



CARLOS ESTEBAN NAVARRO

Describing the complexities of developing an eVTOL's turnaround
concept of operations at vertiports

School of Aerospace, Transport and Manufacturing
Airport Planning and Management

MSc
Academic Year: 2024 - 2025

Supervisor: Dr Berkcan Uyan
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This thesis is submitted in partial fulfilment of the requirements for
the degree of MSc Airport Planning and Management

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Abstract

Urban Air Mobility (UAM) represents a transformative shift in short-distance transportation, promising fast, sustainable and congestion-free travel using electric Vertical Take-Off and Landing (eVTOL) aircraft. While significant progress has been made in airspace integration and aircraft development, limited attention has been given to ground operations, specifically, the turnaround process at vertiports. This research addresses that gap by exploring the operational, infrastructural and regulatory complexities of eVTOL turnaround, with the aim of supporting the development of a Concept of Operations (ConOps). The study begins with a comprehensive analysis of eVTOL typologies, vertiport classifications and turnaround practices from both fixed-wing and rotary-wing aviation. A thematic literature review reveals a lack of standardised procedures and highlights emerging challenges related to infrastructure, charging, stakeholder roles and scalability. To gain deeper insight, six semi-structured interviews were conducted with stakeholders across consultancy, regulation, manufacturers, infrastructure and ground support services. These were analysed using thematic analysis supported by NVivo software.

Findings indicate that eVTOL turnaround is not directly comparable to existing aviation models. Key differentiators include the dominance of electric charging or battery swapping, limited standardisation, the evolving regulatory environment and the need for automation. Stakeholders identified major challenges in assigning responsibilities, ensuring coordination and integrating safety protocols, particularly under constraints of infrastructure size and electricity availability. The study concludes that the development of a flexible, scalable turnaround ConOps is essential for the viability of UAM. While current uncertainties limit the finalisation of standard procedures, early planning and stakeholder engagement can facilitate safer and more efficient operations.

Keywords: UAM, ConOps, challenges, develop, vertical, helicopter, ground, stakeholders, interviews, thematic analysis

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List of Abbreviations

AAM	Advanced Air Mobility
ANSP	Air Navigation Service Providers
APU	Auxiliary Power Unit
ATC	Air Traffic Control
ATM	Air Traffic Management
ConOps	Concept of Operations
CURES	Cranfield University Research Ethics Committee
eVTOL	Electric Vertical Take-Off and Landing
FAA	Federal Aviation Administration
FATO	Final Approach and TakeOff Area
GIS	Geographic Information Systems
GSE	Ground Support Equipment
LCY	London City Airport
MRO	Maintenance, Repair and Overhaul
OEM	Original Equipment Manufacturer
SOP	Standard Operating Procedure
TLOF	Touchdown and Lift-Off Area
UAM	Urban Air Mobility
UASP	UAM Service Provider
UATM	Urban Air Traffic Management

1 Introduction

This chapter offers an overview of the research conducted, outlining both the underlying motivations and the scope. It begins by presenting the research problem and motivation to contextualise the analysis, followed by a detailed explanation of the research aim and objectives. The chapter concludes with the explanation of the structure of the study.

1.1 Motivation and Research Problem

UAM or Advanced Air Mobility (AAM) represents a transformative shift in the way people and goods are transported across urban and suburban environments. Enabled by recent advancements in eVTOL technologies, automation and battery performance, UAM aims to alleviate ground congestion, reduce travel time and support sustainable urban development. With major aerospace firms, startups and regulatory bodies investing heavily in this sector, the industry is approaching a crucial inflexion point, as seen in Figure 1-1, representing the Gartner Hype Cycle for the AAM.

eVTOL aircraft offer several advantages, including reduced noise and emissions, point-to-point transport and the ability to access densely populated or underserved areas. However, realising the full potential of UAM depends not only on vehicle development but also on the design and integration of vertiports.

Developing efficient, scalable turnaround operations at vertiports is one of the key operational challenges facing the industry. Vertiports must be compact, rapidly adaptable and need to be integrated into urban environments. Turnaround procedures must be fast, safe and cost-effective to support the high-frequency, short-range missions typical of UAM.

Moreover, the economics of UAM remain uncertain, hinging on high asset utilisation, minimal ground time and regulatory clarity. However, some consultancies value the UAM industry in billions of pounds in the upcoming years. For example, PwC (2023) expects an annual impact of £2.1 billion in socioeconomic benefit just in the United Kingdom by 2040. The complexity of

coordinating vehicle operations, energy requirements, airspace management, and passenger experience presents a unique research opportunity. It is important to mention that this research focuses on the UAM used by passengers, discarding cargo operations.

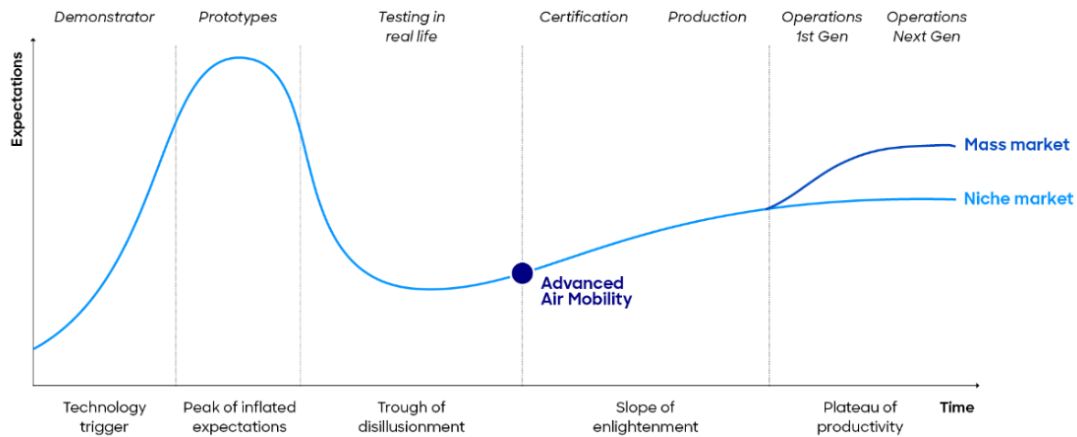


Figure 1-1. Gartner Hype Cycle for AAM. Source: (Hader & Baur, 2024)

1.2 Aim and Objectives

This research aims at describing the complexities of developing an eVTOL's turnaround concept of operations at vertiports. To achieve this aim, the following four research objectives have been defined.

1. To characterise the different types of vertiports and eVTOLs, regarding their size and technical and physical characteristics, respectively.
2. To identify the most relevant aspects of the current processes of a turnaround of fix and rotor aircraft.
3. To identify the current perspective and situation of stakeholders about the turnaround process and possible challenges.
4. To describe the challenges to create the ConOps.

1.3 Research Project Structure

This research project is split across five sections. Section 2 sets the background to the research, detailing eVTOL and vertiport concepts as well as describing the turnaround process and explaining what a ConOps is. Section 3 critically assesses the literature and current UAM ConOps surrounding the topics linked to the research objectives, followed by the methodology in Section 4, which sets a framework for the research. Section 5 shows the results of the thematic analysis and discusses the findings of the interviews. The final chapter (Section 6) offers a summary of the findings, implications, limitations and ideas for further research.

2 Background

UAM represents a transformative shift in the transportation landscape, proposing the use of eVTOL aircraft to enable safe, efficient and sustainable air transport within and around urban environments. Led by advances in electric propulsion, automation and digital connectivity, UAM aims to alleviate congestion in dense metropolitan areas and redefine the concept of short-haul travel. To fully grasp the potential and complexity of UAM systems, it is essential to understand its core components: eVTOL vehicles, vertiports, the turnaround process, and the foundational planning tool known as a ConOps. Hence, this section aims to set the basis for the reader to understand what will come next.

2.1 eVTOL Concept

eVTOL aircraft are the cornerstone of the UAM ecosystem. These aircraft are designed to operate using electric propulsion and have the unique capability to take off and land vertically, much like a helicopter. However, they are built to be safer, quieter, more efficient and more sustainable than traditional rotorcraft.

eVTOLs vary widely in design, reflecting different operational priorities such as range, payload, speed and noise profile, but all of them with the ability to carry between two and five passengers. The eVTOLs can be classified regarding many different aspects, but they tend to be classified according to their propeller system like The Vertical Flight Society (2025) does. There are currently over a thousand eVTOL prototype models, which are divided into three main categories: vectored thrust, lift+cruise and multicopter. See Table 2-1 of some examples and Figure 2-1.

The main difference among these three types of eVTOL is that vectored thrust eVTOLs use all their thrusters for both lift and cruise, whereas lift+cruise eVTOLs use different thrusters for lift and cruise, and multicopters only use thrust for lift. The vectored thrust and lift+cruise eVTOLs are fixed-wing aircraft, whereas multicopters are rotatory-wing aircraft. The advantages of multicopters include good hover and VTOL characteristics as well as being the best performers for noise-constrained environments. Conversely, they are limited in cruise speed,

are less efficient and hence, have less range. The lift+cruise aircraft have less system complexity, whereas vectored thrust eVTOLs reduce efficiency losses and allow very efficient cruise flight configurations, but the system is more complex (Bacchini & Cestino, 2019; Brühl et al., 2021; Preis et al., 2025; Shamiyeh et al., 2017; Straubinger et al., 2020).

Table 2-1. eVTOL models. Source: Adapted from Preis et al. (2025) and The Vertical Flight Society (2025)

Company	Model	Configuration	Number of seats
Volocopter	Volocity	Multicopter	2
Joby Aviation	Joby S4	Vectored thrust	5
Volocopter	Voloregion	Lift+cruise	4
Wisk	Wisk Generation 6	Vectored thrust	4
eHang	eHang 216	Multicopter	2
Lilium	Lilium Jet	Vectored thrust	7
Archer	Archer Maker	Vectored thrust	2
Vertical Aerospace	VX4	Vectored thrust	5
Eve Air Mobility	Eve	Lift+cruise	4



Figure 2-1. Examples of different eVTOL configurations: VoloCity (left) Source: (Volocopter, 2025), Joby S4 (centre) Source: (Joby Aviation, 2025) and Eve (right). Source: (EVE, 2025)

In terms of ground operations, some other aspects are also reliable in terms of design differences between eVTOLs. Some eVTOLs have wheels, other have skids and other neither. This characteristic will influence on how they taxi through the vertiport. Another factor important for the turnaround process is how big is the aircraft and whether or not it can carry luggage apart from passengers.

2.1.1 Differences with Helicopters

Although both helicopters and eVTOLs are capable of vertical take-off and landing, the similarities largely end there. This subsection outlines the main differences between eVTOLs and helicopters, researched from different ConOps and articles: (Airservices Australia & Embraer Business Innovation Center, 2020; EVE, 2022; Northeast UAS Airspace Integration Research Alliance, Inc., 2021; O'Reilly et al., 2024; Schweiger & Preis, 2022; UK Air Mobility Consortium, 2022).

eVTOLs introduce a fundamentally different technological and operational approach, shaped by their electric propulsion systems and innovative airframe designs. While helicopters rely entirely on rotor-based lift throughout all flight phases, many eVTOL aircraft transition to wing-based lift during cruise, as outlined before. This hybrid flight model allows for more efficient forward flight and longer range for a given energy expenditure. However, the transition phase (from vertical lift to wing-supported cruise flight) can reduce manoeuvrability and responsiveness compared to helicopters, particularly at low speeds or during complex manoeuvres.

The noise footprint of eVTOLs is another major differentiator. Though noise levels will vary by design, eVTOLs are engineered to be significantly quieter than helicopters, making them more suitable for operations in noise-sensitive urban environments. This acoustic advantage is essential for public acceptance and regulatory approval in densely populated areas. In terms of environmental impact, eVTOLs offer zero operational emissions when powered by electricity or hydrogen, whereas helicopters continue to rely on fossil fuels. That said, the reliance on batteries introduces some operational constraints, such as eVTOLs having limited endurance and generally being unable to hover for prolonged

periods, a function that helicopters perform better. However, assisted taxiing methods are being developed for eVTOLs, like using conveyors or autonomous towing platforms.

Recharge time and energy management are key logistical concerns for eVTOL operations. Between flights, most eVTOLs will require charging or battery swapping infrastructure, adding complexity to turnaround operations and requiring careful integration with vertiport design. In contrast, helicopters can refuel quickly and continue operations with minimal downtime. However, the trade-off for this added complexity in eVTOL operations is significant cost efficiency. Electric propulsion systems reduce both maintenance and energy costs, and over time, these savings are expected to make eVTOL travel considerably more affordable than conventional helicopter services. As autonomy becomes more prevalent, further cost reductions may be passed on to passengers, making aerial transport accessible to a broader segment of the population.

Moreover, market demand for UAM services is projected to exceed that of traditional helicopter operations. This is not only due to improved affordability, but also because eVTOLs are specifically designed for short-distance urban missions, which align more closely with daily transportation needs. Their scalability, low noise, and environmental sustainability make them better suited for high-density operations in cities, unlike helicopters, which have remained niche due to high costs, noise and limited landing infrastructure. Overall, while helicopters offer unmatched flexibility in certain domains, eVTOLs are poised to redefine aerial mobility in urban environments through technological innovation, cost-effectiveness, and community compatibility.

2.1.2 Phases of Flight

The operation of UAM flights, particularly those involving eVTOL aircraft, can be broken down into six distinct phases: pre-flight, departure, en route, approach, landing, and post-flight as observed in Figure 2-2. These phases collectively represent the full operational cycle of a UAM mission and are supported by both automated systems and human actors to ensure safe, efficient and scalable

urban air transport (Airservices Australia & Embraer Business Innovation Center, 2020; Brühl et al., 2021; EVE, 2022; UK Air Mobility Consortium, 2022).

- Pre-Flight: activities in the pre-flight phase involve all preparations required before take-off. This includes vehicle readiness checks, battery charging, flight planning and passenger boarding. Advanced automation and real-time data exchange play a key role during this phase, enabling booking systems to communicate with fleet operators and the UAM Service Provider (UASP).
- Departure: the period in which the eVTOL departs from the Final Approach and TakeOff Area (FATO) or stand until it reaches cruise altitude, including taxi, take-off and climb.
- En Route: in this middle stage, operations commence once the eVTOL reaches its designated cruise altitude and until it begins the approach to the destination vertiport.
- Approach: the approach is initiated as the eVTOL aligns with the approach path to the destination vertiport. During this phase, the aircraft descends and the pilot assesses whether to continue to land or execute a missed approach in an off-nominal procedure.
- Landing: it covers the final phase of flight, from the decision point to touch-down at the designated FATO. If the vertiport layout includes a separate stand, the eVTOL may taxi from the FATO to this position.
- Post-Flight: this phase marks the conclusion of the flight operation when the eVTOL stops moving. Passengers disembark and ground staff inspect the eVTOL and perform necessary servicing tasks, such as battery recharging. If required, the aircraft may be moved to a storage facility, undergo overnight charging, or receive maintenance.

Turnaround operations, defined as the time between one flight ending and the next one beginning, are considered to span both the post-flight and pre-flight phases.



Figure 2-2. Phases of UAM flight. Source: (Airservices Australia & Embraer Business Innovation Center, 2020)

2.2 Vertiport Concept

Vertiports are the physical foundation of the UAM system, serving as the critical interface between eVTOL aircraft and the urban environment, hence, the interface between ground and airspace. All the information provided in this subsection has been extracted from different articles and UAM ConOps: (Boeing & Wisk, 2022; EVE, 2022; Lineberger et al., 2019; Northeast UAS Airspace Integration Research Alliance, Inc., 2021; Schweiger & Preis, 2022).

Unlike conventional heliports or airport terminals, vertiports are purpose-built to support the unique operational, technical and logistical needs of eVTOL. These facilities enable safe and efficient passenger and cargo handling, high-power charging or battery swapping, pre-flight inspections, and traffic coordination. Their integration into urban transport networks is key, often involving connections to existing ground transit modes such as rail, metro and road networks. Vertiports must also accommodate features such as passenger lounges, security screening, fire suppression, automated access control and real-time operational monitoring. An example of a vertiport model can be seen in Figure 2-3.



Figure 2-3. Vertiport infrastructure. Source: (Airservices Australia & Embraer Business Innovation Center, 2020)

Within the broader category of vertiports, three main types of infrastructure are emerging, each tailored to a specific role within the UAM network: vertihubs, vertiports and vertistations (Figure 2-4).

- Vertihubs: they are the largest and most complex facilities, functioning much like small regional airports for eVTOLs. Typically located on the periphery of urban or suburban areas, vertihubs serve as centralised nodes for eVTOL fleet operations across a city or region. They are designed to support not only boarding and de-boarding of passengers, handling cargo and recharge eVTOLs, but also more intensive services such as Maintenance, Repair and Overhaul (MRO), longer-term parking for long-range vehicles and centralised operational control centres. In addition to hangar space and technical infrastructure, vertihubs may include administrative offices, pilot training facilities, and accommodations for support staff, making them essential for resilience and continuity in UAM operations.

- Vertiports: they are the medium-scale facilities typically located within urban centres near key destinations such as business districts, shopping hubs and major transportation interchanges. Their core function is to serve as high-throughput access points for passenger and cargo transfers. Although smaller than vertihubs, they must support multiple simultaneous take-offs and landings, feature rapid charging or battery swapping systems and provide basic MRO capabilities. Because of their central location and expected passenger volume, vertiports are likely to include customer waiting areas, ground staff and advanced safety and security systems. However, they will not generally support long-term parking or full-scale maintenance operations.
- Vertistations: they are minimal landing and take-off points often comprising only one pad. These facilities are ideal for extending network coverage into suburban or low-density areas and in some cases may repurpose existing helipads. Due to their compact footprint, vertistations typically lack high-voltage charging or MRO capabilities, but they may still offer basic services such as weather monitoring, simple passenger shelters or waiting areas, help desks and basic security. Installation and operational costs are lower, making vertistations a flexible solution for last-mile connectivity and cargo drop-off or pick-up in peripheral zones. One example could be the recent built vertiport in Bicester, shown in Figure 2-5.



Figure 2-4. Types of vertiport. Source: (Lineberger et al., 2019)



Figure 2-5. Bicester vertiport. Source: (Skyports News Team, 2024)

Apart from these three categories, each vertiport can be designed differently, locating the terminal and the different pads and stands in different positions. As it will be explained in detail in Section 3.2, the most common topologies for vertiports are linear, satellite and pier, following the same concept as airport terminals.

2.2.1 Differences with Heliports

While both heliports and vertiports support vertical take-off and landing operations, they differ significantly in design, infrastructure and operational purpose. The main difference is the frequency of operations (Reczek, 2020).

Heliports are built for conventional helicopters and typically include a helipad, minimal passenger facilities and limited support systems. They are designed for low-frequency, high-noise operations and are not optimised for high-throughput or sustainable transport (Northeast UAS Airspace Integration Research Alliance, Inc., 2021).

Vertiports, in contrast, are specifically developed to support eVTOLs. They require advanced infrastructure such as high-capacity electric charging or battery-swapping systems, automated traffic management integration and seamless connectivity with ground transportation. Vertiports are intended to

support higher flight frequencies, shorter turnaround times, quieter, zero-emission aircraft and some include passenger amenities.

2.2.2 Passenger Journey

The passenger journey can be separated into five main stages: request service, go to the boarding zone, check-in, boarding the eVTOL and arrive at the final destination, as illustrated in Figure 2-6 (EVE, 2022; Wisk & Skyports, 2022).

The passenger aiming to travel by eVTOL will make a booking through a digital platform. Once confirmed, the passenger will go to the vertiport and be guided by signage and wayfinding systems, the passengers arrive at the boarding area where they undergo a streamlined check-in process, including security screening, luggage weighing if necessary and a safety briefing. Thereafter, the passengers are escorted to the eVTOL aircraft, handing over the luggage for storage, taking the seats and fastening the seatbelt for departure. Once landed at the destination vertiport, the passengers disembark with their belongings and follow signs or staff instructions to exit the facility.



Figure 2-6. Passenger journey with an eVTOL. Source: (EVE, 2022)

2.3 Turnaround

Turnaround refers to the set of procedures carried out between an aircraft's arrival and its next departure. Efficient turnarounds are critical for maintaining high throughput and maximising fleet utilisation to reduce airlines' costs, but it is also critical for airports, allowing them to increase their capacity (Antonio et al., 2017). The different processes are illustrated in Figure 2-7 and further explained below with information extracted from: (Airbus, 2024; Antonio et al., 2017; IATA, 2013; Schmidt, 2017).

The turnaround of a commercial aircraft relies on a coordinated set of processes supported by Ground Support Equipment (GSE). Turnaround duration depends on factors such as aircraft type, passenger and cargo volume and the operator's business model. For example, low-cost carriers aim to do a turnaround of an A320 or B737 in 30-45 minutes. While some tasks follow a strict sequence, many can be performed in parallel by different service providers. The process begins with chocks being placed at the wheels, followed by the connection of ground power, allowing the engines and Auxiliary Power Unit (APU) to be shut down. If required, pre-conditioned air is supplied. At terminal gates, a passenger boarding bridge connects to the front left door, while on remote aprons, stairs are used at both the front and rear doors for deboarding. As passengers exit, baggage and cargo are unloaded, potable water is replenished and catering services exchange trolleys. Waste water servicing follows strict hygiene protocols and may vary based on aircraft tank configuration. Refuelling occurs after all passengers have disembarked, in line with safety regulations. Simultaneously, the flight crew conducts external checks, prepares flight systems, and assesses airworthiness, while the cabin crew inspects emergency equipment and prepares the interior. After unloading, new cargo and baggage are loaded. Once fuelling is complete, passengers board, a final headcount is taken and the aircraft prepares for departure. Power shifts back to the APU, chocks are removed, and if parked nose-in, a pushback is performed.

On the other hand, helicopter turnarounds are generally shorter, between 5 to 15 minutes, and also less structured than those for fixed-wing aircraft. Key processes include passenger exchange, refuelling if necessary and visual inspection and systems check.

Therefore, the eVTOL's turnaround would be a mix of both airplanes and helicopters. The main processes expected in the turnaround are boarding and deboarding of passengers, battery management, cabin cleaning and visual inspections (Wisk & Skyports, 2022).

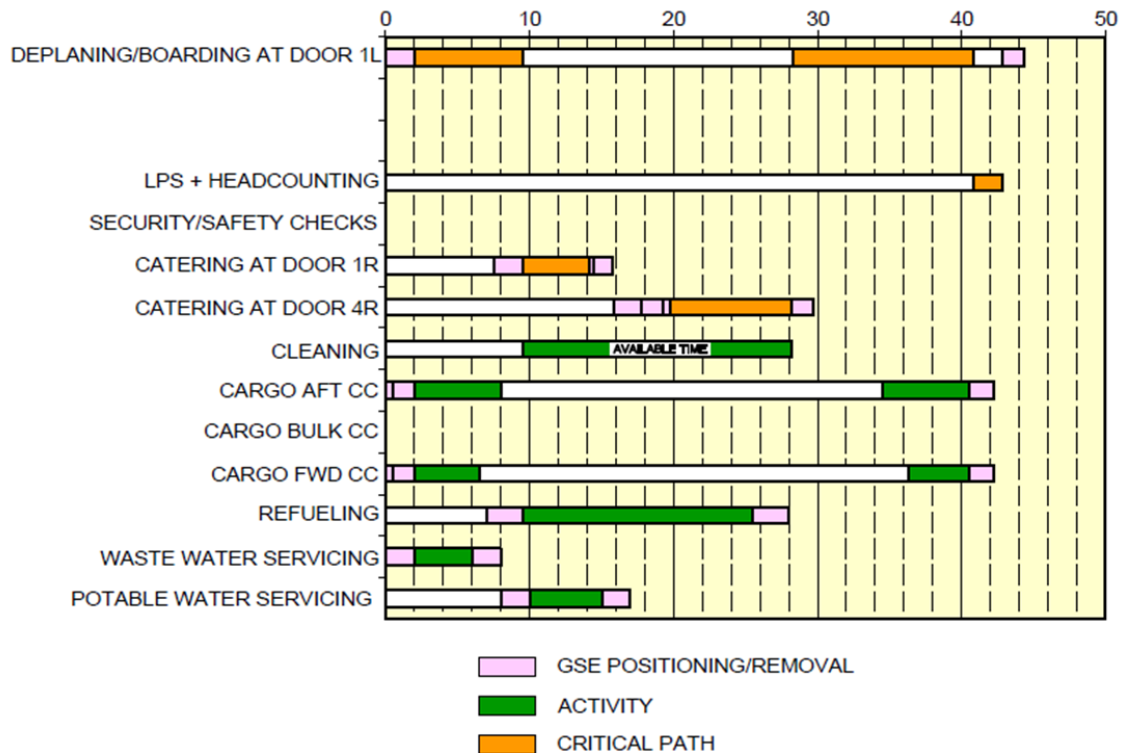


Figure 2-7. Turnaround time chart diagram. Source: (Airbus, 2024)

2.4 ConOps

A ConOps is a foundational document that describes how a system will operate in its intended environment. In aviation, it defines how various elements, such as personnel, aircraft, equipment, facilities and supporting services, will interact to achieve safe, efficient and coordinated operations. More than a general overview, a well-developed ConOps provides a detailed understanding of these interactions at a granular level, serving as a bridge between strategic planning and technical implementation. By clearly defining roles, interfaces and expected performance under nominal and off-nominal conditions, a ConOps helps align stakeholders, supports regulatory compliance and informs the development of procedures, infrastructure and technology (The Vertical Flight Society, 2023).

A ConOps in the UAM industry should include an operational overview, describe the mission and objectives, provide a conceptual architecture and system description, detail the capabilities, limitations, assumptions and constraints, and explain the normal and off-nominal procedures as well as describe the roles of all the stakeholders and users involved.

2.5 Summary

After a comprehensive review of the key components of the UAM ecosystem, readers should now have a clear understanding of the subject before delving into the following sections. Consequently, both objectives 1 and 2 have been addressed in this section, as the various types of vertiports and eVTOLs have been characterised and the turnaround processes for aircraft and helicopters have been explained. In addition, the next section will provide further insights related to both objectives, relying on existing literature and various UAM ConOps. Moreover, this literature review of current developments in this emerging industry will help identify a research gap, thereby providing a rationale for the work undertaken in this thesis.

3 Literature Review

The following review of the literature aligns with the research objectives 1 and 2 by examining and evaluating the most relevant studies on the UAM industry. They have been grouped by main themes, such as airspace, design and turnaround. Additionally, some information is provided regarding stakeholders and the potential impacts on the community, to finish with the current challenges of the UAM industry and outline the gap in the literature identified.

3.1 Airspace

Effective integration of eVTOLs into urban airspace depends on the development of Air Traffic Management (ATM) and Urban Air Traffic Management (UATM) systems. These systems must handle high-density, low-altitude traffic flows in complex urban environments. Several key documents contribute to the understanding of this emerging domain.

Some recent concepts of operations consider the operations of eVTOLs, but they tend to focus mainly on airspace operations. Deloitte Consulting LLP (2020) identifies the challenges of UAM integration into airspace after twelve interviews and a two-day workshop with more than a hundred industry experts, outlining the challenges in efficient, resilient, safe and scalable airspace operations. The Federal Aviation Administration (FAA) via the Federal Aviation Administration (2023) also provides a very good understanding of the UAM architecture, focusing only on the airspace and mentioning only a vertiport when it explains which data the vertiport operator has to provide to other stakeholders in order to land safely. It explains the airspace structure, the existence of corridors, the roles of each service provider, including the ones of the FAA, and different UAM scenarios step by step. In the next Figure 3-1, the UAM corridor within the airspace can be observed.

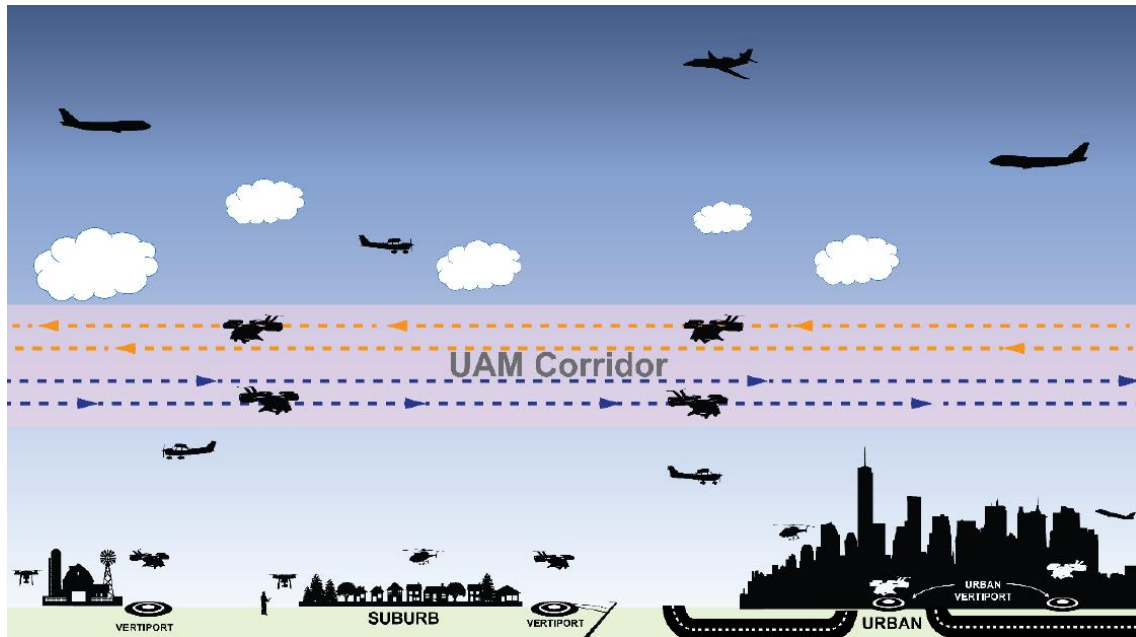


Figure 3-1. UAM corridor. Source: (Federal Aviation Administration, 2023)

Furthermore, Boeing and Wisk (2022) specifically describe the operations of uncrewed eVTOLs, and, following the same structure as the other ConOps, it describes the operations from flight scheduling, departure, in-flight, landing and post-flight in terms of communications and Air Traffic Control (ATC) duties, but for the particular case of eVTOLs without pilots. It also details flight rules and hazards coming from this type of operation.

The report of Lascara et al. (2019) outlines the critical role of modular airspace segmentation and trajectory-based operations. It advocates for the use of digital communication and automation to reduce the workload of pilots and controllers. Vascik and Hansman (2018) complement this view by identifying ATC limitations in dense urban areas and emphasising the need for automation in decision-making processes.

The Airservices Australia and Embraer Business Innovation Center (2020) expand on these ideas by introducing a decentralised UATM architecture. This model incorporates features such as strategic deconfliction, dynamic re-routing and integration with vertiport scheduling. It simulates at the same time the vertiport operations and the operations at Melbourne Airport, identifying different challenges, such as traffic mix, airspace saturation and situational awareness, to

later on do fast time simulations to improve them. Airservices Australia and Embraer Business Innovation Center (2020) is not the only ConOps providing information about airspace integration within an airport, Schweiger et al. (2024) and UK Air Mobility Consortium (2022) also include it. UK Air Mobility Consortium (2022) provides a ConOps for the London environment, outlining the regulatory challenges regarding airspace integration, including scaled UAM operations or low-level flying in congested urban airspace, and a case study of implementing a vertiport at London City Airport (LCY), describing its implications for the ATC at LCY. Schweiger et al. (2024) study the airspace network of a vertidrome network composed by 20 vertiports in the city of Hamburg with two different technics: slot-based approach and trajectory-based approach. Then, they include an airport shuttle route and prove that the integration of UAM traffic within the Hamburg Airport ATC work processes was feasible, although it implies an increase in workload by 44%.

The article of Agostinho and Bento (2022) studies the airspace operational limitations in Brazil, relying on the ConOps of Airservices Australia and Embraer Business Innovation Center (2020). It considers limitations such as operating near other aircraft, minimum safety altitudes, weather reports and the minimum required and recommended navigation, communication and surveillance equipment. This study concludes that the current operational environment in Brazil, regarding ATM rules and operational regulations, is capable of adapting eVTOL in UAM environment for low density operations.

The integration of eVTOLs into urban airspace hinges on advanced ATM systems to manage dense, low-altitude traffic in cities. Key studies highlight challenges such as scalability, safety and automation. Several concepts focus on airspace operations, including corridor structures and the roles of service providers. Specific work on uncrewed eVTOLs, decentralised architectures and simulations of vertiport operations reveals issues like traffic mix, controller workload and situational awareness. Overall, automation, modular airspace and stakeholder coordination are essential.

3.2 Vertiport Location, Design and Capacity

The physical layout and operational design of vertiports are critical to supporting rapid and safe turnarounds. There are already manuals such as Civil Aviation Safety Authority (2024) and Japan Civil Aviation Bureau (2023) that serve as a guide to vertiport standardised design. In addition, the literature covers several infrastructure models, ranging from repurposed heliports to purpose-built high-capacity hubs.

Brunelli et al. (2023) conclude that location and design is highly related to capacity, since the number of pads, FATOs and taxiway distribution will depend on the design, which at the same time depends on the size of the vertiport, mainly dependent on the location selected.

Before designing the vertiport, it needs to be located somewhere. Studies have already been done in order to outline the challenges and the methods to locate vertiports (Brunelli et al., 2023; Rohrmeier et al., 2025).

Additionally, Brunelli et al. (2023) summarise and collect several studies regarding locating vertiports, outlining requirements and challenges such as obstacle clearance, environmental constraints like wind restrictions, possible noise impacts in the urban context and the downwash effect affecting the neighbouring areas. Also, it states that the location of a vertiport is crucial for the interconnection with ground transportation, as Preis (2021) concludes after doing interviews and considering 69 factors affecting the choice of placing a vertiport. There are also analytical tools, like Geographic Information Systems (GIS), to analyse data to locate the vertiport. Data analysed includes socioeconomic variables, points of interest, ground transportation nodes, potential rooftops and noise constraints. As an example, Rohrmeier et al. (2025) study the site selection using GIS at San Francisco Bay Area.

A central concern in vertiport design is how to optimise spatial layout for safe, high-throughput airside movements while accommodating the operational constraints of eVTOLs. As Vascik and Hansman (2018) highlight, vertiport layout is a major constraint. Multiple studies emphasise that the configuration of landing

pads, stands and taxiways directly affects efficiency and conflict risk (Ahn & Hwang, 2022; Schweiger et al., 2024). For that reason, in recent years, so many researchers have focused their research on the capacity of airside vertiport operations concerning their design. Figure 3-2 illustrates a possible vertiport layout.

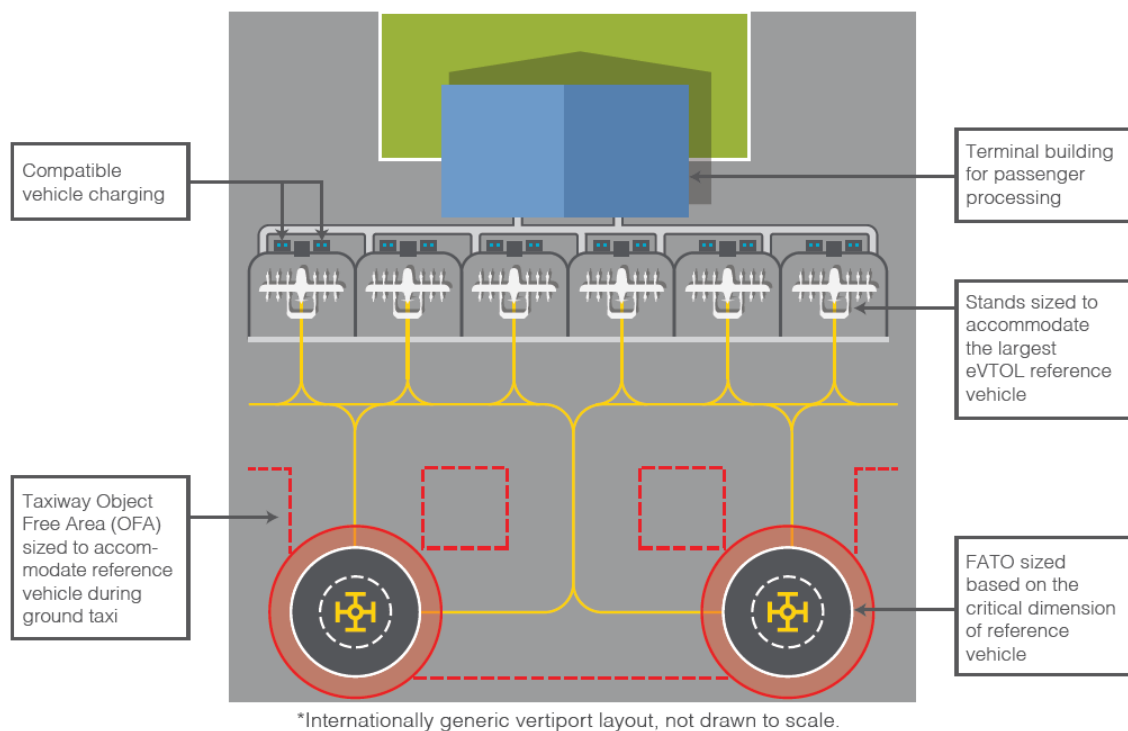


Figure 3-2. Example of a vertiport layout supporting around 20-30 movements per hour. Source: (Wisk & Skyports, 2022)

Zelinski (2020) presents some vertiport topologies with four Touchdown and Lift-Off Area (TLOF) and evaluates their relative surface area utilisation based on how TLOF and parking stands are connected via taxiways. It also considers different wind conditions.

Multiple studies emphasise the role of agent-based simulations to model operational dynamics. For instance, Preis and Hornung (2022a, 2022b, 2022c), leverage agent-based models to simulate vehicle behaviours and bottlenecks, revealing key operational dependencies. While Preis and Hornung (2022c) find that the main cause of delay is peaks in demand which exceed the temporal capacity, Preis and Hornung (2022b) conclude that delays increase exponentially

when pads and gates surpass a threshold capacity. Preis and Hornung (2022a) find similar results, identifying as vertiports' layout design drivers the pad and gate operations, peaks in demand and the imbalance between arrivals and departures. These layout drivers showed high operational sensitivity expressed in exponential increase of delay.

Other studies utilise vertiport capacity envelopes. Vascik and Hansman (2018) find that the two key features of the ground infrastructure are the ability to locate the TLOF in a desirable area and the throughput capacity of the TLOF. On the other hand, Vascik and Hansman (2019) discover through a sensitivity study over four vertiport topologies (satellite, pier, linear and remote apron) that a key factor for vertiport design is the ratio of gates to TLOF pads and that the capacity of a vertiport with multiple TLOF is higher if those pads can operate independently. In line with this approach, Ahn and Hwang (2022) compare the satellite, pier and linear vertiport layouts qualitatively and quantitatively by computing the TLOF and gate utilisation rates, applying it to a future vertiport that will be located at Gimpo Airport's parking lot.

A lot of research has been done on capacity because as Schweiger et al. (2021) state, the service quality and passenger experience also needs to be addressed. This article outlines two key performance indicators for the level of service at vertiports, which are delay and punctuality. In addition, in this article, they calculate arrival and departure flow based on continuous demand distribution in order to estimate how many gates are necessary to achieve certain level of service, maximum flow rates and operational deviations.

To conclude, vertiport design and location are vital for safe and efficient eVTOL operations. Key challenges include balancing spatial layout, capacity and environmental constraints like noise and wind. Location affects intermodal connectivity and is evaluated using tools like GIS. Studies show layout elements (pads, taxiways and gates) directly impact throughput and delays, especially during demand peaks. Agent-based simulations reveal bottlenecks and the sensitivity of delay to layout configurations. Various topologies (satellite, pier, linear and remote) offer differing capacities, depending on gate-to-pad ratios and

independent pad operations. Ultimately, vertiport performance is measured through delay and punctuality, driving research into optimal infrastructure for high service quality.

3.2.1 Taxiing

Taxiing operations, defined as the ground movement of aircraft between pads, gates and service areas, and the last procedure before beginning the turnaround as well as being the first one after finishing the turnaround, pose a unique challenge in vertiport environments due to limited space, safety requirements, and the vertical takeoff and landing capabilities of air taxis. Several studies emphasise the critical need for efficient and conflict-free taxiing protocols to ensure safety and operational fluidity.

The study developed by Zelinski (2020) and already mentioned earlier, also focuses on taxiing. It identifies how surface geometry, vehicle paths and pad layout directly impact taxiing efficiency and potential bottlenecks. This aligns with findings from Vascik and Hansman (2019), which demonstrates that taxiway design significantly affects throughput and aircraft separation requirements, differentiating whether the eVTOL is tugged, self-propelled with wheels or it hovers. These three types of taxiing are also distinguished by Preis and Hornung (2022b), which after 17 interviews conclude that taxiing is a key procedure in the vertiport operations. Simulation-based insights from Preis and Hornung (2022b) further reveal how conflicts and delays in taxiing paths can have a cascading impact on scheduling and turnaround. Conversely, Schweiger et al. (2022) only describe the airside operations assuming that the taxiing is done with external devices, to ensure safety and safe energy.

From a design standpoint, the ConOps of Northeast UAS Airspace Integration Research Alliance, Inc. (2021) introduces structured, automated taxiing pathways that aim to maximise vertiport capacity while minimising conflicts, especially in tightly packed urban areas. In addition, taxiing procedures are explained in detail. Boeing and Wisk (2022) and Wisk and Skyports (2022) are two ConOps that explain specifically the taxiing procedures for tugged eVTOLs to minimise energy usage.

Together, these works illustrate that taxiing is not a negligible phase in UAM operations, but a vital link in ensuring safe, efficient and high-throughput vertiport systems, requiring careful coordination of spatial layout, vehicle behaviour, and automation.

3.3 Turnaround

Turnaround operations which comprise the time between an aircraft's arrival to the gate and its next departure from the gate (as further explained before), emerge as a key constraint in vertiport performance and UAM scalability. Several studies emphasise the importance of optimising turnaround time to ensure high-frequency, high-reliability services in urban contexts.

The turnaround is very well known in the aviation industry, which has been critically studied for aircraft, since it is crucial, for both airports and airlines, to minimise the turnaround time by optimising each task.

Simulation-based approaches like the ones done by Antonio et al. (2017) and Schmidt (2017) show that stochastic factors such as weather, staffing, or passenger flow can create delays. Antonio et al. (2017) study the critical path of an aircraft's turnaround, concluding that the most critical path is the disembarking-cleaning-boarding, and the less critical one is associated with the tasks of catering, refuelling and maintenance. They reach that conclusion by analysing the processes and timings of a B737-800 and introducing different random times and changes in the turnaround design. Meanwhile, (Schmidt (2017) collects and summarises information from different studies regarding operations and simulations of the aircraft's turnaround. A major finding also aligned with Antonio et al. (2017) is that the sequential order of passenger, cabin processes and refuelling often constitutes the critical path, and that the passenger behaviour is critical but uncontrollable. The boarding can be improved by different strategies, like separating passenger groups or designing novel cabin layouts that facilitate the boarding process. Schmidt (2017) also mentions ground operational challenges, including the increased boarding and de-boarding time, schedule disruptions and the reduced aircraft utilisation when not being able to optimise the turnaround time. Similarly, the European Commission (2024) explores how

turnaround times must be co-optimised with airspace availability and network capacity, outlining that the main reasons for delays in the turnaround process are lack of information sharing, deviation from original planning and increased demand in security processes.

Additionally, the ConOps of hydrogen and electric aircraft of the Airport Compatibility of Alternative Aviation Fuels Task Force (2025) describes the turnaround of an electric aircraft, mentioning that the only process that would be different from a fuel aircraft is the charging process instead of refuelling.

Regarding turnaround processes at vertiports, it is not as well studied as aircraft turnaround at airports. Only some ConOps and a few articles have been found describing the turnaround process as a hall or studying the critical path of it.

Schweiger et al. (2022) discover a gap in the literature regarding vertiport ground operations and focus their research on the airside operations of a vertiport, aiming to develop a concept of operations. Timings of processes and taxiing are detailed, but it just outlines that the turnaround time is 600 seconds, without explaining each specific subtask of the turnaround. The article of Vascik and Hansman (2019) already mentioned in the prior subsection, consider a turnaround time between 30 and 600 seconds to simulate the airside operations, also without specifying why this exact time. Additionally, it states that the turnaround time has huge implications on the ratio of gates to pads, which is one of the main design drivers, as outlined in the prior subsection. Schweiger and Preis (2022) elaborate a systematic review of different articles regarding different topics of vertiports. They include a review of different articles studying vertiport turnaround times, concluding that the turnaround time assumed by different researchers varies, but can be distinguished between short and long turnaround. Short turnaround would be done in vertistops and include passenger boarding and de-boarding, and partial charging/refuelling can occur. Researchers assume a turnaround time between 0.5 and 10 minutes. On the other hand, 30 minutes of turnaround time is assumed for long turnarounds at vertiports or even at vertihubs, where fully charging and minor maintenance activities might be conducted.

The study of Brühl and Fricke (2022) focuses on the charging process of the turnaround. They use critical path methods to decompose and analyse turnaround tasks such as passenger handling, battery swapping, and maintenance, assuming that battery charging or replacement often dominates ground time. Therefore, they analyse three different charging methods, including plug-in charging, underbody charging and swapping the battery, and finding that the total turnaround time when charging with underbody technology is only 13 minutes, whereas when plugging-in takes 51 minutes. When swapping the battery, the total ground time is about 21 minutes.

Then, some UAM ConOps mention the turnaround of eVTOLs at vertiports like the ones of Boeing and Wisk (2022), Deloitte Consulting LLP (2020), EVE (2022) and Wisk and Skyports (2022) being the main processes parking, charging, cabin cleaning, maintenance and passenger boarding and de-boarding. Furthermore, EVE (2022) describes some necessary tasks that will be performed, such as cleaning, charging and line maintenance, outlining the challenge of how to deal with luggage and the need of implementing standards of procedures. And Deloitte Consulting LLP (2020) explains the difficulties of the procedures of handling aircraft between flights to ensure safety.

Together, these ConOps state the basis of the turnaround and the studies underscore that efficient turnaround management is central to vertiport capacity, user satisfaction, and the economic viability of UAM systems, but they do not specifically describe the exact subtasks and the implications to all the stakeholders of the turnaround process.

3.4 Stakeholders

UAM systems represent a complex network of stakeholders, each playing a crucial role in the safe, scalable, and sustainable deployment of vertiport infrastructure and services. Across the reviewed literature, stakeholder coordination is repeatedly emphasised as a foundational requirement for operational success.

The Airservices Australia and Embraer Business Innovation Center (2020) and Deloitte Consulting LLP (2020) both stress the importance of multi-level stakeholder collaboration, identifying government regulators, UAM operators, Air Navigation Service Providers (ANSPs), and urban planners as core actors. These documents underscore the need for shared governance frameworks to enable airspace integration, regulatory alignment, and safety assurance.

Technical operations bring in additional stakeholders. For example, the Airport Compatibility of Alternative Aviation Fuels Task Force (2025) highlights energy providers and vertiport designers as essential for establishing safe, resilient charging/fueling ecosystems. Their role intersects directly with sustainability goals and aircraft turnaround performance.

The Northeast UAS Airspace Integration Research Alliance, Inc. (2021) introduces further layers, incorporating autonomous system developers, data infrastructure providers, and ground operations teams into the vertiport stakeholder map. Automation and real-time coordination demand seamless interaction between digital infrastructure and physical operations.

Schweiger et al. (2021) and Wisk and Skyports (2022) bring attention to passenger-facing stakeholders, including mobility service providers and emergency response agencies, who ensure accessibility, service quality, and public acceptance.

Finally, the landscape survey presented in Straubinger et al. (2020) recognises the role of academia and industry consortia in shaping standards, promoting innovation and addressing societal concerns like equity and noise.

These sources illustrate that UAM success depends not just on technology or infrastructure but on building collaborative ecosystems of stakeholders aligned through clearly defined operational roles, shared objectives and regulatory cohesion.

3.5 Community

The integration of vertiports into urban environments brings forward several community-related challenges, particularly concerning noise, equity and public acceptance. The literature reviewed highlights how these facilities, while technologically innovative, must be developed with sensitivity to the social and environmental footprint they impose.

The study of Dance and Gomez-Agustina (2021) provides direct evidence of the negative externalities heliports can generate in densely populated areas. The research shows that noise disturbances from rotary-wing aircraft, particularly during approach and takeoff, have measurable effects on residents' quality of life, including reported increases in stress, sleep disruption and general dissatisfaction. Community complaints were found to be highly correlated with flight frequency and time of day, underscoring the need for strict operational curfews and noise abatement procedures.

Expanding on this, Deloitte Consulting LLP (2020) addresses the need to build public trust through proactive engagement. It highlights that community concerns must be integrated into planning from the outset, especially in terms of site selection, air corridor routing and equity in service access. It also calls for the inclusion of public stakeholders in regulatory and decision-making processes, ensuring that UAM benefits do not worsen existing socio-economic divides.

Further, Straubinger et al. (2020) emphasise that long-term adoption depends not only on technical feasibility but also on community buy-in. The authors argue that environmental impact assessments, transparent communication and localised consultation are essential to avoid resistance similar to that seen with historic infrastructure projects like airports or highways.

In summary, while vertiports promise mobility enhancements, their success hinges on minimising social disruption. Prioritising community feedback, noise mitigation, and equitable access is fundamental to ensuring a socially sustainable UAM ecosystem.

3.6 Challenges

UAM faces five critical challenges for successful implementation, including airspace integration, certification, public acceptance, battery technology and infrastructure (Netherlands Aerospace Centre, 2019).

- Airspace integration: it is essential, as existing ATC systems can manage limited VTOL traffic, but large-scale operations demand new systems to handle increased density, autonomous flights, seamless ATM integration, voiceless communication and urban navigation accuracy.
- Certification and liability: they are complex due to evolving regulations, especially for autonomous vehicles. Without clear compliance and liability frameworks, the business model may falter. Industry consensus standards and data-driven proof of safety are proposed to accelerate certification.
- Public acceptance: concerns about noise, third-party risk, privacy and inequity must be addressed. Public support will depend on safety perception, privacy safeguards, equitable access and demonstrated societal benefits.
- Battery technology: it remains a technical hurdle, with current batteries offering low energy density, limited range, and slow charging. Research into fast-charging solutions and alternative systems like hydrogen fuel cells is ongoing, but immature.
- Infrastructure: it is a major operational barrier. Vertiports must be widely deployed and integrated with urban transport systems, yet funding, regulation and spatial planning remain unresolved.

These challenges align not only with the ones stated in (Deloitte Consulting LLP, 2020), as shown in Figure 3-3, but also with all the literature review, where each article or ConOps focuses on a main problem or challenge, as summarised in the next Table 3-1.

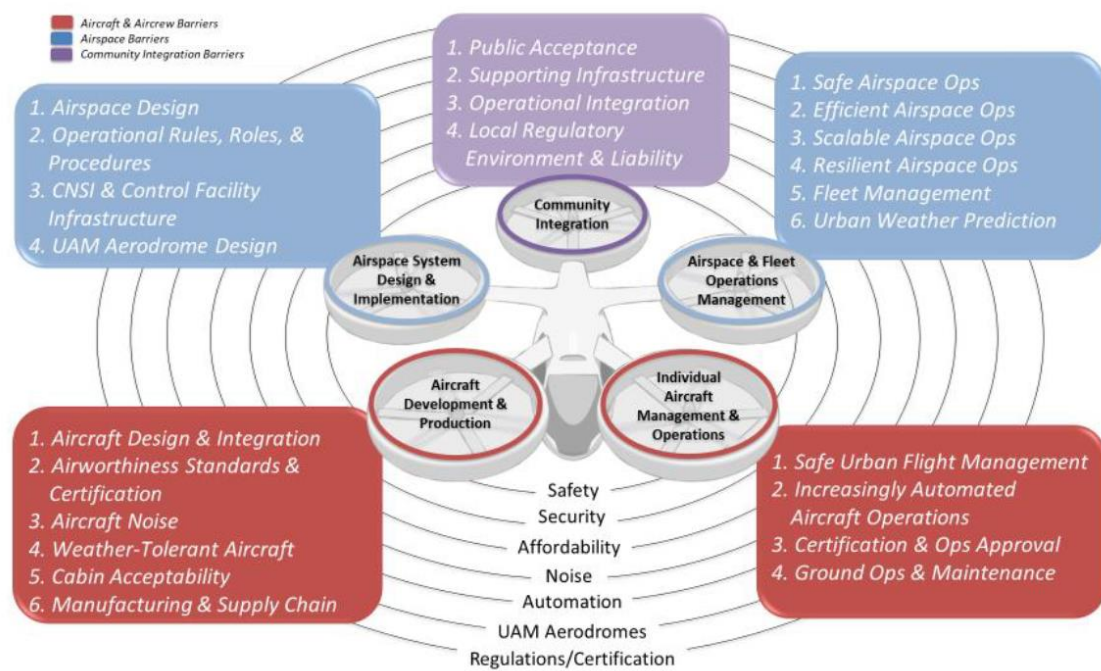


Figure 3-3. UAM organisational framework and barriers. Source: (Deloitte Consulting LLP, 2020)

Table 3-1. Main UAM challenges identified

Topic	Challenge	Reference
Airspace	Operate near other aircraft and congested airspace	(Agustinho & Bento, 2022; Airservices Australia & Embraer Business Innovation Center, 2020; UK Air Mobility Consortium, 2022)
	Navigation and communication equipment	(Agustinho & Bento, 2022)
	Weather reports	(Agustinho & Bento, 2022)
	Workload of controllers	(Airservices Australia & Embraer Business Innovation Center, 2020; Lascara et al., 2019; Schweiger et al., 2024)
	Automation	(Lascara et al., 2019; Vascik & Hansman, 2018)

	Noise, communities	(UK Air Mobility Consortium, 2022)
	Uncrewed eVTOL	(Boeing & Wisk, 2022)
Location	Environmental constraints	(Brunelli et al., 2023)
	Obstacle clearance	(Brunelli et al., 2023)
Design	Vertiport layout and capacity	(Vascik & Hansman, 2018)
	Taxiing efficiency	(Zelinski, 2020)
Turnaround	How to deal with luggage	(EVE, 2022)
	Implement standardised procedures	(EVE, 2022)
	Safety	(Deloitte Consulting LLP, 2020)
Stakeholders	Communication and collaboration	(Airservices Australia & Embraer Business Innovation Center, 2020; Deloitte Consulting LLP, 2020)

All of these challenges described demand coordinated efforts in regulation, technology, infrastructure and public engagement to make UAM viable and scalable.

3.7 Summary and Literature Gap

As evidenced, organisations, regulators, consultancies and academics have done a great deal of work on many aspects of the UAM industry. ConOps of the UAM environment as a whole and specifically regarding airspace integration and vertiport layout and capacity analysis, have been the most common topics of previous research, demonstrating that the UAM industry is something new and is becoming more popular among organisations and academics. Conversely, more investigation needs to be done regarding ground operations, safety standards, developing of regulations and identifying the roles of each stakeholder within the UAM ecosystem. Within this section objectives 1 and 2 have added further insights to the ones explained in the prior chapter.

Therefore, a gap in the literature review has been found regarding the specific procedures for the eVTOL's turnaround process. Therefore, this research aims to contribute to the UAM industry by filling the literature gap in the eVTOL's turnaround, key for the development of vertiports to make eVTOL operations a reality.

Later on, the next section will explain the methodology followed to achieve the third and forth objectives, which are identifying the current perspective of stakeholders about the turnaround process, using semi-structured interviews and describe the challenges to develop a turnaround ConOps.

4 Methodology

This section presents the research methodology followed to achieve mainly the third and fourth objectives and complementing objectives 1 and 2 and gather data which will be analysed and discussed in the next chapter. The methodology is based on the research onion, and semi-structured interviews are conducted as a methodological approach.

4.1 Theoretical Considerations

The first two layers of the research onion focus on the theoretical considerations of the research, as seen in Figure 4-1: philosophy and approach to theory development.

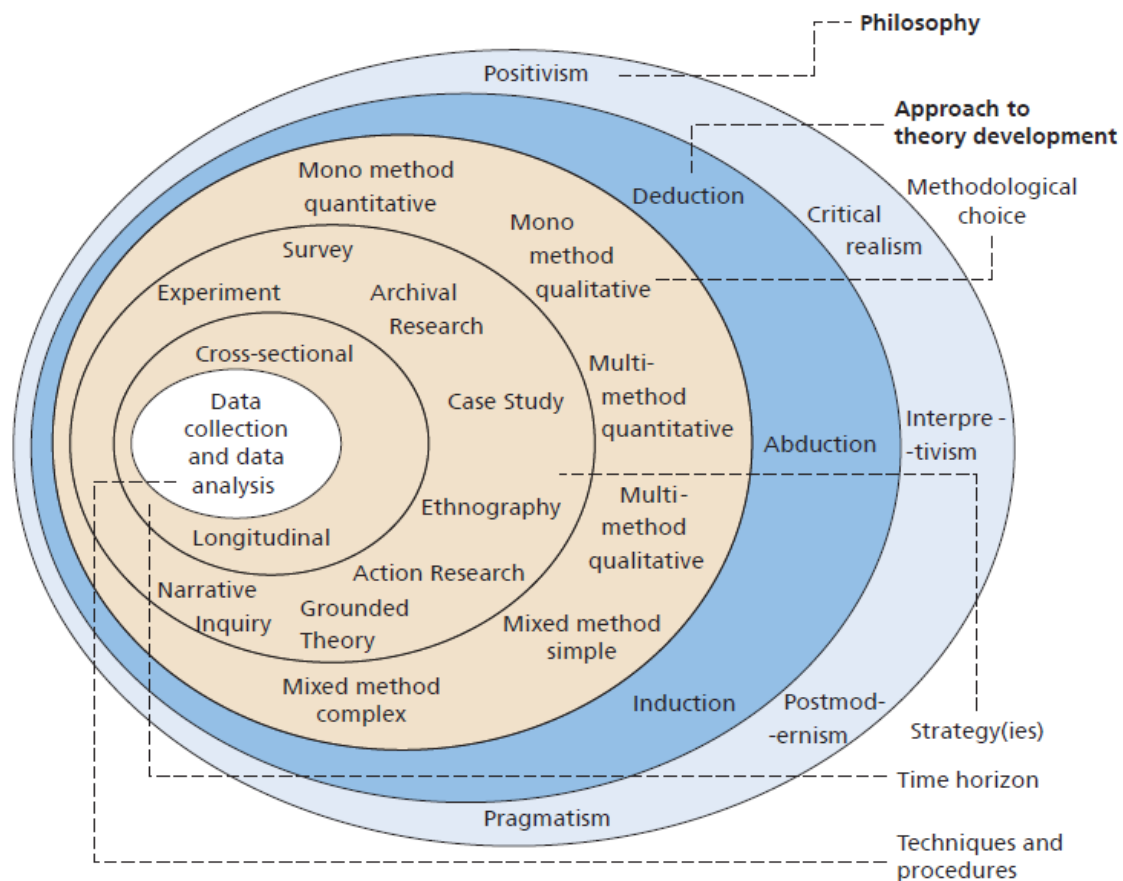


Figure 4-1. The research onion. Source: (Saunders et al., 2019)

In alignment with the aim of this study, the selected research philosophy is pragmatism. Pragmatism conceptualises knowledge as being grounded in

experience and typically employs empirical methods such as surveys, interviews, and case studies to generate understanding (Žukauskas et al., 2018). This approach shares certain commonalities with interpretivism, which also regards knowledge as being derived from human experiences and emphasises the subjective interpretation of meaning. Interpretivism is frequently associated with qualitative research and presents a valid alternative to pragmatism. The principal distinction between these two philosophies lies in their underlying purpose. According to Bryman and Bell (2015), interpretivism seeks to gain a deeper understanding of phenomena that are valued for their intrinsic interest, while pragmatism is oriented towards the production of actionable knowledge that is valued for its practical utility. Hence, pragmatism results as the best philosophy for this research.

The approach to theory development adopted in this research is inductive. Unlike the deductive approach, which begins with a predefined hypothesis derived from existing theoretical frameworks, the inductive approach does not rely on an initial hypothesis. Instead, it allows theory to emerge as a result of the research process. In this context, theoretical insights are developed from empirical observations and findings gathered during the study (Saunders et al., 2019).

4.2 Methodological Approach

Although alternative data collection methods, such as surveys and group workshops were initially considered as a qualitative approach, interviews were chosen for this research project. Interviews represent the most commonly employed method for collecting qualitative data (Jamshed, 2014; Kircher & Zipp, 2022). Hence, a mono-method qualitative research is done.

While expert group workshops could have offered valuable insights, they present certain limitations. As noted by Bryman (2016), some participants can dominate the conversation, whereas others can feel uncomfortable to give their opinions in front of others (Roulston, 2011). On the other hand, given the contemporary and relatively specialised focus of this research, surveys were dismissed, as more useful information and insights were likely to be obtained with individual interviews. Additionally, when trying to collect data from managers or employee

with high responsibility within the company, a higher response rate is expected when inviting them to an interview rather than sending a questionnaire (Saunders et al., 2019).

Additionally, the time horizon of the research is cross-sectional, because the interviews are a snapshot of the UAM industry at the particular moment of the research, having done all the interviews in just three weeks, which is a very short period for the UAM industry to evolve and hence the participants to change their opinion (Saunders et al., 2019).

4.2.1 Interview Design

Semi-structured interviews are preferred over structured and unstructured interviews so that in the interview there are some established questions, giving the possibility to open-ended questions with follow-up questions, to gain extra data which interviewees might not be aware of. Additionally, among the various interview formats, semi-structured interviews are particularly favoured when the research objective is to gain an in-depth understanding of the participants' perspectives (Adeoye-Olatunde & Olenik, 2021).

Therefore, the interview was structured to encourage open conversations based on key questions, while also allowing flexibility to explore a wide range of unexpected topics by avoiding strictly defined themes (Suau-Sanchez et al., 2020). To ensure high-quality data, the questions were designed to promote discussion without influencing or leading the participants' responses (Kallio et al., 2016). Before developing the interview questions, a deep review of existing literature was conducted. This theoretical approach helped build a solid understanding of the subject and ensured the researcher could explain complex or unfamiliar concepts to participants when necessary (Braun & Clarke, 2006).

An additional measure to ensure ethical integrity in the research consisted on assigning numbers to participants. This approach was implemented to preserve confidentiality and protect participants' identities, thereby preventing any potential identification by readers.

4.2.2 Sampling

Purposive sampling was used as a sampling technique to select the interviewees. It is a non-probability sampling technique which is ideal to select specific experts of the UAM industry and is a technique which does not require interviewees to be a representative number of the population (Adeoye-Olatunde & Olenik, 2021). Additionally, snowball sampling was used through a vertiport operator contact to get more interviewees with knowledge in the UAM industry. Participants were selected so that they would accomplish several criteria, including being involved in the UAM industry for at least one year and the willingness to sign an informed consent so that the information can be used in the research.

With this criteria was intended to reach out interviewees with experience in the UAM industry and also aiming to have the opinion from different companies, acting as different stakeholders of the turnaround process. The interviewees were contacted via email or LinkedIn.

4.2.3 Interview Medium and Questions

Before each interview, participants were provided with the consent form and the interview questions, as well as being informed that their responses would remain anonymous. Later on, at the start of each interview, the interviewees were again informed that the interview was going to be transcribed and recorded. Signing the consent form was required to confirm that they understood the purpose and procedures of the research and interview. Additionally, the interviewer gathered relevant background information about the participants in order to facilitate effective communication and establish a positive rapport.

All the interviews were conducted online using Microsoft Teams. Doing the interviews online eliminated travel expenses and enabled the inclusion of a broader range of experts, from different nationalities and working in companies based in the Middle East and different countries within Europe. This cost-effective and flexible approach allowed participants to schedule the interview at a time that best suited their professional commitments. All interview recordings and

transcripts were securely stored on a university platform accessible only through a protected login system.

As noted by Jamshed (2014), semi-structured interviews typically last between 30 minutes and over an hour. The interviewer aimed to keep each meeting within a reasonable time frame to ensure a comfortable experience for the participants.

The interview was designed to last around 30 minutes. A total of twelve questions were developed (listed in Table 4-1), where some of them are the principal ones, and others are follow-up questions depending on responses. Not every question was required to be asked in every interview, as it could disrupt the flow of the interview and might have already been discussed with the main questions. In the middle of the interview, spontaneous follow-up questions were asked, to enhance the qualitative result of the responses.

Table 4-1. Interview questions

Introduction	
1	Can you briefly describe your role in the vertiport/eVTOL ecosystem? Company? Years of experience?
Turnaround process	
2	What do you understand by the turnaround process for eVTOLs at vertiports and how does it differ from aircraft and helicopters?
3	What infrastructure components are critical to enable efficient turnaround for eVTOLs?
4	Which part of the turnaround process do you see as the most complex or risky?
Challenges of a ConOps	
5	What do you think are the biggest challenges in defining a standardised ConOps for eVTOL turnaround?

6	Are there uncertainties in the operational, regulatory, or technological domains that make ConOps development difficult?
Stakeholders	
7	What stakeholders need to be involved in the turnaround process, and how should they coordinate?
8	Do you see gaps in responsibility or communication that could hinder operations?
Regulatory and safety considerations	
9	What regulatory challenges do you foresee in implementing a turnaround ConOps?
10	How should safety be integrated into turnaround procedures?
Scalability and flexibility	
11	How should the turnaround ConOps be designed to be scalable and flexible, depending on different vertiport configurations and eVTOL operating?
Summary	
12	What do you consider the biggest barriers to the implementation of an efficient turnaround ConOps?

The first question was designed to determine the role and experience of the participants and be able to justify whether they meet the eligibility criteria. Questions 2 to 4 were designed to understand how the different stakeholders view the eVTOL's turnaround, outlining key differences with aircraft and helicopters and identifying problematic aspects, whereas questions 5 and 6 are direct questions designed to get the response about the challenges of elaborating a ConOps. While questions 7 and 8 aimed to understand the role of the stakeholders involved, questions 9 and 10 were asked to know if the participants think there will be regulatory challenges and safety considerations, if they were

not mentioned in questions 5 and 6. Finally, question 11 was useful to understand if the different types of vertiports and eVTOLs influence the ConOps and question 12 was asked to do a summary of the interview's main idea.

4.2.4 Thematic Analysis

The data collected from interviews is exclusively qualitative and although there are various methods to analyse this data, thematic analysis is the foundational method for qualitative analysis (Braun & Clarke, 2006). This method requires analysing data by identifying and interpreting themes or patterns across all the data gathered from interviews. It provides a systematic yet flexible framework that helps researchers code data in relation to their research questions. Its accessibility and adaptability make it suitable for both large and small datasets, enabling rich, detailed and complex insights (Saunders et al., 2019). There are different ways to elaborate a thematic analysis, but the most common one, and is the one that is used in this research consists of six stages (Braun & Clarke, 2006):

- Familiarisation with the data: transcribe the interview, correct the transcription and get familiar with the data to later work properly.
- Generating initial codes: identify interesting keywords, sentences or paragraphs and group them in labels called codes to simplify textual data.
- Searching for themes: start to group initial codes into main themes identified, sharing patterns, ideas or relationships.
- Reviewing themes: review critically the themes and ensure they offer insights into the research question.
- Defining and naming themes: clearly define the final themes and give them a proper name.
- Reporting the results: group and summarise all the information by themes and subthemes.

The thematic analysis is done using the software NVivo (2023) which enables to code the interviews efficiently and offers further insights to know which words are more frequent or whether all the interviews talk about a specific subtheme or not.

With the designed questions shown in the prior subsection, some predefined themes are expected as the outcome of the interviews. The first theme would be the participant's background, followed by the description of the turnaround. This theme is expected, at the same time, to include several subthemes, such as the differences with helicopters and aircraft, the infrastructure and the electric charging of eVTOLs. Finally, a big theme of challenges is also predicted to appear, with subthemes like communication, responsibility, regulations and safety.

4.2.5 Ethics Approval

An ethical approval was necessary in this research due to the involvement of human participants. Before data collection began, an application was submitted to Cranfield University's ethics committee. After confirming that there were no conflicts of interest and that no sensitive or protected data would be used, the project received approval from the Cranfield University Research Ethics Committee (CURES) on 24th June 2025 (reference: CURES/25782/2025), as documented in Appendix A.

4.3 Summary

With the methodology explained, the reader can have a clear understanding and idea of the steps followed and thoughts considered to select semi-structured interviews as a methodological approach. Additionally, the sampling criteria and the different questions are justified. All the data obtained in the interviews is analysed via a thematic analysis technique, which best suits in this research. Next section provides the results of this thematic analysis and discusses them to set the challenges to develop a ConOps.

5 Analysis of Results and Discussion

This chapter presents the findings derived from the semi-structured interviews, with key themes and subthemes identified through the application of thematic analysis. At the same time, the results are discussed, comparing the different stakeholders' perspectives and setting the key challenges to develop a turnaround ConOps.

5.1 Preliminary Results

In total, there were seven participants in the research, listed in Table 5-1, along with their job title, company and experience. Although contacting 14 people, it was only possible to interview seven of them. Other potential participants that were contacted include: Original Equipment Manufacturer (OEM), energy providers, helicopter operators, charging supply, more vertiport operators and more consultants. If it were possible to have a meeting with all these 14 candidates that were contacted, it would have been ideal, since they are almost all the stakeholders involved in the turnaround. Nevertheless, interviewing these seven available participants was quite interesting, all of them with different backgrounds, different companies, hence acting as different stakeholders, and with knowledge and experience in the UAM industry, which was a requirement set in the methodology in order to select a participant. As specified in Table 5-1, it was possible to interview people working in consultancy, regulations, infrastructure, OEM and GSE. Additionally, it is not only important the current role they have, also their background, the majority of them coming from the aviation industry, and even Interviewee 4 with a background in different companies of the UAM industry, including two eVTOL manufacturers and a UATM airspace. Conversely, one of the seven interviews was not analysed, since Interviewee 1 did not have enough knowledge about the UAM industry and eVTOLs to consider it for the results.

Table 5-1. Participants interviewed, date and length

Interviewee number	Role	Company	Years UAM industry	Interview Date	Interview Length (min)
1	CEO	GSE distributor	1	16/07/2025	30
2	Associate director	Aviation Consultancy	3	04/07/2025	45
3	Vertiport planner	Vertiport operator	6	30/06/2025	25
4	Managing director	Vertiport infrastructure	6	26/06/2025	30
5	Vertiport policy specialist	Regulator	2.5	03/07/2025	45
6	Aerodynamics engineer	OEM	1	08/07/2025	27
7	CEO	Aviation Consultancy	12	16/07/2025	30

The data collected from all the interviews was analysed using the software NVivo (2023) which enables doing a thematic analysis. After reading and familiarising the transcriptions of the interviews, the data is coded and grouped by themes and subthemes. The main themes discovered were the ones already predefined in the methodology, which makes sense because of the way the questions were asked. These themes are the participants' background, the description of the turnaround and the challenges to elaborate a Conops for eVTOLs' turnaround.

On the other hand, the subthemes were not as the predefined ones, since more subthemes have been identified. All the themes and subthemes are summarised in the next Table 5-2.

Table 5-2. Thematic analysis

Objective	Theme	Subtheme	Description
Identify the current perspective and situation of stakeholders about the turnaround process	Turnaround process	Differences with current aviation	Identification of the differences of eVTOLs and UAM ground operations with the current aviation (battery, automation, passenger journey, GSE need it)
		Charging	Description of the complexities and novelties of electric charging of eVTOLs
		Battery swapping	Description of the complexities and novelties of swapping batteries of eVTOLs
		Infrastructure for turnaround	Identification of the infrastructure need it for this new technology
		Air traffic management	Outline the relation of ground operations with air traffic
		Stakeholders involved	Identification of the different stakeholders and its integration

Describe the challenges to create a turnaround ConOps	Challenges to develop a ConOps	Coordination and communication	Description of the different participants' views of this challenge
		Responsibility	Discussion of assigning responsibilities between the different stakeholders
		Regulatory	Definition of the different regulatory challenges of the UAM industry which affects turnaround operations
		Safety	Identification of different safety challenges described by the interviewees
		Flexibility and scalability	Perception of the participants regarding the flexibility and scalability of vertiports
		Electricity network	Description of the concerns of the provision of electricity and all the electric infrastructure

Additionally, Nvivo allows for the elaboration of a wordcloud of the most frequent words of the data analysed. Therefore, Figure 5-1 shows the wordcloud of the six interviews analysed, illustrating the 300 most frequent words, where the top ones are; vertiport, turnaround, charging, aircraft, operator, differently, eVTOL, regulator, among others. In contrast, Figure 5-2 illustrates a wordcloud of the most frequent words of each one of the participants, observing that the most used words differ between them, since every participant focuses more on their role and their perspective of the UAM ecosystem, which differs from each stakeholder. For instance, Interviewee 4's (the vertiport infrastructure developer) key keywords are

vertiport, FATO, electric charging, whereas Interviewees 2 and 7 (the consultants) speak more widely about everything.



Figure 5-1. Wordcloud of the 300 most frequent words of all the interviewees together



a) Interviewee 2



b) Interviewee 3

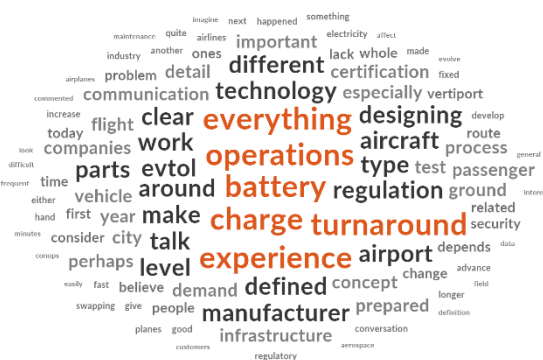


Figure 5-2. Wordclouds of the 300 most frequent words of each interview

5.2 Turnaround Process

Figure 5-3 below shows the various subthemes identified in the turnaround process of eVTOLs at vertiports. In reality, all of these represent differences from current aviation. However, while in the “differences with current aviation” subtheme, only brief definitions of these differences are provided, the other subthemes require further explanation, as the participants placed greater importance on them. Hence, this subsection serves to identify the current perspectives on the turnaround process at vertiports of the different stakeholders, accomplishing objective 3.

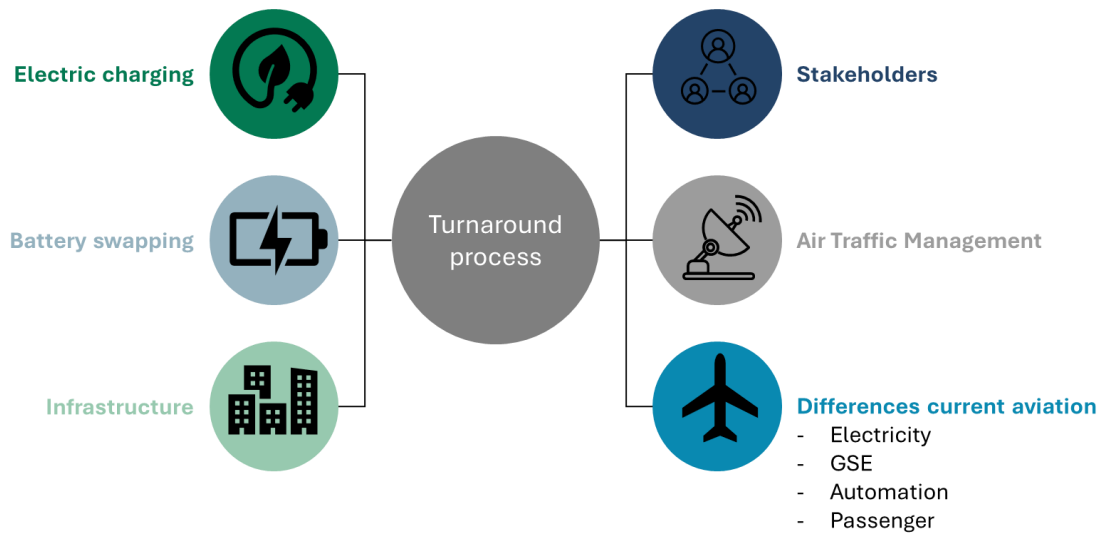


Figure 5-3. Grouping of findings in the turnaround process

5.2.1 Differences with Current Aviation

The most elaborated theme centres on how eVTOL operations differ from helicopters. Interviewee 2 starts answering with “I think overall the process for eVTOL will be a bit different from what we will normally see” and offers a comprehensive view, pointing to standardised procedures, changes in fuelling methods, the complexity of safety checks, and the multifunctional roles of ground crew. They argue eVTOL turnaround is more complex, especially given the reliance on digital diagnostics and the likely presence of unpiloted aircraft in the future. Interviewees 3, 4 and 5 provide complementary insights, from safety protocols related to lithium-ion batteries to taxiing challenges due to limited onboard energy. Interviewee 5 (the regulator) further emphasises regulatory differences, especially regarding whether charging can occur while passengers are onboard. Interviewee 6 reinforces this, stating many procedures mimic those of helicopters, but charging infrastructure introduces major differences. Together, the interviewees paint a picture of eVTOL operations as both more flexible and more demanding, requiring new skills and awareness from all personnel involved. Since the infrastructure and the refuelling are so different, they are explained in different subsections below.

Automation

Another key particularity of eVTOLs is the automation of processes, something that Interviewees 2 and 3 see as both an enabler and a necessity for safe and efficient eVTOL turnarounds. While Interviewee 3 envisions a gradual replacement of human-operated tasks like security with autonomous solutions, Interviewee 2 emphasises digital diagnostics and electronic checks, pointing to a near future where the technological interface dominates preflight and safety operations. Both underscore that automation is not just a feature, it is a structural transformation.

Passenger turnaround

A key topic to outline is the passenger movement, which is expected to be more streamlined than at commercial airports, yet more structured than helicopter services. While Interviewee 6 describes a more traditional process (cleaning, boarding, and pre-flight checks) mirroring today's helicopter operations, Interviewee 2 envisions light security measures, biometric ID systems and digital pre-check apps. Interviewee 3 adds that turnaround should aim for readiness within five minutes, albeit with some form of check-in and Interviewee 7 questions how the embarking and disembarking of passengers would look like.

GSE

GSE needs in eVTOL operations appear relatively minimal compared to conventional aviation, and they are still emerging. Interviewee 2 imagines two primary vehicle types: those for passenger transport and those to tow aircraft. Robots and hydraulic lifts, as mentioned by Interviewee 4, will likely be employed to reduce manual labour and enhance precision. Interviewee 5 notes that eVTOLs may often need tugs, as they may not taxi under their own power to reduce battery consumption.

5.2.2 Charging

According to all interviewees, the process of electric charging is one of the most critical aspects of eVTOL turnaround, and it is an area that will require significant infrastructure investment. Regarding the charging time, the participants differ in the minutes needed. On the one hand, Interviewee 2 points out, the charging process for eVTOLs could take only between 5 to 15 minutes, depending on battery capacity and the technology used. However, this is still a developing area, as Interviewee 2 says “the technology for this fast charging of the eVTOL batteries is being developed”. On the other hand, Interviewee 3 expands on this, noting that a full recharge could take up to 45 minutes (three times more than Interviewee 2 mentioned). While rapid charging is a possibility, there is a risk of damaging the batteries, a concern echoed by Interviewee 4, who stresses that charging times exceeding 15 minutes may adversely affect the batteries' longevity. Interviewee 4 saying “electric charging process is what penalises you a lot the turnaround”, outlines that electric charging is the critical path of the turnaround as Brühl and Fricke's (2022) study. As such, interviewees suggested that a balance between charging speed and battery health must be achieved to ensure efficient operations. These numbers consider a wide range of time and align with the ones of the literature review in Section 3.3, where Schweiger et al. (2022), Schweiger and Preis (2022) and Vascik and Hansman (2019), estimate a charging time of less than 10 minutes and Brühl and Fricke (2022) consider around 45 minutes, like Interviewee 3.

Infrastructural demands are another challenge, as highlighted by Interviewee 7, who points out that ensuring a sufficient energy supply is crucial to preventing delays during the turnaround process. Additionally, Interviewee 5 notes the logistical challenges that arise from managing multiple aircraft simultaneously, particularly with the varying levels of charge and power required for different eVTOL models. These charging needs require a well-organised system of power distribution and management, particularly in locations with high energy consumption.

5.2.3 Battery Swapping

Whether the best option is to recharge batteries or swap them is uncertain, hence, interviewees discuss the advantages and disadvantages of swapping batteries.

Interviewees, particularly Interviewee 2 and Interviewee 5, emphasise the logistics and safety requirements associated with battery swapping. While potentially faster than charging, like Interviewee 2 affirms “swapping of course takes 5 minutes” and as demonstrated before in Section 3.3 with the research of Brühl and Fricke (2022), this process requires substantial infrastructure for storing and handling heavy batteries. Moreover, regulatory concerns related to recertifying the aircraft after battery swaps remain a significant barrier, as highlighted by Interviewee 7. Interviewee 4 also highlights regulatory problems regarding aircraft designs like those of Volocopter, where battery swapping is integral to the model. They outline the engineering challenges such as, batteries must be robust, waterproof and thermally stable to be swapped in various climates or even survive water landings. Interviewee 5, the regulator, relies on the current OEM, where only one or two are working on swapping batteries, due to legal complexities, since swapping a battery constitutes an aircraft modification, which usually requires certification by an engineer. Conversely, Interviewee 6 views swapping as a potential game-changer for long-distance or high-frequency routes, to reduce turnaround times. But there are uncertainties in implementation, particularly in standardising designs and assessing long-term viability.

It is curious to note the different perspectives of the participants, since the OEM interviewee does not mention anything of regulatory problems and the regulator only highlights the recertification of the aircraft after a modification, whereas the others mention several regulatory, logistical and infrastructure problems. However, it can be concluded that swapping offers speed but introduces complications related to engineering, certification, space requirements and supply chain logistics. Its adoption will likely depend on the mission profile of the vertiport or aircraft operator.

5.2.4 Infrastructure for Turnaround

All of the six interviewees gave their opinion on the infrastructure necessary for turnaround, since it was specifically asked. The group's consensus is that turnaround efficiency is tightly bound to infrastructure resilience, flexibility and scalability, and that it is complex because it must support both the unique needs of eVTOLs and the scale of operations in urban areas.

Interviewee 2 offers a detailed breakdown of infrastructure needs: electric grids, cooling systems, communication networks, maintenance facilities and passenger facilities, as identified in Section 2.2. The other consultant, Interviewee 7, and also Interviewee 6 align with the opinion of Interviewee 2, highlighting the logistical challenges that come with the increased need for space, including the storage and transportation of batteries and the requirement for precise infrastructure that can handle fluctuating energy demands. In addition to those statements, Interviewee 4 discusses vertical integration, such as elevators in rooftop vertiports and energy shortages in remote areas, while Interviewee 5 focuses on the importance of stand design for safety and accessibility by affirming “the stand itself is the most important piece of infrastructure”, in terms of size, passenger safety and proximity and distribution of the charging facility. Interviewee 3 agrees on the importance of a holistic design approach because any weak link can become a bottleneck.

In this subtheme, different opinions are observed for each interviewee, mainly because they act as different stakeholders of the turnaround process and are experts in their specific area. While both consultants and the OEM share insights of the hall infrastructure needs, the interviewee working in a vertiport infrastructure company and the regulator focus on the movement logistics and the design, which affects safety, respectively.

5.2.5 Air Traffic Management

An aspect that only two interviewees mention (Interviewee 2 and 5) but still important within the turnaround process is the ATM and UATM, even though operations largely occur on the ground, as Interviewee 2 states “If anything

happens over your vertiport, it affects all the ground operations”. As they note, flight preparation, including permissions for landing and takeoff, is inseparable from the wider cycle. Interviewee 5 highlights this by discussing the operational pressure created by tightly scheduled landings at single-stand vertiports, stressing the need for precise turnaround timing.

5.2.6 Stakeholders Involved

The range of stakeholders involved in eVTOL turnaround operations extends beyond traditional aviation stakeholders like ground handlers and air traffic controllers. Interviewee 3 and Interviewee 5 both emphasise that, aside from the typical aviation roles like vertiport operator and airline, external stakeholders such as energy suppliers, regulators, local authorities and rescue services will play pivotal roles in ensuring the safety and efficiency of eVTOL operations, always maintaining constant communication, as explained in Section 3.4 with the different literature review and ConOps investigated.

One challenge highlighted by Interviewee 5 is the integration of ATC with ground operations, particularly since eVTOLs will operate based on visual flight rules, and early-stage operations may not fully integrate with ATC systems. Additionally, Interviewee 4 highlights the importance of the weather services to provide and update instant information, not only at the vertiport, but also of the entire route.

5.3 Challenges to Develop a ConOps

As Figure 5-4 below shows, the challenges to develop a turnaround ConOps can be grouped into six main subthemes, which are explained throughout this subsection. No one is more important than others, but the interviewees focus more on some of them. The ones that have been coded more in the thematic analysis are regulatory, coordination and communication, and safety. Therefore, this subsection serves to accomplish the fourth objective.

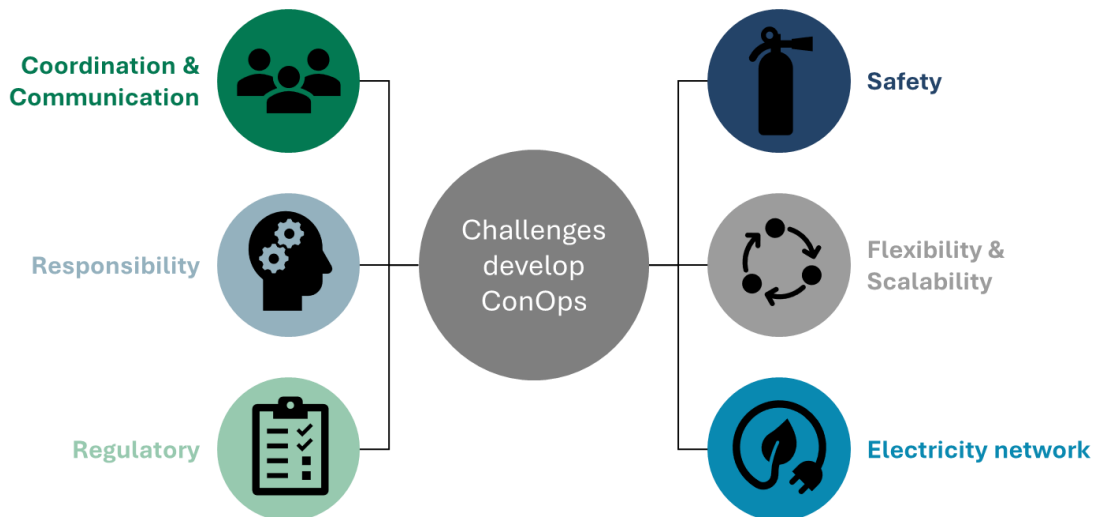


Figure 5-4. Grouping of findings in the challenges to develop a turnaround ConOps

5.3.1 Coordination and Communication

Coordination and communication between various stakeholders, from eVTOL manufacturers to vertiport developers and regulators, emerge as critical factors among all the participants, to take into account to properly explain in the turnaround ConOps.

Interviewee 2 stresses the need for a seamless communication system between vertiports and eVTOLs, including air traffic and unmanned traffic management systems. There is a shared concern about the difficulties in regional and local integration of these systems, given the existing complexity in linking UATM and ATM. However, Interviewee 2 also points out that a unified, digital, and instantaneous communication framework will help not only with operational efficiency but also safety, ensuring all stakeholders have 360° visibility. Interviewee 5 adds to this perspective, expressing concerns about the lack of timely information from OEMs. This delay in receiving operational details from the manufacturers significantly impacts the pace of developing ConOps. Further, Interviewee 5 outlines the importance of clear communication between regulators and vertiport developers. Without this exchange, there is a risk of regulatory confusion and operational misalignment. The complexity of this task becomes even more evident when considering larger vertiports. Interviewee 7 raised

concerns about how delays, diversions and miscommunication could have ripple effects across the entire system. With the increased volume of traffic and the complex coordination between various stakeholders, any communication breakdown could disrupt operations on a large scale.

In contrast, Interviewees 3, 4 and 6 do not see problems in communication. Interviewee 3 suggests that synchronisation is very important, highlighting “each other needs to be synched and that’s where a very important management software which we are also developing”. While Interviewee 4 outlines that they, as a vertiport infrastructure designers, have frequent communication with OEMs, Interviewee 6 (the OEM) affirms that by saying “in communication it is very fast, it is very frequent” and talking with different stakeholders “we talk a lot with the regulatory entity and with customer airlines, collaborators. Above all, is for good, because trying to move forward this the development of the regulation, is very frequent”.

Although some participants think there is open communication and others think the contrary, it is clear that the varying perspectives of the interviewees suggest that while technological solutions can provide some answers, effective coordination requires constant and open communication between all parties involved. Also, it aligns with what has been observed in other UAM ConOps identified in Section 3.4 and with the description of a ConOps in Section 2.4.

5.3.2 Responsibility

Responsibility in the eVTOL ecosystem, especially when considering ground crew operations, is another focal point to have in mind when developing a turnaround ConOps, and is aligned with the communication challenge mentioned before, as Interviewee 6 underscores the need for cooperation between regulators, manufacturers and developers to clarify responsibilities and avoid gaps in the ConOps.

Interviewee 2 discusses the need for clear definitions of responsibility, particularly regarding who is responsible for what tasks during the turnaround process. There will need to be specific roles for ground personnel, with a clear delineation of

responsibilities for the ground handler versus the pilot and other stakeholders. Similarly, Interviewee 5 states that battery swapping, for instance, might need to be done by an engineer due to the legal implications of changing a critical component, suggesting that clear responsibility protocols will be crucial to ensure safe and compliant operations. Interviewee 7 raises concerns about this point regarding the legal liability in the event of errors when swapping batteries. As ground personnel may not have the same level of training or certification as engineers, understanding who is responsible for safety checks and maintenance will be vital to mitigating risks.

5.3.3 Regulatory

Regulatory issues are a central theme throughout the interviews, being the subtheme coded more times. All the participants agree on the preliminary maturity state of UAM regulations, which strongly affects the development of a turnaround ConOps of this new mode of transport.

Interviewees 2 and 5 both mention the lack of clear and universal regulations for eVTOL operations. The regulatory landscape is still evolving and the absence of standardised procedures complicates the development of ConOps. As Interviewee 2 notes, technology is advancing much faster than regulation and regulators struggle to keep pace with the rapid innovation in eVTOL designs and capabilities. Interviewee 3 adds that regulatory bodies like the FAA and EASA are in the process of developing guidelines as eVTOL technology evolves, but this creates uncertainty. The fluid nature of these regulations means that ConOps must be developed in parallel with ongoing regulatory changes, making it challenging to finalise operational procedures until regulations are stabilised, which affects the understanding and creation of the turnaround ConOps.

Moreover, Interviewee 5 highlights how the slow flow of information from OEMs to regulators and developers is a bottleneck. Without complete data from manufacturers, regulators are unable to finalise safety standards, operational protocols, or certification requirements, thus delaying the development of ConOps. This frustration is compounded by differing regulations across jurisdictions, which can further complicate the rollout of eVTOL operations on a

global scale. Interviewee 4 describes the situation as one where regulators are still largely reliant on existing frameworks for heliports and airports, and ICAO regulations will not be released earlier than five years from now. Finally, Interviewee 7 highlights an example of how battery swapping could become a significant regulatory issue. In the current regulatory framework, swapping batteries would likely require the aircraft to be recertified, which presents both logistical and safety challenges to consider in the ConOps.

5.3.4 Safety

Safety remains essential in the development of the turnaround ConOps for eVTOLs, as highlighted by all the participants and agreeing that, since it is aviation, there will be high standards of safety.

Interviewees 2, 3 and 7 emphasise the need for comprehensive safety measures, particularly when dealing with the unique challenges posed by electric propulsion and battery systems. These include protocols for battery overheating, fire prevention and emergency response. Interviewee 2 also stresses that all personnel, whether on the ground or in the air, must have access to real-time safety data to ensure that every eVTOL operation is carried out safely.

Interviewee 5, who is the regulator, further adds that safety protocols must cover not only the aircraft but also the safety of personnel. As eVTOL operations move into urban environments, the protection of people in and around the vertiport becomes crucial, particularly concerning the downwash generated by the aircraft. Interviewee 6 similarly highlights the need for rigorous firefighting systems tailored to address potential fires from batteries in case of thermal runaway. Additionally, Interviewee 4, as a vertiport infrastructure designer, apart from highlighting the risks of fire compared to fuel aircraft, adds a different perspective, outlining the possible infringement of safety protection zones in airside, putting at risk the ground operations.

Another important aspect of safety to take into account to develop a turnaround ConOps is the role of automation within vertiport operations and the turnaround process. Interviewee 3 highlights the role of automation, suggesting that it adds

a necessary layer to operations, especially when using AI-enabled systems like biometric recognition for security. This technology promises to streamline passenger and operational management by reducing manual check-ins or interventions unless something goes wrong. Interviewee 2 further elaborates that such automation is essential for the safe and efficient management of the vertiport environment, stressing that without the integration of these systems, operations could not be conducted safely.

5.3.5 Flexibility and Scalability

Interviewees were specifically asked about the flexibility and scalability of vertiports, and they agree that flexibility is a significant concern, particularly when dealing with different aircraft models and the unique challenges they present.

Interviewee 2 highlights that there are multiple types of eVTOL aircraft, each with unique characteristics requiring tailored operating procedures. For example, the specific needs for ground handling and turnaround operations will vary significantly depending on their design. This variability means that flexibility in ConOps is crucial to accommodate the various models expected to enter service. Modular designs, according to Interviewee 6, might be the answer to scaling up infrastructure in response to growing demand. This approach ensures that as passenger volumes increase, vertiports can expand their capacity quickly and efficiently.

Interviewees 3 and 4 acknowledge that while ConOps might be described at a high level, it is the adaptation of Standard Operating Procedures (SOPs) to individual aircraft and vertiport conditions that will drive operational efficiency. This sentiment is echoed by Interviewee 5, who highlights the adaptability needed to scale operations as aircraft sizes and terminal volumes grow.

5.3.6 Electricity Network

Providing electricity to vertiports and eVTOLs is another issue to consider when developing the ConOps. Interviewees 4 and 5 speak about the difficulties and different possibilities of providing electricity to rooftop vertiports, which will affect ground operations. Interviewee 5 also states that electricity access and supply

will vary significantly depending on the location of the vertiport. While larger, more remote vertiports may have the flexibility to scale their electrical systems, urban vertiports will need to ensure that the power grid can handle the high electricity demand required by multiple eVTOLs charging simultaneously. They suggested that careful planning will be required to ensure a scalable electrical infrastructure is available as the eVTOL market grows. Additionally, Interviewee 6 reinforces the importance of preparing for future electrical demand by designing facilities that can handle substantial increases in electricity consumption over time.

Apart from that, Interviewee 2 raises concerns about the green energy transition, noting that while today's infrastructure can handle high electricity demands, the long-term goal is to integrate sustainable energy sources like solar or wind power into vertiports. As the demand for electric charging infrastructure grows, this transition to more green energy sources will become even more critical in reducing the environmental footprint of eVTOL operations.

They pointed out that modular facilities, which can expand as demand increases, will be essential in managing this growing need for electricity. This forward-thinking approach is necessary to prevent bottlenecks in power delivery and ensure a seamless experience for both operators and passengers.

5.4 Summary

Following the thematic analysis of the interview data, the findings were categorised into two main areas: the turnaround process and the challenges associated with developing a turnaround ConOps. These categories directly contribute to achieving objectives 3 and 4, respectively. As a result, current stakeholder perspectives have been identified and the key challenges in formulating a turnaround ConOps for eVTOLs have been outlined. Furthermore, certain insights shared by participants have reinforced and expanded upon the information presented in Sections 2 and 3, thereby supporting the fulfilment of objectives 1 and 2.

6 Conclusions

This last section is comprised of three subsections to explain the main findings and implications of the research, as well as some limitations found while doing it and, finally, future research suggestions. Therefore, the whole section summarises the research and focuses on how the main aim has been addressed, and by completing each one of the four objectives, the aim of describing the complexities of developing an eVTOL's turnaround ConOps has been accomplished.

6.1 Main Findings and Implications

UAM and the operations of eVTOLs represent a rapidly evolving aviation concept, focused on enhancing urban and regional transport with improved sustainability, efficiency and convenience. The academic literature provides a strong foundation on the technical aspects of eVTOL aircraft, particularly around propulsion systems, battery technologies and vehicle configurations. However, comparatively fewer studies address the operational and regulatory frameworks needed to support the real-world deployment of this technology, particularly the turnaround processes at vertiports, as seen along all Section 3.

To achieve the final aim, four objectives were proposed. First of all, an extensive review of the UAM industry, aviation industry and literature review was done to enable the reader to understand the topic of the thesis and state what there is today and what has been already researched. Therefore, objectives 1 and 2 were accomplished by characterising the different types of vertiports and eVTOLs and understanding and identifying the turnaround processes of airplanes and helicopters.

Thereafter, semi-structured interviews were conducted and thematically analysed to achieve objectives 3 and 4, that is, identifying the current perspectives of stakeholders regarding turnaround processes and describing the challenges to create the turnaround ConOps for eVTOLs at vertiports.

This study contributes to this emerging field by focusing specifically on eVTOL turnaround operations. Supported by semi-structured interviews with professionals from various UAM-related backgrounds, including infrastructure, regulatory bodies, OEMs and consultancies, the research captures the diverse perspectives currently shaping the future of vertiport operations. These expert insights, shaped by varied professional experiences and levels of seniority, reflect the fragmented and often contrasting views within the sector.

A notable outcome of the interviews is the consensus that turnaround operations for eVTOLs cannot be simply adapted from conventional aviation models. Instead, they demand a new operational paradigm, driven by electric propulsion, rapid turnaround times and digital automation. Furthermore, stakeholders repeatedly highlighted that the eVTOL industry cannot be treated as a homogeneous sector. Each eVTOL use case introduces different operational, technological and financial implications, and this research underscores the importance of distinguishing between them.

The findings demonstrate that turnaround operations at vertiports are likely to emerge as a bottleneck unless addressed early. Key technical and logistical challenges include the dominance of electric charging (or battery swapping) in turnaround time, the variation in eVTOL design and the need for automation and standardised ground procedures. Importantly, the study also reveals that stakeholders do not always share a common vision for UAM operations, with diverging perspectives on issues like battery management, regulatory oversight, communication and scalability.

The interviews validated that while eVTOLs are technically ready for limited operations, the ground infrastructure and regulatory ecosystem remain in early development. Stakeholders largely agreed that flexibility must be embedded into ConOps from the outset, particularly given the uncertainties around aircraft design, vertiport layouts and energy availability.

This research offers practical and theoretical insights into a specific yet underdeveloped area of UAM operations, which is the turnaround process for eVTOLs at vertiports. Its contribution to the current literature is significant, as it explores operational and daily challenges to consider when developing a ConOps

One of the most relevant contributions of this study is the recognition that eVTOL turnaround process must be treated independently. Each turnaround model is shaped by the characteristics of the aircraft type, vertiport layout, expected frequency of operations and the energy supply of the infrastructure. Therefore, the operational framework for a high-throughput urban vertiport may differ substantially from that of a remote or rooftop facility. This confirms the importance of developing adaptable procedures rather than rigid, universal guidelines.

Furthermore, the expert interviews reveal that UAM stakeholders operate with partial knowledge and in a highly dynamic regulatory environment. While most participants agreed on the broad principles necessary for safe and scalable turnaround operations, their views diverged significantly on technical specifics. This diversity of opinion reflects the broader uncertainty in the industry and highlights the challenge of defining standardised practices at this early stage.

Rather than treating this uncertainty as a limitation, the research underlines its strategic importance. The ongoing lack of clarity on issues like battery swapping feasibility, safety protocols and electric grid capacity should be interpreted as evidence that the industry is still in an exploratory and adaptive phase. As such, this study encourages researchers and practitioners to remain flexible in their assumptions and methodologies, acknowledging that operational models will evolve over time as technologies and regulations mature.

The implications of this work also extend to regulatory and policy-making circles. It reinforces the urgency for interim regulatory guidance to support the safe trial and deployment of eVTOL services. In parallel, the findings suggest that early-stage infrastructure development must prioritise scalability and modularity, allowing for future adjustments as the eVTOL ecosystem evolves.

From an academic perspective, this research demonstrates the value of thematic analysis in structuring and interpreting qualitative insights within an emergent field like UAM is. The method worked well for finding common themes across different stakeholder groups, helping to reveal how their operations are connected. However, future research could also use other methods, like the Delphi method or a mix of qualitative approaches, also making use of surveys, to compare results and confirm new ideas. This would make the conclusions stronger, especially in areas where there is not much data yet.

6.2 Limitations

This study, like all research, has its limitations. Given the emerging and rapidly evolving nature of the UAM industry, the findings may lose relevance or accuracy over time. The research intentionally focused on a relatively unexplored area, which means there was limited existing data to reinforce the conclusions beyond what was gathered during this study. Additionally, while interviews provided valuable insights, time constraints, which were necessary to accommodate the busy schedules of participants, meant that the questions had to remain brief, potentially limiting the depth of responses. Another consideration is that most insights reflect the European or Middle Eastern landscape, since the participants work there, hence, probably excluding perspectives from other important markets. Furthermore, it would have been much better to interview more participants, trying to get information from other stakeholders involved in the turnaround process of eVTOLs.

6.3 Future Research

Numerous areas within vertiport ground operations and the wider UAM industry still require further exploration in future research. First of all, with the basis of this thesis, future researchers could describe a general ConOps for the turnaround process of eVTOLs, detailing how stakeholders need to communicate and who is responsible for what and also they could describe how ground movements could look like, for later on simulate them with fast time simulations using softwares such as CAST or AirTop.

Additionally, regarding the UAM industry, future research should delve deeper into the technical challenges associated with integrating and implementing UAM within existing transportation systems. There is also a need for more quantitative studies on various eVTOL use cases to generate reliable data that can support industry stakeholders. Moreover, social acceptance and the effective promotion of eVTOL operations should be key areas of focus in upcoming studies.

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Appendices

Appendix A Ethical approval letter

In this Appendix the Cranfield University Ethics Approval is provided.



24 June 2025

Dear Mr Esteban Navarro ,

Reference: CURES/25782/2025

Project ID: 29339

Title: Describing the complexities of developing an eVTOL's turnaround concept of operations at vertiports

Thank you for your application to the Cranfield University Research Ethics System (CURES).

We are pleased to inform you your CURES application, reference CURES/25782/2025 has been reviewed. You may now proceed with the research activities you have sought approval for.

If you have any queries, please contact CURES Support.

We wish you every success with your project.

Regards,

CURES Team