RESEARCH SUPERSONIC WORLDPORT

COMPLEX PROJECTS
ENERGY

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INDEX

ABSTRACT

Airports are gateways in global connectivity that demand efficient and climate-conscious solutions due to the increasing number of air traffic passengers, the demand becomes even more important. Innovations such as supersonic airplanes, hydrogen fuels, biometrics, self-safe check-ins, and automated baggage handling are proposed solutions to the problem of increasing the number of passengers, efficiency, and safety. However to apply these solutions the functioning of airports needs to be reimagined. This research explores the paradigm shift needed in airport design, emphasizing technological innovations and collaborative spaces to address environmental challenges and support the dynamic growth of the aviation industry. The theoretical foundation of this research is based on theories of future aviation that guide and support the research. Employing methods like literature research, fieldwork, and interviews establish well-rounded research. Consequently, the research aims to yield outcomes that will inform and support design decisions.

01 INTRO

Airports play a pivotal role in global connectivity, serving as gateways to the world. These gateways are complex structures where passenger flows must be watched, journey times shortened, high standards of security maintained and many different needs catered for all under one roof. Due to a substantial increase in the demand for airport capacity, driven by a rising number of passengers, air travel has become more common to billions of travellers. In 2012, 2.8 billion passengers utilized air travel. In the International Air Transport Association 2050 report, experts anticipate that by 2050, aviation transport will accommodate 16 billion passengers with a continuous upward trend (IATA 2011). Meeting this demand poses a significant challenge, necessitating efficient and climate-conscious organization of the entire operational process involved in aircraft activities. Considering that the aviation industry is at the forefront of technological innovation and aerospace engineering breakthroughs it seems that this demand can be met. However, in a world where sustainable, efficient, and effective innovations become a reality, the megastructure airport designs focused on passing the time must be reimagined. Additionally, integrating knowledge about technology across various disciplines has become increasingly vital in advancing innovation. (Abbas et al., 2013) Airports, as dynamic and complex transportation hubs, can benefit immensely from adopting a multi-disciplinary approach to foster technological advancements. That is why airports should not only cater to travel but also become innovation hubs, where various specialists from around the world can exchange knowledge.

1.1. PROBLEM STATEMENT

The modern aviation industry is experiencing rapid growth, evident in the alarming increase in passenger volumes. Meeting the demand of increasing air passengers by implementing new technologies not only necessitates a meticulous reorganization of the operational processes within airports but also demands a conscientious approach toward climate-conscious practices. The emergence of smart airports, integrating technologies like supersonic travel, hydrogen fuels, biometrics, self-check-ins, and automated baggage handling are transforming the industry (Rajapaksha & Jayasuriya, 2020).
Climate-conscious practices are one of the most important aspects of innovations since the world is facing an environmental crisis that poses a threat not only to Europe but the whole world. That is why the European Commission is enforcing different proposals like the European Green Deal in which making Europe the first climate-neutral continent in the world is a binding commitment. (Delivering the European Green Deal, 2021)
But making policies is not enough, professionals all over the world work on helping to reach the climate-neutral goal by creating better and faster technologies, one of the fields where a lot of innovation is happening is the aviation industry. Various companies are developing commercial planes that travel faster than the speed of sound. According to Destinus, their airplanes will fly 'At velocities more than 5 times the speed of sound' people will be able to reach the other side of the world within 3 to 4 hours. The aircraft will be more compact compared to traditional intercontinental planes, accommodating 100 passengers instead of the typical 500-600 passengers. Additionally, this will be made possible on Co2-neutral, green hydrogen fuel by the year 2032 (Destinus, 2023).). Another company claiming to develop supersonic airplanes, which are already ordered by various airlines, like American Airlines or Japan Airlines, is BoomSupersonic. They are developing commercial airplanes that fly two times faster than the speed of sound and can accommodate up to 88 passengers (Boom - Supersonic Passenger Airplanes, 2023).
To make these innovations environmentally responsible hydrogen is often proposed as a new aviation fuel. Hydrogen can be used as a clean fuel, and it has the advantage of of producing water vapor as the primary byproduct when burned, making it a potentially environmentally friendly option.

However, using hydrogen in aviation also poses significant technical challenges. As described by Jacobs (2022) there are three potential airport infrastructure scenarios for the supply and storage of hydrogen for use in fuelling hydrogen-powered aircraft:
- the delivery of liquid hydrogen directly to the airport by truck;
- the use of a hydrogen gas pipeline with on-site liquefaction;
- the use of electrolysis for hydrogen production on-site at the airport.

The last option being the most fitted for a global international airport, because the energy can be also used to provide power to the terminal building and ground handling, creating a self-sufficient airport. Of course, this kind of infrastructure needs space, and according to the Aerospace Technology Institute (2022) an airport with a flow of ca. 40 million passengers a year needs to provide 130.000m2 of space to implement this strategy.
At the moment all airports are designed to accommodate the long waiting times with various duty-free shops and restaurants. These are also a big part of the airport's profit, which will be not discussed in detail in this research. This can be seen in the latest designs like Beijing Daxing International Airport or Jewel Changi Airport, each including around 300 shops and restaurants. (Phoon, 2019) The current waiting and check-in times at airports, averaging around three hours, appear excessively prolonged in light of the supersonic speeds associated with future air travel. Since the future is all about environment, efficiency, and effectiveness, technological innovations regarding check-ins and baggage handling are relevant topics that can influence the architecture of future airports.

Micro-X has developed a highly promising check-in system in terms of both time efficiency and safety. They assert that their system ensures a secure check-in process within just 30 seconds, it includes baggage screening, and their check-in stations occpy only one-seventh of the space required by traditional check-in setups (Bogaisky, 2023). This could mean that a much larger number of passengers could be handled in a smaller area of an airport. Another highly promising advancement in airport baggage handling technology is the Fleet automated baggage handling. Its capabilities include alleviating workers from physically demanding tasks, improving flight security, monitoring luggage until it's loaded into the aircraft, and optimizing the quality and packing density with its patented picking unit. (Van der Lande, 2023.) This automated handling of baggage could result in a space with no people so for example there would be no need for daylight.

Lastly, as mentioned by Abbas et al. (2013) a key to successful innovations is a multi-disciplinary approach. At the moment aviation companies are often competing with each other instead of working together for a better future. (Proponent, 2018) That is why it is important to create a space where various experts from around the world can work together.
Considering all the aviation innovations, it is clear that there is a need for a new approach in airport design, where new flows based on future capacity of airplanes and the speed of flows are taken into consideration. Additionally, a yet-to-be-designed multi-disciplinary space for innovative growth should be implemented in the airport area.

1.2. RESEARCH QUESTIONS

Taking into account the environmental challenges and challenges posed by a growing number of passengers and technological innovations, the following main question should be asked regarding the future architecture of airports:

- How to design an airport to accommodate the reconfigured European aviation industry?

Supported by the following sub-questions:
What will change in airport design based on the anticipated increase in passenger volumes?

- What processes at airports will be changed due to new flows based on technological innovations and different aircraft capacities and speeds?
- How do the environmental implications impact airport design considering challenges associated with the adoption of supersonic travel, hydrogen fuels, and other technological innovations in airport operations?
- How can airports effectively implement hydrogen infrastructure for aviation, considering the technical challenges?
- Which architectural strategies can be employed to create multi-disciplinary spaces within airports, fostering collaboration among experts from various fields in the aviation industry?

02 RESEARCH FRAMEWORK

The conceptual framework is based on two scientific articles describing the main aspects of future airports, followed by innovations regarding airplanes, hydrogen fuel, check-in and baggage handling systems in the commercial aviation industry.

2.1. THEORETICAL FRAMEWORK

The theoretical framework is based on an article published in Aviation Journal in 2017 written by Alexander Medvedev, Professor head of the Chair of Aviation transport, member of the TTI Research committee, member of the Latvian Operation Research Society; member of the Latvian Association, professor at institutions of higher education, manager of theoretical training and examination of the EASA Part-147 training Centre at TTI Academic and professional aviation centre TSI/APAC, Iyad Alomar, MSc in engineering, training manager and Deputy of Quality manager of the EASA Part-147 training Centre at TSI/APAC (TTI Academic and professional aviation centre) and Slawomir Augustyn, Assistant Professor, an assistant Professor at the National Defence University (Warsaw, Poland). Where they describe how in terminal buildings airlines, airport operators, and businesses are collectively aiming to offer uninterrupted services and support to passengers and airport visitors. Medvedev et al. (2017) foresee that the future visions of modern airports will revolve around three main elements:

- Enhancing the comfort of passengers during the handling process;
- Increasing capacity and quality on the ground in the terminal buildings and the air in airplanes;
- Minimizing the environmental footprint through initiatives such as clean energy projects to reduce CO2 emissions.

Additionally, as explained in the article "Airports of the Future: The Development of Airport Systems" written by Professor De Neufville, an expert in Engineering Systems and Civil and Environmental Engineering at the Massachusetts Institute of Technology, there will be an evolution in airport systems. He describes how there are emerging trends that point towards a future with more focused specialization in airport operations. De Neufville (2003) categorizes the following three major airport types:

- Short-haul airports: These airports aim to provide cost-effective services, particularly for short-haul flights;
- Cargo airports: Dedicated to serving integrated freight operators, these airports prioritize the efficient handling of cargo operations to meet the demands of the industry (de Neufville, 2003);
- Day and night intercontinental airports: These airports cater to global international passenger traffic, operating around the clock to meet the demands of huge passenger flows.

Considering Europe's intent to promote high-speed train travel within the continent, designing an airport focused on short-haul flights would not fit into the vision of the future (European Court of Auditors, 2018). Cargo airports, which are specialized for transporting goods, also deviate from the human-centric nature of commercial airports

and do not fit into the established framework. The most reasonable focus lies on intercontinental airports, considering the advancements in supersonic travel are primarily aimed at long-haul flights. Moreover, the vision of Europe to advance high-speed train travel across the continent further emphasizes the strategic significance of intercontinental airports, making them a relevant objective in the broader context of Europe, Germany, and Berlin.
That is why the researched innovations need to be related to at least one of the topics described by Medvedev et al. and fall into the context of intercontinental commercial travel. The following aviation innovations are used as a framework for this research: supersonic air travel, hydrogen fuel, biometric security, self-check-in stations, automated baggage handling systems, and online duty-free shopping.

2.2. RELEVANCE

Airports stand as crucial nodes in global connectivity, functioning as gateways to the world. With a growing air travel demand, reaching 16 billion passengers by 2050, the aviation industry faces the challenge of efficiently accommodating this growth while trying to minimize its effects on the environment. 'Technological innovation is a "double-edged sword" and is considered a significant contributor to issues, such as climate change, ecological imbalances, and worsening pollution, and an effective means to solve environmental and sustainable development problems' (Fan & Shahbaz, 2023). Therefore it is important to rethink airport design to facilitate new efficient, effective, and environment-conscious technologies and collaborative spaces for airport staff, airlines, and technology partners encouraging innovation. These spaces can serve as hubs for collaborative efforts in advancing airport technologies, improving operational processes, and minimizing the contribution to climate change.

03 RESEARCH METHODS

To conduct this research field, literature, mapping, and interview methodologies are used. Field and interview methodologies are used to verify, support, and complement the literature and mapping methodology.

3.1. LITERATURE RESEARCH

In order to create a program for a new type of airport, the already existing airport programs need to be analysed. The case study approach will be applied. Airports consist of a landside, a terminal and an airside, these general aspects can be researched in a less detailed way. After that considering area-yearly passenger flow, a ratio can be determined and the program of the most efficient airports can be researched in more detail. This will be done by using the existing floor plans and calculating the percentages of different spaces. This way will ensure a list of necessary spaces is established. After that using the described possibilities of various technological innovations, the program can be adapted. Next, the new spaces that are needed to support an intercontinental innovation hub can be added. After completing this process architectural specialist should be consulted.

3.2. LITERATURE AND INTERVIEW

Literature, online resources, and interviews will support the research of the possible client. Finding out what parties own the airports around the world is the first step to getting an understanding of the possible client. Additionally, since this research is not about a general airport, companies investing and creating applicable technological innovations in the field of aviation need to be researched. This way it can establish what other companies could be a part of this project. Contacting the companies by email or phone is a possibility. Finally, to verify if the innovations of various companies are realistic an interview with a professor of aerospace engineering at TU Delft should be held.

3.3. MAPPING AND FIELD RESEARCH

The fitting site for such a huge and important structure as an airport is crucial. To establish if the site is suitable for an airport, research based on mapping and field visit is necessary. Finding out the connectivity and identifying surrounding areas is needed. Additionally, analysing possible future scenarios regarding expansions are important.

04 DESIGN BRIEF

This design brief gives an overview of the current state of the process regarding the program, the client, and the site of the project.

4.1. PROGRAM

To analyse how the airports function and what kind of spaces are needed the following airports are used as references:

- Schiphol
- Frankfurt airport
- Heathrow
- Fiumicino
- Singapore airport
- Hartsfield-Jackson

Looking at the big scale it can be seen that the terminal buildings can have different shapes and forms, however there is a similarity in the way the buildings spread. The terminals seem to have 'arms' which spread to different sides to accommodate as many airplanes as possible. It is also clear that there is a division between the land and airside and the terminal building functions as a gateway to the airside. In front of the terminal buildings, there are various facilities to accommodate the big flow of people. On the land side, every airport has an enormous area of parking spaces, and there are bus stops and train stations, Heathrow additionally even has a metro station. This ensures the connectivity and accessibility of airports. The exact numbers can be seen in figure 3. The average of these can be used to determine the amount of parking spaces needed at the Supersonic airport. On the airside one of the most important aspects is how the airplane runways are positioned, the runways are positioned in a way to make the take-off and landing of airplanes easier. The runways often enclose the terminal building. There are also different configurations of the terminal buildings in connection to the airplanes, which can be seen in figure 5.

According to data from the reference projects, it can be concluded that the airports Heathrow and Hartsfield Jackson can handle the highest number of passengers in the smaller area. The square meter–passenger ratio of Heathrow is 0,0057m2 per passenger and of Hartsfield Jackson 0,0058 per passenger. As a Supersonic Worldport needs to be even more efficient a ratio of 0,0055m2 per passenger should be used. This ratio can be used to determine the starting point of the area needed for Supersonic Worldport after the amount of passengers is established.

Taking into account the European data of air passengers the expected number of intercontinental air passengers in Germany in 2030 can be calculated. In Germany there are a lot of airports, but the main ones are located in the south of Germany. These are the Frankfurt and Munich airports, in total, these airports handle 45% of air travel from and to Germany. Since the policy of Europe is to travel by train the smaller airports can be diminished in the future, which leaves 55% of intercontinental travellers to travel through Supersonic Worldport. This equals to 38.500.000 passengers a year.

The total area of the Supersonic Worldport based on the references should then equal to 211.750m2, however this number needs to be adjusted as innovations and new strategies will be implemented.

Figure 1. Pictures of reference projects

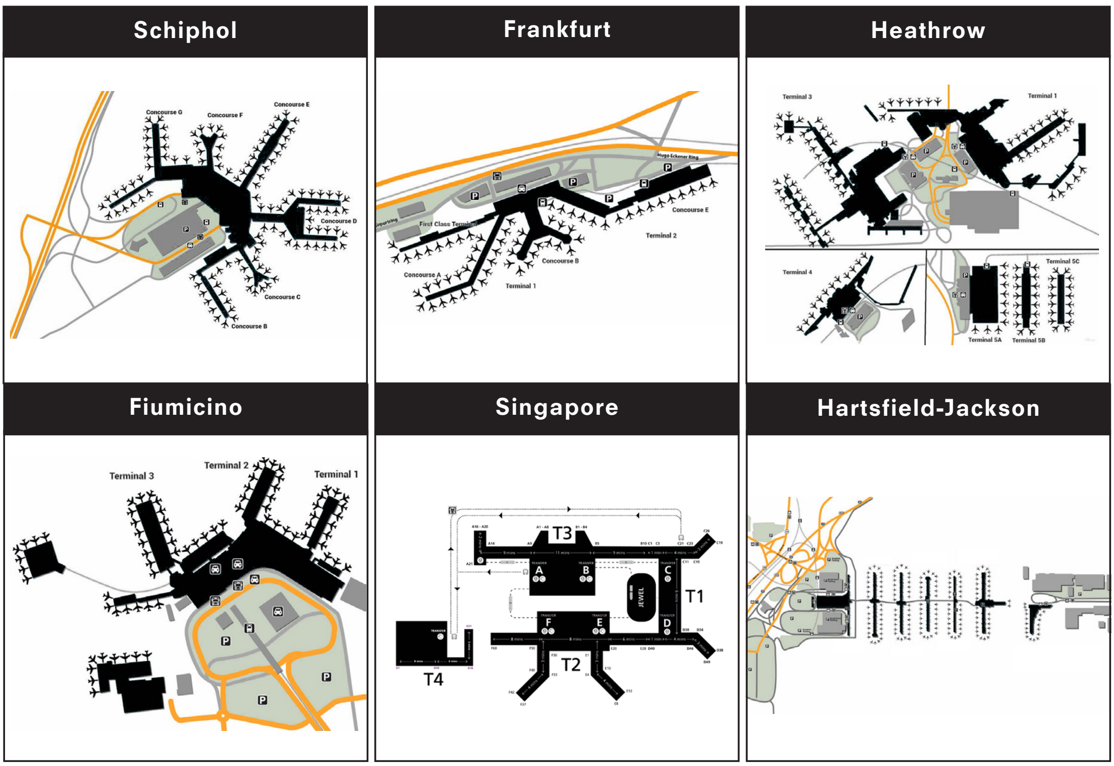


Figure 2. Lay-out of reference projects

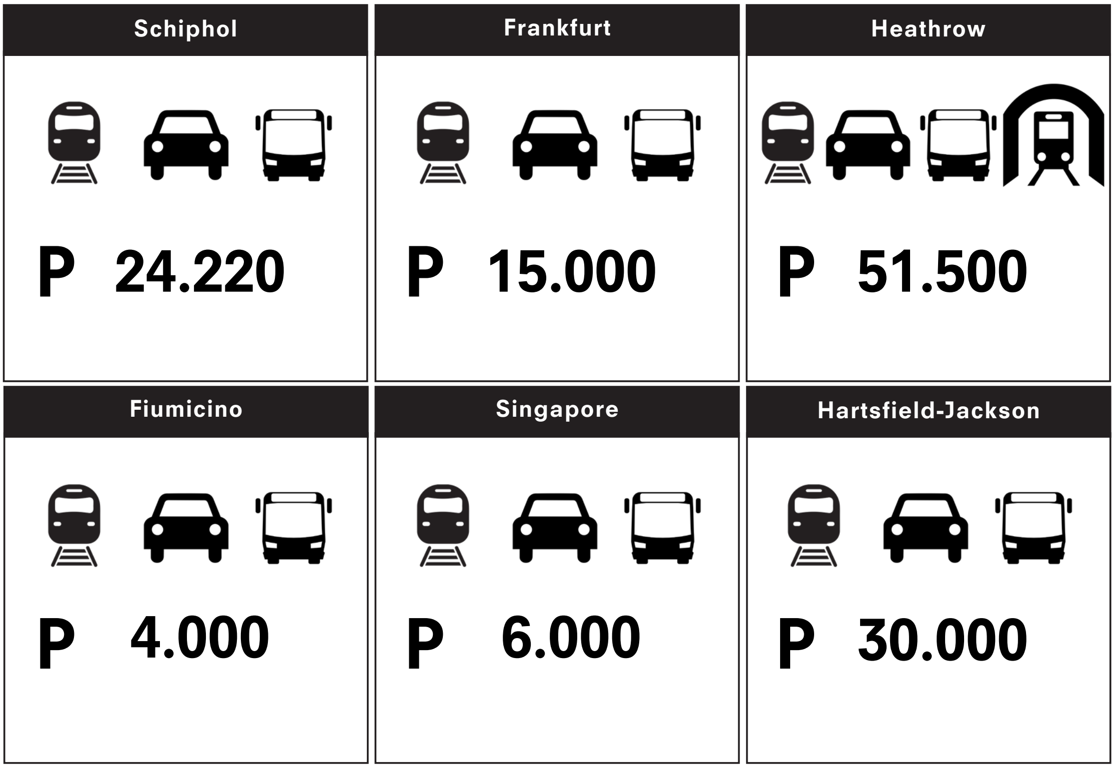


Figure 3. Data of reference projects

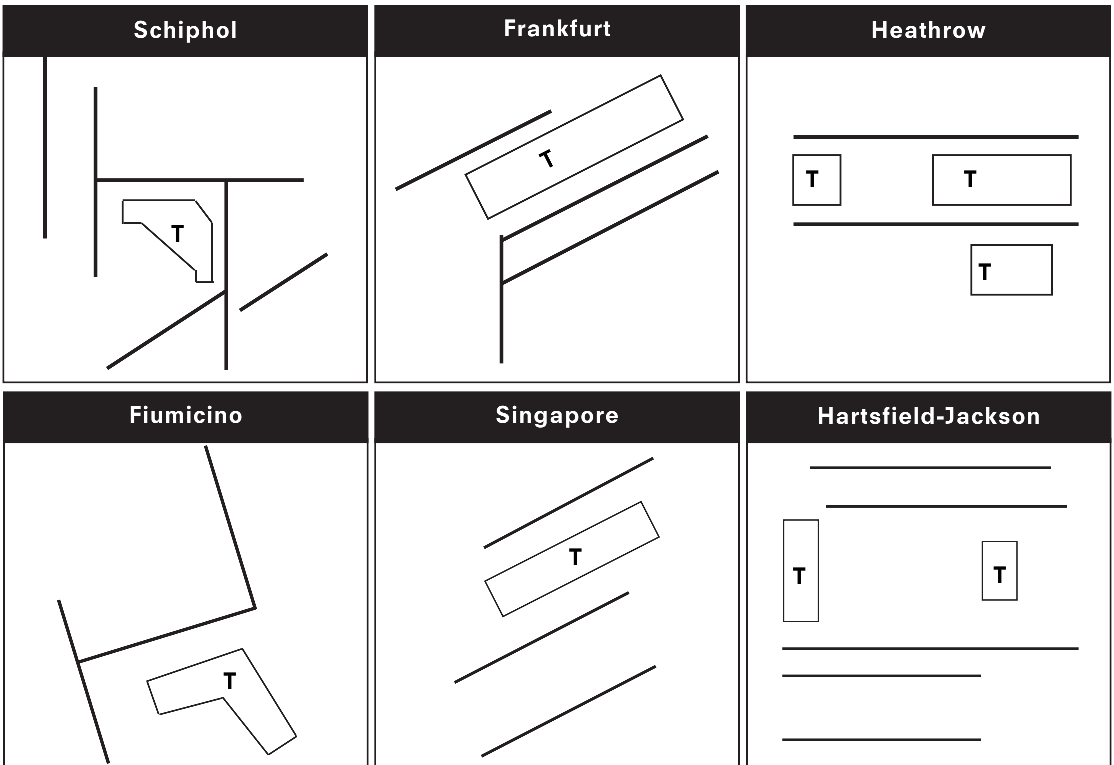


Figure 4. Terminal - runway relation scheme of reference projects

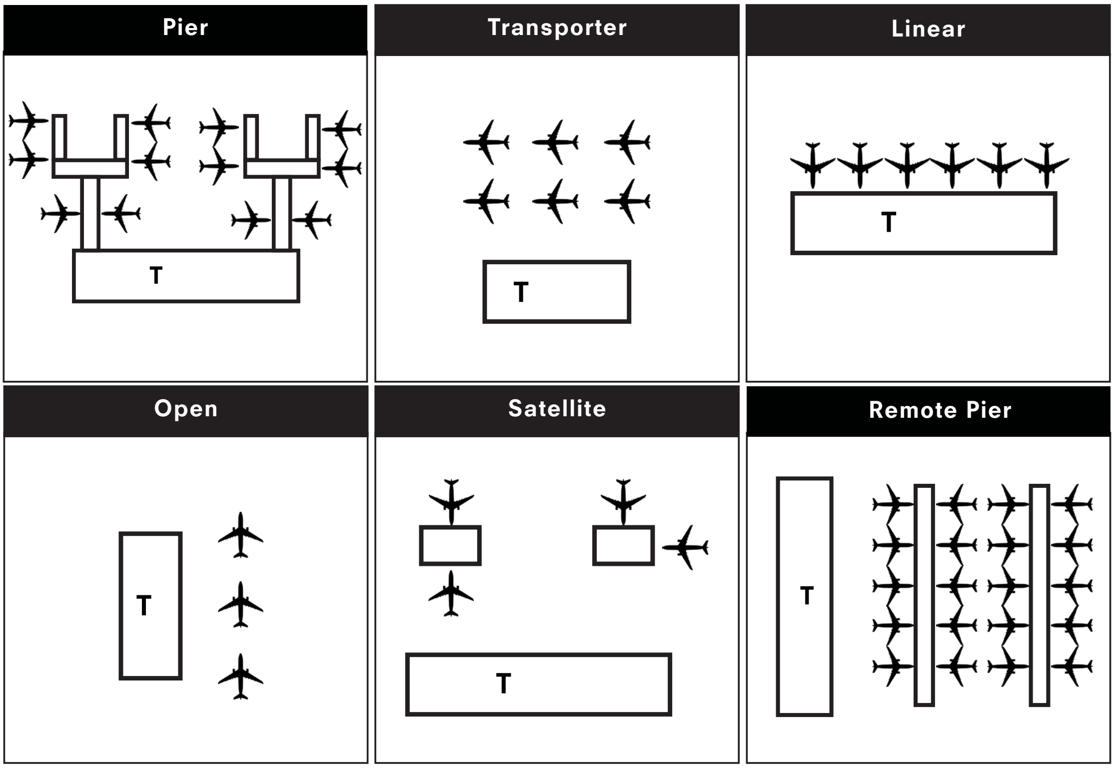


Figure 5. Terminals configurations

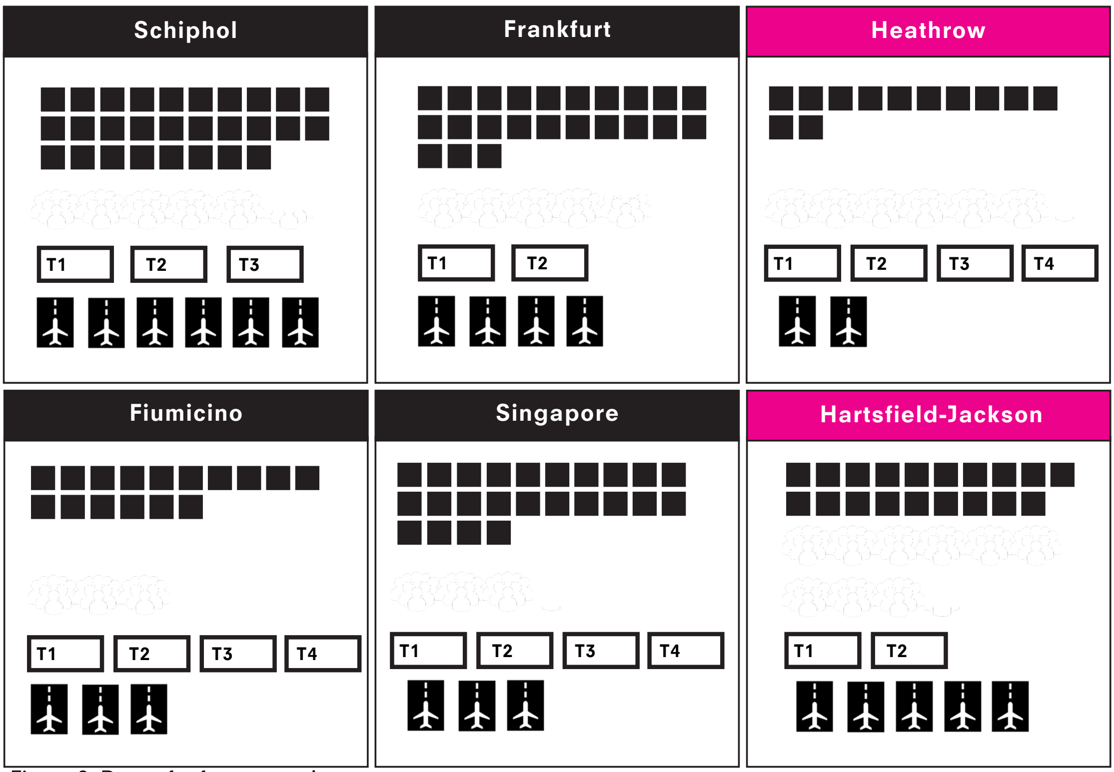


Figure 6. Data of reference projects

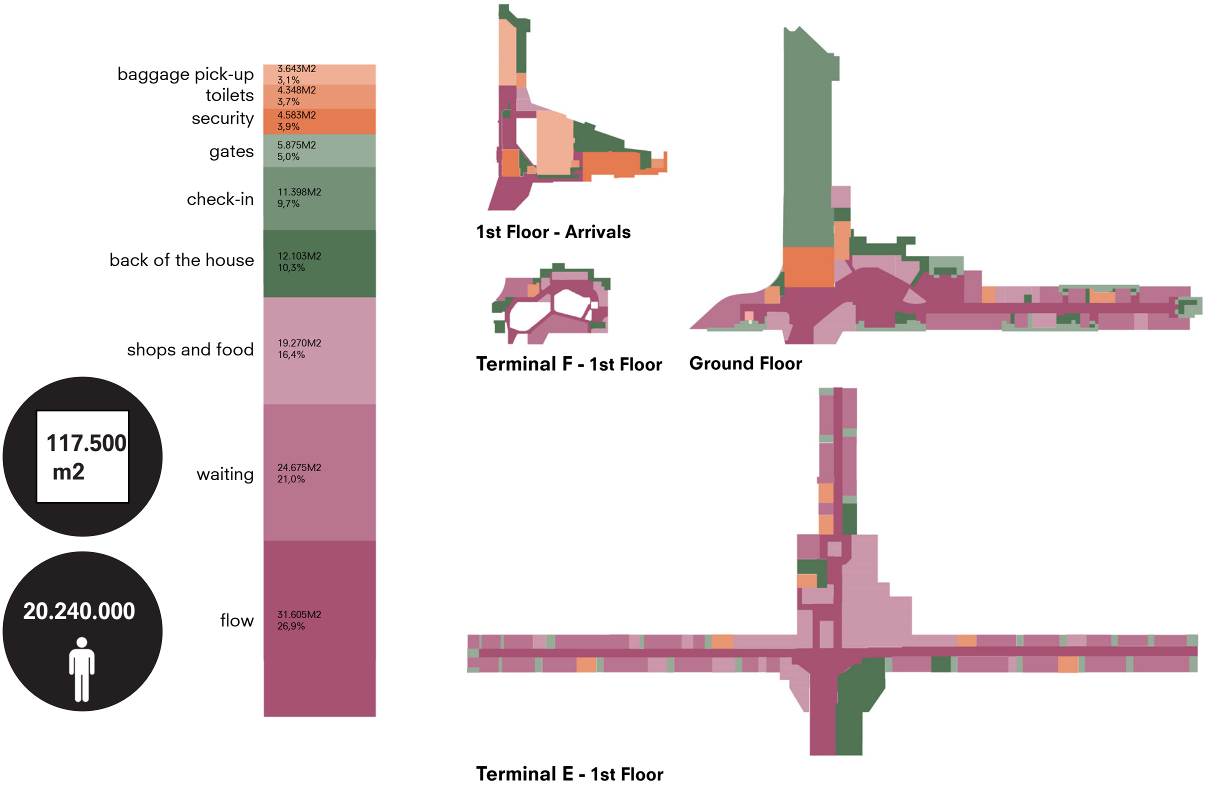


Figure 7. Program bar & floor plan of Hartsfield-Jackson

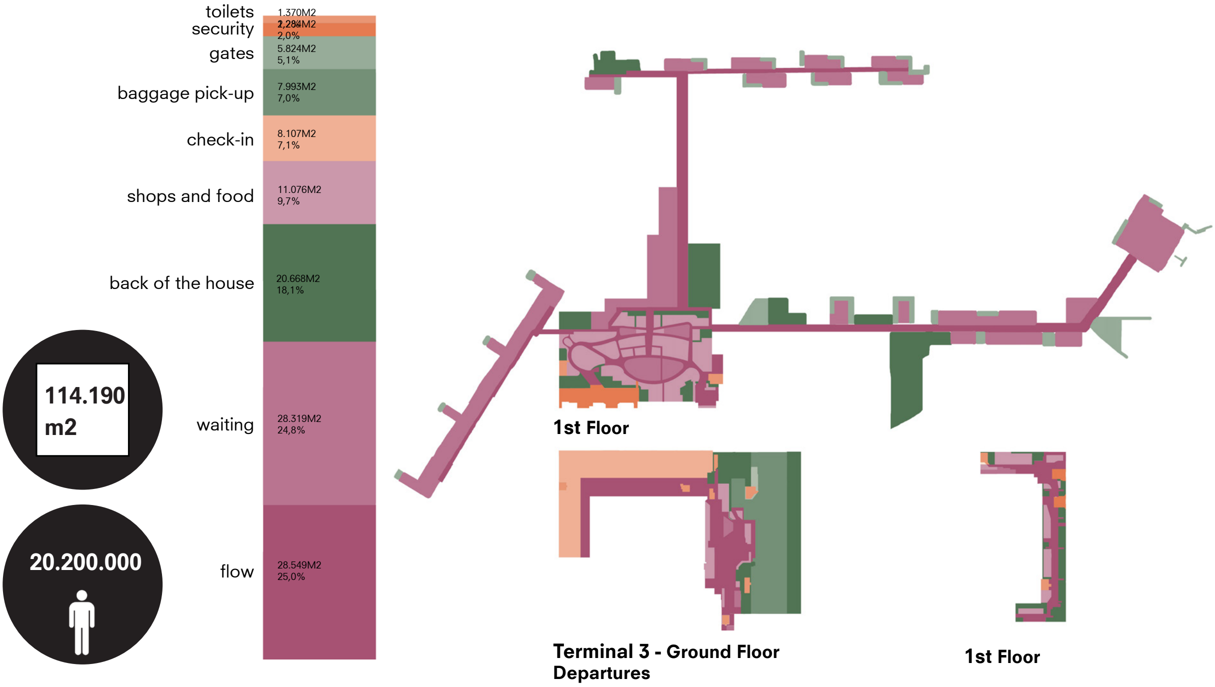


Figure 8. Program bar & floor plan of Heathrow

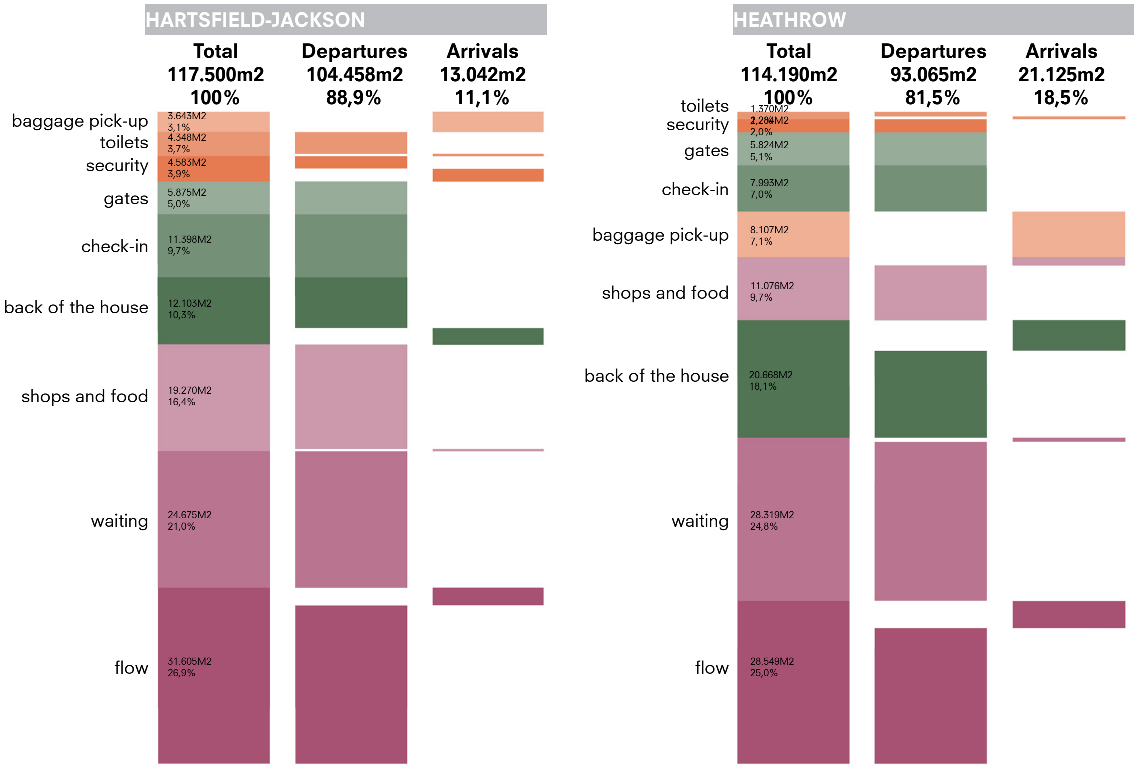


Figure 9. Program bars

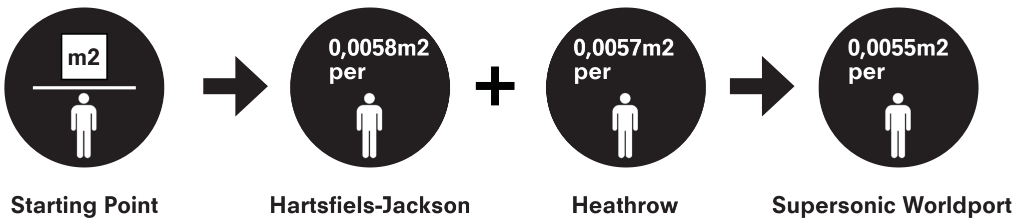


Figure 10. Calculation of m2 per passenger for the Supersonic Worldport

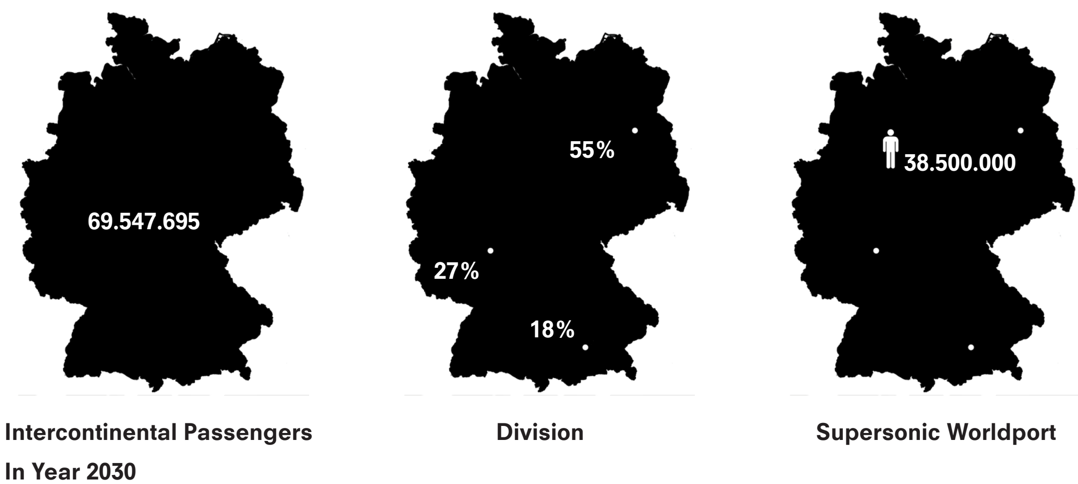


Figure 11. Calculation of passengers at Supersonic Worldport in 2030

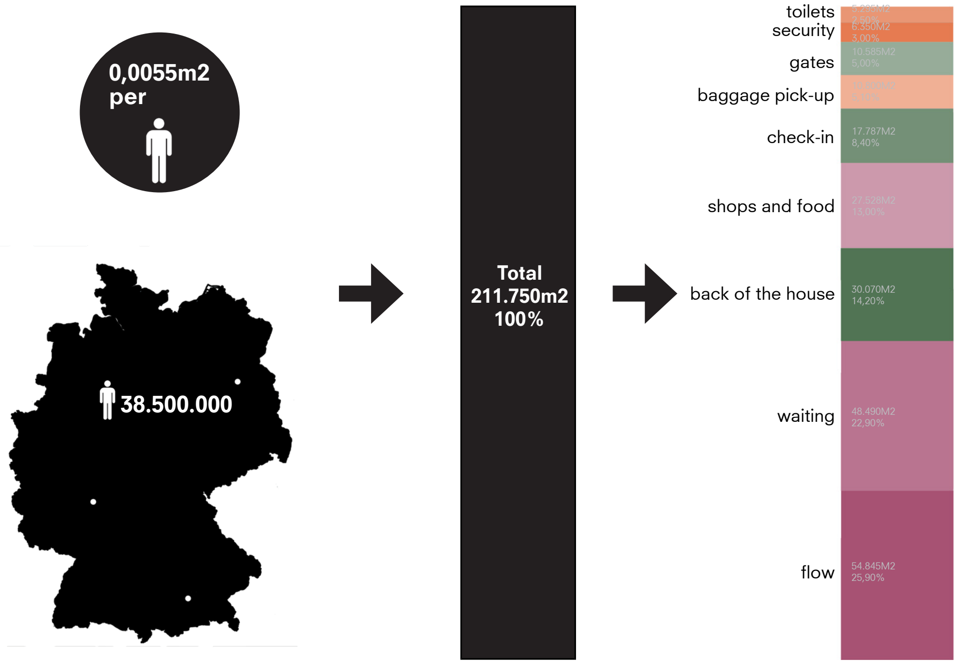


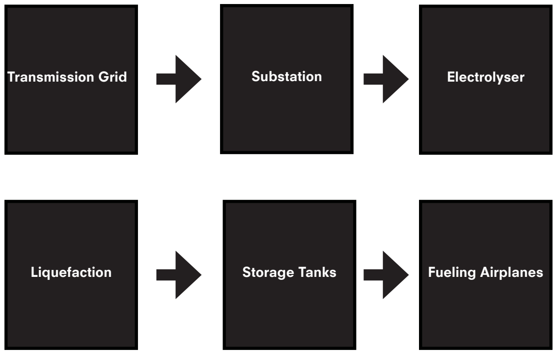
Figure 12. Calculation of m2 at Supersonic Worldport in 2030 based on references

The strategies and innovations that are the heart of this project are:

a. hydrogen fuel
b. supersonic airplanes
c. biometrics
d. automated baggage handling
e. 30 seconds security screenings
f. reserve and collect shopping

Figure 13. Overview of innovations

a. Acording to Aerospace Technology Institute (2022) there are three ways hydrogen can be implemented into airports. Option 1 is producing hydrogen off-site and transporting it by tanks. Option 2 is also producing hydrogen off-site but supplying it by a gas pipeline, this way hydrogen needs to be only liquefied at the site. The third option includes the whole structure needed to produce hydrogen on-site. Electrolysis, liquefication, and storage are all located near the airport. Which option is the most fitted to a certain airport is based on the scale of the airport, it's environmental goals and available space. For the Supersonic Worldport which is a front-runner of innovation and environmental consciousness, option 3 is the most fitted. When looking for the site, the area needed for the hydrogen structure needs to be taken into account, as it equals 130.000m2.



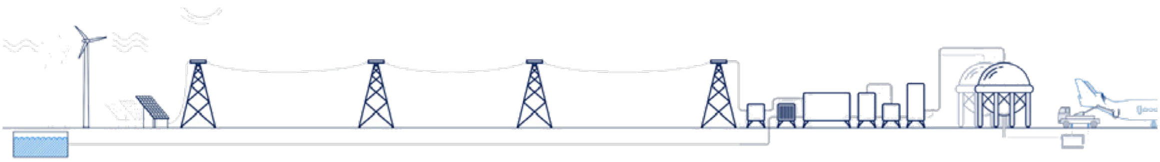


Figure 14. Hydrogen infrastructure

b. The supersonic airplanes claim to need a runway of between 3 – 4 km. The Destinus airplanes will be ca. 12m x 34m and fit around 100 passengers on board. According to Aerospace Technology Institute (2022) airplanes on hydrogen will need 30 minutes for a turnaround. Considering this and the maximum amount of passengers per hour (4.500) it equals to 23 gates. Federal Aviation Administration Advisory Circular (1989) describes that the space between the wings of airplanes needs to be between 6 and 7,5 meters. Considering the shape of the airplanes 7,5 meters is used to calculate the space needed for the gates.

Figure 15. Picture of Supersonic airplane

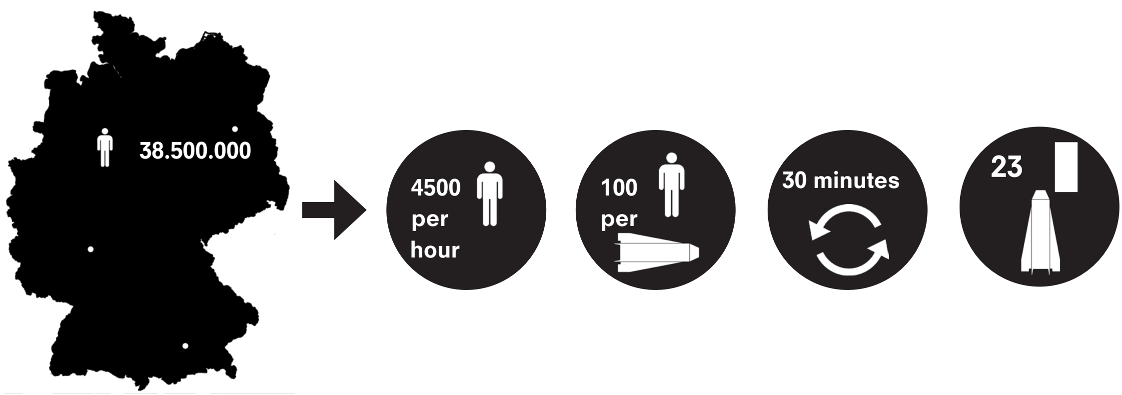


Figure 16. Calculation for the needed gates

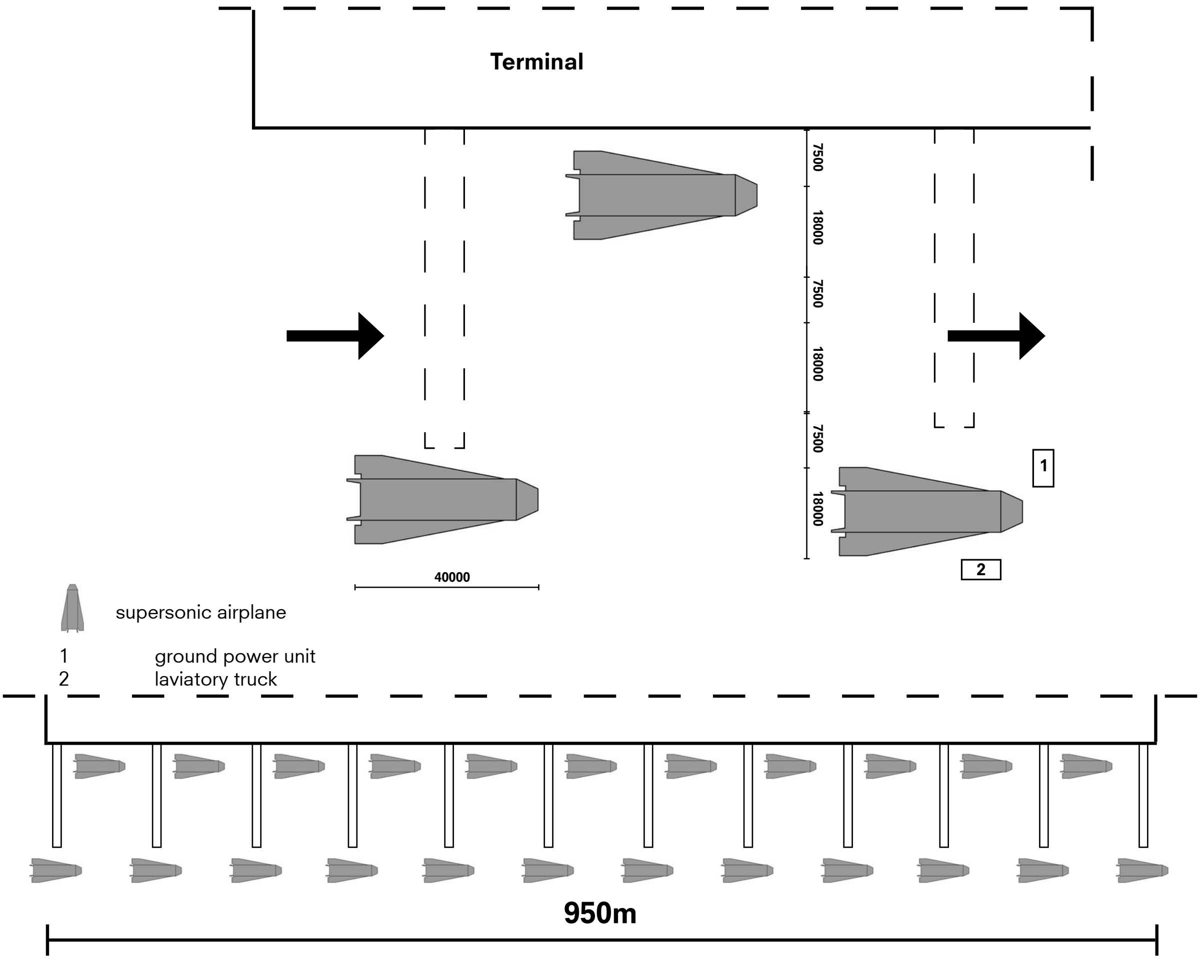


Figure 17. Space needed for the gates

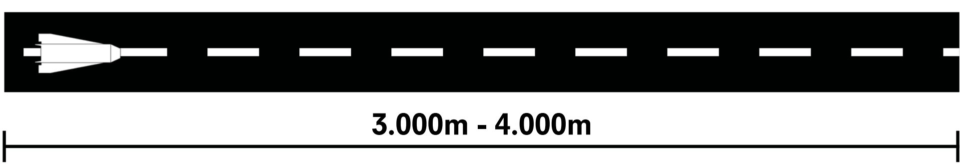


Figure 18. Runway for supersonic airplanes

c. According to a study done at European airports about 85% of passengers walk through biometric gates within 15 seconds without any problems. Unfortunately, elderly people often don't understand how the system works, which results in queues. However, since there are usually 5 or 6 e-gates instead of one traditional one, the process still can go on. The traditional border guard usually takes about 10 seconds to process a person. (Oostveen et al., 2014) This research shows that a combination of human border guards and e-gates is the best option for efficiency.

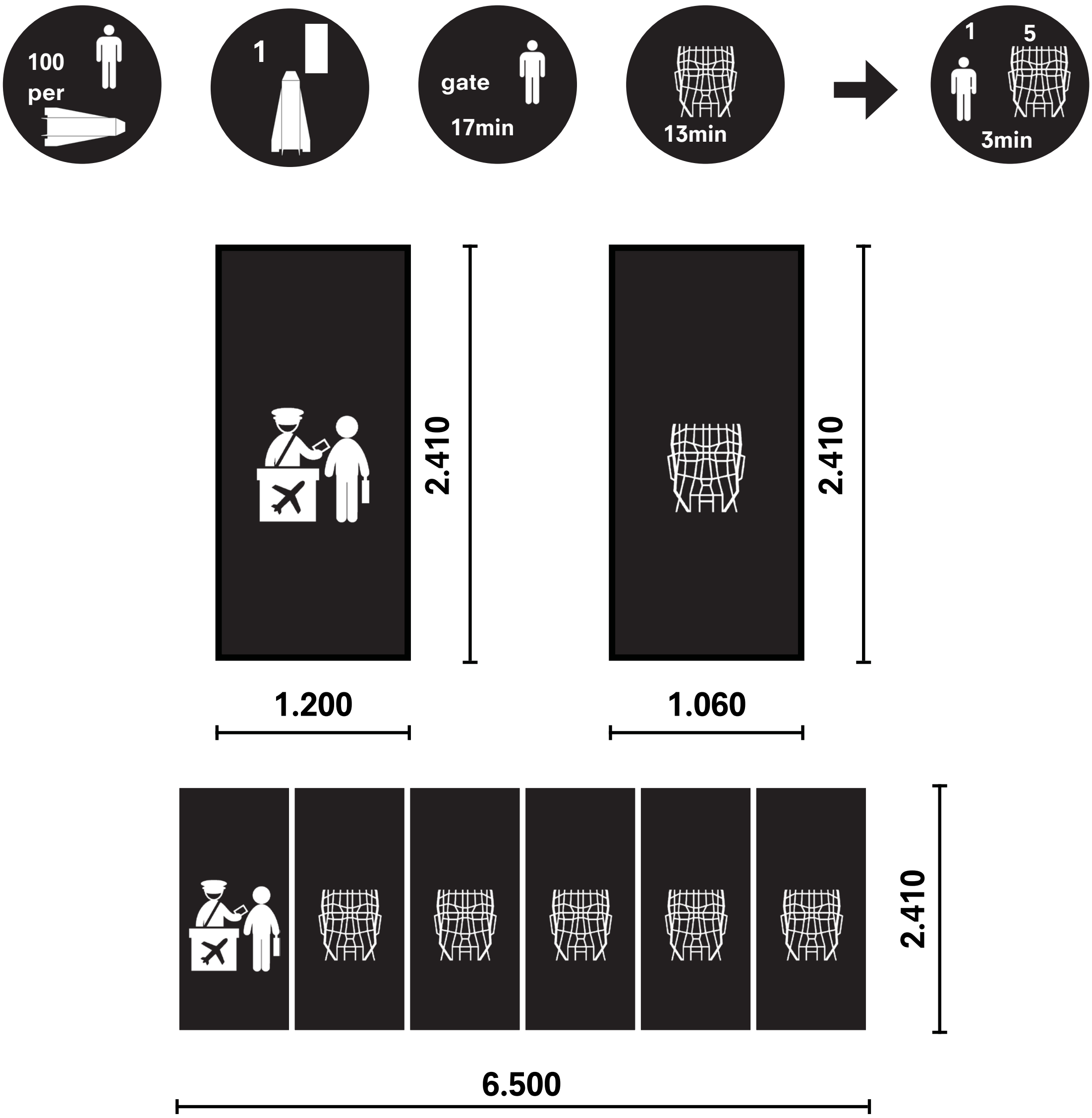


Figure 19. Calculation and measurements needed for e-gates

d. A baggage handling system at airports is a complicated process. After being dropped by the passenger a baggage needs to be checked for any suspicious items and transported to the right airplane by humans. This process can take up to 40 minutes.
By using self-drop points and in the back of the house robots instead of people the process can be made more efficient and safe. To do this the right amount of counters and robots are needed. To calculate this a formula from UNSW Sydney (2003) is used.

Since the Fleet robots handle one baggage at a time, 81% of passengers always have an extra baggage with them and it can take up to 30 minutes to handle one baggage, there are 1320 baggage robots needed in the back of the house. Considering the measurements and the space that these robots need to move, there should be at least 4000m2 of baggage handling area.

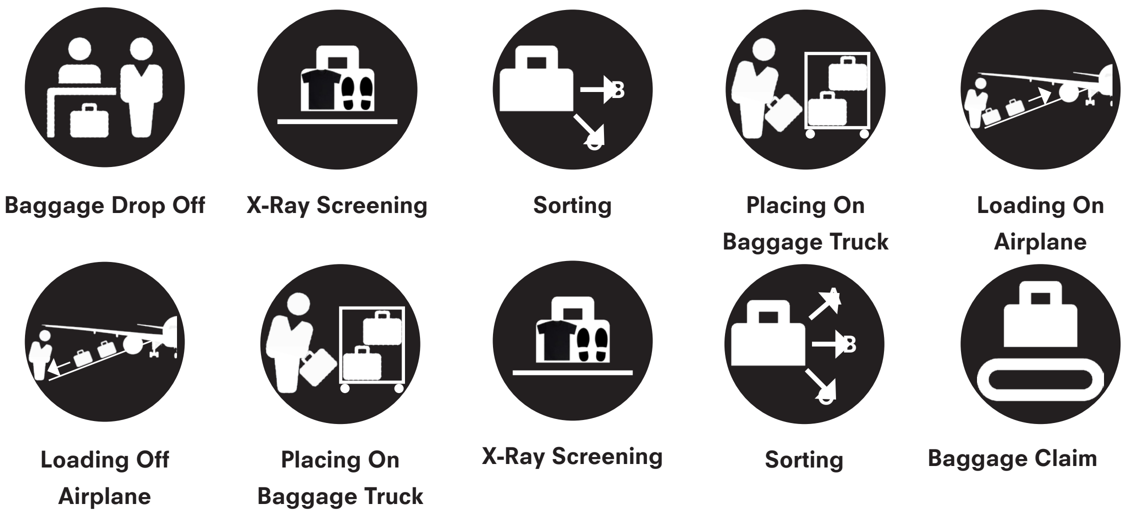


Figure 20. Traditional baggage handling system

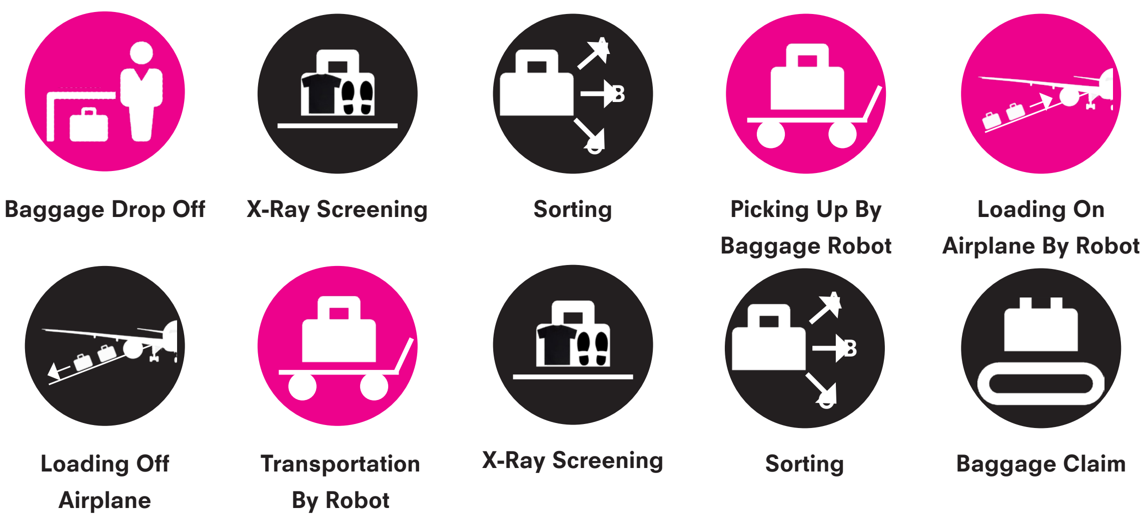


Figure 21. Highlighted the parts changed at the Supersonic airport

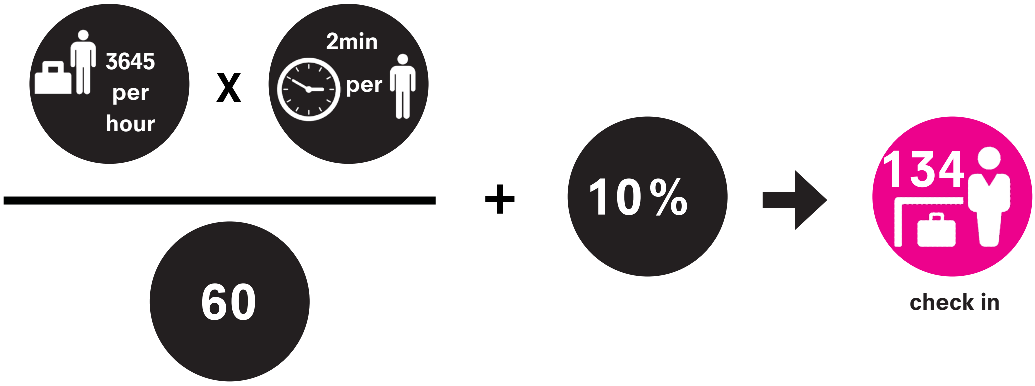


Figure 22. Calculation based on UNSW formula

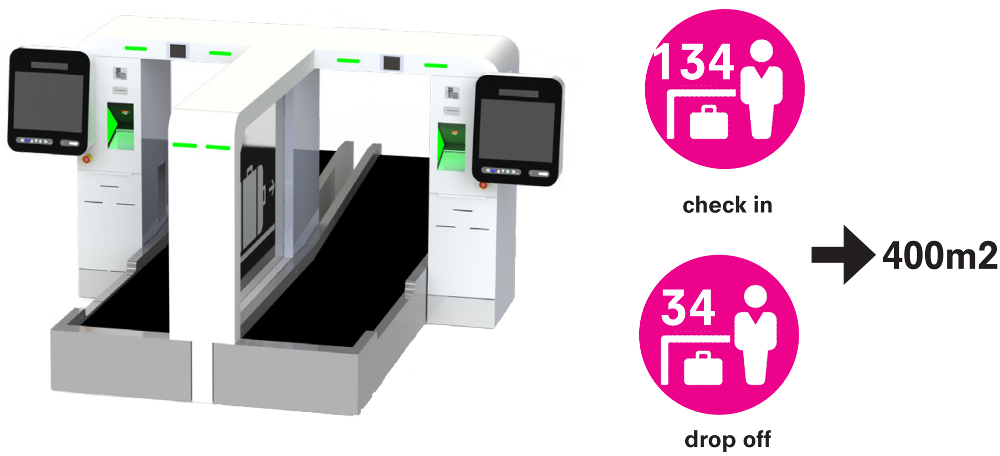


Figure 23. Calculation on space needed for the counters

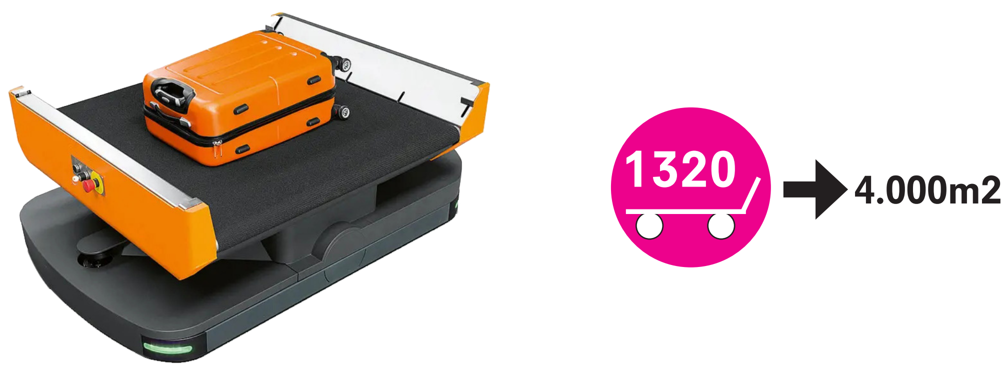


Figure 24. Calculation space needed for the robots

e. Micro-X is a self-check-in that scans the passenger and their carry-on luggage. As stated by Forbes (2023) it happens within 30 seconds and as it can be seen in figure X the box is only 3m by 3m. The amount of check-in boxes is calculated according to the formula from UNSW Sydney (2003). According to the formula the space needed would be 747me, however the producer states that these check-ins need 1/7 of the traditional area, which equals to 2.600m2.

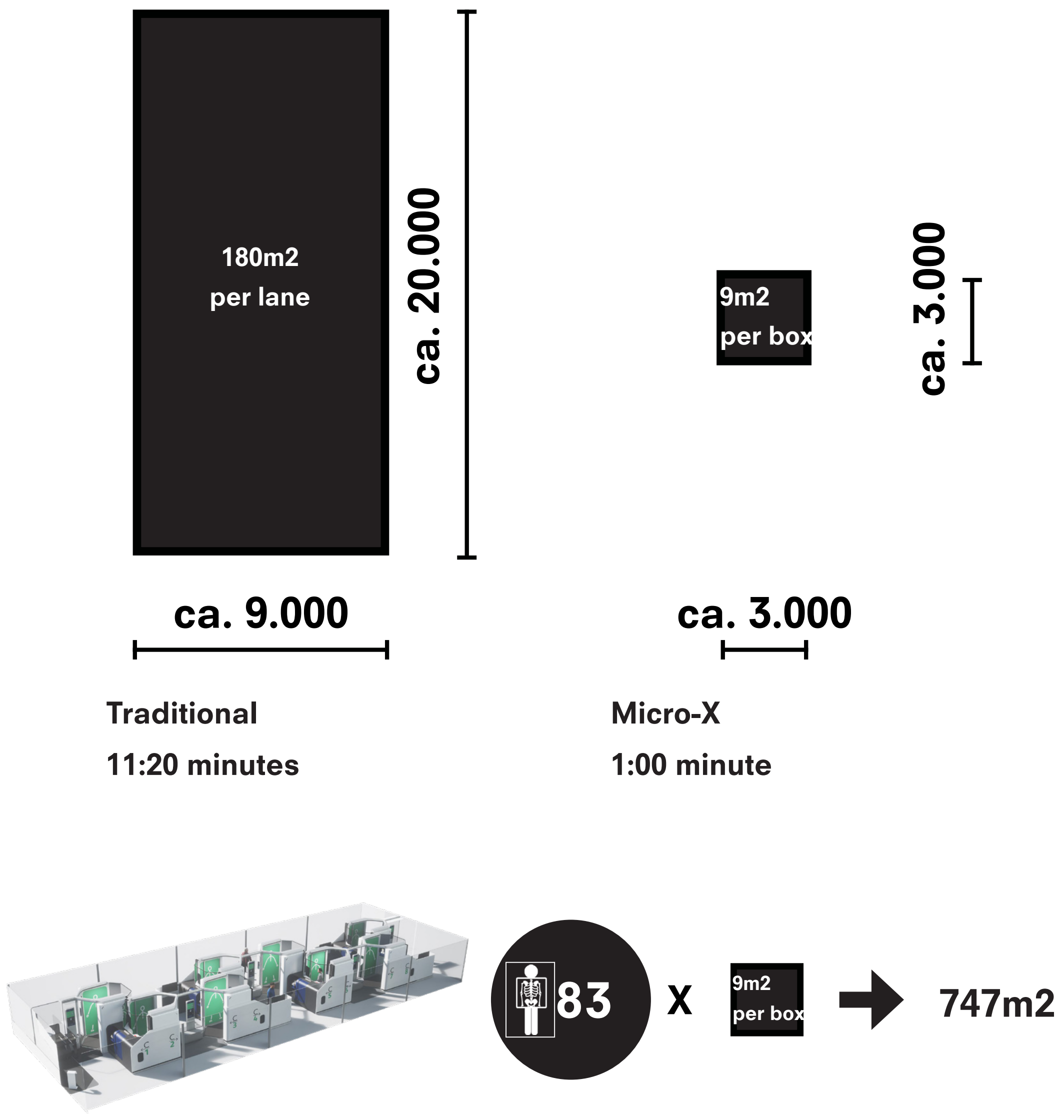


Figure 25. Calculation space needed for the check-ins

f. A big result of applying innovations equals to a much shorter travel and waiting time which makes the shops and food centres not a necessity anymore. That is why the space reserved for shops and food is dropped by 2/3. Looking at the program bar it would result in an area of 9.150m2.

The schemes below show how much time it takes to travel from Berlin to New York in a traditional way and in a Supersonic way.
As it can be seen more than 8 hours of travel time is saved by using Supersonic.

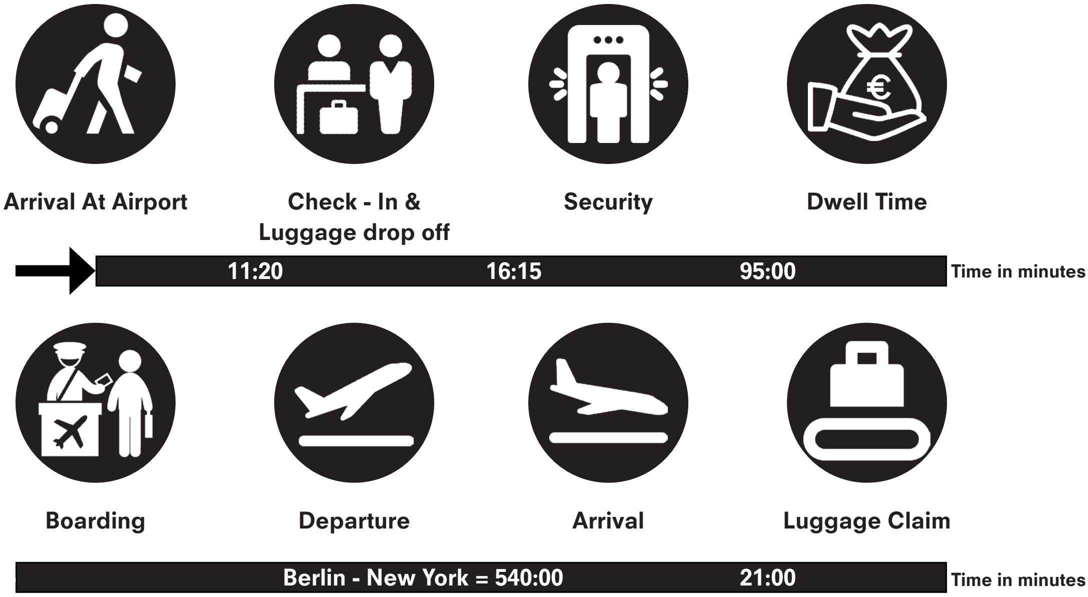


Figure 26. Traditional passenger journey from Berlin to New York

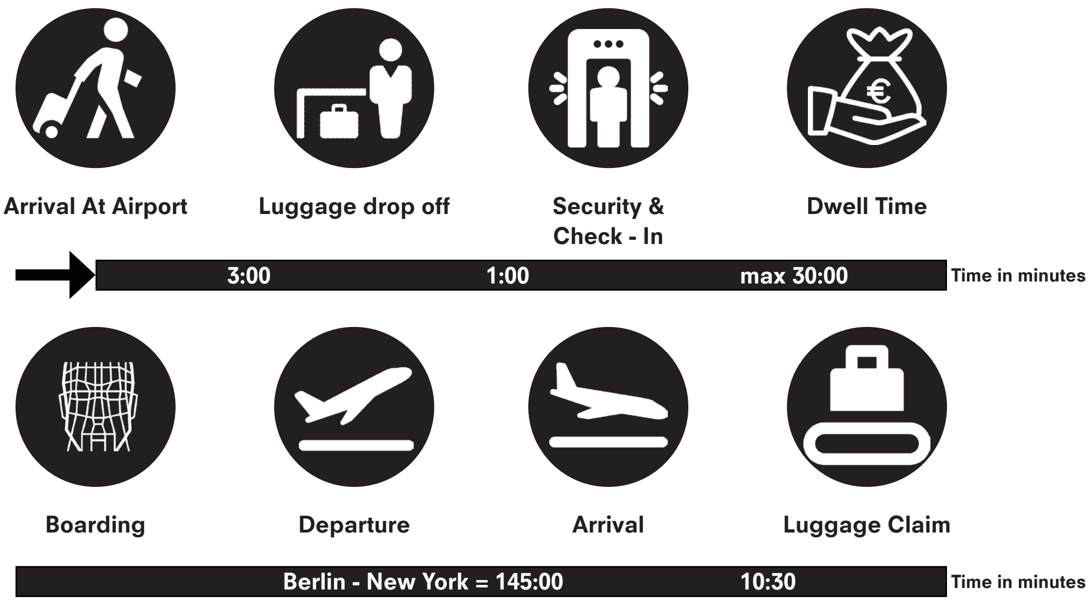


Figure 27. Supersonic passenger journey from Berlin to New York

Based on all the described innovations the program bar can be adjusted to the Supersonic way as shown in the figure below.

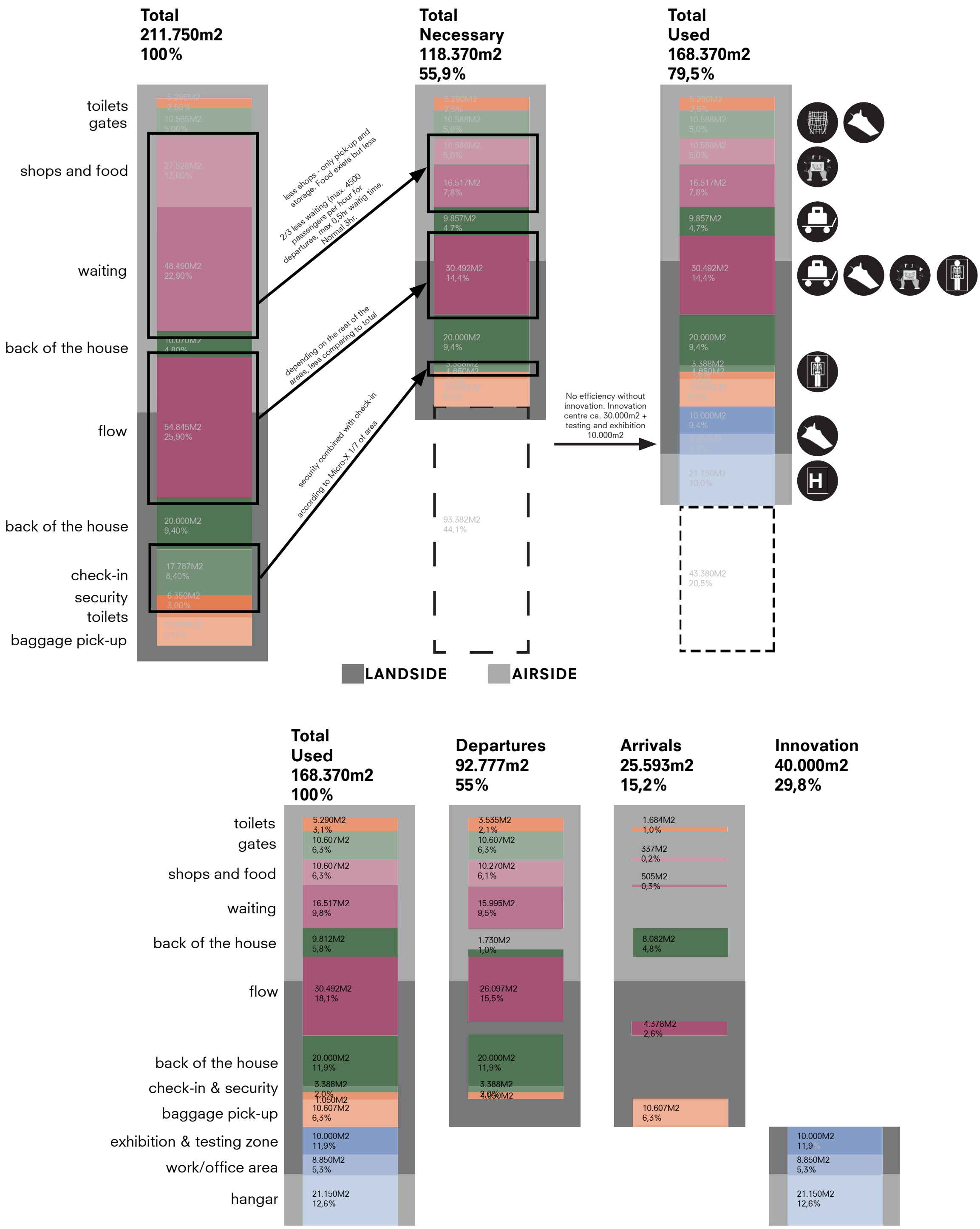


Figure 28. Supersonic program bar

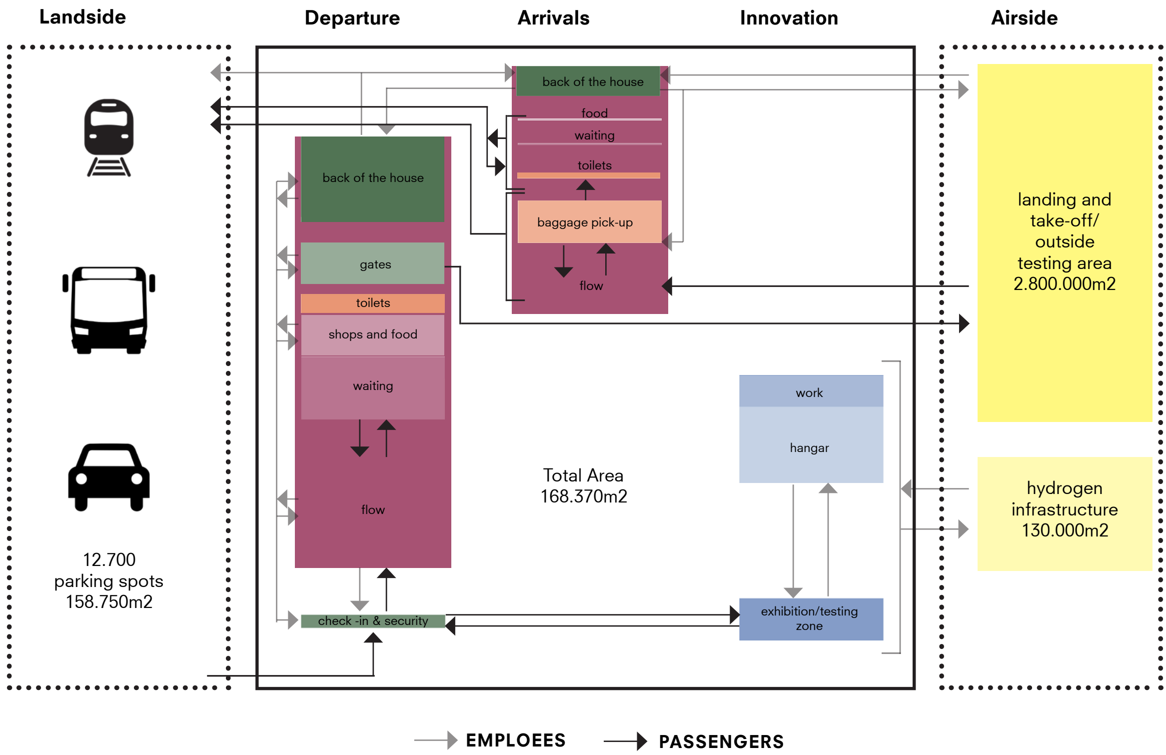


Figure 29. Supersonic relation scheme

4.2. CLIENT

European Union wants to reduce flights and connect Europe by train. (Efficient and Green Mobility, 2021) This means that by 2050 only Supersonic airports should be functioning within European borders. EU has an ongoing project called Project Horizon which has a fund of 95,5 billion euro to support various innovation projects. The goals of the project are sustainable development, scientific impact, and innovation growth. A part of the budget is reserved for the aviation industry. That part of the project is called Clean Aviation and it has a budget of 4,1 billion euro. As the Supersonic project fits perfectly within the goals of the European Union, the Supersonic airport in Berlin should be the first of many and be a representative of the European Union. That is why the EU should initiate and finance the project.

Airports are usually owned by the government, for example, the Brandenburg airport is owned by Germany, the State of Brandenburg, and the State of Berlin. However, since this project initiates innovation and cooperation the part-takers need to be involved as clients also. That is why 50% of the Supersonic airport will be owned by the state and 50% by private companies. To ensure the companies follow European policies all of the private clients are European companies. The overview of the clients in shown in figure 31.

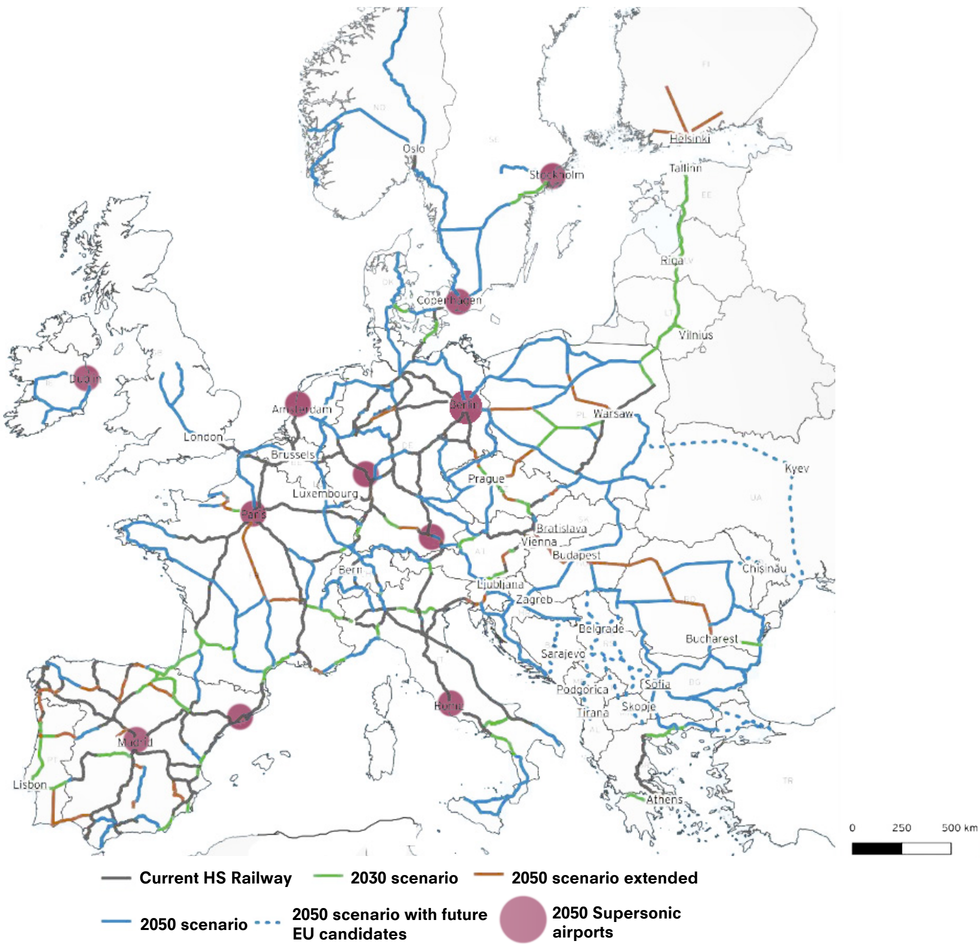


Figure 30. Overview high speed railway and Supersonic airports in Europe by 2050

Figure 31. Overview clients

4.3. SITE

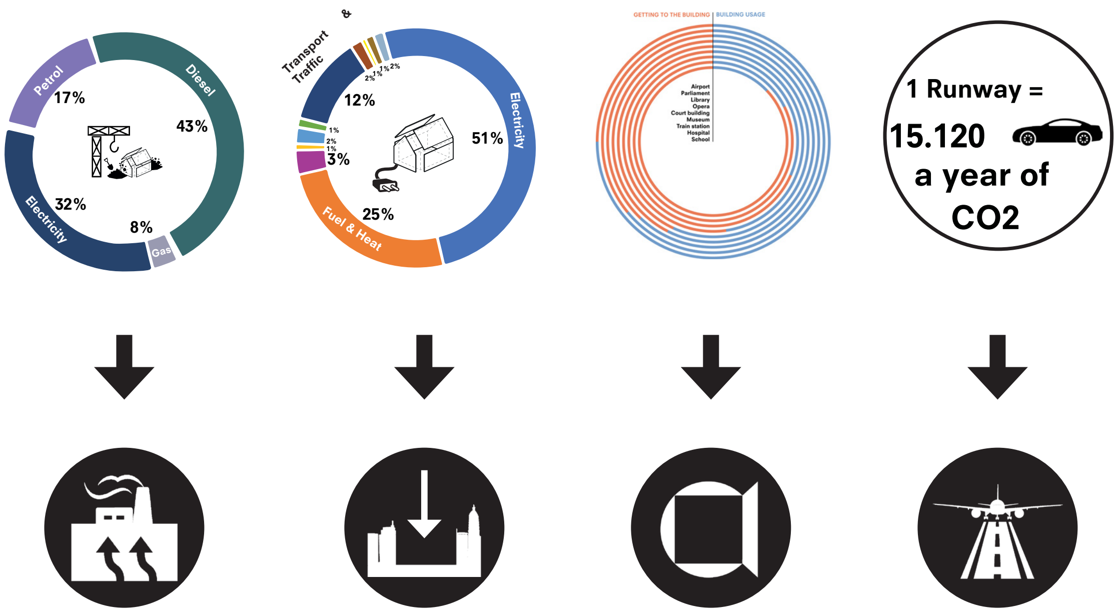
Site requirements are divided into three categories, namely energy, area, and building. Different requirements in these three categories are analysed on scales from L to S.

Energy requirements are based on the building environment's energy point of view. Retrofitting of bare land within city borders is beneficial as it helps with densification. There are different ways to produce green energy, however, geothermal energy is the most stable form of green energy, and considering the amount of energy needed solar panels, wind tribunes and bio-waste are not feasible. A bit part of the energy used in the built environment is people getting to their destination, since an airport has a big flow of people it needs to be connected to public transport. Supersonic Worldport needs a good connection through various modes of transportation, building roads and airplane runways costs a lot of energy which is why it is beneficial if already existing infrastructure can be reused.

Area requirements are focused on spatial aspects of the location.

As it is known airports expand over time that is why space for growth needs to be taken into consideration. Nature is important for the environment, it produces oxygen, and absorbs water and CO_2, that is why nature-rich areas should not be considered as a possible site. Dense areas should not be demolished because creating these already costed energy, so the embodied energy would go to waste. There should be no living spaces in a radius of 4km around the airport area regarding safe noise distance.

Building requirements are focused on the exact position of the terminal building. A terminal building is a connection between the air and land side, the terminal building needs to be built along this line if existing. If a terminal building is added on an already existing airplane infrastructure it should not interfere with the already existing airplane movements. Since it is not only the airport area that expands over time but also the terminal building, it should have enough space to be expanded in the future. If the terminal building is placed next to an already functioning airport, it can not interfere with it as this would harm the finance.



Retrofit: Build on existing potentials

Build on geothermal energy potentials

Build with the aim to provide energy-efficient mobility

Minimal additions to infrastructure

Figure 32. Overview energy requirements

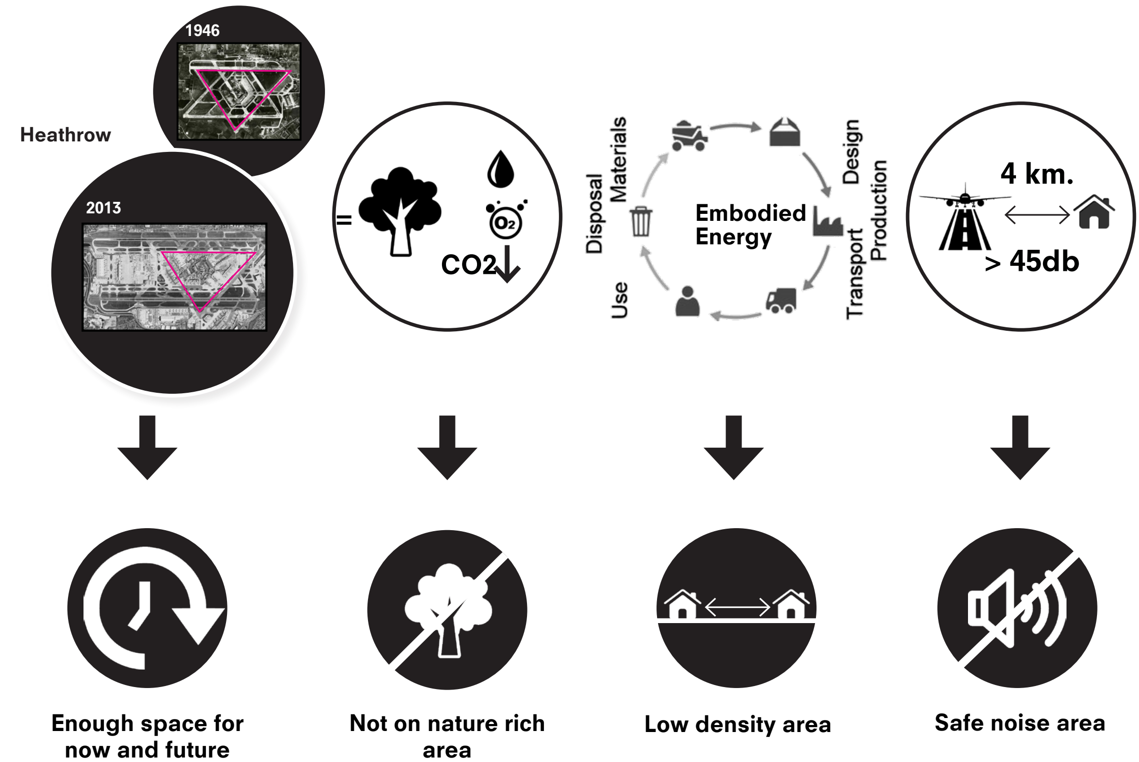


Figure 33. Overview area requirements

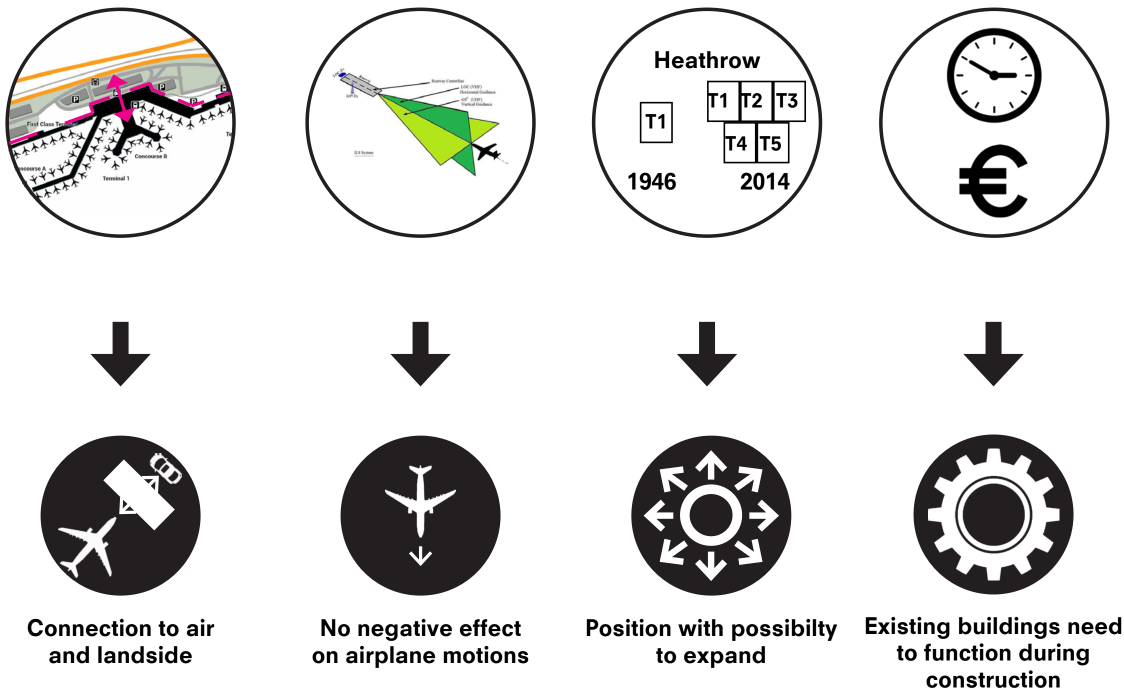


Figure 34. Overview building related requirements

Based on the described requirements the site at the Brandenburg airport is chosen.

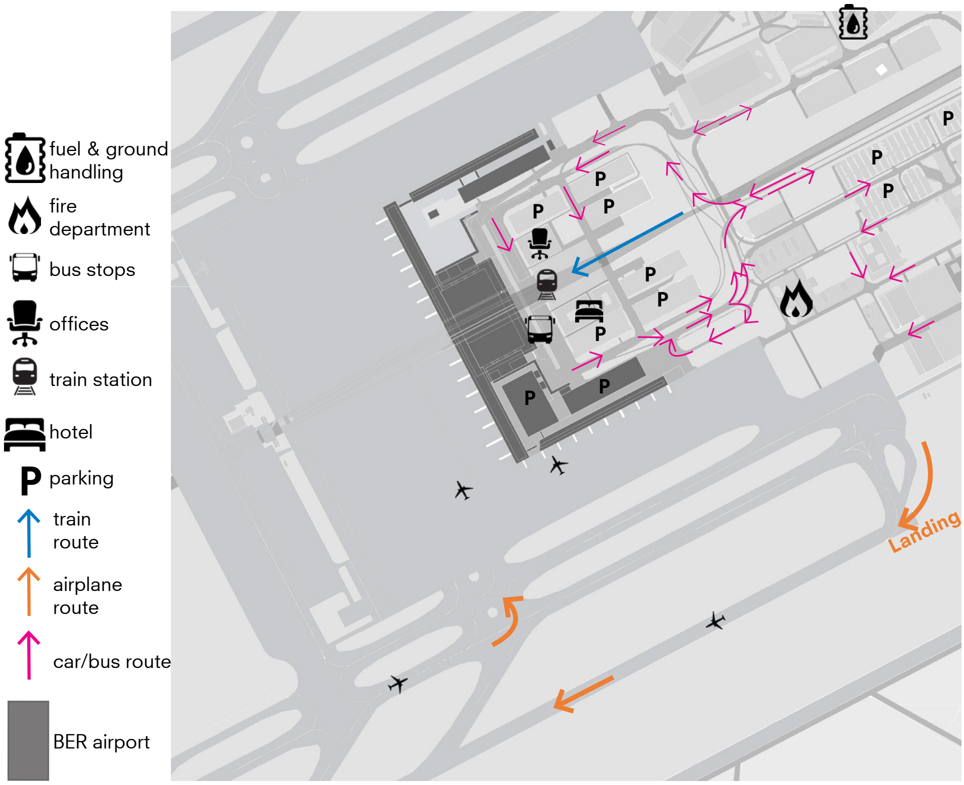


Figure 35. Site in the year 2023

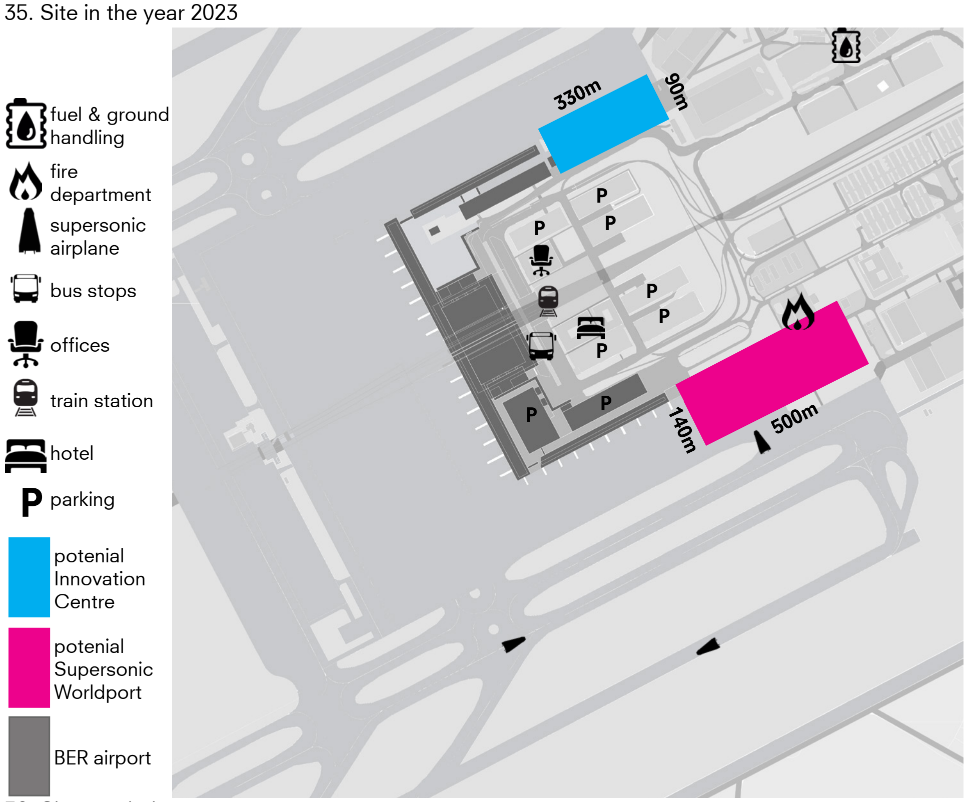


Figure 36. Site restrictions

Figure 37. Site roads movements overview

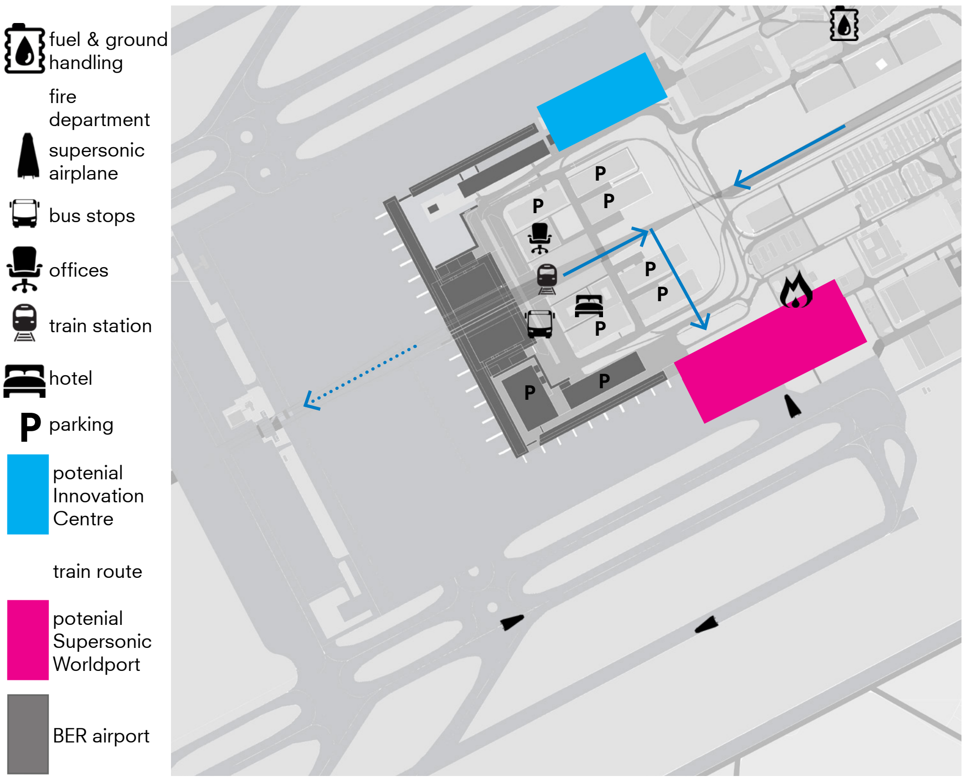


Figure 38. Site train movements overview in the year 2030

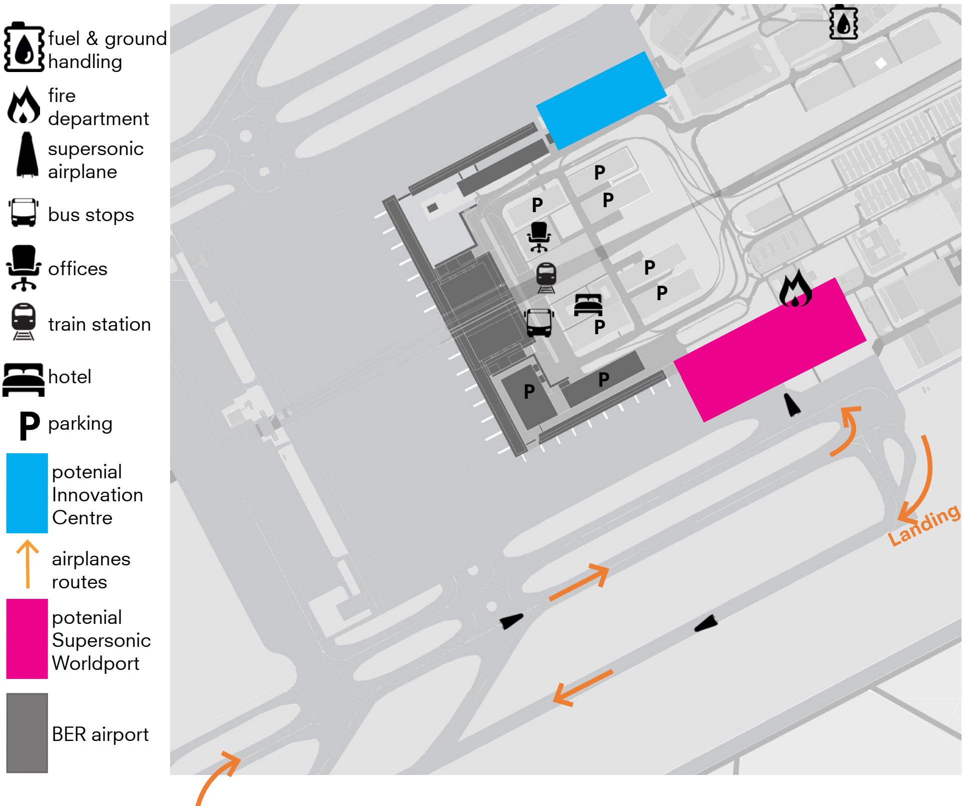


Figure 39. Site airplane movements overview in the year 2030

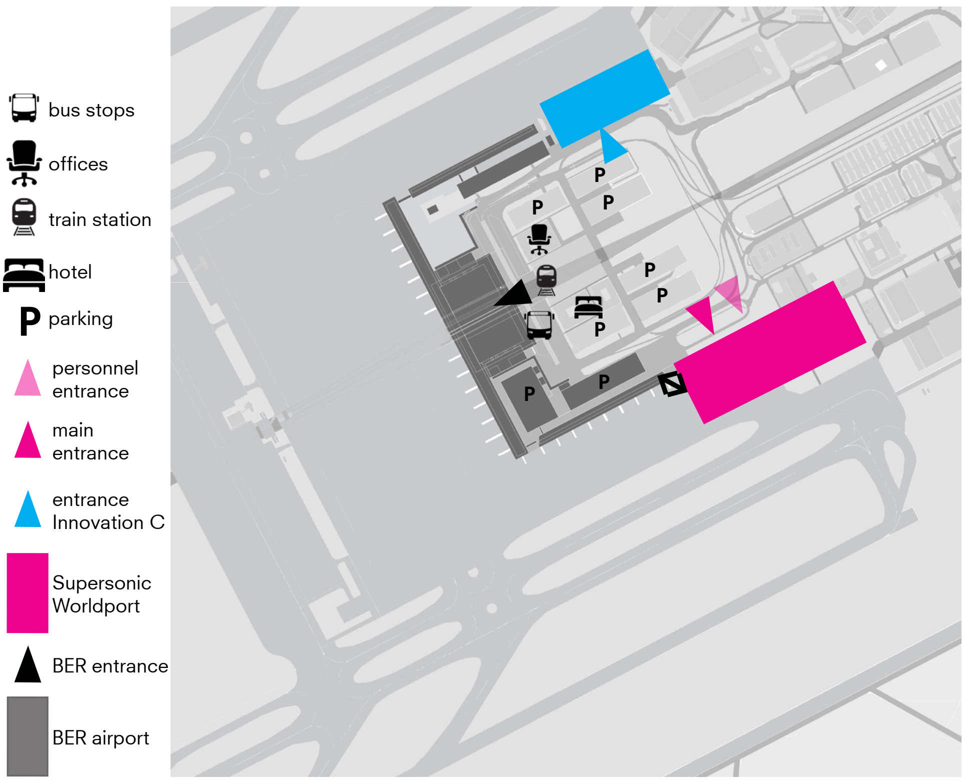


Figure 40. Site entrances overview in the year 2030

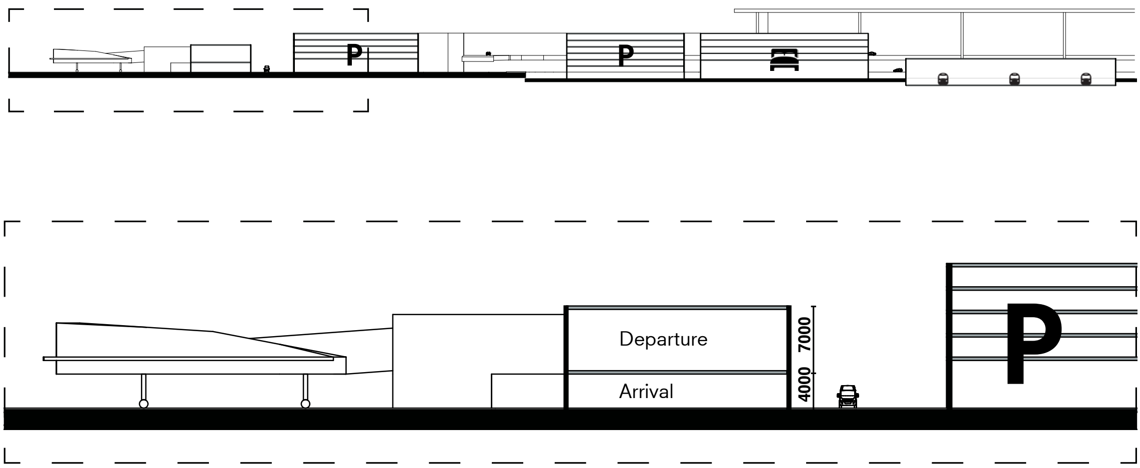


Figure 41. Site section

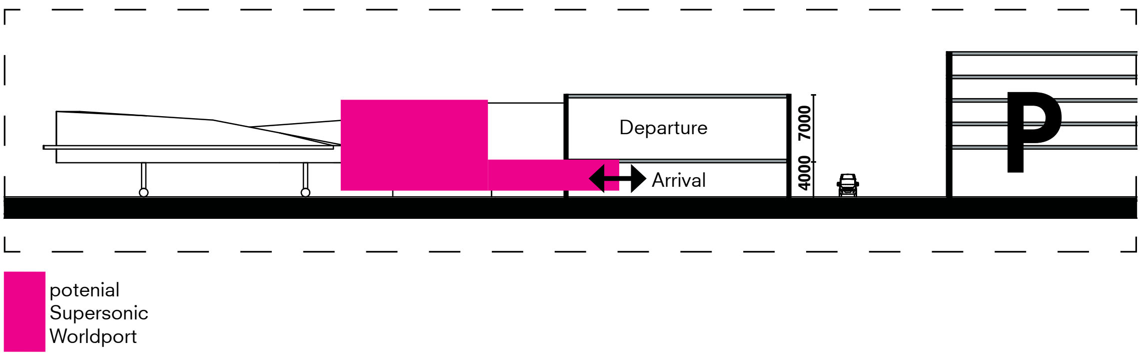


Figure 42. Site section showing the connection between new and existing airport

4.4. CONCLUSION

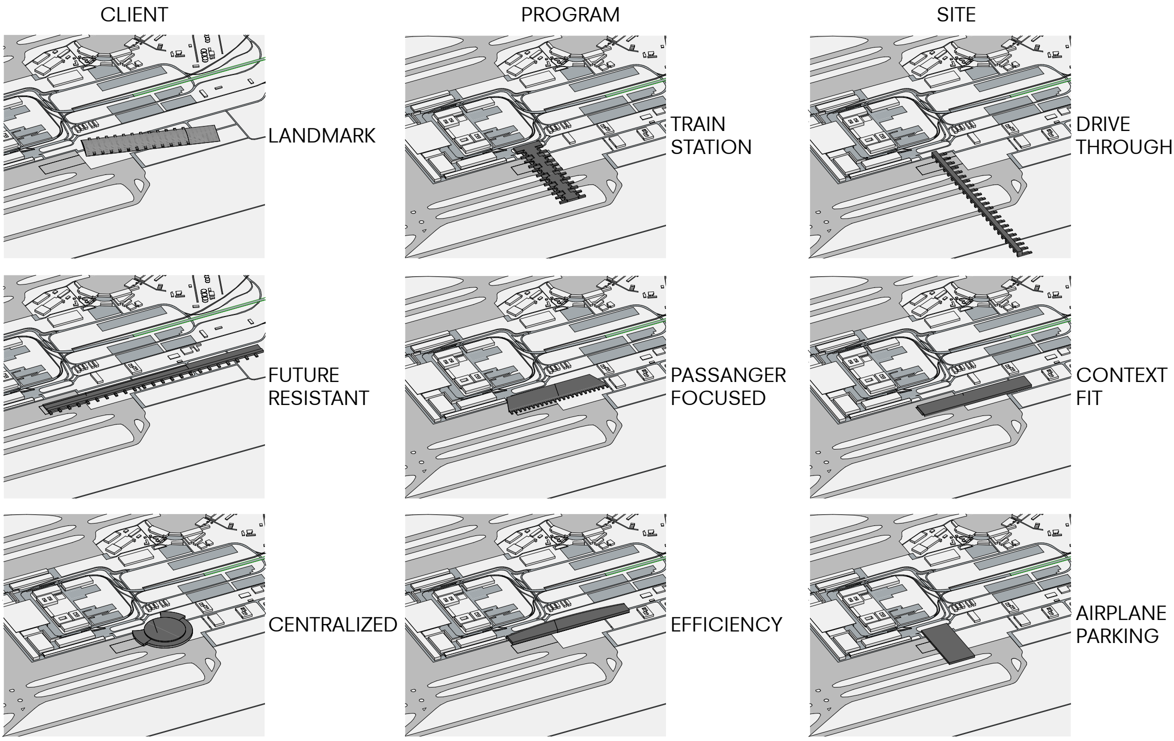


Figure 43. Design options based on different themes

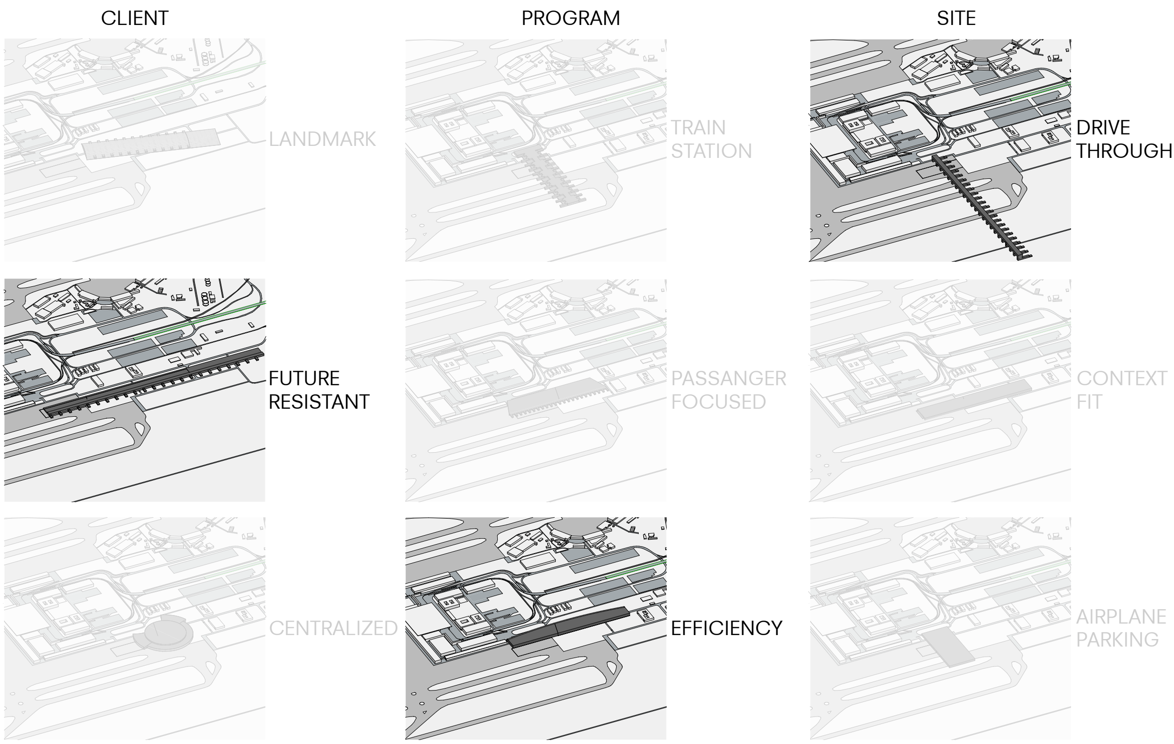
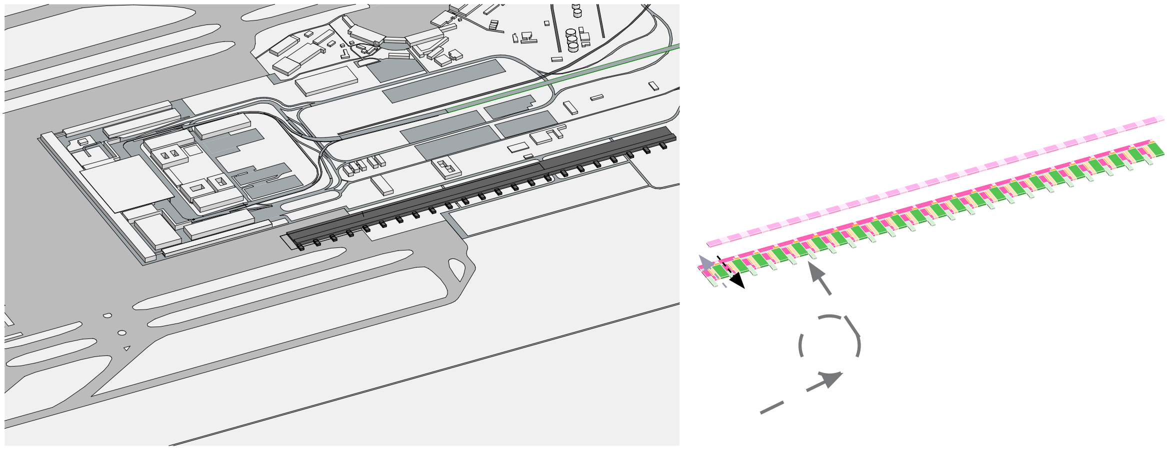
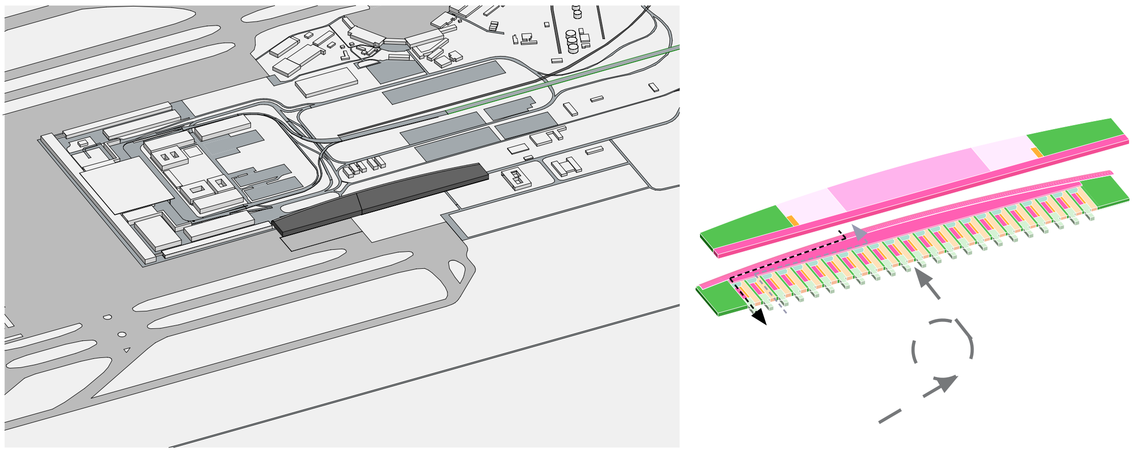


Figure 44. Chosen design options

CLIENT - FUTURE RESISTANT



PROGRAM -EFFICIENCY



SITE - DRIVE THROUGH

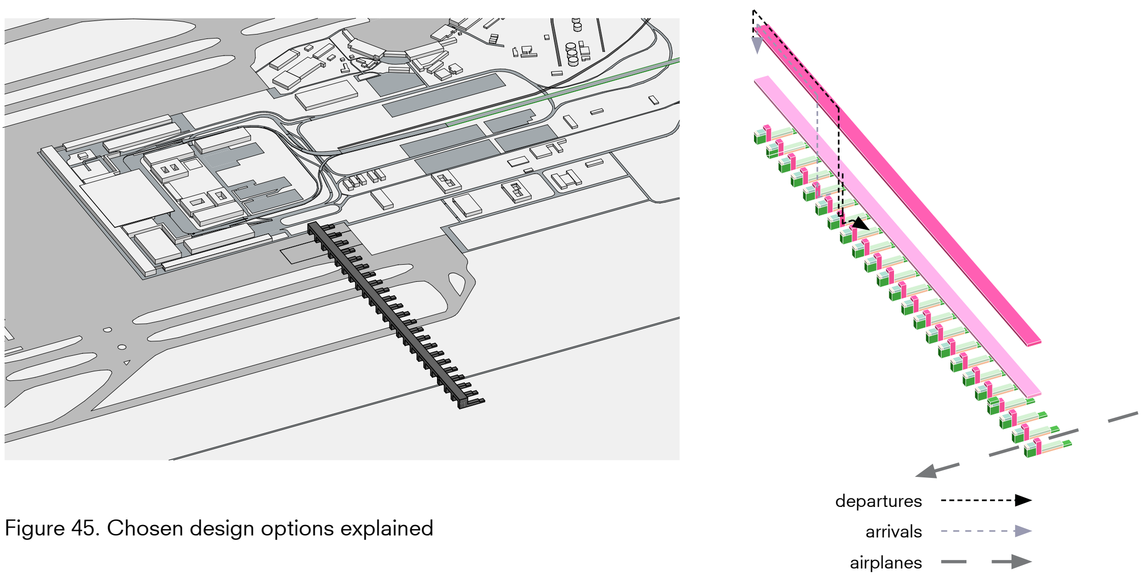
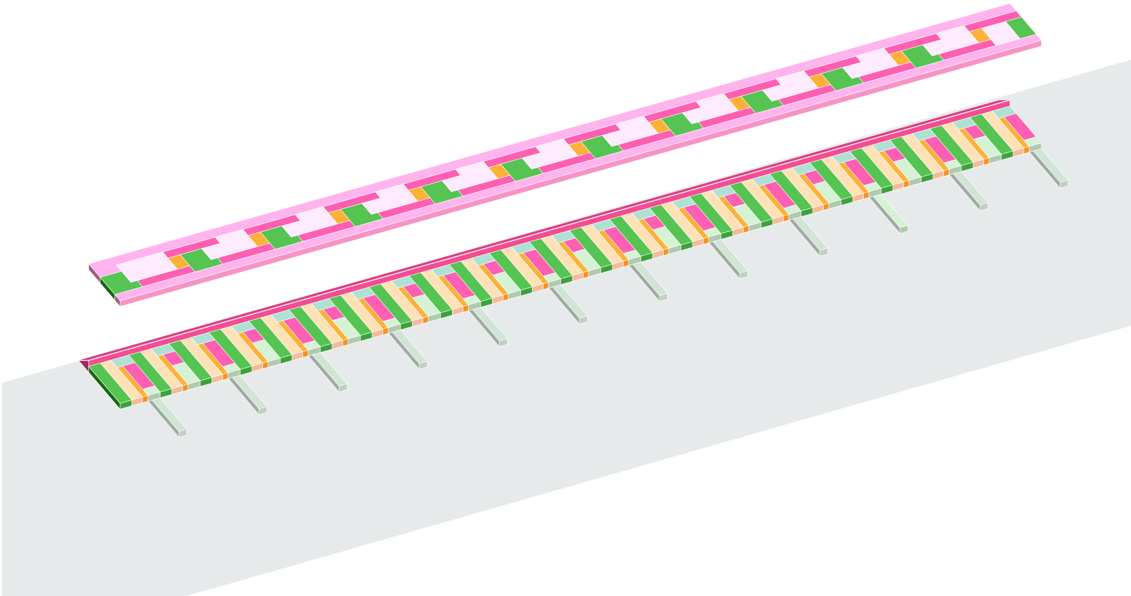


Figure 45. Chosen design options explained



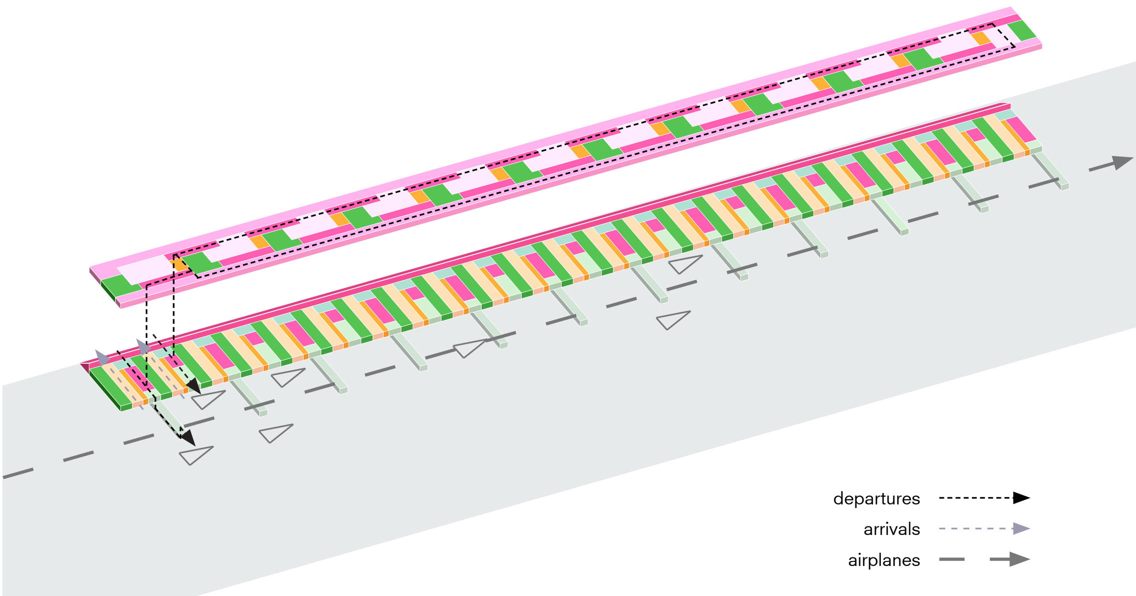


Figure 46. Basic program and flows of the Supersonic Worldport

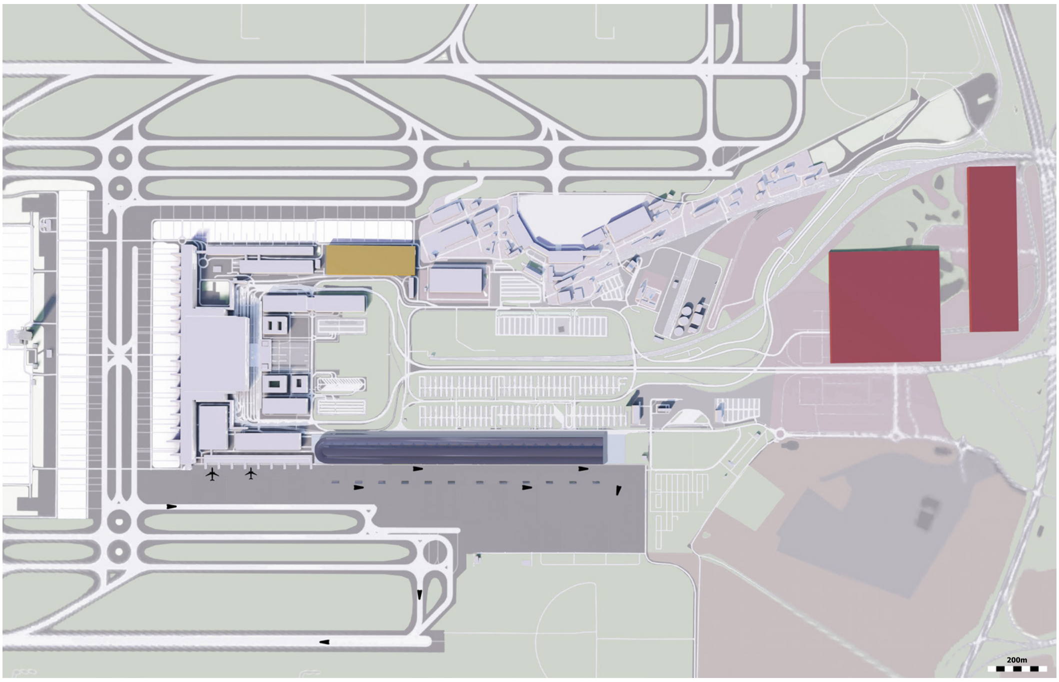


Figure 47. Positioning of project elements

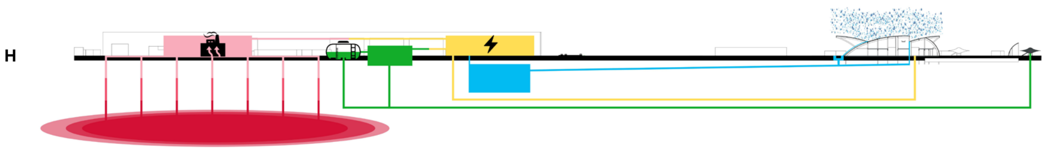


Figure 48. Overview energy production and consumption

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