RESEARCH METHODS PAPER

SKY HUB

An innovative aviation facility in city centre

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complex projects

TU Delft

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INTRODUCTION

01

The chapter, introduction, will cover the Thesis Topic, Problem Statement following the Research Question and sub-questions.

1.1 THESIS TPOIC

As Germany's capital city, compared to 2022, in 2023, Berlin welcomed a great increase in visitors, at the same time, Because of the concern about climate change as well as the goal of zero pollution action by the European Commission, it is time to make an effort to figure out an innovative alternative to deal with the substantial demand for transportation services as well as the new urban centre within the city[1]. In 2021, Berlin municipality announced the diesel driving bans, which can justify the environmental sustainability to the citizens and promote low-emission to reduce air pollution. In the Vision of Berlin in 2030[2], the authority aims "…It will be successful and sustainable in terms of climate and energy, city-friendly and future-proof in terms of mobility, its inhabitants caring and committed to living together in a modern and socially responsible society. …" [3]

This research will examine the potential of coordinating with the diverse vicinity and architecture ranging from traditional to conventional evolution, aiming to shape a safe, intelligent and sustainable transport facility proposed thanks to the pursuit of unparalleled quality of life and Advanced Air Mobility (AAM)[4].

Figure 01. Berlin Citizens propose the largest CAR-FREE area in the world[5]

Figure 02. Projected percentage change from 2017 to 2030 in the number of people highly annoyed by noise from rail, road and aircraft under conservative and optimistic scenarios in the EU-27[6]

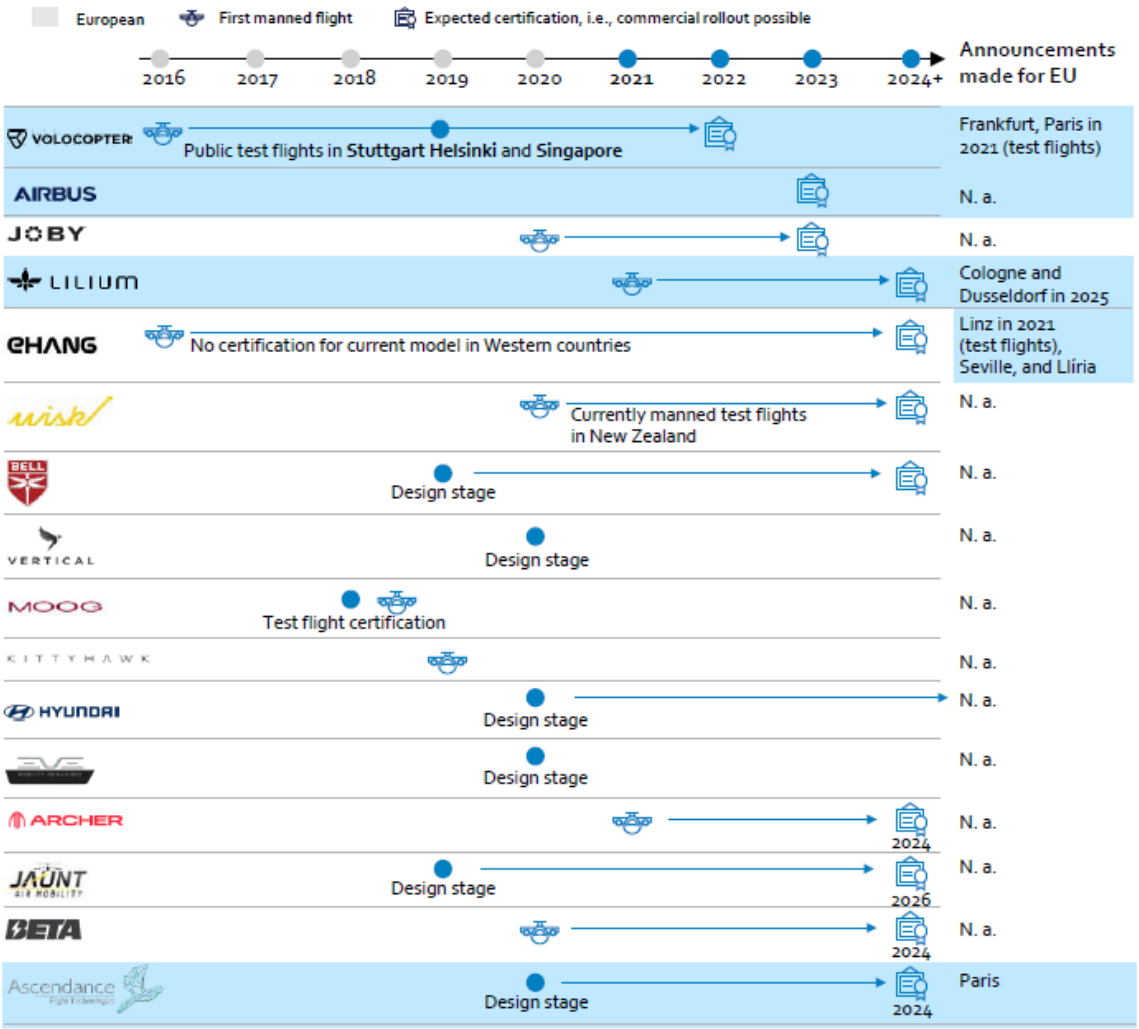

Figure 03. Passenger vehicle certification announcements(non-exhaustive)[7]

1.2 PROBLEM STATEMENT

Because of the increasing number of tourist market[8] as well as the limited space of ground for future transport infrastructure development, Vertiport as an innovative and conventional heliport provides the potential to build up a new layer of mobility in air space. At the same time, the power adoption of electricity can also enhance the pursuit of low emissions for the city's future master plan. As of 2022, the development of UAM and AAM was in an early phase[9]. Vertiports are expected to vary in different scales with a range of capacities. It depends on the traffic load of the city. Currently, the establishment of vertiports appears to be predominantly occurring through partnerships between seasoned infrastructure entities and manufacturers of Urban Air Mobility (UAM) vehicles[10]. How to create a platform as a laboratory to balance the demand of the traffic volume, environmental sustainability as well as the advanced development of mobility evolution[11].

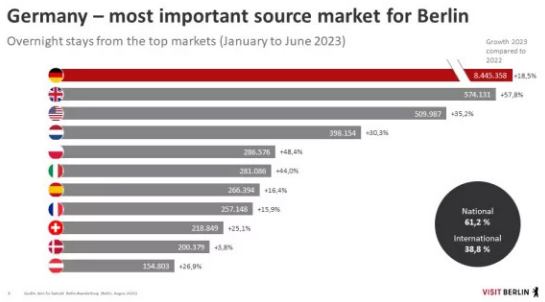

Figure 04. The growing tourist market of Berlin city in 2023[12]

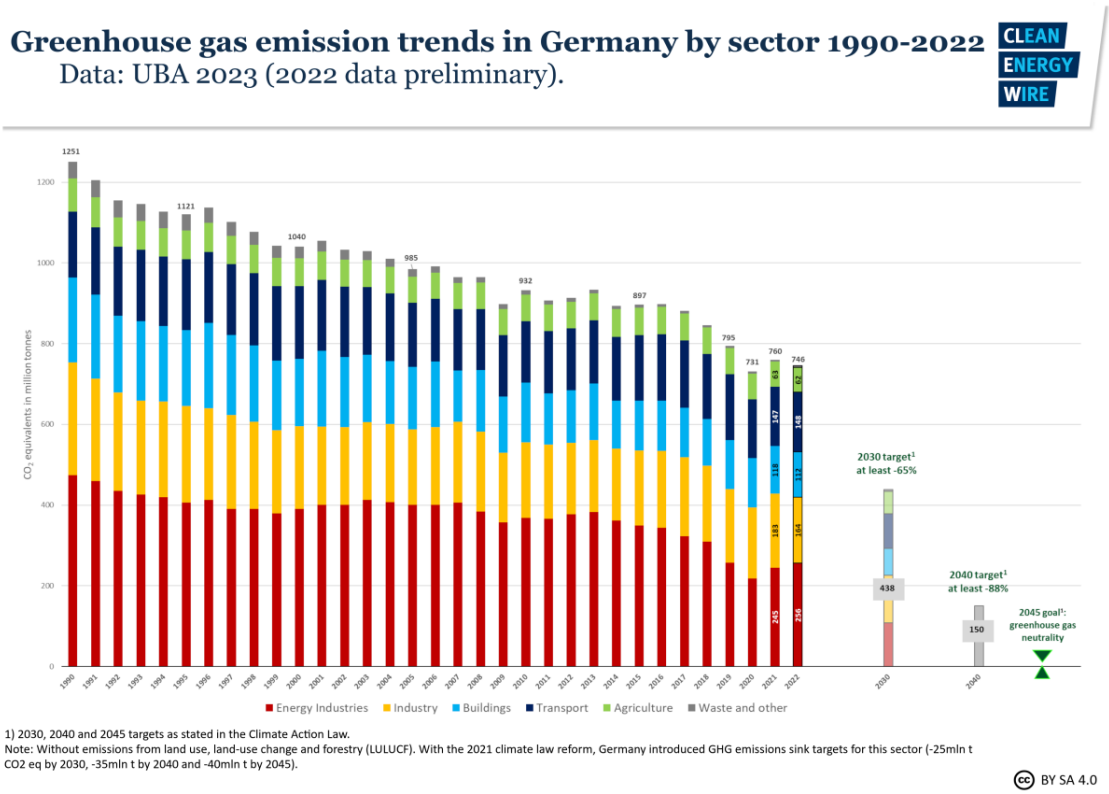

Figure 05. Greenhouse gas emission trends in Germany by sector 1990-2022[13]

1.3 RESEARCH QUESTION(S)

The research question arises from the problem,

"**How can we establish an innovative aviation infrastructure into a city centre?**"

To promote the concept of UAM (Urban Air Mobility)/AAM (Advanced Air Mobility), the introduction of vertiport design as an innovative and sustainable heliport drives the transport efficiency and processing service for the rising number of regional travellers.

Following the 3 ideas below, the goal is to propose a design brief regarding the demand that presents a unique opportunity for integrating eVTOLs as a transformative mobility solution for the future of Berlin. Establishing a vertiport within the city as a promising urban aviation infrastructure that enhances its local identity bolsters its capacity to serve growing tourists and fosters connectivity within the surrounding community.

1. What if Berlin established a **new aviation facility** to facilitate the European Union's ambition?
2. How can a vertiport content the society's **sustainable and future proof concerns**? What can be **changed** in the vertiport design?
3. What is the **architectural fundamental** of a vertiport?

Keywords:

Vertiport, Infrastructure design, UAM (Urban Air Mobility), Aviation infrastructure, Transformative mobility,City centre, Berlin

Figure 06. Collage for the research question

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RESEARCH FRAMEWORK

02

The chapter will examine the theoretical framework including the relevance of the Design Brief and related research regarding the thesis topic.

2.1 THEORETICAL FRAMEWORK

This research will address two main aspects following three primary literature materials. One is from the perspective of human experience with architecture, and the other is from technical considerations such as the functional concerns of airport design. Therefore, the necessary infrastructure for a vertiport is determined by adopting an airport's architectural concept and operational procedures. The research framework operates on the premise that a vertiport's passenger facility can be characterised as akin to a commercial airport. An airport typically comprises three distinct zones: Airside, Terminal building, and Landside. Within a city, Landside, the shared public space for passenger arrivals and departures, is distinct from the terminal building, which functions as the area where passenger processes are executed.

Three primary references are the book, AIRPORT ENGINEERING: PLANNING, DESIGN, AND DEVELOPMENT OF 21ST- CENTURY AIRPORTS by Norman J. Ashford, Saleh A. Mumayiz, and Paul H. Wright in 2011, and the research article, Design Criteria and Accommodating Capacity Analysis of Vertiports for Urban Air Mobility and Its Application at Gimpo Airport in Korea by Byeongseon Ahn and Ho-Yon Hwang in 2022 and the report, Study on the societal acceptance of Urban Air Mobility in Europe by EASA(European Union Aviation Safety Agency) in 2021.

From the perspective of architecture and urban planning, how citizens experience Berlin City is a focus. Firstly, in the book, "THE ART OF BUILDING CITIES,"[11] the author, Camillo Sitte, claims that the most impressive architecture and streetscape from the angles is where the first scenery travellers come into view for giving a grand first impression. Furthermore, in Le Corbusier's project, the Geometric "Radiant City,"[12] quite a range of drawings are from an aerial perspective. Concurrently, regarding the technological development of mobility in the EU, the literature on eVTOLs has five main focuses: Passenger transport, Delivery, Civil surveillance and other operations, Sovereign functions and Signal emitting.[13]The fundamental requirement of vertiport design will be the higher accessibility of the vertiport[14] as well as the electricity infrastructure connection[15] for the future vertiport operation, which concerns should be addressed in the coming chapter.

2.2 REVELANCE

For Berlin city, introducing eVTOLs (electric take-off and landing) aircraft provides strategies to approach a green and compact city proposed by the Berlin municipality.[16] UAM reduces 100% local emissions for electric propulsion compared to a helicopter with conventional kerosene propulsion. Moreover, the benefit of time savings is 15-40 mins[15], such as a city-to-airport transfer in Paris by air taxi, which could be 2 to 4 times faster than a car drive on a Thursday evening during rush hour[17]. Under the report published by EASA, selected European cities were assessed based on KPIs' performance as follows.

The key performance indicators (KPIs) encompassed various factors: the size of the city, anticipated trip volume, distance from the airport to the city centre, travel duration between the airport and city centre using the quickest alternative mode of transportation (such as taxi, car, or public transit) during peak hours, congestion levels, taxi expenses for the airport journey, and favourable weather conditions (including the percentage of weather-related causes contributing to total arrival delays and annual precipitation in millimetres)[18]. Each KPI was assigned a weighting factor to modify its influence on the comprehensive ranking score. Following the KPIs, Berlin got a high score, 78.3/100[19], in the assessment of introducing Vertiport as a new infrastructure to the citizens.

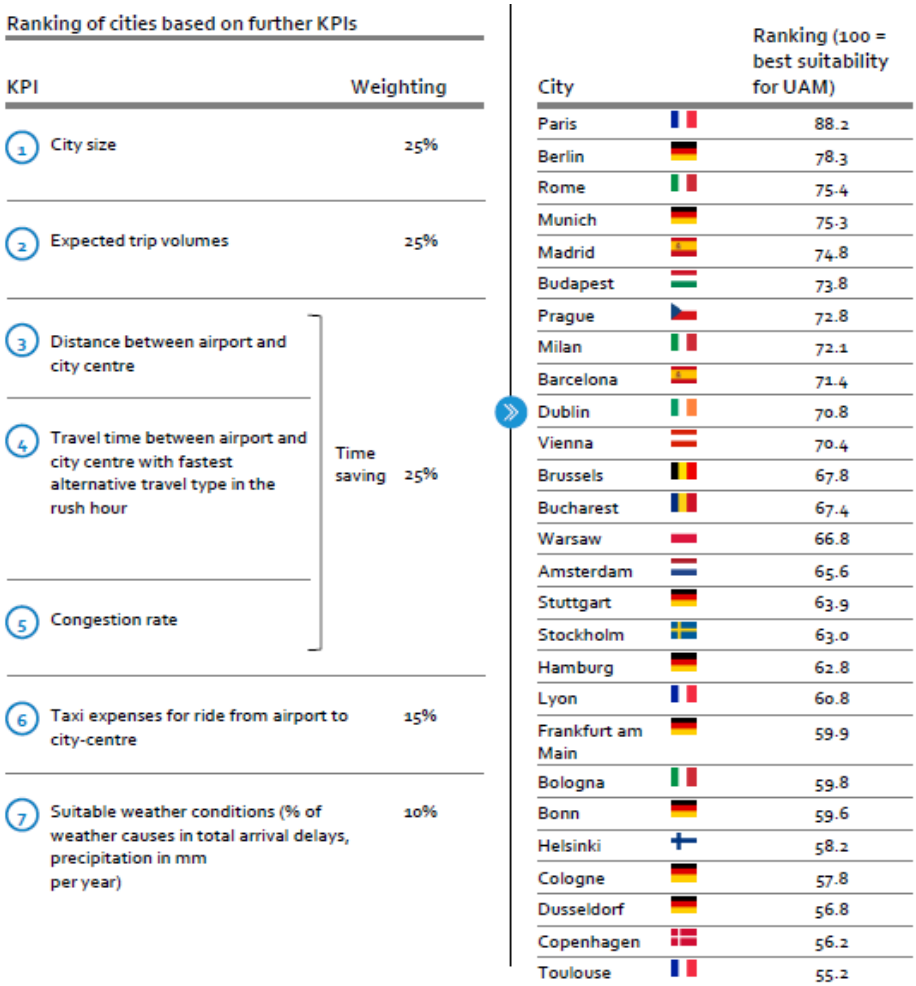

Figure 07. Target cities ranking process for the airport shuttle use case[20]

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RESEARCH METHODS

03

The chapter, Research Methods, will indicate this research from Program, Client and Site aspects as the fundamental materials for the Design Brief, which will be addressed in the next chapter.

Based on the literature reviews, quantitative study and a series of precedent studies of Vertiports, Heliports and airports, the Research methods will follow sub-points Typology, Program and Relation scheme. The first step is quantitative research for the number of passengers per hour following the minimum sqm required for the Vertiport design for the estimation of the terminal building's GFA (Gross Floor Area), the necessary number of flights satisfying the passengers per hour and the fundamental area for the airside. All estimations above and calculations for this research are following the book, AIRPORT ENGINEERING: PLANNING, DESIGN, AND DEVELOPMENT OF 21ST-CENTURY AIRPORTS by Norman J. Ashford, Saleh A. Mumayiz, and Paul H. Wright in 2011, and the research article, Design Criteria and Accommodating Capacity Analysis of Vertiports for Urban Air Mobility and Its Application at Gimpo Airport in Korea by Byeongseon Ahn and Ho-Yon Hwang in 2022 and the report, Study on the societal acceptance of Urban Air Mobility in Europe by EASA(European Union Aviation Safety Agency) in 2021.

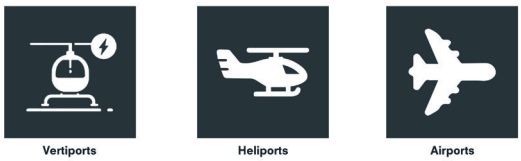

Figure 08. Vertiports, Heliports, Airports as the main research categories

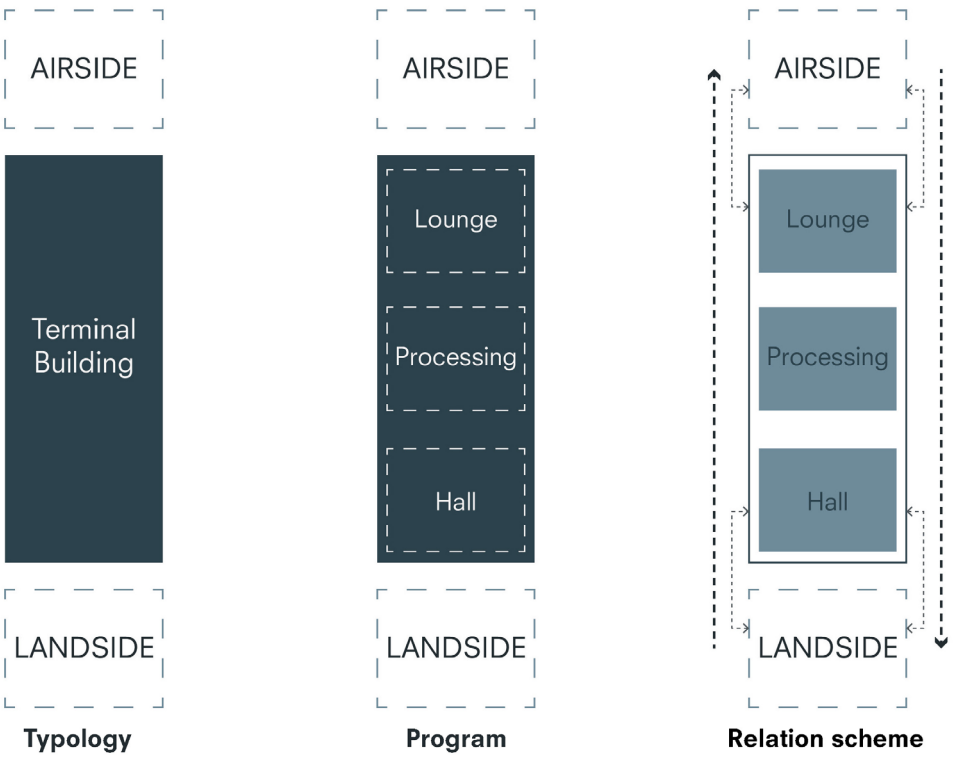

Figure 09. Content of Research Methods

The following points, Typology [Heliport/ Vertiports], Landside, and Airside are all developed for further study of program breakdown, the preliminary program bar and the realtiob scheme of this vertiport research project.

Typology

There are four main typologies of Heliport, Satellite, Linear, Pier and Remove apron, as well as three research typologies of Vertiports, Satellite, Linear and Pier. By summarising the studies of the typology, the most common and efficient typology is the Pier typology following **one TLOF pad and five gates**.

Landside

Regarding landside, selected heliports are the primary material for the research because of their inner-city location as well as the similarity of take-off and landing ways with eVTOLs. The connectivity with the surrounding vicinity, such as the nearby public transport system and surrounding programs, is the decisive factor in the site location selections for the vertiport's terminal.

Airside

As a future-oriented project, this vertiport project's total number of annual passengers is around 7.1 million domestic and regional travellers from Germany, Poland and the Czech Republic. This project has four types of eVTOLs with four different capacities, ranging from 1, 4, 6 and 40 passengers per flight.

The program of SKY HUB should not only satisfy 7.1 million passengers but also follow the modularised pattern of one TLOF pad + five gates to meet the total travelling goal in the coming 2030. Moreover, the ambition of optimising the connectivity within the inner-city of Berlin is the focus point of the Landside organisation.

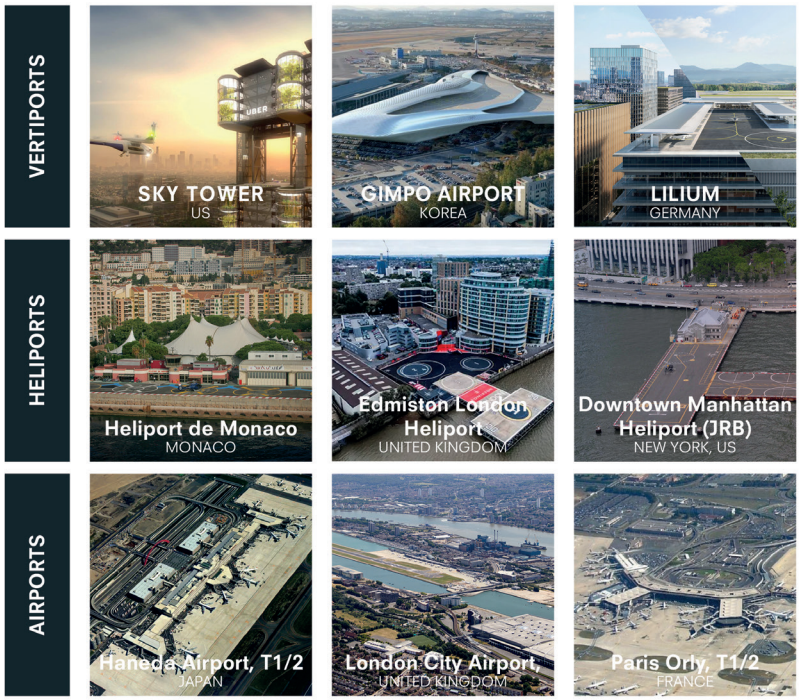

Figure 10. Selected precedents of vertiports, heliports and Domestic airports

3.1 PROGRAMME

The programme study is divided into two parts: the percentage of Airside and Terminal buildings and the percentage of key programmes within the terminal building. Firstly, the difference in the percentage of Airside and Terminal buildings is used to clarify the sizes and capacities between the heliport and proposed vertiport design projects mentioned above. Secondly, the program breakdown of selected airports will be used to analyse the main programmes within an airport: check-in, passport control, security check, baggage claim, luggage, gates, and arrivals. The average percentage of programme breakdown will be treated as the preliminary programme bar for the Design Brief of a Vertiport terminal in the next chapter.

Programme Breakdown

Initially, A qualitative examination of the literature was taken, specifically focusing on the books "Airport Systems" by Neufville et al. and "Airport Planning" by Ashford. These sources provided insights into airport processes and a breakdown of programs. Subsequently, revisiting the selected heliports and airports enables the study of programme breakdowns and programme bars for key spaces in each airport. The preliminary programme bar was created by averaging the programme bars of different precedents. The programme breakdown excludes processes not applicable to a vertiport, such as the absence of baggage handling and claim services due to exclusively carry-on luggage. Additionally, the mentioned literature review findings enable the research to further dissect each key space into functional areas. Leveraging insights from airport processes and systems can be used to identify additional requirements for retail areas, acknowledging their significance in airport revenue generation.

Relation Scheme

The relation scheme was composted by comparing key space relationships in the case studies with their respective relation schemes. Concurrently, this led to the elimination of non-relevant flows for a vertiport, such as separated baggage flows. Additionally, the investigation of the vertical distribution of flows through literature review and the analysis of this aspect in the case studies will be derived from the fundamental requirements for the flow distribution.

In the forthcoming stages of programme development, the strategy is to delve deeper into key space requirements, their detailed configurations, and their interrelations with spatial strategies. This investigation will be carried out through literature reviews and precedent studies. The literature review will specifically focus on the passenger journey within the Vertiport. The first focus is on the landside, which could strengthen the idea of the vicinity of the Vertiport in the design phase and the connectivity with surrounding programme s. The other point is to comprehend the spaces essential for passenger processes as well as the service quality within the terminal building.

3.2 CLIENT

The study relies on an analysis of existing literature. The literature review of this research focused on airport ownership structures and investigated the relationships among various stakeholders in vertiports. The findings revealed that airports in Berlin are the ownership of Airports in Berlin is fully publicly corporatised with shareholders both software and hardware, state authorities and the Federal Republic of Germany. The government typically oversees infrastructure, while private stakeholders, such as airlines for airports and eVTOL developers like Lilium, Volocopter, Uber, Airbus, Kelekona, as well as car developers like Hyundai and Volkswagen for vertiports shown in Figure , contribute to the hardware. Additionally, the research highlighted that 50% of airport revenue is derived from commercial activities, particularly from companies renting retail spaces. This underscores the significance of commercial clients as crucial stakeholders alongside the hardware providers in ensuring the financial success of a vertiport.

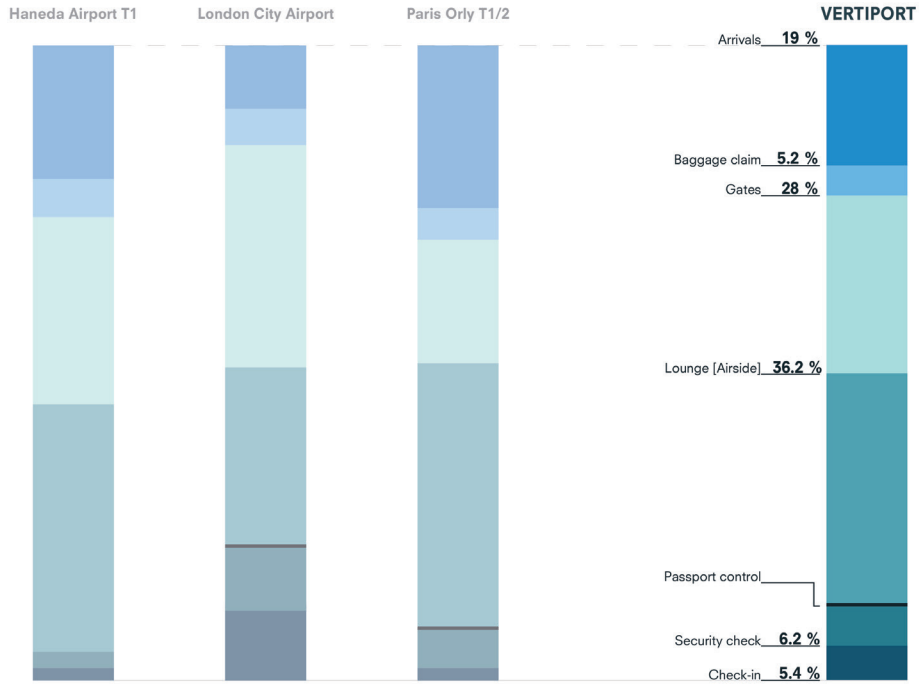

Figure 11. Preliminary Programme study

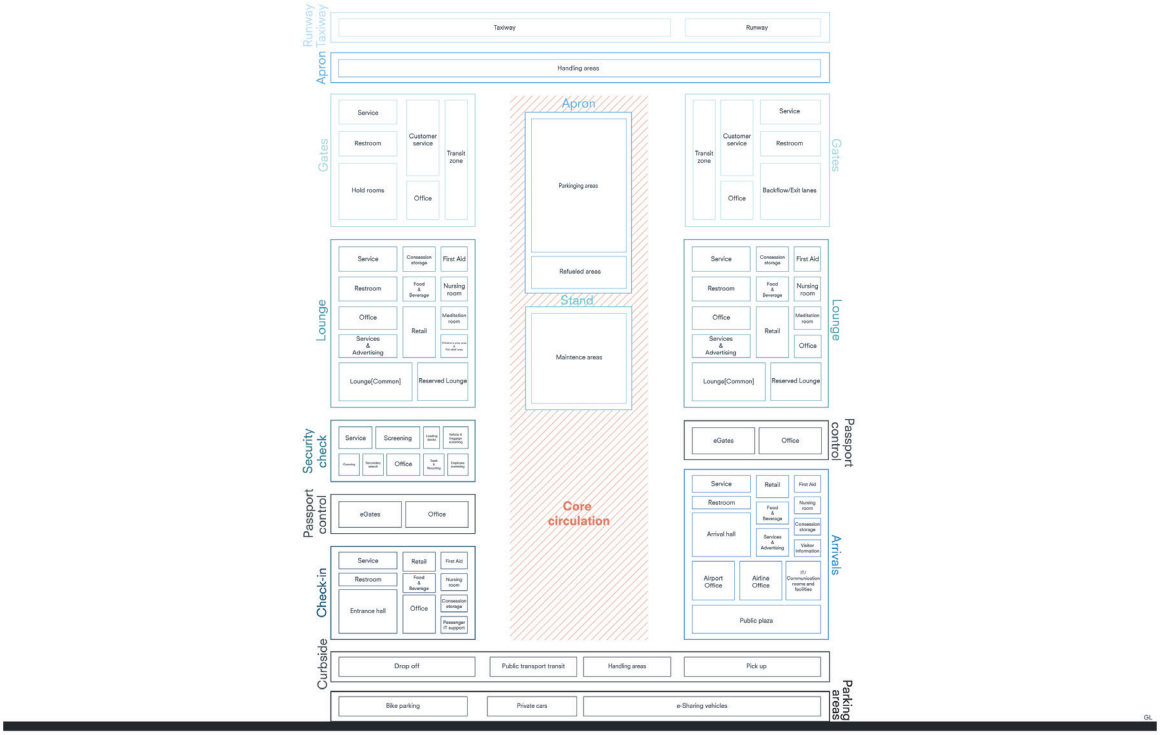

Figure 12. Relation scheme

3.3 SITE

In this research, the site location must follow three specific rules designed by the assigned Group, Material group. As a result, three main rules need to be obeyed.

The common ground of the Group is sourcing. Following the idea, there are three rules: accessibility, Reuse and Prominence. For accessibility, the main requirement is that the site location be selected within a one-kilometre distance of existing waterways or railways for construction transportation. Regarding Reuse, 33% of local materials are required, which should be sourced within a one-km radius of the site. The last point, Prominence, is that the site location should be at a represented area of Berlin following the map made by the Material group to showcase the material collection of nine typologies.

Based on the Group's required rules for site location, to further develop rules for the proper site location of Vertiport, precedent studies of Heliports and qualitative research of Vertiports' landside indicate several points for the inner-city location. Firstly, in terms of vertiports vicinity, restaurants, hotels, parks and other public shared facilities with the value of tourism. Secondly, regarding public transport, vertiports are required to be located close to car parks, bus stops or stations, waterways, railways and other public transport. The third point concerns the site plot; because of the minimum area of Vertiport, the availability of space in Berlin should be large enough to satisfy the area of the airside, terminal building and part of the landside.

Based on the Group's requirements for choosing a site location. Specifically, for vertiport design, there are six more site criteria for considering more building typology-related site constraints. Therefore, the purpose is to formulate another series of tangible requirements such as Multiple access, Environmental concerns, Prominent location, Vacant plot, Business connectivity and Neighbourhood catalyst. The method of site selection aims to analyse existing conditions to determine the suitability of the site location even though most of the workload is focused on mapping and data analysis, a series of objective methods regarding a sensory-oriented way of verifying a site's potential for the next step. The chosen site is Rummelsburger Bucht, a mixture of recreational and residential areas in Berlin characterised by the surrounding context and open waterway. Thanks to having a site location with such a water feature, the water feature naturally creates the uniqueness of the landscape. Meanwhile, it assigns a certain degree of security to the vertiport, shielding it from the massive and dense population. The site analysis covered five scales, zooming in from the country/state-wide to the vicinity scale. Factors such as the public transport network, neighbouring land use, accessibility, building height and the development zone of the district drove the site analysis and ultimately informed the design brief.

Figure 13. Group requirements of the site location

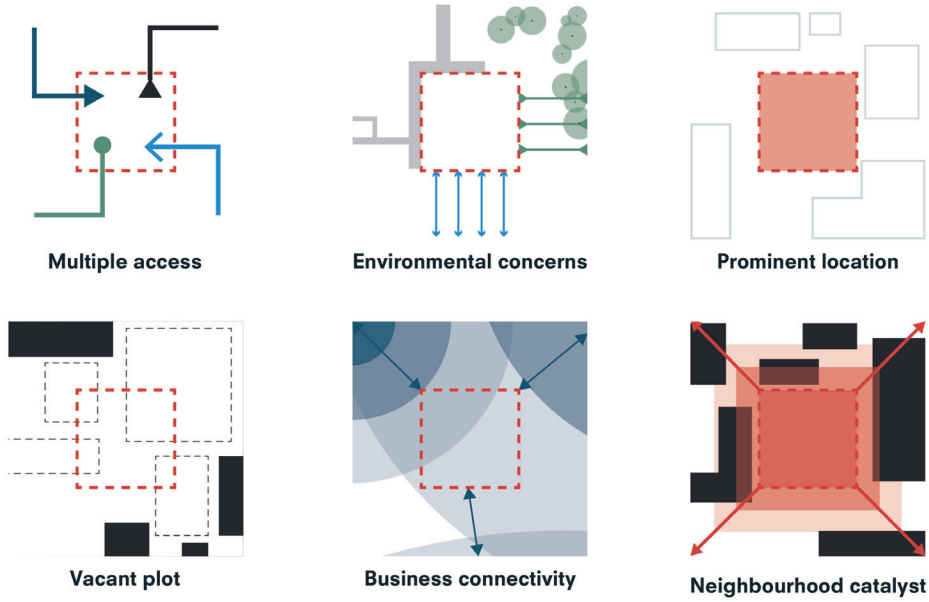

Figure 14. Site criteria for vertiport design, SKY HUB

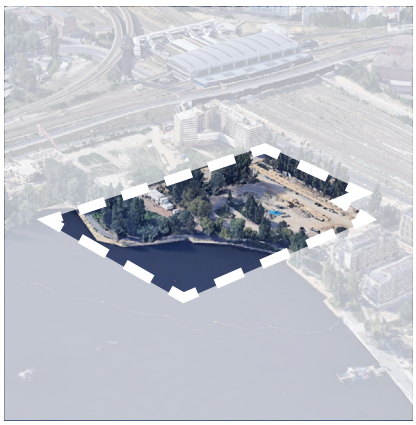

Figure 15. (Left, top) Aerial view of site

Figure 16. (Left, bottom) Public transport network

Figure 17. (Right, top) Land use

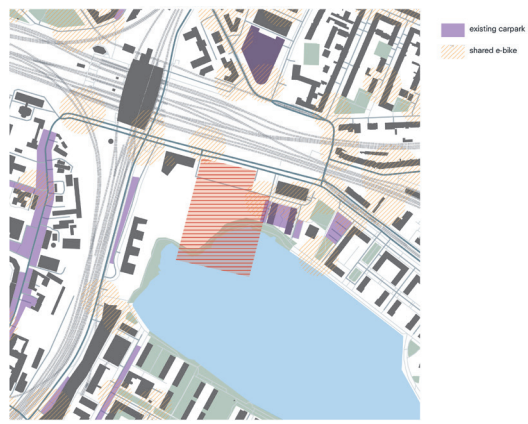

Figure 18. (Right, bottom) Parkign areas

DESIGN BRIEF

04

The chapter, Design Brief, will be briefly explained with visualisations of current development as an outline and possible outcome for further developementof Design.

The design brief consisting of subchapters of the client, programme and site analysis is meant to provide the necessary framework for the formulation of design strategies.
Keeping that in consideration, it is valuable to revisit the research question to establish distinct project objectives that will guide how the gathered data will manifest in the shape of a design brief.
The project ambitions are the following:

Redefine the future of aviation
Considering how it aims to be a public building, SKY HUB should provide a space to challenge the current airport architectural expression and form and define a benchmark of vertiport with the consideration of sustainability and low carbon emission to satisfy the EU commission's ambition in preserving climate change.

Interlock vertiport with City centre
The idea behind this proposal is to provide a way to promote the inner-city aviation infrastructure which can not only integrate the building appearance into the urbanscape of Berlin city but also underline the relationship between the public and the vertiport and a way of doing so is by having a degree of openness to the building and enhancing the connectivity with the neighbouring context.

Optimise the flow within future air mobility
By adjusting the program within the vertiport terminal building and introducing software stakeholders to improve the travelling procedure, such as platforms for submitting travelling documents or a ticketing system. It can reduce the demand for space within the terminal and reduce the waiting time in the building; thus, programmes and passenger administration within the building can be well compact to minimise the land demand within the inner city and challenge the vertical form of the aviation infrastructure typology.

4.1 PROGRAMME

Typology

Based on the literature review of the typology of Heliports and Vertiports, the most efficient typology is Pier typology, following the number of 1 TLOF pad + 5 gates for vertiport design.

Landside

In accordance with the findings of precedent studies in heliports and vertiports, the landside should satisfy the connectivity with its vicinity, such as public transport, waterways, parks and spots with touristic value.

Airside

The airside will focus on the capacity and efficiency of its transport volume. The goal is to provide at least 820 passengers per hour to satisfy the 7.1 million passengers annually.

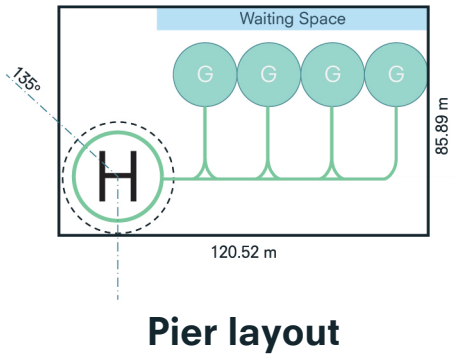

Figure 19. Selected layout for the airside of the vertiport

Figure 20. Fundamental programmes of Landside

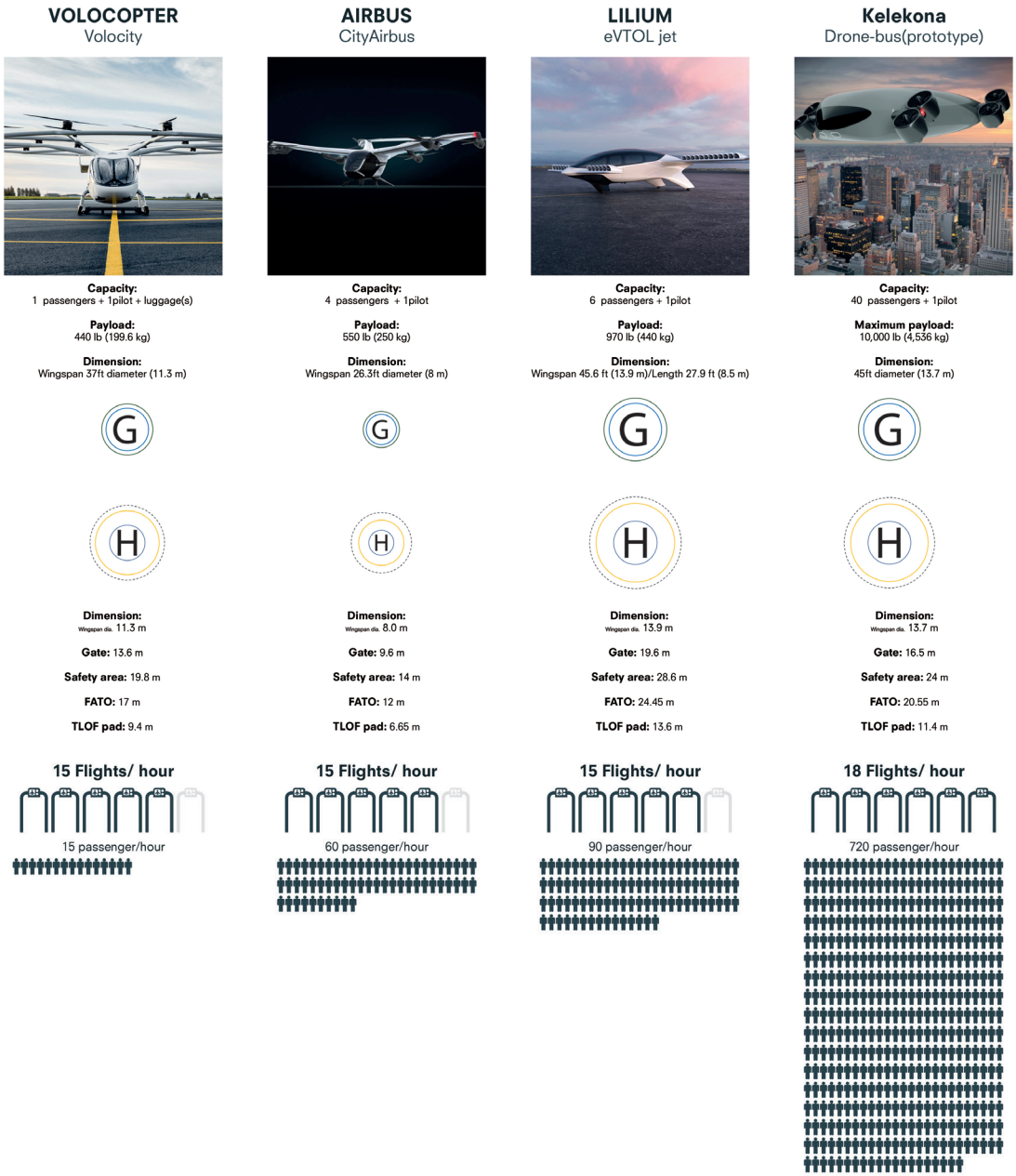

Figure 21. Basic information on selected eVTOLs, including capacity, dimensions and number of flights per hour

Programme Breakdown

Based on the literature review, within the leading the following programmes, Check-in, Security Check, Passport control, Lounge, Gates and Arrivals, each program will be subdivided into four parts: Service, Public Other and Airline, as shown in the Figure. At the same time, because of the goal of connectivity with the surrounding context. The percentage of the Public will be the most significant space.

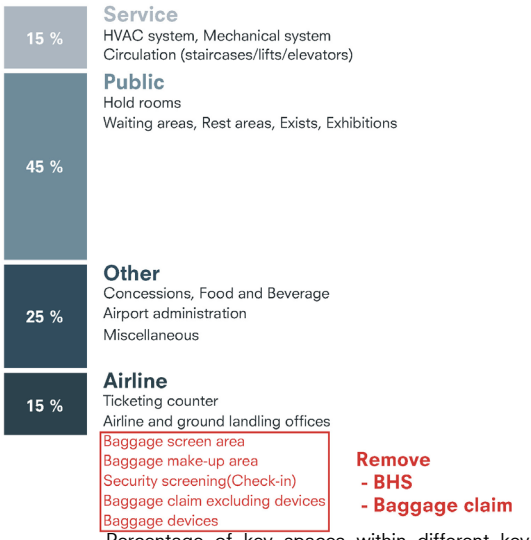

Figure 22. Percentage of key spaces within different key programmes

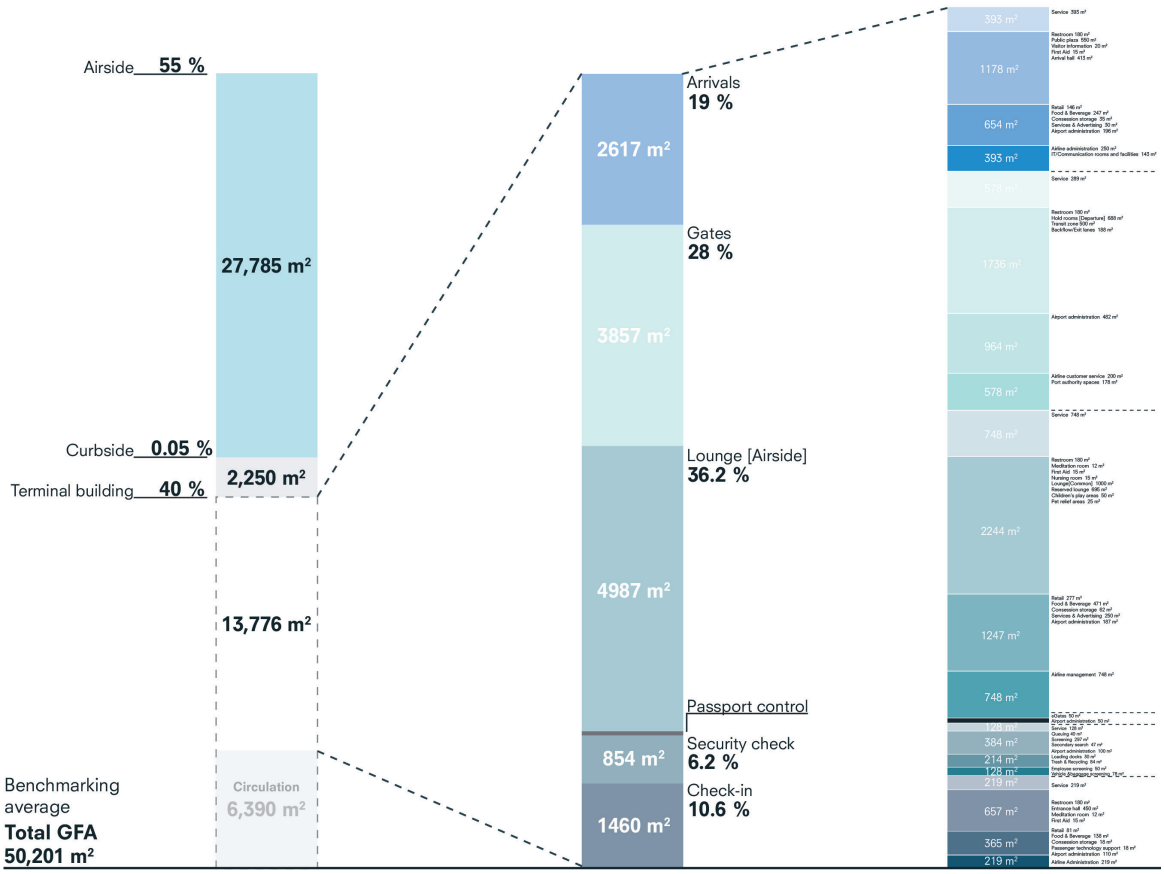

Figure 23. The conclusion of programme breakdown and the detail programme bar with percentage of key spaces

Relation Scheme

Further development of the sectional relation scheme for a vertiport will only allow carry-on luggage. The final relation scheme of the terminal building can still be divided into three parts: groups, Administration, Passengers and eVTOLs. The core circulation within the middle area links all programmes. Moreover, the programmes, Check-in and Arrivals, will share the Hall space, directly connecting to the vicinity of the vertiport.

The flow of passengers and luggage will be combined into one and follow the regulation for satisfying the level of service – A in the terminal building, which provides passengers with a more comfortable and smooth journey in the vertiport. The last point of this relation scheme is that the compact circulation among eVTOLs, administration and passengers can optimise the flow of the future aviation infrastructure.

Figure 24. Icons of ONLY carry-on luggage of vertiport

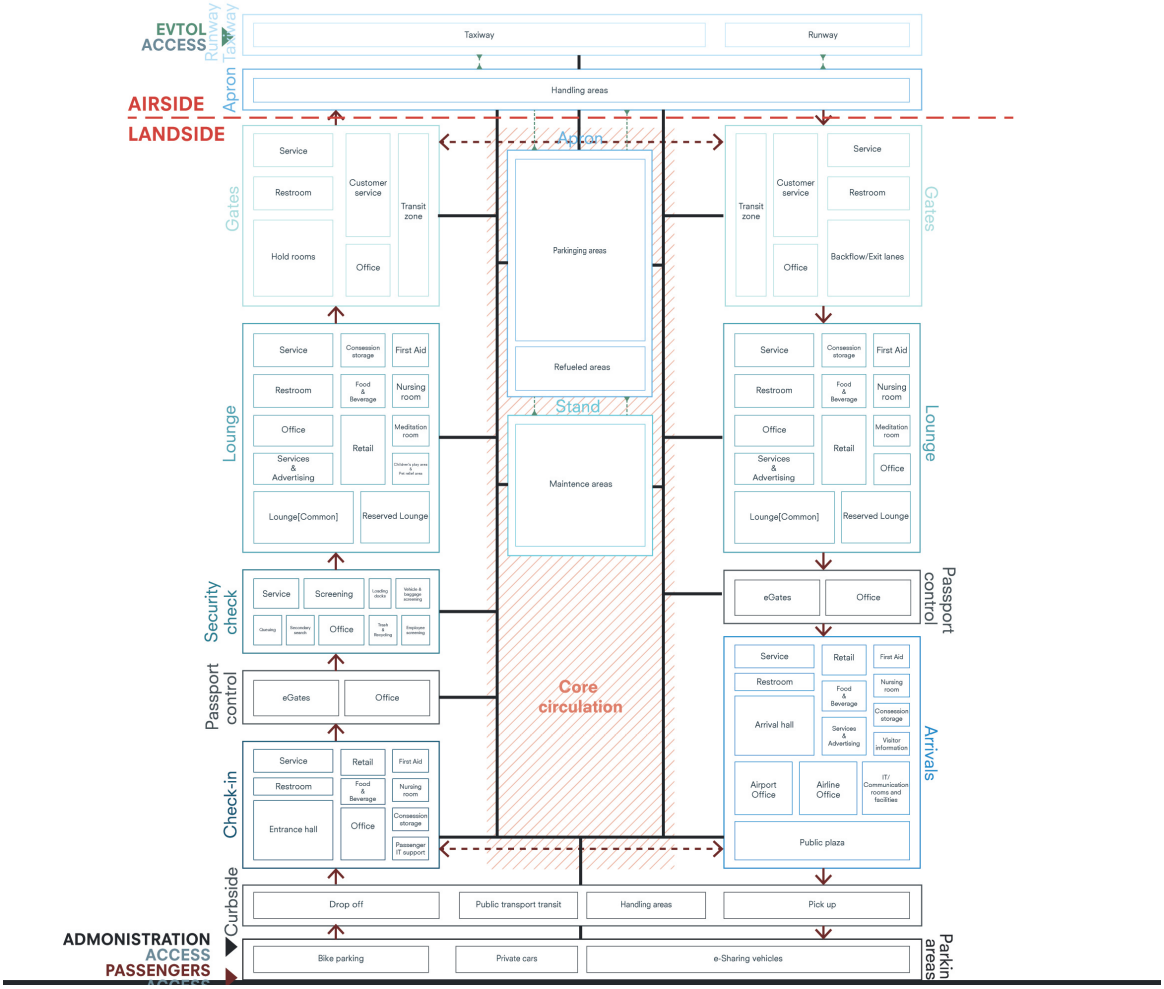

Figure 25. Relation scheme based on the flow of passengers, administration adn eVTOLs

4.2 CLIENT

The government owns airports and infrastructure with a contract with private stakeholders. The responsibility for the infrastructure of the vertiport will lie with the government, while stakeholders contribute to the physical assets. In the context of airports, the airlines serve as stakeholders, whereas, in the case of vertiports, eVTOL developers like Lilium, Volocopter, Uber, Airbus and Kelekona play a crucial role. These eVTOL developers emerge as significant stakeholders, contributing essential hardware components. Concurrently, Bolt, Uber, and BVG will provide software services to support the passenger journey experience.

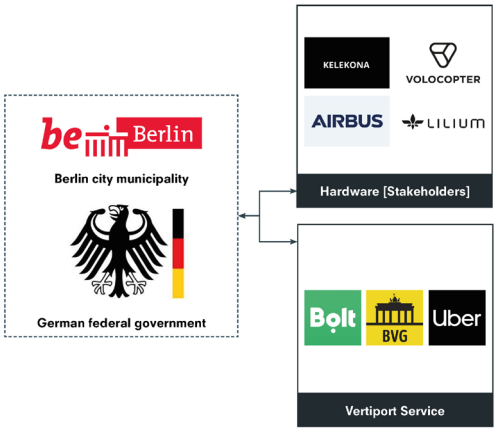

Figure 26. The division of ownership,key stakeholders of eVTOLs and service stakeholders

4.3 SITE

According to the site research and analysis, there are three site ambitions: challenging the verticality of aviation infrastructure, introducing a new layer of air mobility and creating an integrated urbanscape. Vertiport as an innovative aviation infrastructure is essential to identify the future proof of the pursuit of zero-emission, environmental sustainability and new architectural expression of the building typology. Thus, the three ambitions shall contribute to the vision of the Vertiport in Berlin, underlining its role as a future-proof aviation infrastructure and as a new addition to the public space realm. Following the underlined site conditions and the programme analysis, the research process moves to the final stage: massing study. The massing study has provided a good look into how combining the necessary program relation scheme with the site conditions is possible. After completing the study of positioning, the vertiport will be placed at the plot right next to the water surface rather than close to the train station and in the waterway to maximise accessibility as well as connectivity with the surrounding vicinity. The massing study concludes that the rotated tower with the research of relation scheme and pier layout for eVTOLs operation is suitable for the vertiport design in the next step. However, the point that still needs to be mentioned is that the further spatial organisation and intervention of material study should consist of the following design phase of the volume study.

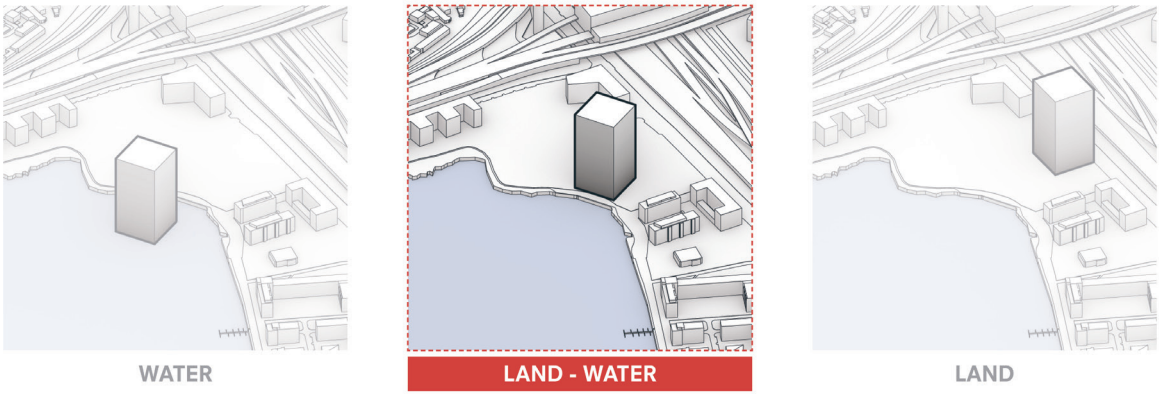

Figure 27. Positioning study of vertiport

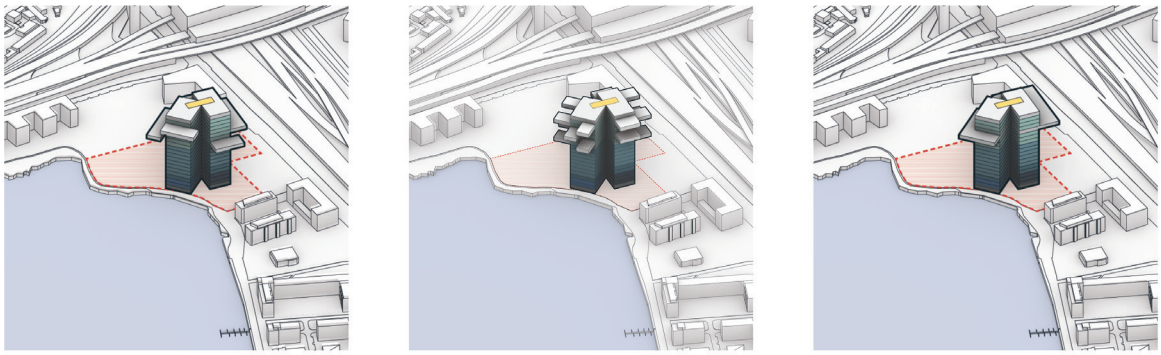

Figure 28. Iteration of massing study

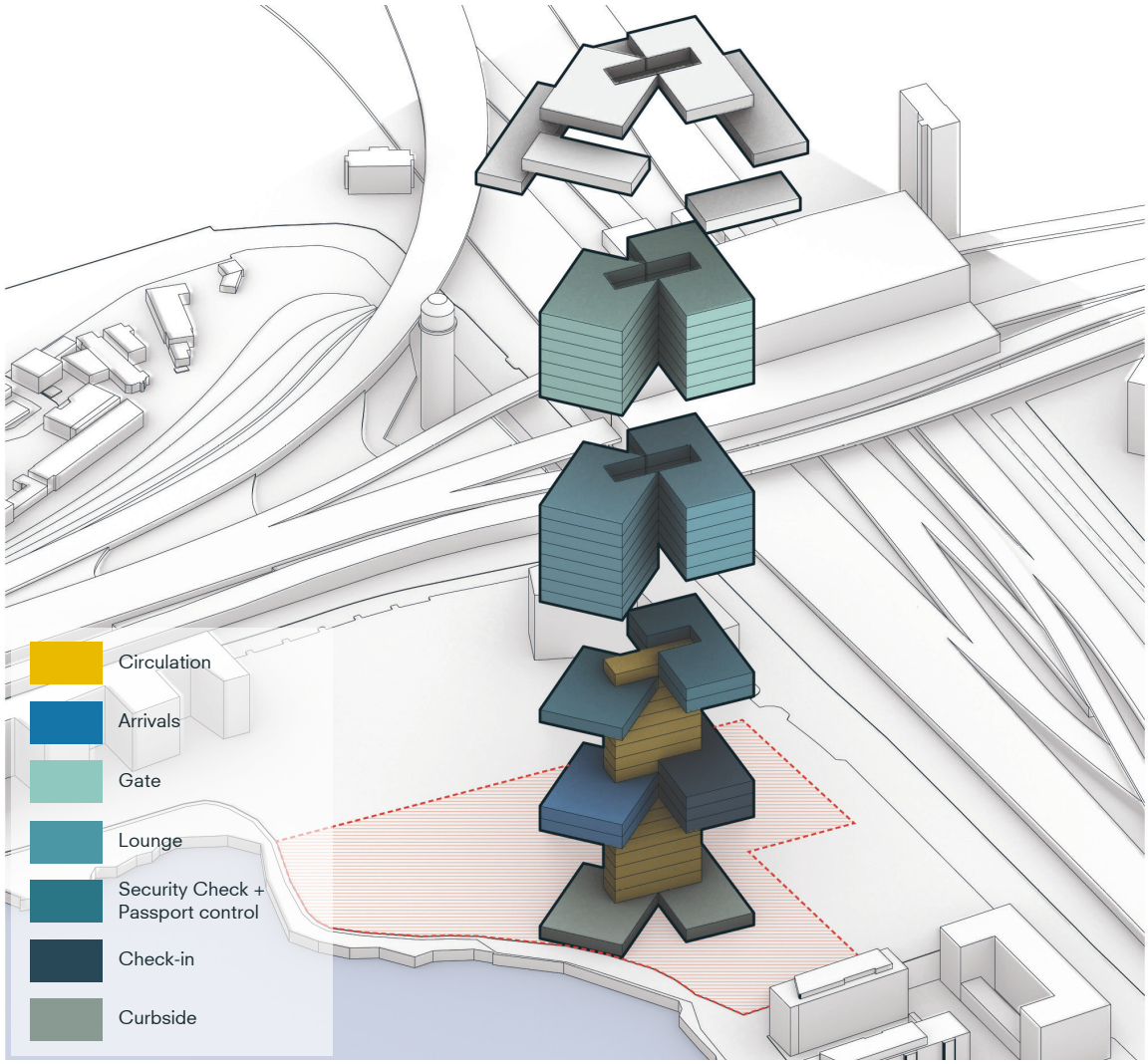

Figure 29. Exploded isometric of the selected massing[LAYERS]

4.4 CONCLUSION

Upon completion of the design brief, the graduation project will progress to the design phase, which is built upon the specifications outlined in this article, along with the subsequent inquiries:

Upon completion of the design brief, the graduation project will progress to the design phase, which is built upon the specifications outlined in this article, along with the subsequent inquiries:

1. How can **materiality** affect the **architectural expression** of **an aviation infrastructure design**?

2. What **spatial evolution** can be challenged in a vertiport design?

Although not comprehensive, these two queries encompass aspects of architectural design, including spatial organization, material selection, and infrastructure design. The design brief seeks to provide a structured framework with specific criteria for the vertiport design in Berlin city. However, the examination of spaces and programs will take on a more practical dimension in the upcoming phase. Consequently, research into materiality, various spaces within the vertiport, and aesthetic exploration will be conducted to extend the research process beyond the initial research question and the theme of the Complex Projects studio.

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5.2 FIGURES