infrastructural requirements on the aerodrome design. The circular has an important function for international progress on UAS, but does not define a final set of requirements yet, since unmanned aircraft concepts are still under development.

On the European level, several Commission Implementation Regulations apply for UAS. Most importantly, the Commission Implementing Regulation (EU) 2019/947 defines the three categories for UAS operations: 'open', 'specific' and 'certified'. Still, no infrastructural requirements are defined in this framework. Furthermore, the EASA is working on a regulation, which aims to "create and harmonise the necessary conditions for manned and unmanned aircraft to operate safely in the U-space airspace" (EASA, 2020) and published an opinion for this purpose in January 2020. This document focuses on aircraft operation in uncontrolled airspace or as uncontrolled traffic. It will therefore be important when realizing an air transport chain connecting suburban or rural airfields. Still, there are no further requirements on aerodrome design defined in this document, either. Another general legal framework is given by the Regulation (EU) No 923/2012 laying down the common rules of the air and operational provisions regarding services and procedures in air. This regulation is again transferred into national law by the EU member states. In Germany, the resulting Air Traffic Regulation (LuftVO, 2015) does not specify infrastructural requirements due to UAS yet. In fact, according to LuftVO, operations of UAS within the range of 1.5 kilometers to an airfield are only permitted with a specific authorization.

4. Discussion

The previous section has comprehensively presented the status of legal matters that incur to an airfield within the proposed research strategy. We now move on to summarize and discuss this status in order to determine advantages and challenges that need to be taken into account when establishing the envisaged airfreight system. Table 1 gives a brief overview of this discussion. National legal framework is not mentioned in order to improve clarity.

Table 1. Existing legal framework incurring to an airfield in the proposed airfreight system

Subject	Existing regulations/documents	Defined requirements	Technical feasibility
Airfreight handling	ICAO Annex 17, Security (EC) No 300/2008, (EU) 2015/1998, (EU) 2019/103	Security controls, protection from unauthorized interference	Feasible
Aerodrome design	ICAO Annex 14, Aerodromes – Volume I EASA CS-ADR-DSN	Design parameters: runway, taxiway, apron, obstacle clearance, visual aids	Feasible
Drone aerodrome design	-	Not clarified yet	Presumably feasible
Heliport design	ICAO Annex 14, Aerodromes – Volume II, ICAO Doc. 9261 EASA CS-HPT-DSN	Design parameters: FATO, TLOF, taxiway, apron, obstacle clearance, visual aids	Presumably feasible
Unmanned Aircraft Systems	ICAO Cir 328 EASA Opinion 01/2020 (EU) 2019/947, (EU) 923/2012	Not clarified yet (target of using established aerodrome design parameters)	Not clarified yet

Regarding airfreight handling, the proposed delivery chain will work within the known system framework. We can therefore transfer the established legal framework to our use case, and clarify the concluding requirements, which constitutes an advantage when realizing the necessary conditions. In detail, a restricted area ensuring the protection of the aircraft and the airfreight is one of the major requirements. Since the majority of commercial

airfields have low traffic volume and basic infrastructural facilities, the required restriction of public access may not be provided in most locations yet. Necessary adaptions need to be established in this context in order to make the airfield suitable for the considered use case.

With respect to aerodrome design, the fixed-wing light aircraft requires established ground infrastructure in terms of runways, taxiways, apron, and obstacle clearance. As we aim at keeping conventional aircraft dimensions, we expect the available aerodrome infrastructure to be sufficient to the proposed airfreight concept, which highly supports the use of this type of aircraft for the proposed delivery chain. Additional facilities such as visual aids need to be examined in a specific investigation. Because visual aids are mainly realized by installing additional equipment, they are not assessed as a crucial issue to a legal feasibility of the proposed delivery chain. To this moment, electrical or hydrogen powered aircraft, which are the envisaged aircraft for our research, are not in daily use. We consequently expect possible further changes regarding the requirements of the airfield when operating aircraft with innovative propulsion technologies.

VTOL aircraft as heavy lift drones have been experiencing an intense technological progress in recent years. As a VTOL-related Special Condition framework has been published recently, it is expected that regulative authorities such as ICAO, EASA or the Federal Aviation Administration (FAA) will focus on developing a legal framework within the next years in order to define VTOL specific aerodrome infrastructure for the first time. This development is depending on the existence of regulations to the according type of aircraft. As a first approximation, presumable legal requirements can be deduced from existing regulations for heliports, as they constitute another established VTOL aircraft. For the envisaged airfreight delivery chain, we need to combine both airplane and VTOL operations at the airfield and therefore meet the infrastructural requirements for both types of aircraft. As we mentioned in Section 2.2, a significant number of airfields is already available in Germany. Airfields are typically designed for operation of small fixed-wing airplanes and not every airfield is available for helicopter operations in the current stage. Still, we assess meeting the basic infrastructural requirements for airplane and VTOL operations as a feasible task in order to establish the proposed airborne delivery chain. Considering that general aerodrome infrastructure typically extends to a bigger dimension, we propose to expand suitable general airfields by a heliport ground infrastructure. The need for a VTOL specific aerodrome set of rules forms a major challenge when creating the proposed air transport chain using innovative VTOL aircraft.

Besides airfreight handling and aerodrome design parameters, legal requirements also result from the integration of UAS within the proposed use case. This part of air transport research has shown highly dynamical progress within the last decade and has not been transferred into a valid set of rules yet. To this moment, UAS legal matters are very restrictive and do not enable all possibilities that emerge from the recent technological progress. General rules of air transport when integrating manned and unmanned aircraft are currently subject of discussion for international authorities as ICAO, EASA and their member states. The opinions that have been published so far aim at using established aerodrome design parameters for UAS operations. We therefore do not expect necessary adaptions of airfields yet. However, the final assessment regarding the legal feasibility of the proposed airfreight delivery chain depends on the result of the ongoing development of regulations for UAS operations at aerodromes and in their environment.

5. Conclusion and outlook

This research contributes to the development of an automated, emission-free airborne delivery chain, which aims at providing highly time critical express deliveries. The aim of this work was to identify infrastructural requirements for a commercial airfield as part of the proposed airfreight delivery chain. We therefore focused on requirements from legal framework that is already existing or “being under development”. Regulations have been taken into account regarding airfreight handling, aerodrome design as well as unmanned aircraft systems. In summary, the missing regulatory framework for VTOL aerodrome design as well as UAS operations within the airspace and at aerodromes was found to be a challenge that we need to overcome in the near future. Stakeholders such as the aircraft industry, air navigation service providers and further institutions must get together with the responsible authorities in order to discuss the necessary set of rules to these issues. Examining the existing and upcoming legal framework for an airfield processing urban and regional airfreight transport forms the first step for further investigation of this infrastructure. Following research will focus on developing detailed and quantified processes

taking place at this airfield, which have to meet the identified legal requirements. As a next step, we will determine the infrastructural components for the delivery chain and afterwards transfer these considerations into a simulation model providing a more precise analysis in terms of processing facilities and capacity.

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