BERLINER L-BAHN

Implementation of an urban air mobility typology

TU Delft

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COMPLEX PROJECTS
Bodies and Building Berlin
AR3CP100

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Bodies and Building Berlin
Digitalization

Figure 1: New York JFK airport.

INDEX

INTRODUCTION

01

1.1 Topic

Germany has a long history of innovation and development in the field of infrastructure and transportation technology (Moss, 2020). The architecture of the typology around this theme of transportation can be recognized by a modern lifestyle. The use of public buildings and how people live in them is growing along with current design trends. When adding a new mode of transportation to the city's existing network, it is essential for the legacy of today's society to respect the progress of this trend and carefully design for the future.

1.2 Problem statement

In Berlin, the result of Germany's reputation as an evolved car developer can be recognized in the street scene and urban network. The city is dominated by cars, the urban structure is clearly designed for this (Bernhardt, 2020). This high use of cars causes congestion and also has adverse effects on air quality (Jonson et al., 2017).

The city's own ambition is to put an end to the car-centric ideology. The municipality wants to ensure a more environmentally friendly city by making better use of resources and being conscious about energy use. The ambition is to significantly improve air quality by reducing car use. Simultaneously, the goal is to give the development of public transport a higher priority by ensuring that a reliable and sustainable network functions efficiently. The aim is to make this accessible to everyone (Menge et al., 2014).

However, this does not appear to be an easy challenge. Figure 2 clearly shows how a sample survey amply revealed how common it is for Berlin residents to make their daily commute by car. The research by Reckien et al. (2007) has shown that the current city structure is designed in such a way that CO2 emissions by car commuters will not decrease quickly in Berlin.

This travel behavior has been studied by Beige (2012) and visualized in figure 3. It can be seen that within all districts of Berlin the majority moves to or from the central districts. Figure 4 shows the average travel time from the centers of a number of Berlin districts to the Mitte district when using public transport. It is striking that the car alternative in the city has not yet managed to connect all neighborhoods with a fast alternative.
In summary, excessive car use is self-evident in Berlin, with the negative consequence that excessive amounts of exhaust fumes are emitted and thus cause poor air quality. Due to congestion, one has the alternative to travel by public transport. However, this involves long travel times, which means that switching is not encouraged.

1.3 Research question

In order to transform the aforementioned problems into an architectural challenge, Figure 5 explains how the ideas of the subject have been phrased into relevant questions. The focus is on three main topics: mobility, innovation and digitalization. The diagram breaks down the topics into sub-questions, after which these are summarized into more focused questions. These have been re-expressed in a more in-depth way. The two resulting questions on the right of the diagram describe the topic of modularity and the impact of new mobility. These two themes summarized form the research question to be investigated:

"How can a new mode of air transportation be designed to facilitate the increasing demand in transportation of people and good?"

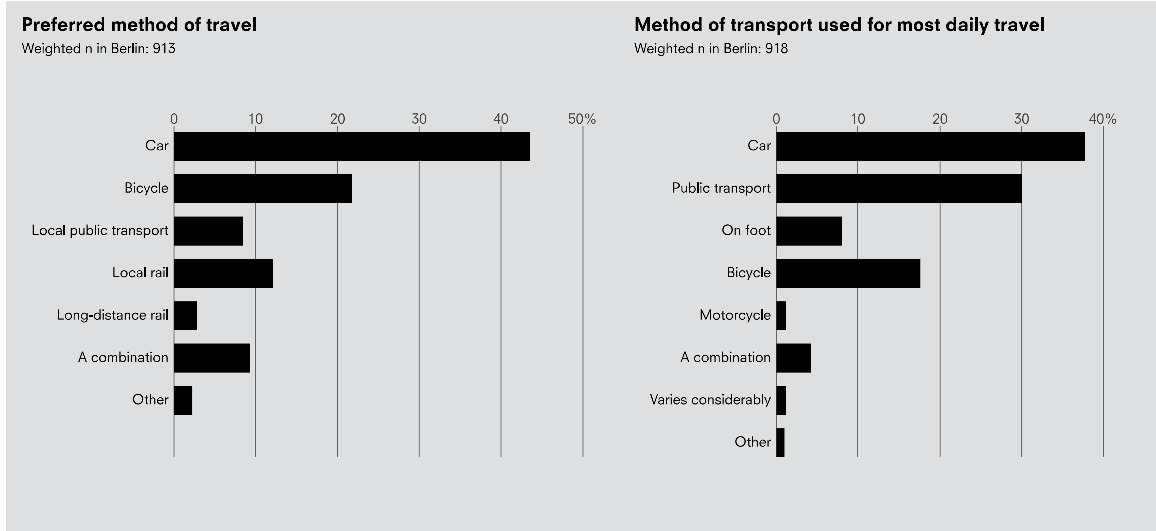


Figure 2: Modes of commute in Berlin.

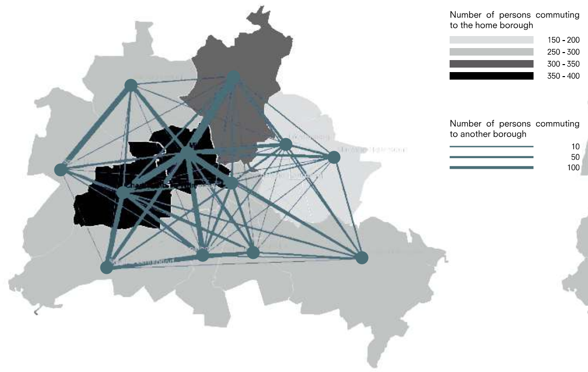


Figure 3: Commute behaviour in Berlin.

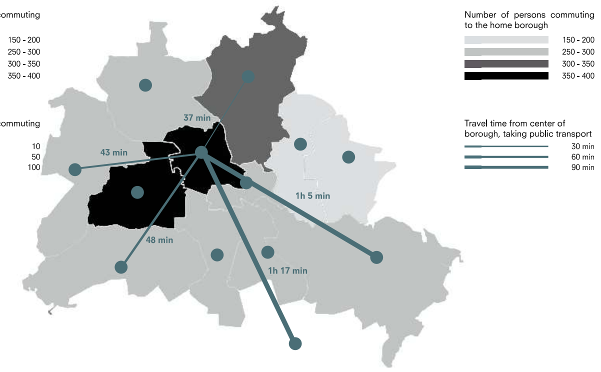


Figure 4: Commute travel times.

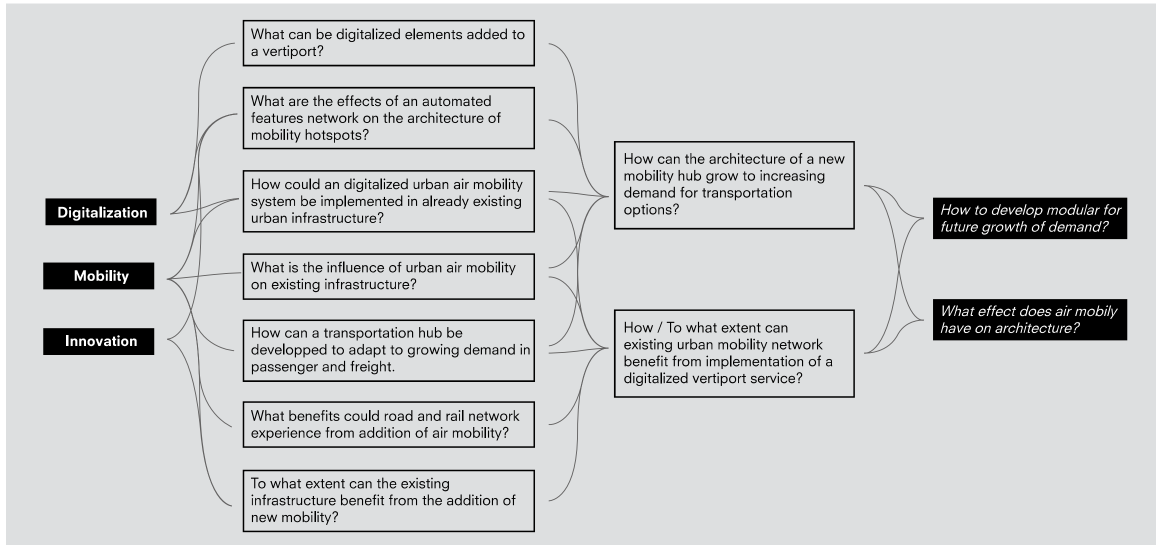


Figure 5: Research topic study.

RESEARCH FRAMEWORK

02

2.1 Theoretical framework

The future of the new urban air mobility (UAM) is discussed in this chapter. In the future, the use of air mobility will be much more integrated into daily life (Peisen et al., 1994). It is necessary to mention that people are certainly open to the concept of drones in public spaces (Khanh et al., 2023). The attitude towards implementing the new mobility has mainly been expressed by the urgency of the deployment, the social benefits and concerns and the impact on the climate (Kalakou et al., 2023).

2.1.1 Air post

Parcel delivery via drones is another application of implementing air mobility in the urban landscape. The advantages of drone use are that the carbon footprint of parcel delivery services is enormously reduced and delivery times become faster and more reliable. It is also an opportunity to solve the last-mile problem. In the last-mile problem, postal delivery services struggle with the last kilometers that a package has to travel. This is currently the least efficient because the addresses of delivery locations are always different and the traffic is unpredictable. When autonomous flying services package fly around automatically, efficiency increases enormously due to the absence of traffic. Postal delivery service DHL, for example, is already experimenting with drone delivery to solve the last-mile problem (Fouat, 2017). For the city of Berlin, Baur et al. (2020) conducted a study into the possibilities of drone parcel delivery within the urban flying regulations and laws, see figure 6. This has calculated that 4 million parcels can be delivered annually by drones in the city. city. This would take a lot of pressure off parcel delivery via the street.

2.1.2 Air mobility

Today's infrastructure problems all run into the problem of leaving little room to expand for future growth. Mobility by air still offers every opportunity for this. A new means of transport that residents of Berlin can use are passenger drones. Prototypes are currently being tested worldwide. Such as the model from figure 7 in Seoul and a model from aircraft manufacturer Airbus in figure 8. Figure 9 shows the same distances as presented in figures 3 and 4, now with average flight speeds, which significantly reduces travel times. The new form of mobility does come with a great responsibility and obligation for further research into, among other things, safety, reliability and connectivity (Torens et al., 2021).

2.2 Relevance

In the future, people will move much more towards urban areas (Ritchie, 2023). The development of a new type of infrastructure is therefore essential to keep up with urban growth and to be ready for unexpected situations with regard to the future. space for human movement. In order to continue to provide a healthy and liveable city with reliable mobility, there must be enough alternative means of travel available in the future. The challenge is to connect all modes of transport while allowing them to operate autonomously.

2.3 Hypothesis

Since the network does not yet exist, it can only be logically speculated for the time being how this will develop. In figure 10, 6 concept situations are depicted, each of which could become a future scenario depending on how popular the concept is by citizens and governments. The integration of air mobility depends on institutional commitment. Political institutions will have to act as a catalyst for the development of this technology (Fraske, 2023). How quickly it will happen or in what order cannot be stated with certainty. The scenarios are completely dependent on society's demands and political choices. Another uncertainty that plays a role in the process of developing an appropriate UAM in Berlin is that the concept requires extensive land infrastructure and space (Bauranov & Rakas, 2021). Not everywhere in the city is it possible to fit an airport for UAM. This complicates the situation why an estimate

Factor	Input factors	Roland Berger assumptions	Result	Market size
Regulatory factors	Minimum distances Vertical: **5.500 m** Horizontal: 300 m	Scale factor for **10%** for minimum distances for drone operations	Airspace for one drone	**4.000** drones maximum at the same time
Geographical factors	Berlin area: **892 km²** Berlin urban area: **668 km²**	**60% of urban area** useful for drone operations (no fly zones around airports, governmental buildings, downtown areas, etc.) Layer of drones: (from 60m to 150m; each 30m)	Total airspace volume for drones **36.000 x 106 m²**	Downscale factor of **30%** for smooth operations **1.200** drones flying at the same time
Operational factors	Flight distance: **3 km** Flight time2: **5 min** Turn-around-time between flights: **15 min**	Operating hours per day: **8h** Operational days per year: **280** Parcels transported per flight: **1** Flight occupancy rate: **50%**	Deliveries per drone per day: **12 parcels** and per year: **3.360 parcels**	**4.000.000** parcels delivered annual

Figure 6: Drone parcel delivery research Berlin.

Figure 7: Flying prototype.

Figure 8: City Airbus prototype.

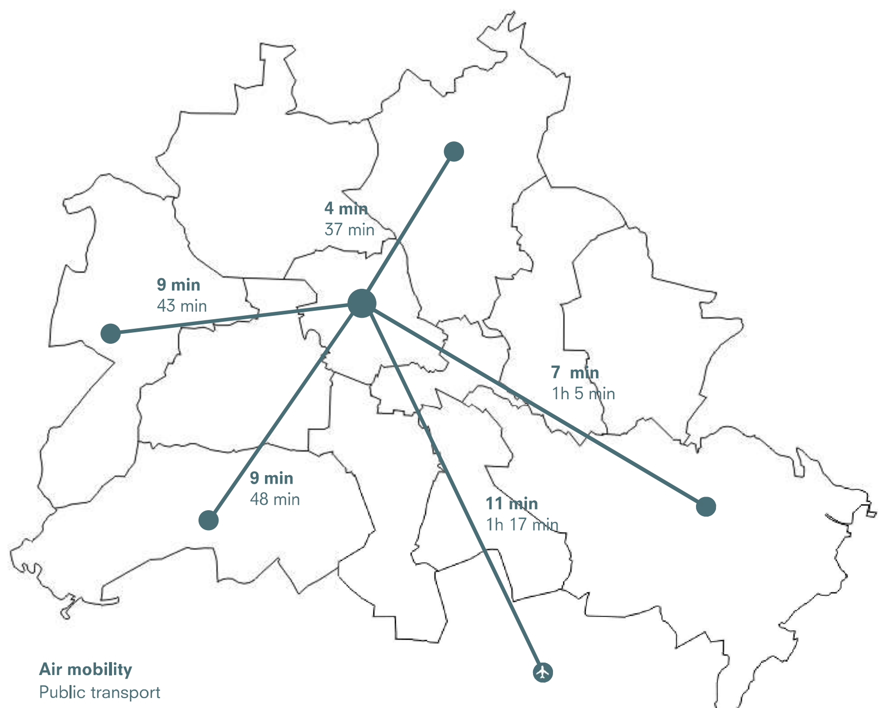


Figure 9: Estimated travel time by drone.

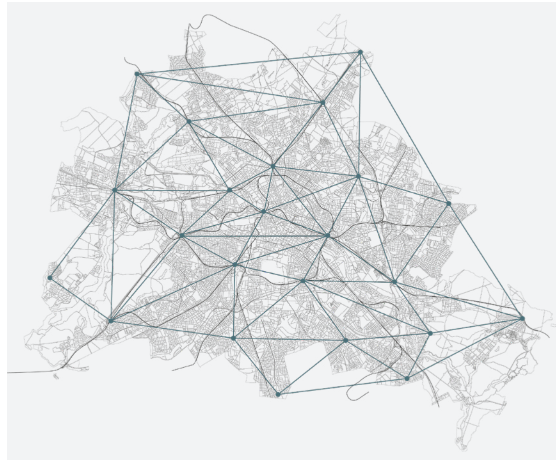
based on a specific scenario is not easy to predict. To absorb these growth risks, the architecture of the new building typology can evolve over time. This means that a modular intervention must be made in the design of the UAM stations, so that they can grow in terminal space in the event of a huge increase in the demand for flying needs. But that also means that when demand decreases, the station buildings can easily be dismantled.

Adopting a modular design means breaking a system into smaller, interchangeable parts. This approach emphasizes flexibility, reusability, and easy maintenance. Each part serves a specific function and can be developed and updated independently. This makes the overall system easier to understand, scale, and adapt over time. In the case of an airport, it means the facility can continuously grow to meet the demands of travelers.

For the development of a new transport network in an existing urban area, priority has been given to development areas. In scenario 7, the connected network of polycentric areas is the basis of the new infrastructure. The city has designated the selected points on the map as areas of high importance that are relevant to its environment for urban development.

Scenario 7: Polycentric oriented

Scenario 1: Airport shuttle

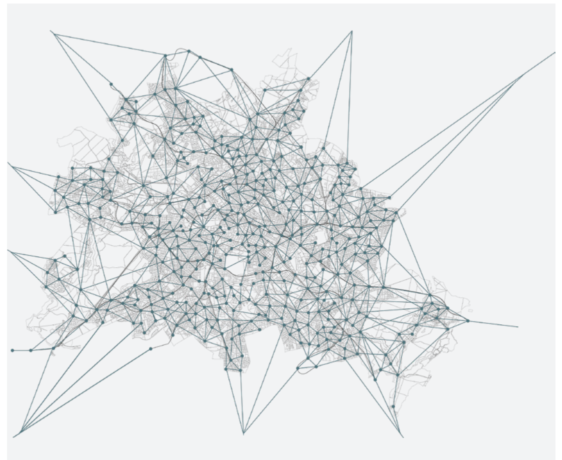


Scenario 2: Interconnected

Scenario 3: Across city center

Scenario 4: Acros outer boroughs

Scenario 5: Platform connected

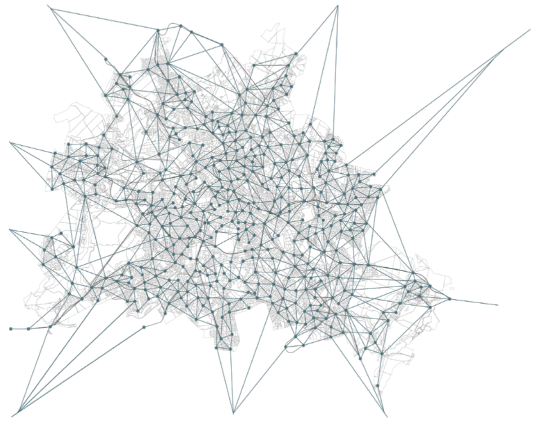


Scenario 6: Intercity connected

Figure 10: UAM infrastructure scenario's.

Polycentric scenario
216.000 passsengers
72 vertiports

Platform scenario
399.120 passsengers
133 vertiports



Intercity scenario
651.041+ passsengers
217+ vertiports

2020
U-bahn and S-bahn:
2.400.000 daily passengers

2030
Public transport +9%
2.616.000 daily passengers

2050
Public transport +7%
2.799.120 daily passengers

2100
Public transport +9%
3.051.041 daily passengers

Figure 11: Timeline hypothesis.

RESEARCH METHODS

03

3.1 Program

The program of this new building typology, from now on called vertiport, will be investigated by looking at case studies. Characteristic elements of the buildings are measured in surface area and benchmarked next to each other in order to make a statement about an average percentage of the total surface area that the vertiport will need in terms of these spaces. Because the vertiport as a typology does not exist, small airports will be considered. The flow of people and overflow of spaces is comparable. One enters a central hall, passes a number of access procedure areas and leaves the building via a terminal. The research will examine 5 small airports, 2 general aviation airports and the research into the program will also include the calculation of the size of the conceptual parcel warehouse as mentioned in paragraph 2.1.2.

3.2 Client

The vertiport will be a new infrastructure that will be connected to the existing public transport network. In essence, it is a service for the residents of the city. To find out which clients are interested in such a service, it will be necessary to look at which parties can benefit from a collaboration with air mobility by looking carefully at the scenarios and finding out via sources which parties are interested in an investment in the part of the network.

3.3 Site

The site is determined by three specific requirements. The first is Free Airspace. It is necessary that there is enough maneuvering space for an air mobility vehicle to be able to take off and land. Sufficient air space around the vertiport is therefore important (Schweiger & Preis, 2022). The second requirement is that it must be built as close as possible to an existing S-bahn station. The connection to the existing network is essential for an effective contribution (Brunelli et al., 2023). The last requirement is the space for future growth. As mentioned earlier, the typology will be able to expand due to an increase in passengers. When searching for a suitable location, possible growth space for the terminals must be taken into account.

DESIGN BRIEF

04

4.1 Program

The case studies for the research into the program were chosen based on the size and passenger numbers on the one hand and the extent to which it is located close to Berlin on the other. To get a broad picture of the scope within which a vertiport can be derived, it is important that the study included a selection of buildings with a varied daily passenger number. This is also to take into account any growth or shrinkage of the modular typology. A range of 23,000 to 230 daily passengers was used for this benchmarking. First, research was done into the percentage distribution of spaces. Here it becomes clear that the following spatial compositions are very similar: 1. departures & arrivals 2. offices & other 3. freight distribution 4. access procedure area and 5. main hall. Three key elements can be recognized here, each of which has claimed roughly a third share of the building layout: 1. Terminal section 2. Functional section 3. Main hall section. However, at the general aviation airports it is noticeable that the benchmarking is less valuable due to the abundance of office space in the building. Although this type of airport could be more similar in surface area to a vertiport, the specific typology is less focused on passengers and more on aviation employees. The benchmark of these two airports was therefore disregarded for the research program and not taken into account. The airports were then divided into small and midsized to better distinguish the areas. There is little difference to be found in all case studies in terms of the range of spaces available and how this is distributed throughout the building. It is striking that at the midsized airports more space is devoted to the functional area. This may be due to the larger group of passengers that have to be processed, which means that more space is devoted to the logistics flow instead of a larger main hall where people generally spend less time. The calculation for cargo space resulted in a clear outcome that can be directly included in the conclusion statement (figure 12). The benchmarks have been combined and a spatial distribution has been made from this, as shown in figure 14. The percentage distribution of space has been rounded off more towards the results of the small airports because the flow of passengers is faster here and the speculation about the design of a vertiport looks more like this.

4.2 Client

Brandenburg Airport is the city's only commercially functioning airport at the moment. Its accessibility can vary enormously per district. A collaboration with a UAM service could benefit the airport in many ways. It significantly improves travel time, allowing travelers to travel more confidently (see figure 7). Another interest of the airport is the development and innovation of aviation mobility. Sharing knowledge and materials for a more sustainable future. In Berlin, public transport is arranged by the BVG transport company. When a new mode of transport is added to the current offering, it will operate best if it cooperates with the current infrastructure network of metro, tram and city buses. As the public transport network, the national train network could benefit from a partnership with UAM. Passengers can transfer to a drone taxi at the train station and travel directly to their destination. A direct connection of platforms from the stations to the landing pads would be a beneficial development that can be seen in the future. When the UAM network expands in the future and public flights are accessible and widely accepted, there might be interest from international train services to take pressure off existing routes. Traveling by train is becoming increasingly popular, but an international station is not always close to the final destination. A partnership with UAM can complete the last-mile delivery of passengers. The postal service DHL is the largest postal service in Berlin and responsible for delivering mail and especially packages in the city. The company is currently already doing experiments with drone delivery (Fouat, 2017). UAM can take pressure off the existing postal delivery system and ensure that less polluting parcel delivery services operate on the streets of Berlin and offer more accurate delivery times.

4.3 Site

When selecting the site, the proposed scenario 3 in figure 9 in section 2.2 was used. The reason for this is that it is most likely that in the initial phase of the emergence of the UAM network, mainly the outermost distances of the ring road will have to be connected. This solves the biggest challenge of public transport, namely the long travel times from the edges of the city center. In later phases, UAM could grow to connect to other leading locations in the city.
The industrial area next to the Westhafen S-bahn station was chosen for the site. The area is recognizable by its characteristic industrial architecture in the form of department stores, sheds, warehouses and storage silos. There are no significantly obstructive high-rise buildings, making it very suitable for the development of a vertiport. The area is a candidate for renovation with a modern master plan. This frees up more space for residents and for quality of life. This means that there will also be enough room for future growth of the vertiport.

Figure 12: Polycentric scenario network.

	Deutsche Bahn Berlin, Germany		Berliner Verkehrsbetriebe Berlin, Germany		Deutsche Post DHL Bonn, Germany
1	Grow sustainable	1	To be carbon neutral by 2030	1	Carbon neutral delivery
2	Increase reliability	2	Reliable urban mobility	2	Experiment transport alternatives
3	Be fully carbon neutral	3	Accessable property typologies	3	Reliable time management
		4	Invest in sustainable infrastructure	4	Solve last-mile dilemma

Figure 13: Client ambitions.

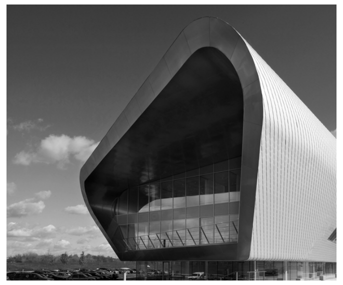
Eindhoven Airport
KCAP | 2013 | NL
International Airport
27.000 m²

Leipzig/Halle Airport
AP Brunnert | year | DE
International Airport
23.000 m²

Paderborn Airport
Architects Unkwown | 2007 | DE
International Airport
8.800 m²

Kassel Airport
RSE+ Architekten | 2009 | DE
Minor International Airport
8.700 m²

General Aviation Schiphol Airport
VMX Architects | 2011 | NL
International Private Terminal
6.100 m²



Farnborough Airport
Reid Architects | 2010 | UK
International Private Airport
4.300 m²

Memmingen Airport
Architects Unknown | 2004 | DE
International Airport
4.000 m²

Distribution Centre
Warehouse storage reseach
4000 m²

Figure 14: Case study projects.

Eindhoven Airport
KCAP | 2013 | NL
International Airport
27.000 m²

Leipzig/Halle Airport
AP Brunnert | year | DE
International Airport
23.000 m²

Paderborn Airport
Architects Unkwown | 2007 | DE
International Airport
8.800 m²

Kassel Airport
RSE+ Architekten | 2009 | DE
Minor International Airport
8.700 m²

General Aviation Schiphol Airport
VMX Architects | 2011 | NL
International Private Terminal
6.100 m²

Farnborough Airport
Reid Architects | 2010 | UK
International Private Airport
4.300 m²

Memmingen Airport
Architects Unknown | 2004 | DE
International Airport
4.000 m²

Distribution Centres
Warehouse storage reseach
Various m²

Figure 15: GFA / capacity ratio.

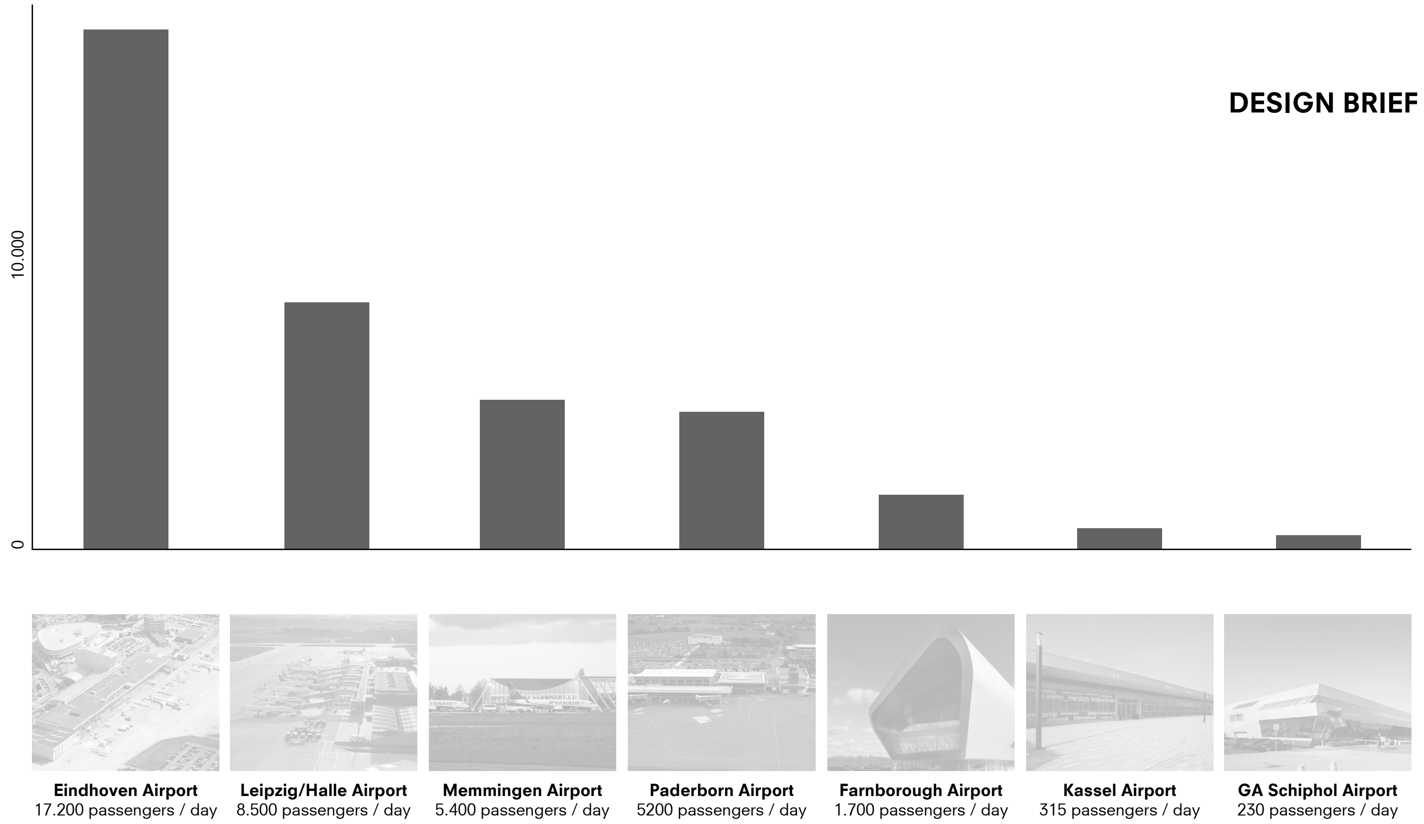


Figure 16: Case study daily passengers.

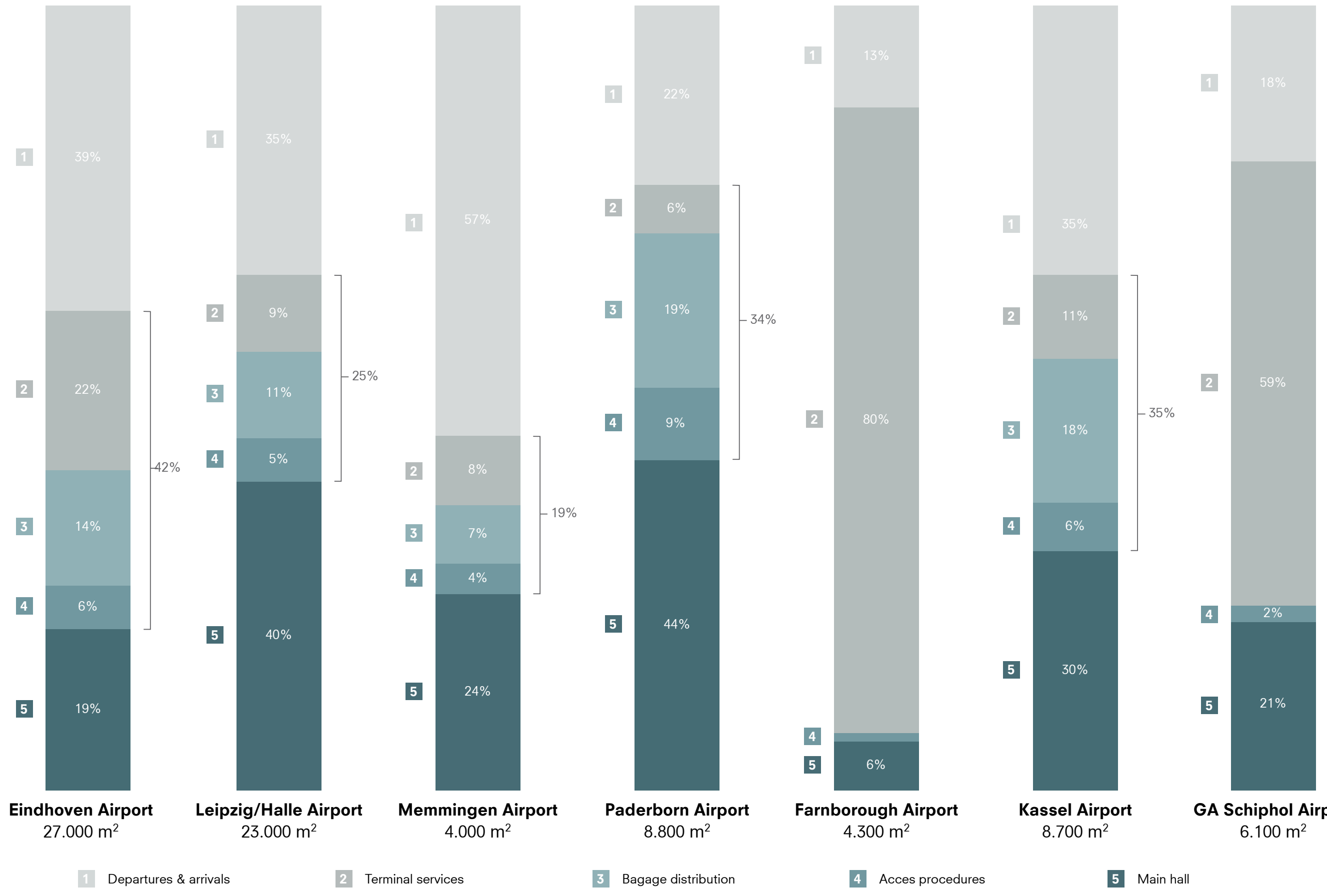
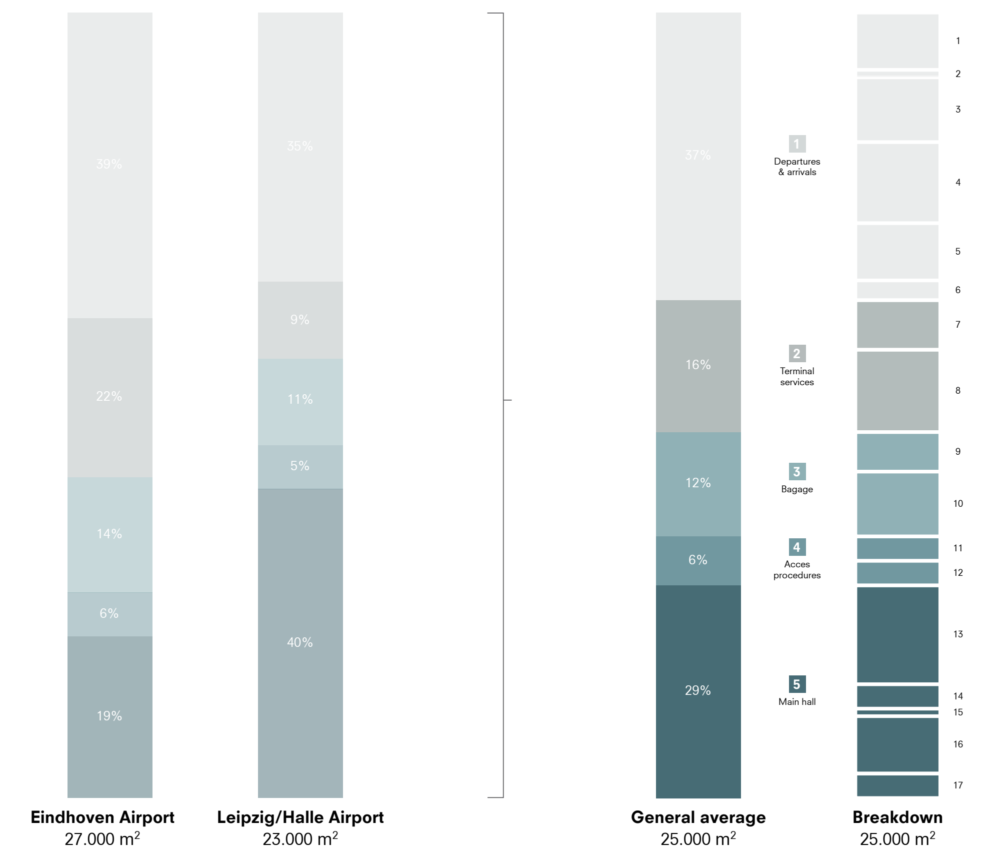
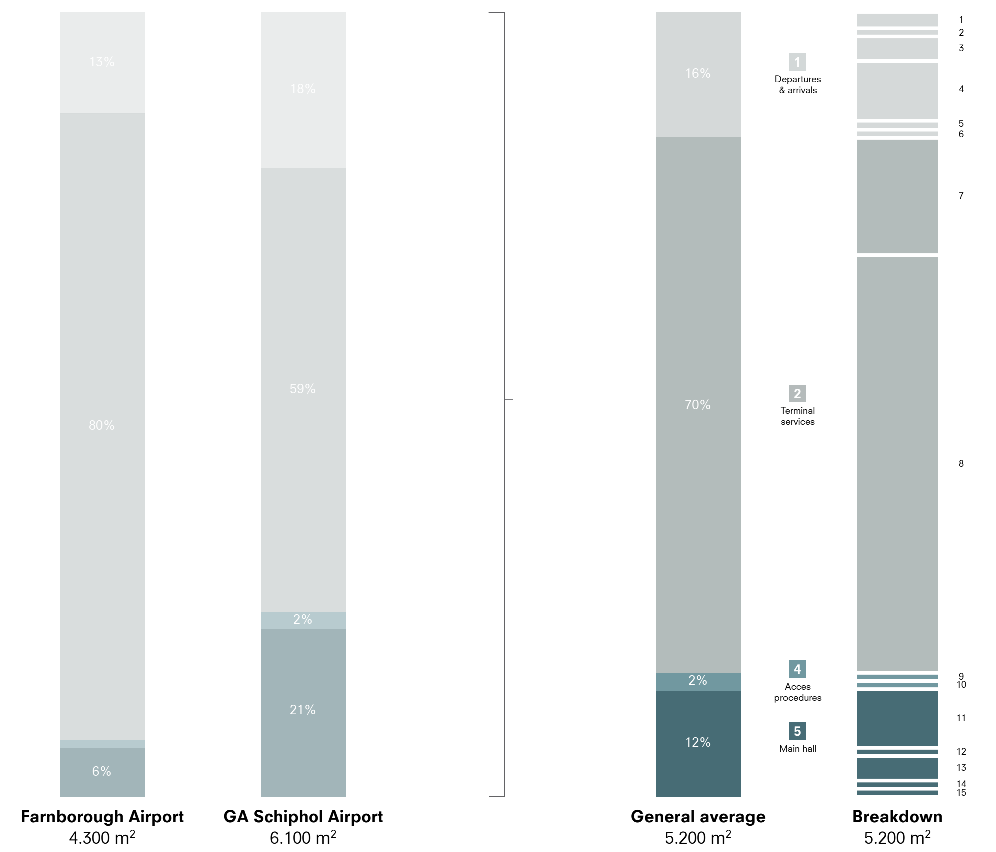


Figure 17: Benchmarks.



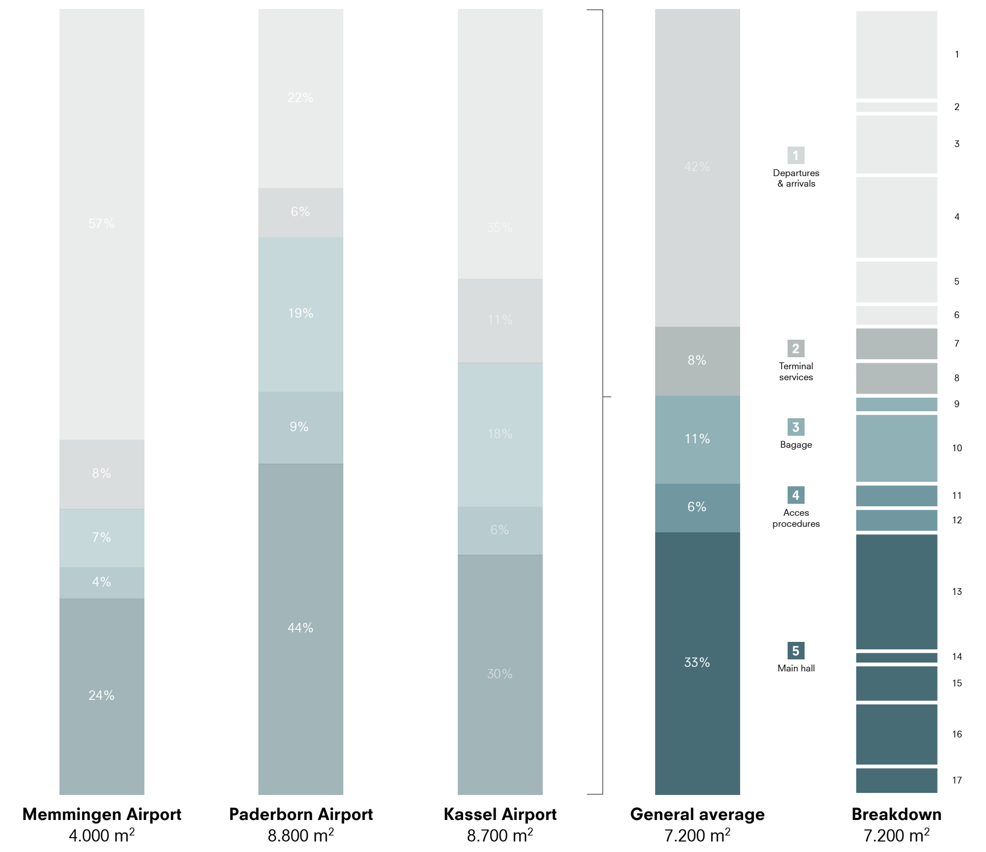
Departures & arrivals	**37%**
1. Gates	7%
2. Ticketing	1%
3. Arrivals area	8%
4. Waiting area	11%
5. Shops & restaurants	7%
6. Restrooms	3%
Terminal services	**16%**
7. Offices & other	6%
8. Maintenance	10%
Bagage distribution	**12%**
9. Ground handling	4%
10. Claim area	8%
Acces procedures	**6%**
11. Check-in counters	3%
12. Security checkpoints	3%
Main hall	**29%**
13. Flow space	15%
14. Transfer services	3%
15. Information desk	1%
16. Retail and dining	7%
17. Restooms	3%

Figure 18: Mid-sized airport benchmarks.



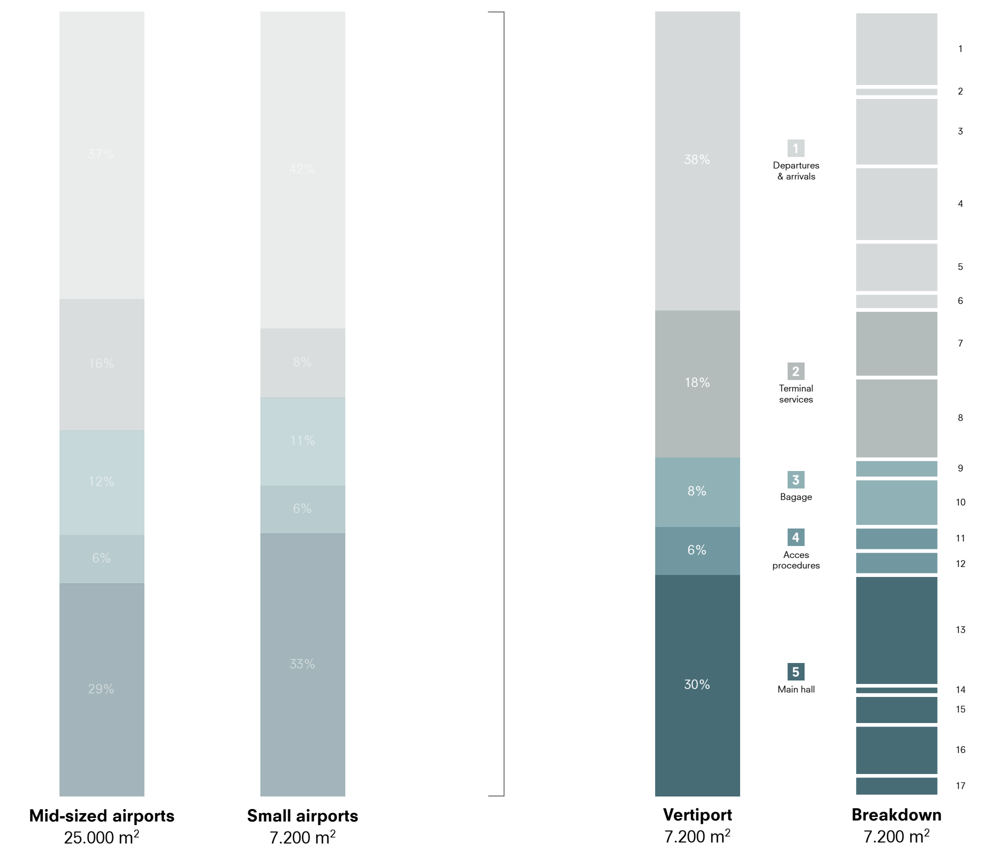
Departures & arrivals	**16%**
1. Gates	2%
2. Ticketing	1%
3. Arrivals area	3%
4. Waiting area	8%
5. Shops & restaurants	1%
6. Restrooms	1%
Terminal services	**70%**
7. Offices & other	55%
8. Maintenance	15%
Acces procedures	**2%**
9. Check-in counters	1%
10. Security checkpoints	1%
Main hall	**12%**
11. Flow space	7%
12. Transfer services	1%
13. Information desk	2%
14. Retail and dining	1%
15. Restooms	1%

Figure 19: General Aviation airports benchmarks.



Departures & arrivals	**42%**
1. Gates	12%
2. Ticketing	2%
3. Arrivals area	8%
4. Waiting area	11%
5. Shops & restaurants	6%
6. Restrooms	3%
Terminal services	**8%**
7. Offices & other	4%
8. Maintenance	4%
Bagage distribution	**11%**
9. Ground handling	2%
10. Claim area	9%
Acces procedures	**6%**
11. Check-in counters	3%
12. Security checkpoints	3%
Main hall	**33%**
13. Flow space	16%
14. Transfer services	1%
15. Information desk	5%
16. Retail and dining	8%
17. Restooms	3%

Figure 20: Small airports benchmarks.



Departures & arrivals	**38%**
1. Gates	10%
2. Ticketing	1%
3. Arrivals area	9%
4. Waiting area	10%
5. Shops & restaurants	6%
6. Restrooms	2%
Terminal services	**18%**
7. Offices & other	8%
8. Maintenance	10%
Bagage distribution	**8%**
9. Ground handling	2%
10. Claim area	6%
Acces procedures	**6%**
11. Check-in counters	3%
12. Security checkpoints	3%
Main hall	**30%**
13. Flow space	15%
14. Transfer services	1%
15. Information desk	4%
16. Retail and dining	7%
17. Restooms	3%

Figure 21: Combined breakdown.

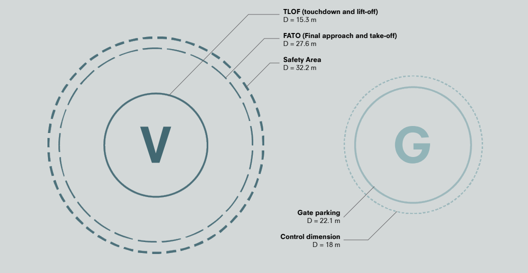
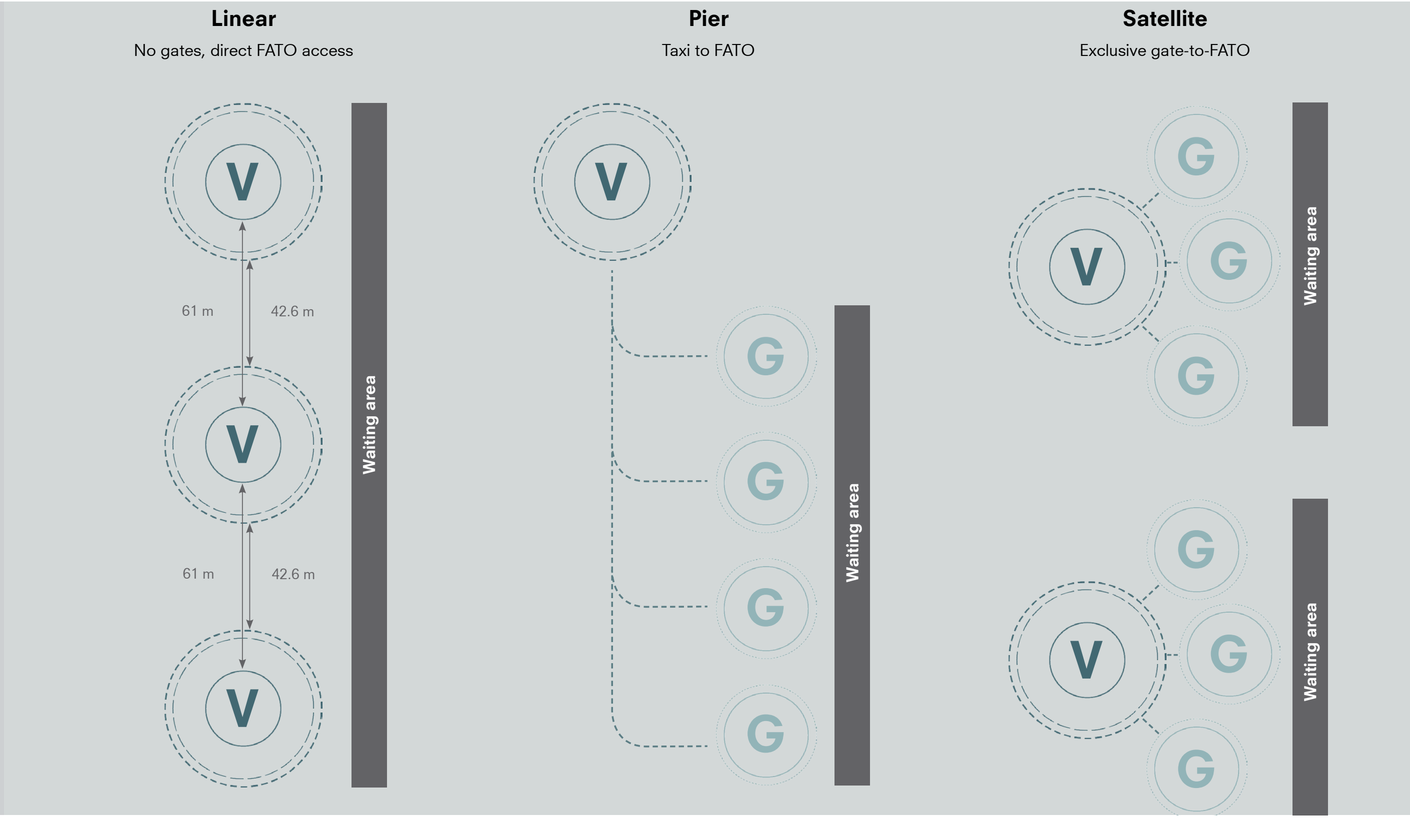
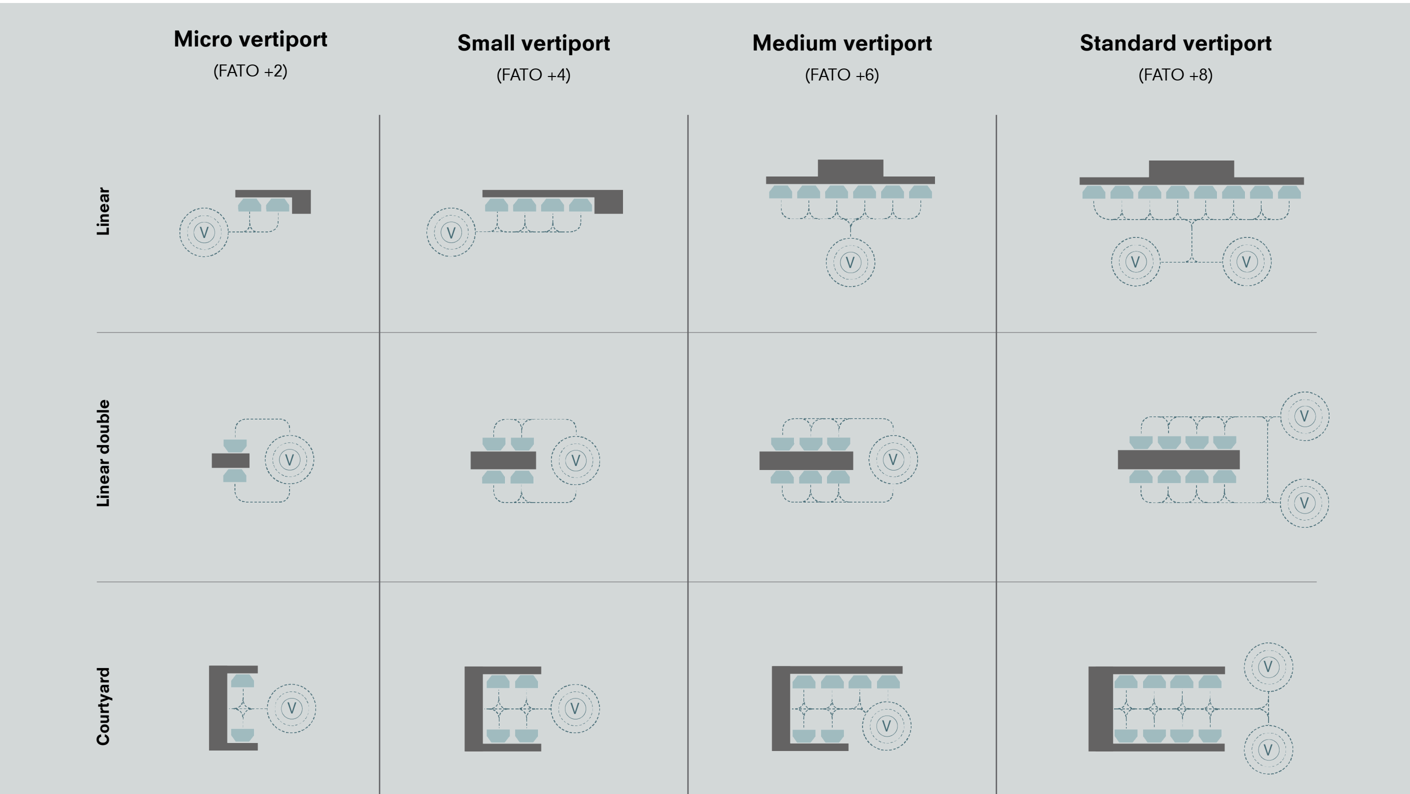


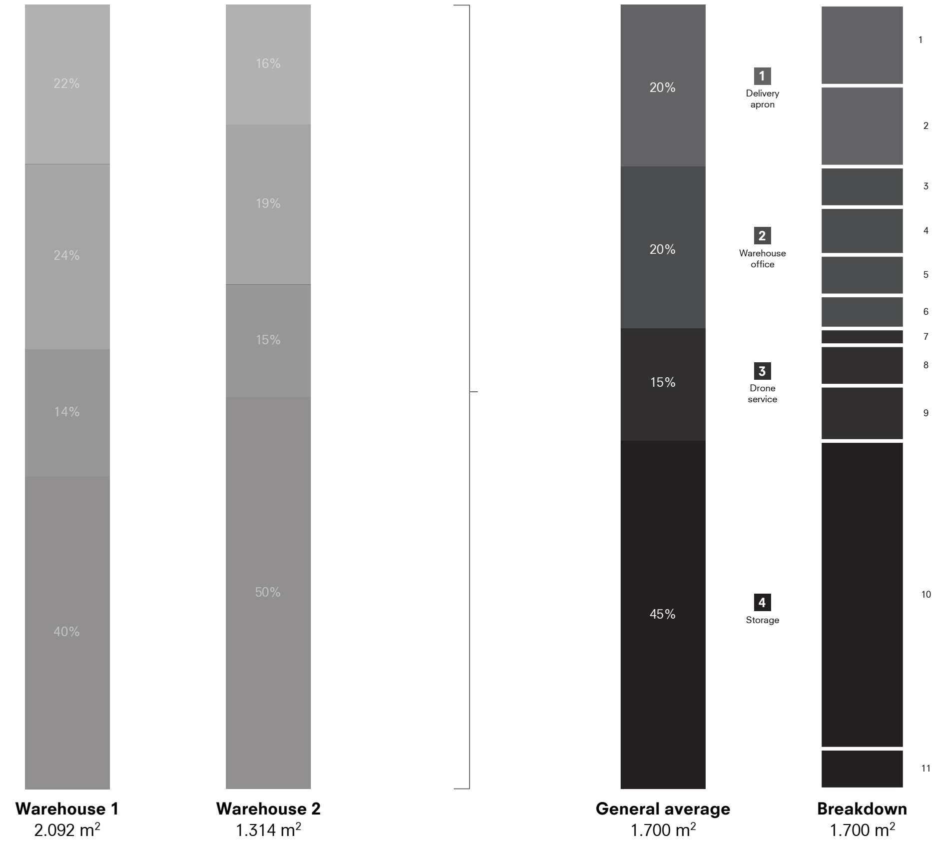
Figure 22: Apron size.

Figure 23: Vertiport gate layout.

Figure 24: Modular gate study.







Delivery apron		**20%**
1. Loading		10%
2. Unloading		10%
Warehouse office		**20%**
3. Shipping and receiving		5%
4. Security		6%
5. Toilets		5%
6. Lounge		4%
Drone service		**15%**
7. Charging		2%
8. Maintenance and repair		5%
9. Drone control center		8%
Storage		**45%**
10. Warehouse racks		40%
11. Data center		5%

Figure 25: Warehouse breakdown.

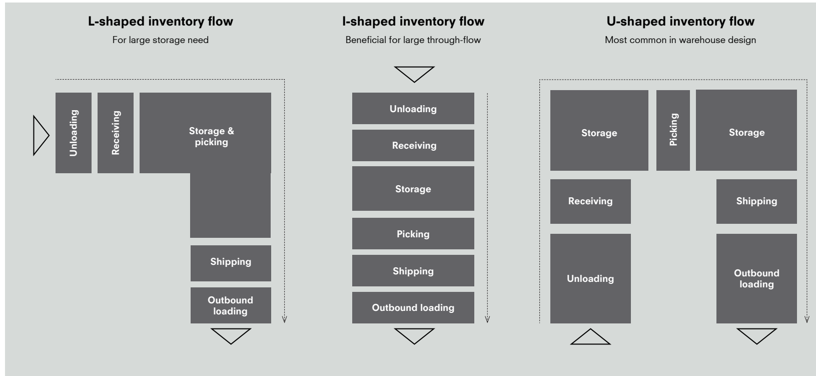


Figure 26: Warehouse layout.

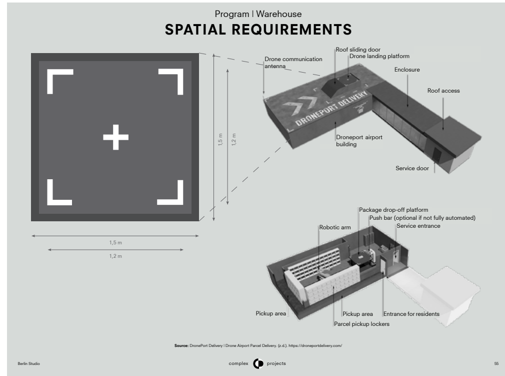


Figure 27: Spatial requirements.

The reference project is a speculative design concept of an enclosure which contains a series of spaces that can be placed as a unit throughout the city. Both on the roofs of existing buildings and in tactical places in public spaces. The idea is that packages are delivered by drones and placed in lockers by a robot arm. You can then collect the ordered package with a personalized code. The package drop-off and collecting platform is an estimated 4 squared meters. The service area must be an estimated 10 squared meters

The drone hub's warehouse will be fully automatic, completely data-driven in the digitalization theme. Robots and AI-controlled mechanisms ensure that the right packages are moved to the drone pad at the right time, so that it can fly away with ease.

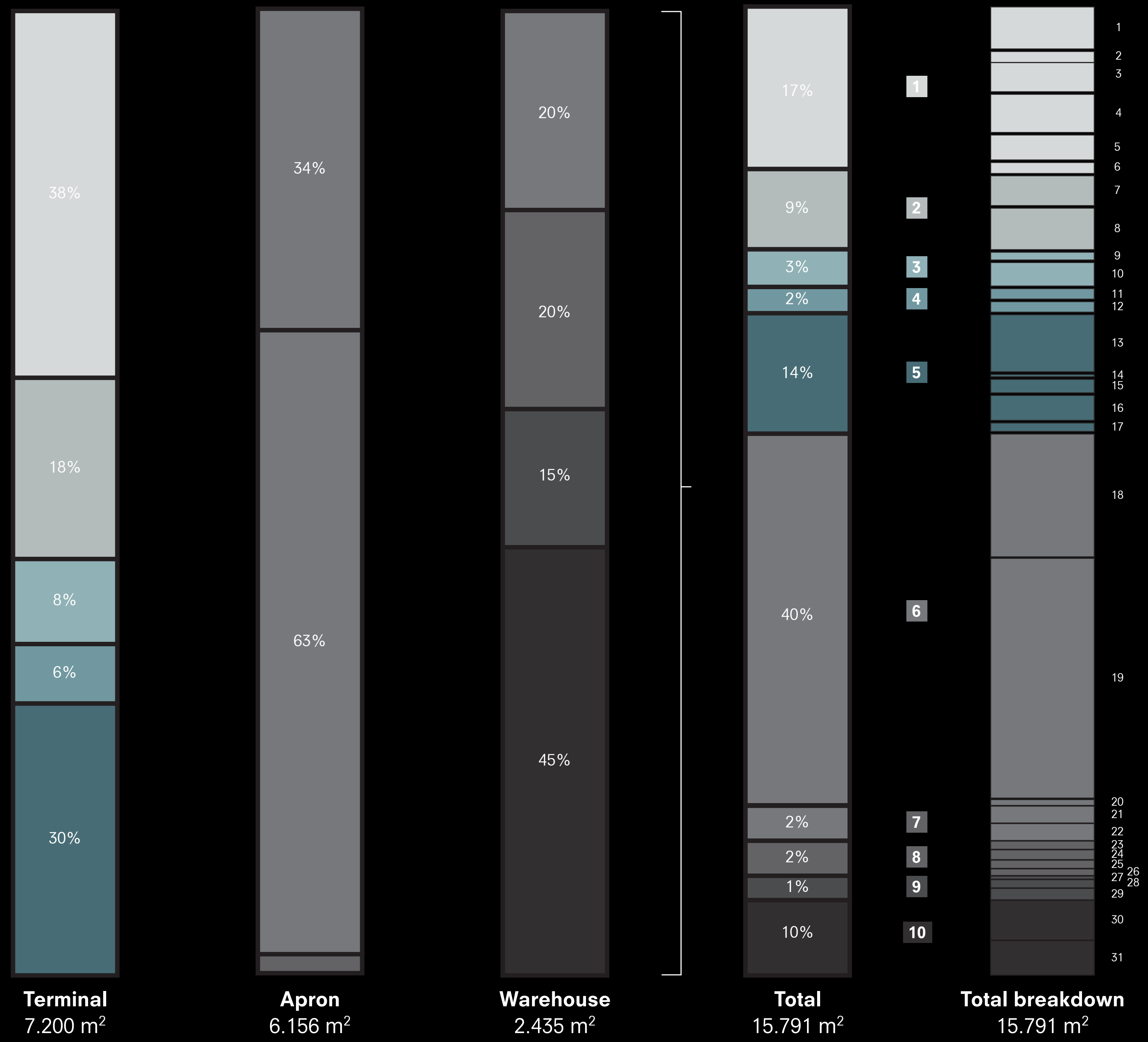
Dependent on package demand. At one time around 1200 cargo drones can be active in Berlin. Those will deliver between 9 and 12 parcels per drone per day. For a storage room there must be a minumum capacity of:
1200 x 12 = 14.400 parcels available.

Assuming that a drone transports standard boxes with the largest having the dimensions of 600mm x 600mm x 300mm, therefore with a volume of 0.108 m³, the warehouse should have a volume of:
0.108 x 14.400 = 1555,2 m³.

1200	14.400	1.555 m³
Drones active	Parcels delivered daily	Required storage

Figure 28: Automated distribution center.

[redacted]



[redacted]

[redacted]

Departures & arrivals	**17%**
1. Gates	4,5%
2. Ticketing	0,5%
3. Arrivals area	4%
4. Waiting area	4,5%
5. Shops & restaurants	2,5%
6. Restrooms	1%
Terminal services	**9%**
7. Offices & other	4%
8. Maintenance	5%
Bagage distribution	**3%**
9. Ground handling	1%
10. Claim area	2%
Acces procedures	**2%**
11. Check-in counters	1%
12. Security checkpoints	1%
Main hall	**14%**
13. Flow space	7%
14. Transfer services	0,5%
15. Information desk	1,5%
16. Retail and dining	3%
17. Restooms	1%
Apron	**40%**
18. FATO	13%
19. Vertipads	26%
20. Charging	1%
Delivery apron	**2%**
21. Loading	1%
22. Unloading	1%
Warehouse office	**2%**
23. Shipping and receiving	0.5%
24. Security	0,5%
25. Toilets	0,5%
26. Lounge	0,5%
Drone service	**1%**
27. Charging	0,3%
28. Maintenance and repair	0,3%
29. Drone control center	0,3%
Storage	**10%**
30. Warehouse racks	5%
31. Data center	5%

[redacted]

Figure 29: Full program breakdown.

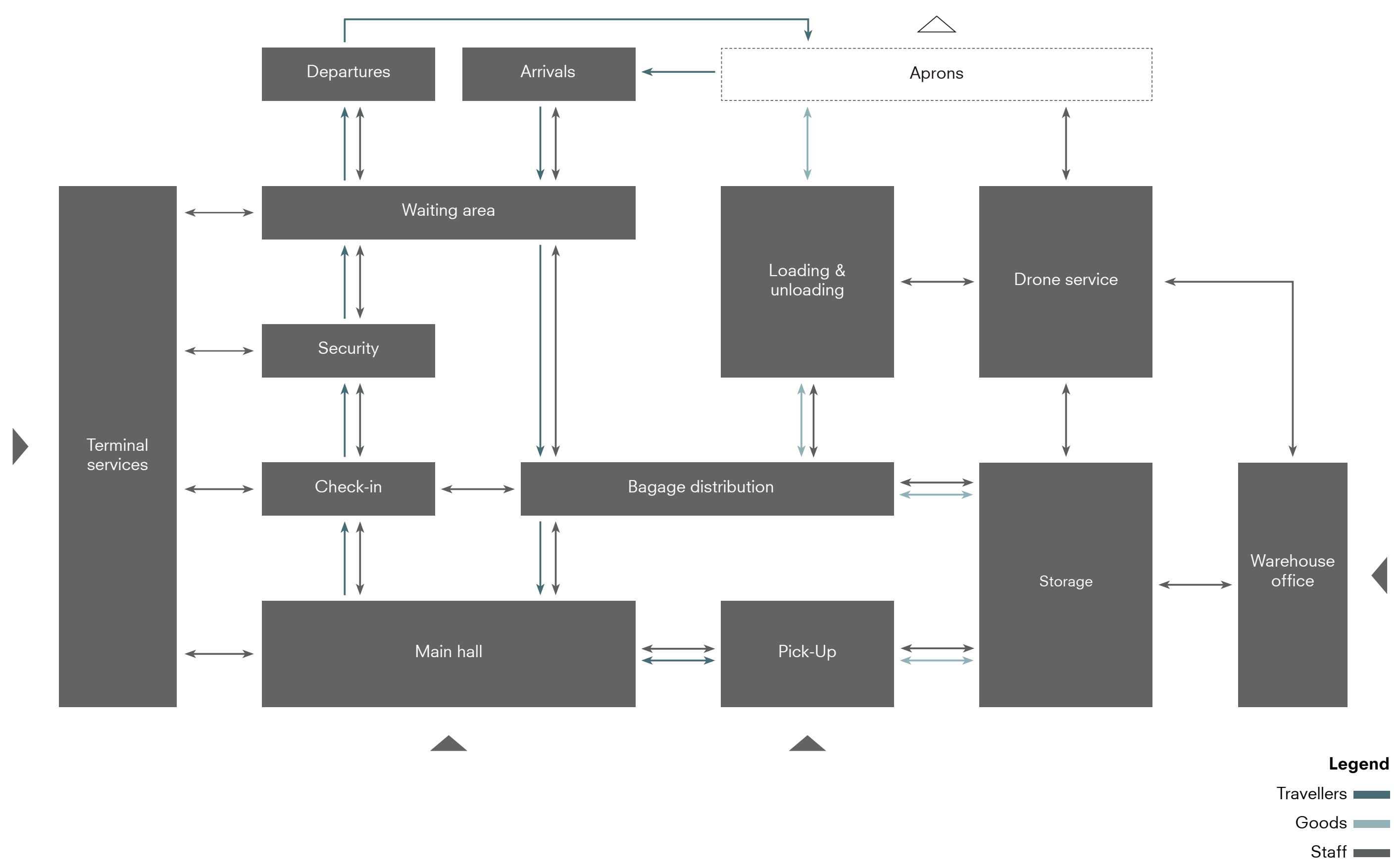


Figure 30: Flow scheme.

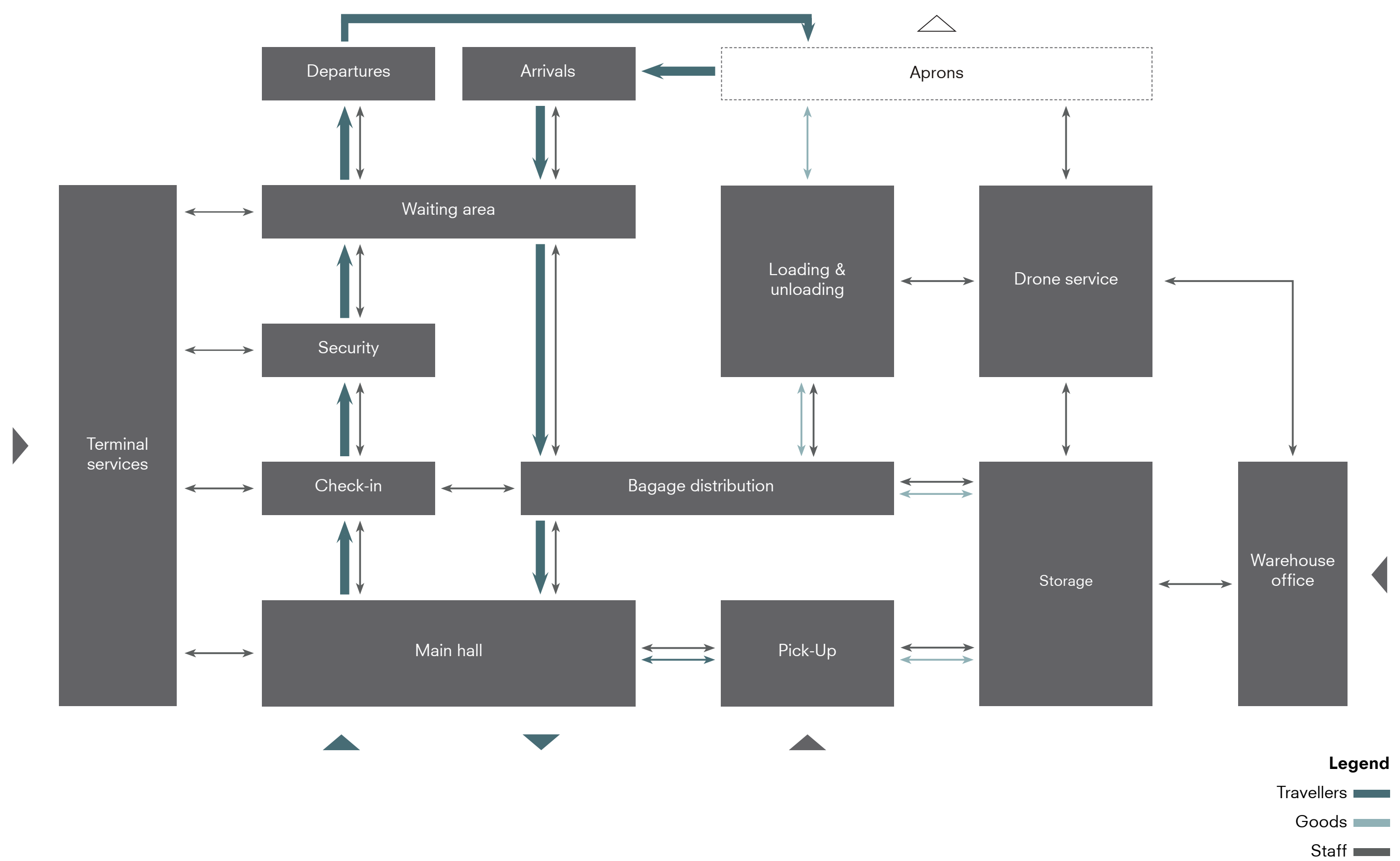


Figure 31: Passenger flow.

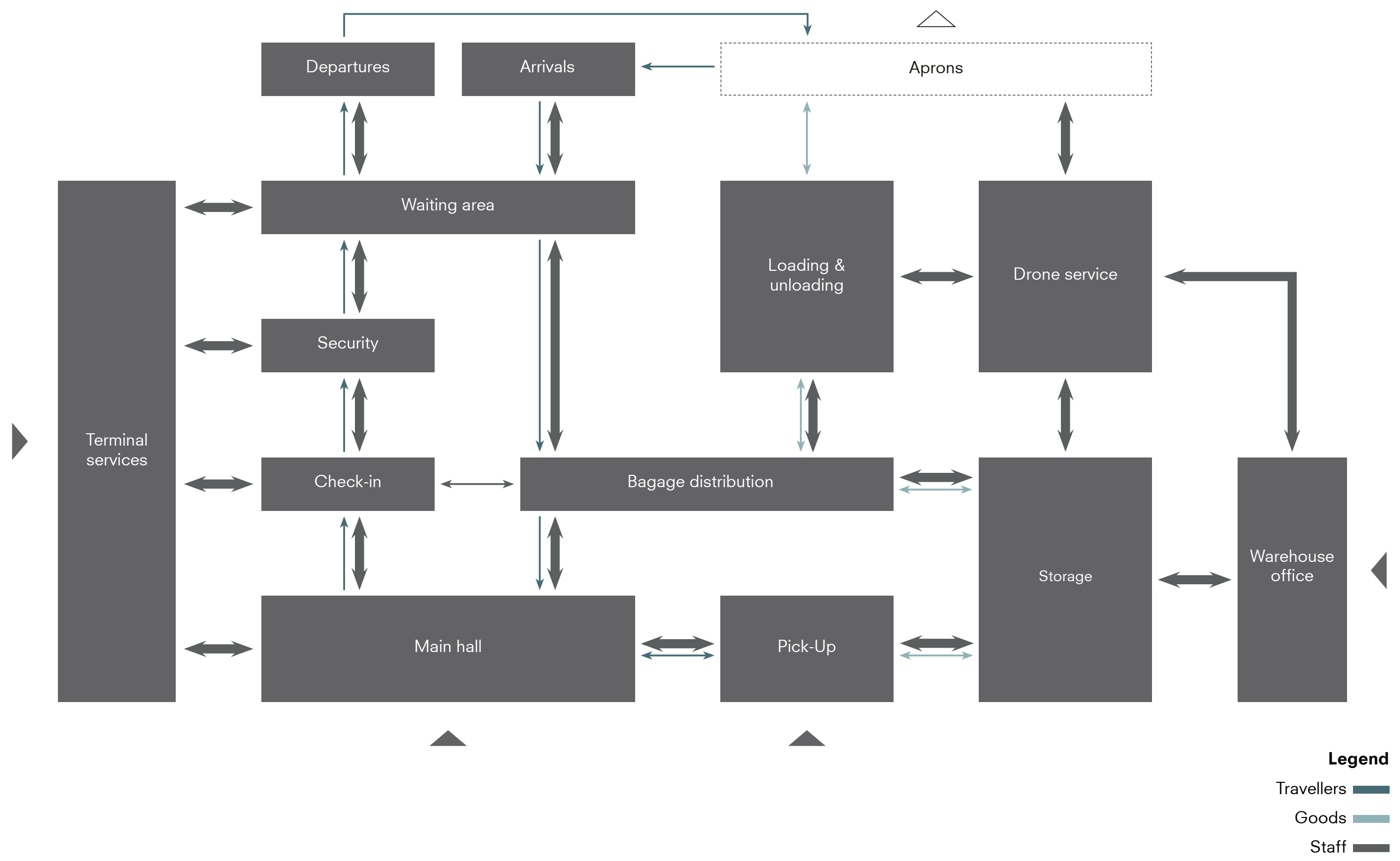


Figure 32: Staff flow.

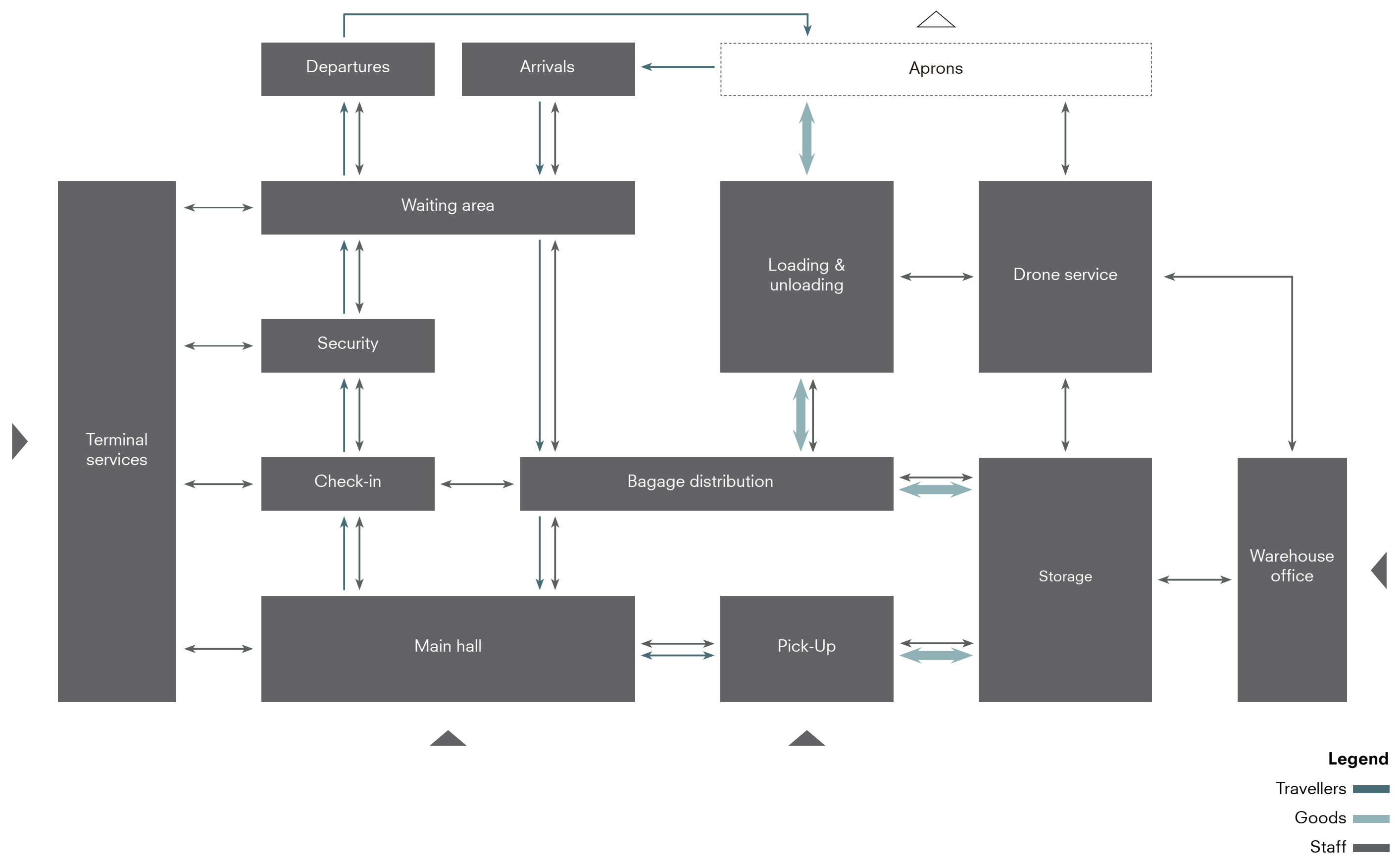


Figure 33: Delivery flow

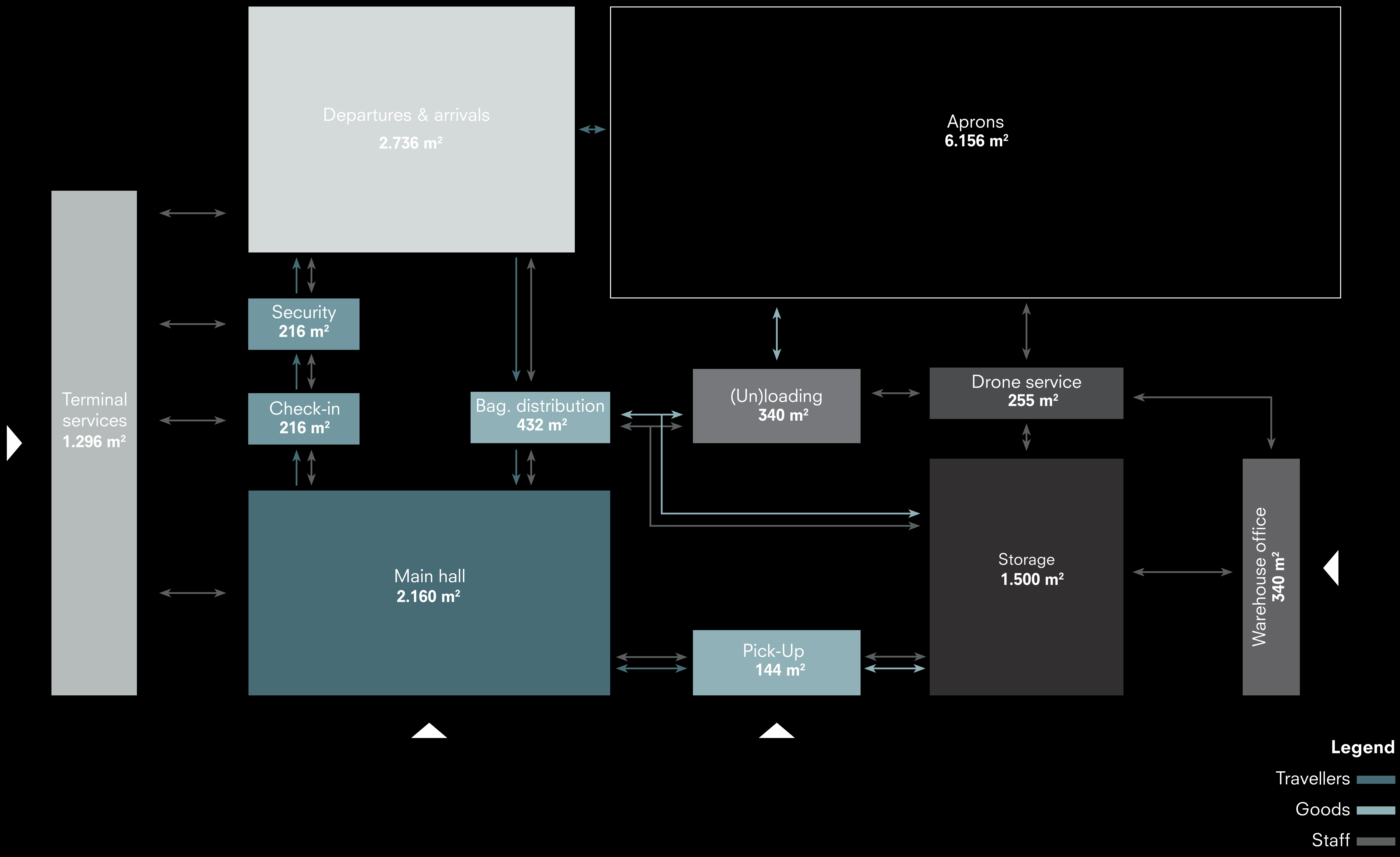


Figure 34: Full program scheme.

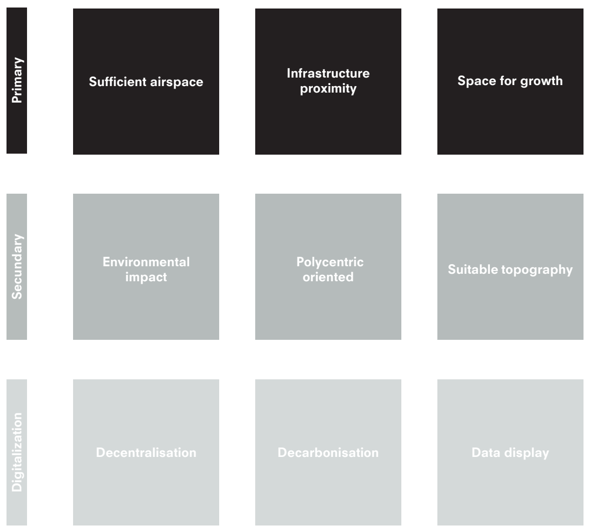


Figure 35: Site criteria.

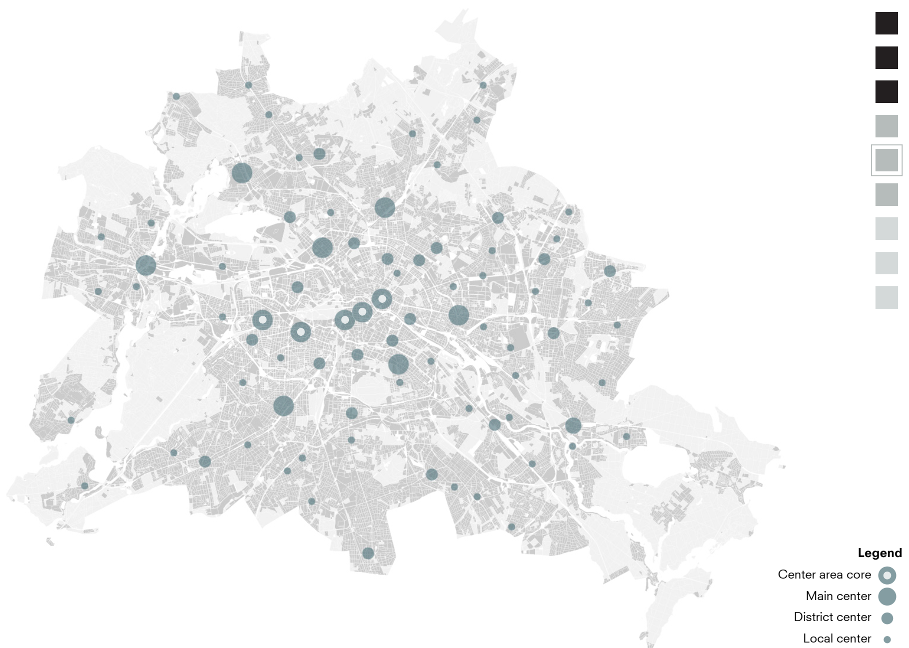


Figure 36: Polycentric city centers.

Figure 37: Public transport.

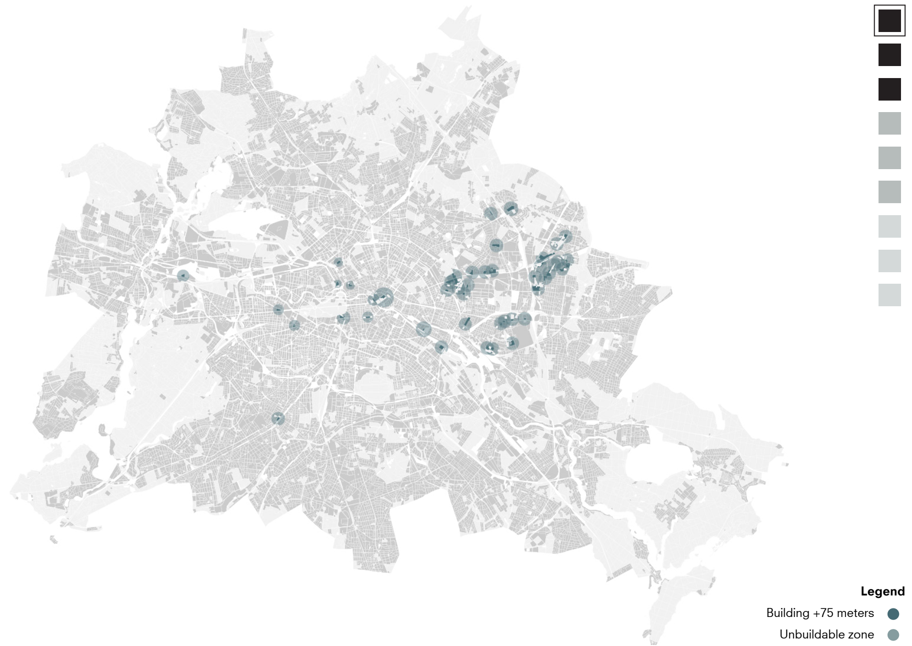


Figure 38: Urban heights.

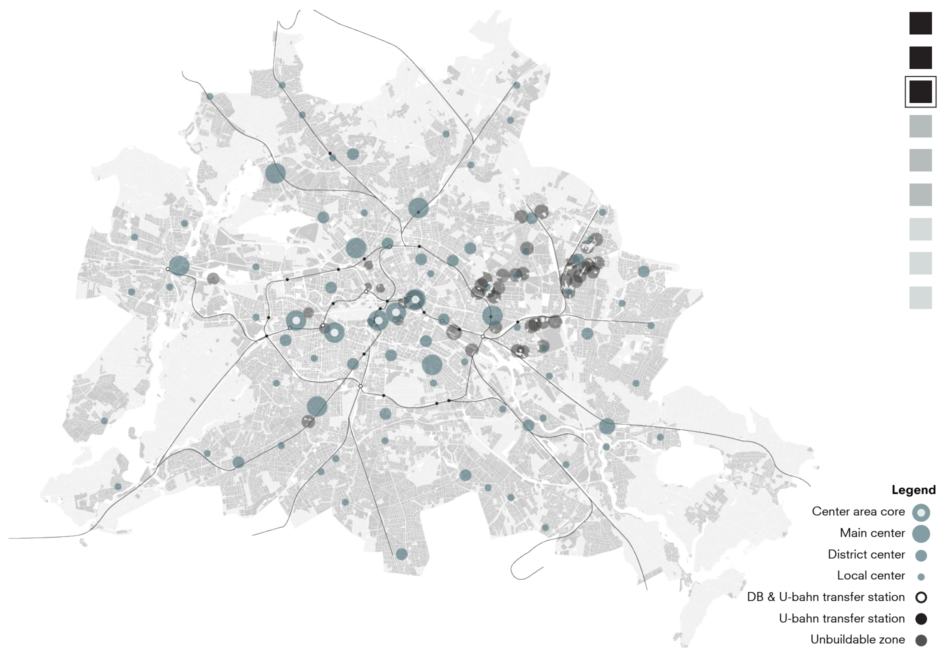


Figure 39: Criteria overlayed.

Figure 40: Suitable spots.

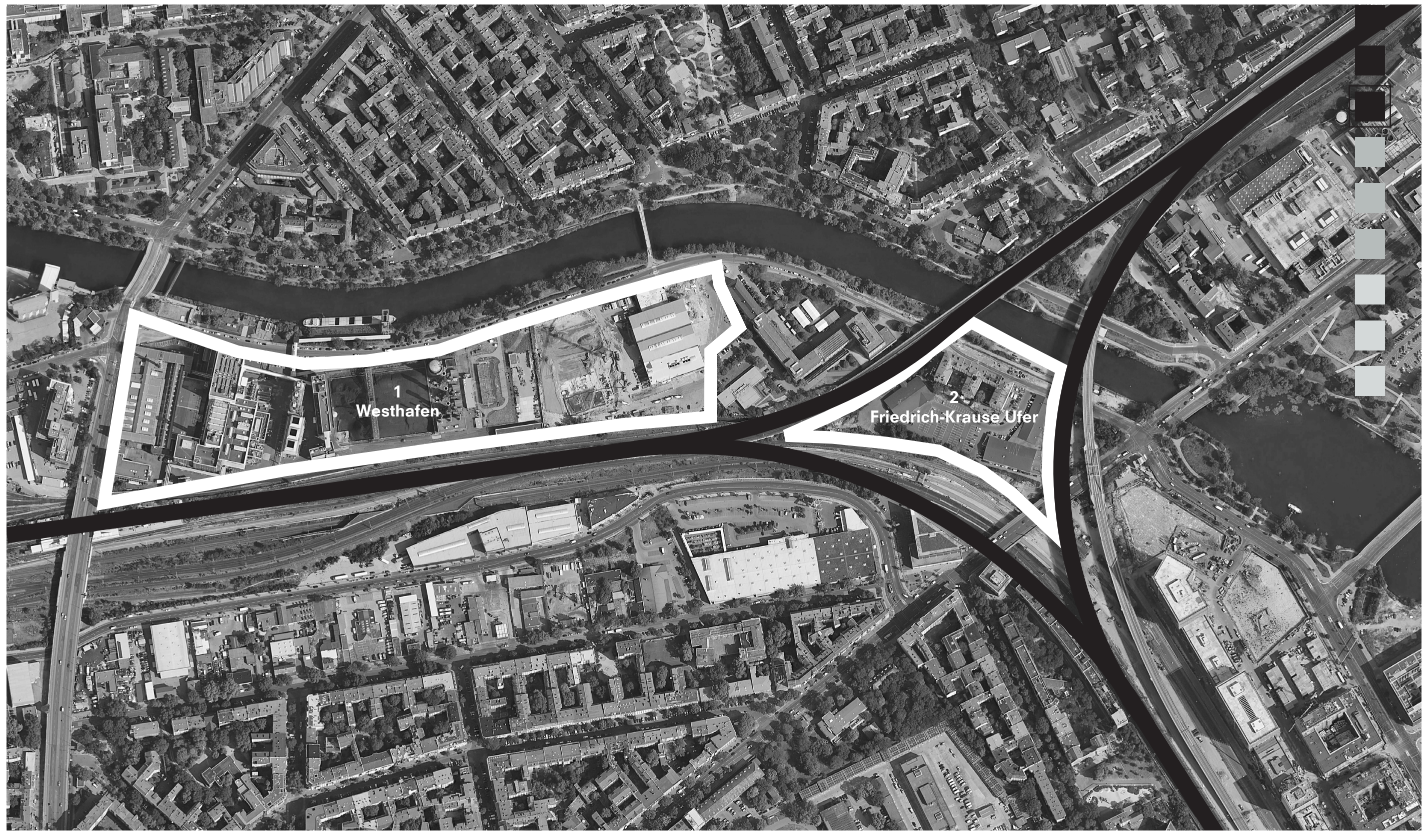


Figure 41: Potential plots 1.

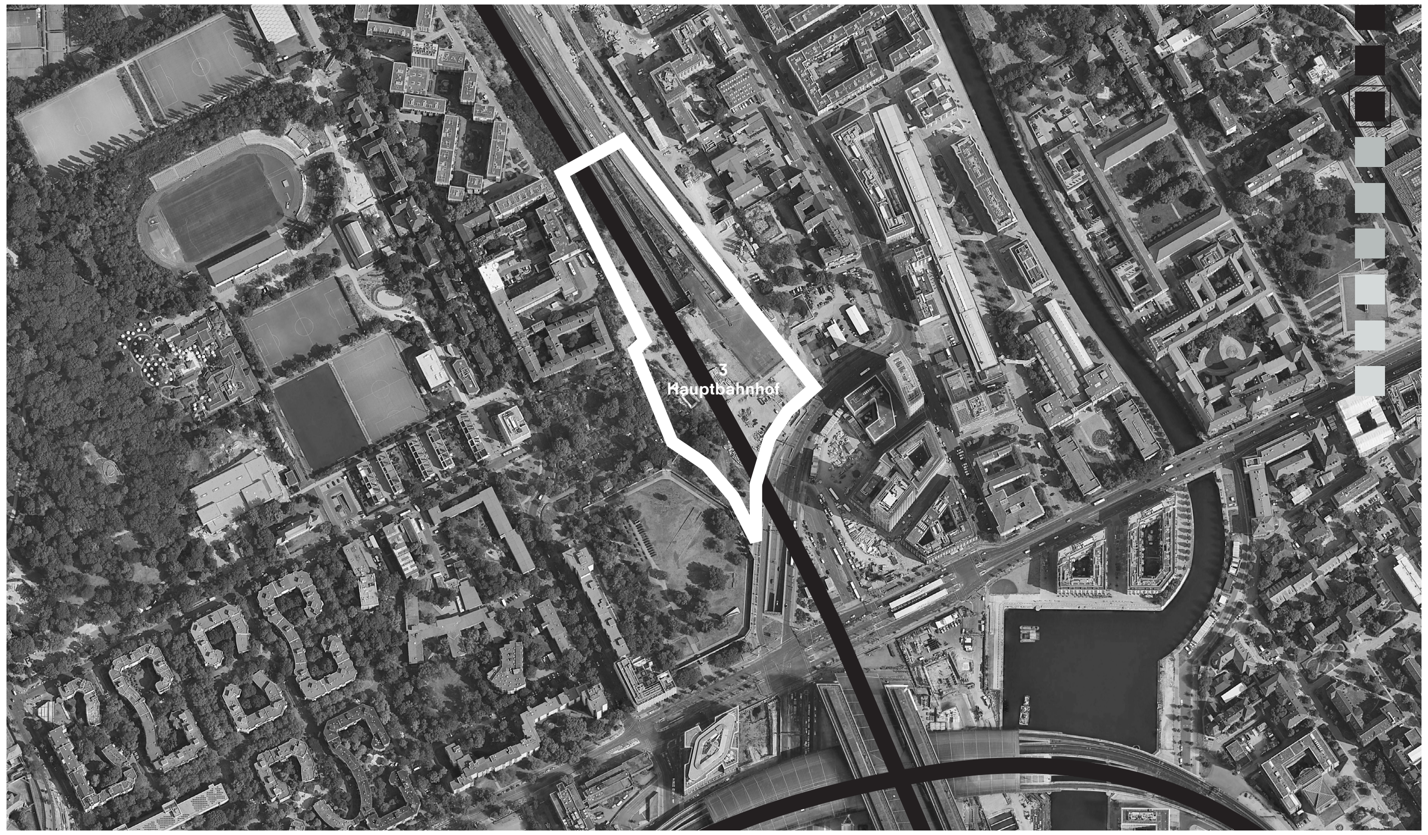
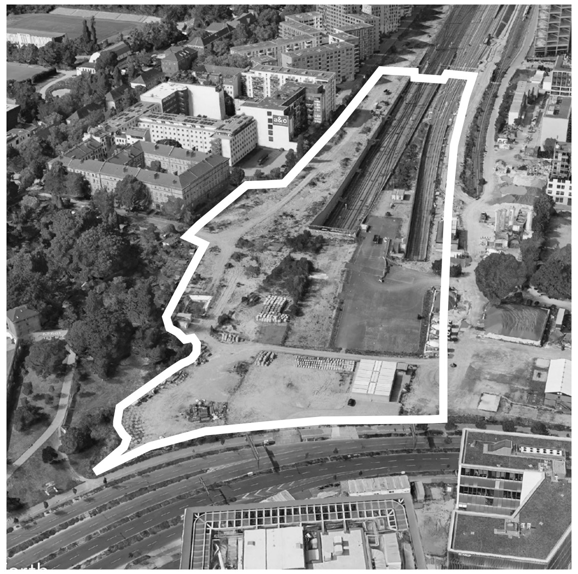


Figure 42: Potential plots 2.

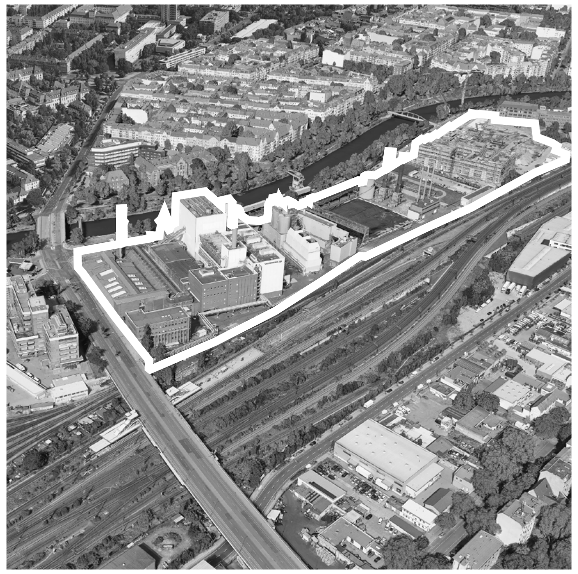


Plot 3: Hauptbahnhof

Surface area: **41.146 m²**
Current use: Construction site

+ Spacious plot with possibility to grow over train tracks
+ Economically located next to urban development area
+ Direct transfer options to DB-trains, S- and U-Bahn
- Blocked from pedestrian area by busy road

Figure 43: Hauptbahnhof analysis.



Plot 1: Westhafen

Surface area: **84.075 m²**
Current use: Turbinenhall Eventlocation

+ Great transfer to new trainstation, S- and U-Bahn
+ Along arterial road and accesable via the canal
+ Centrally located towards developping
- Demolishing of monumental objects is required

Figure 44: Westhafen.

Plot 2: Friedric-Krause Ufer

Surface area: **24.200 m²**
Current use: Construction site and car park

+ In between tracks, great cargo hotspot
+ Directly to the waterfront
- Not directly connected to a station
- Less accessable for quick travellers

Figure 45: FK-Ufer.

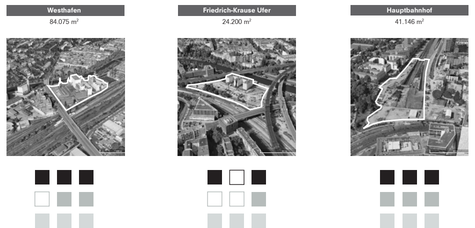


Figure 46: Site examination.

Figure 47: Aerospace facilities.

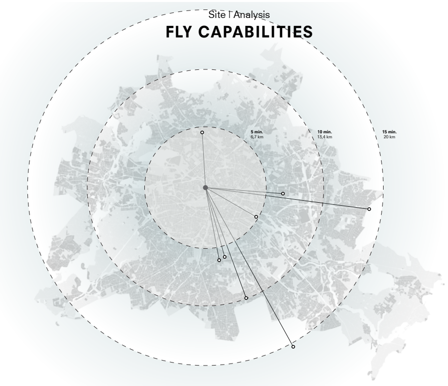


Figure 48: Fly capabilities.

Figure 49: Cargo facilities.

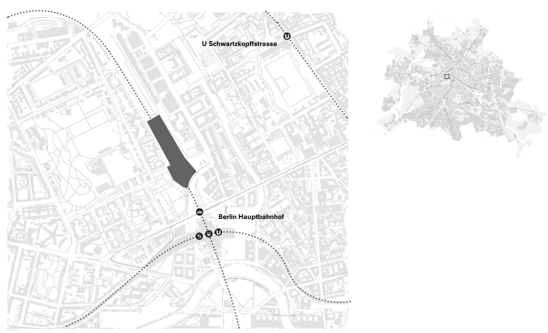


Figure 50: Infrastructure connection.

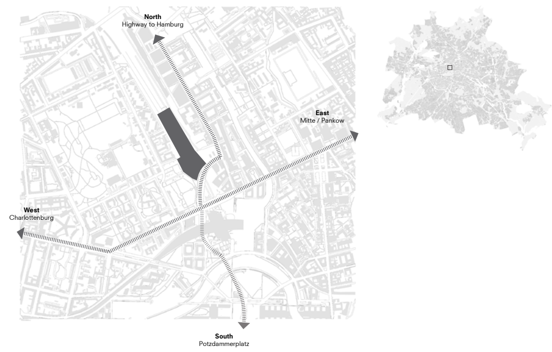


Figure 51: Road accessibility.

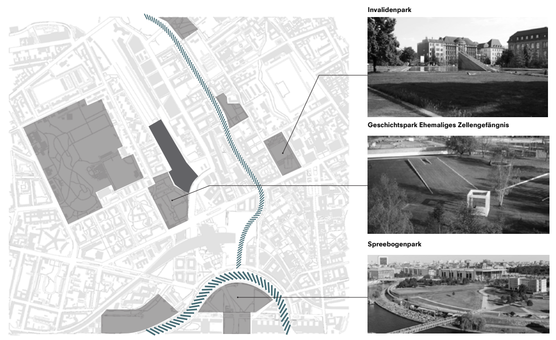


Figure 52: Nature analysis

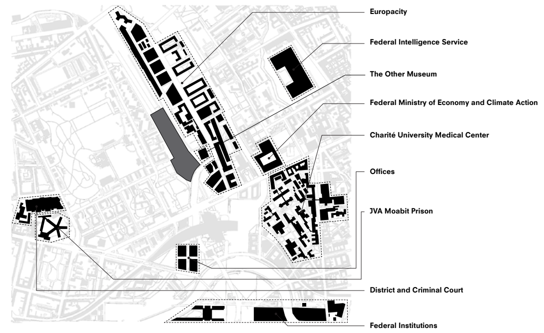


Figure 53: Economic viability.

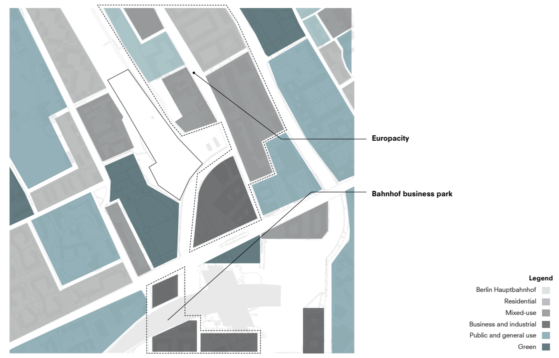


Figure 54: Land use

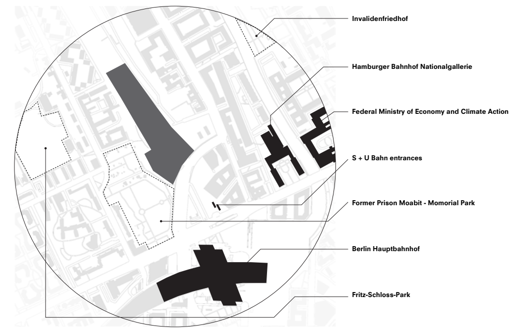


Figure 55: 10 min. walking distance map.

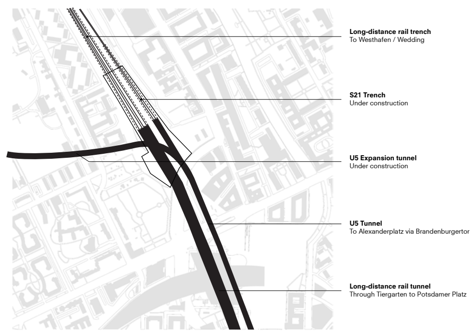


Figure 56: Constraints.

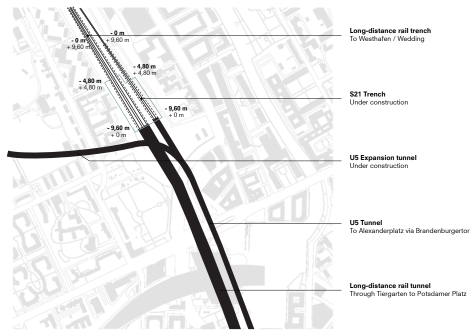


Figure 57: Opportunities.

Figure 58: Site location.

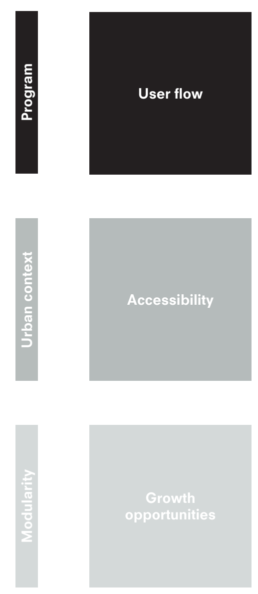


Figure 59: Site specific criteria.

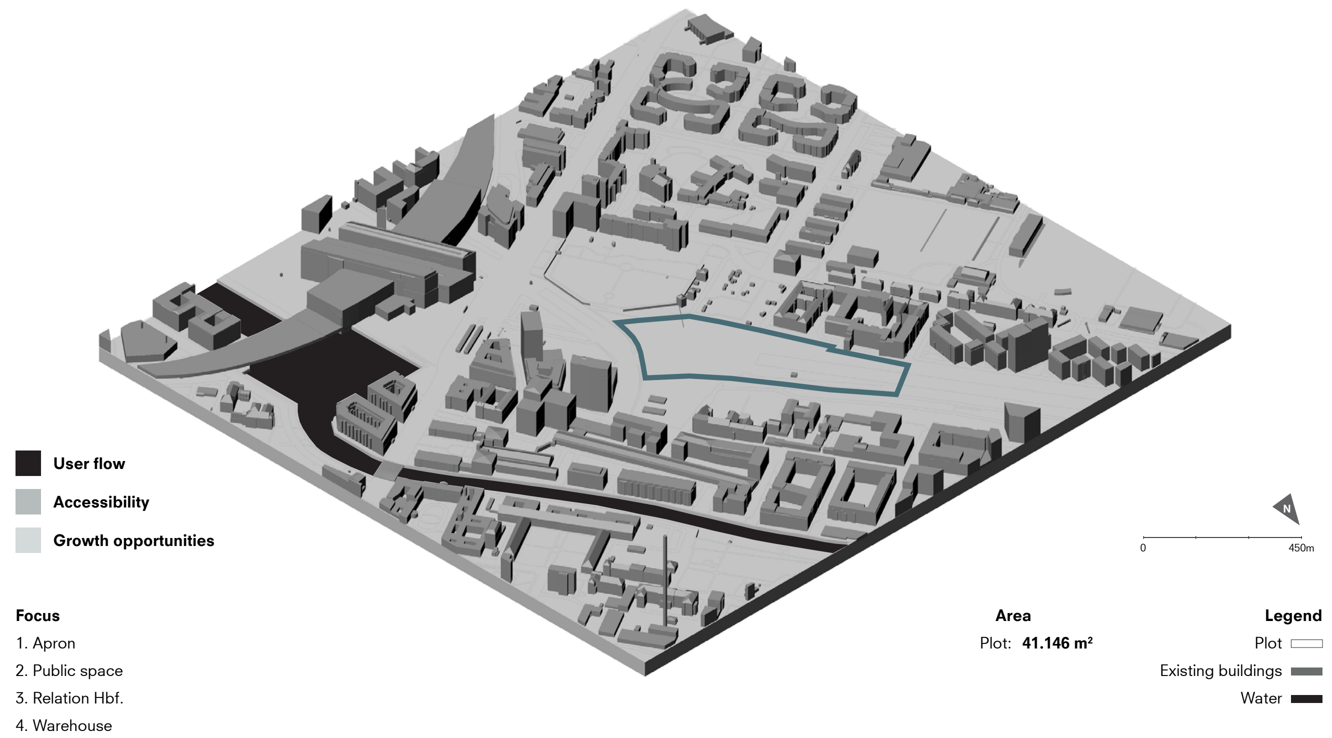
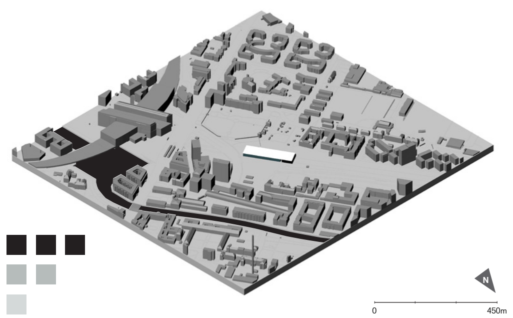
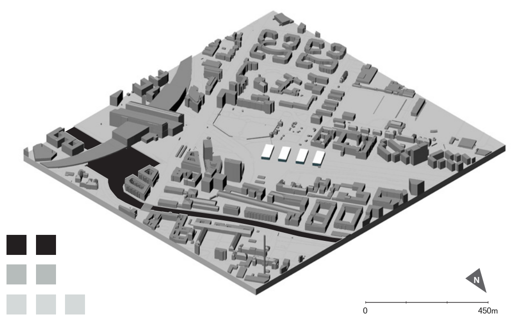


Figure 60: Plot.

Option 1.1
Apron on terminal roof



Option 1.2
Apron on satellite terminals



Aspects
+ Passenger flow vertical
+ Safe apron distance
+ Small footprint
- Inconvenient growth
- Warehouse too far from road

Area
Plot: **41.146 m²**
Footprint **6.640 m² (16%)**
GFA: **19.920 m²**

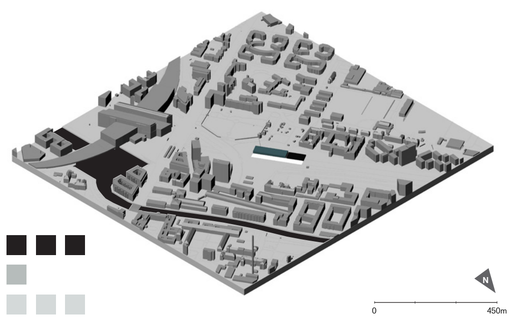
Aspects
+ Strong modularity
+ Dynamic public space
- Confusing flow
- Inefficient warehouse

Area
Plot: **41.146m²**
Footprint **6.768 m² (16%)**
GFA: **20.304 m²**

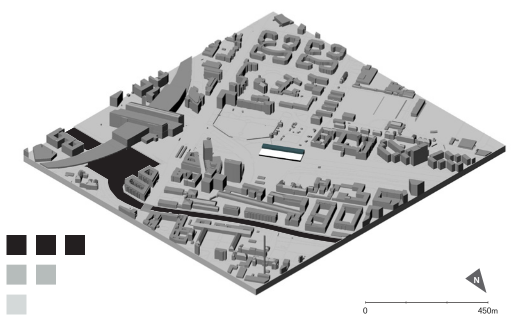
Legend
Terminal
Apron
Warehouse
Existing buildings
Water

Figure 61: Mass focus on apron 1.

Option 1.3
Apron on ground level



Option 1.4
Apron raised, program mixed



Aspects
+ Short distance flow
+ Easy expandable
+ Common terminal design
- Apron limits accessibility

Area
Plot: **41.146 m²**
Footprint **8.016 m² (20%)**
GFA: **15.876 m²**

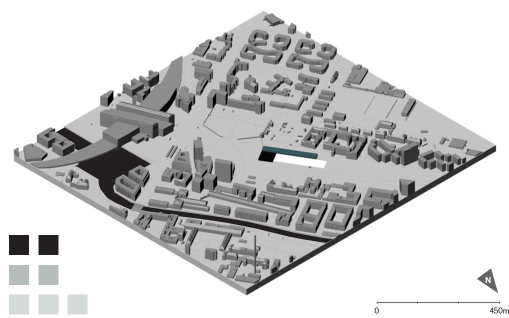
Aspects
+ Integral design
+ Vertical flow
+ Warehouse under apron
- Inefficient expansions

Area
Plot: **41.146 m²**
Footprint **6.435 m² (16%)**
GFA: **16.256 m²**

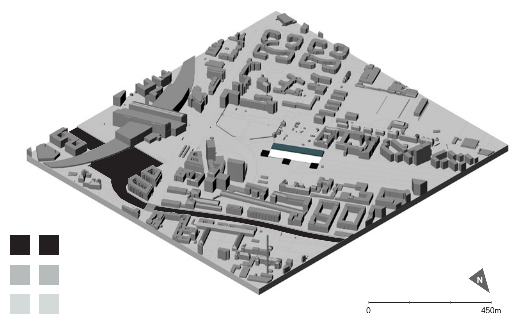
Legend
Terminal
Apron
Warehouse
Existing buildings
Water

Figure 62: Mass focus on apron 2.

Option 4.1
Post & parcel center priority



Option 4.2
Decentralised storages



Aspects
+ Efficient last-mile delivery
+ Growth possible
+ Beneficial for adjacent museum
- Long terminal flow

Area
Plot: **41.146 m²**
Footprint **11.936 m² (29%)**
GFA: **16.704 m²**

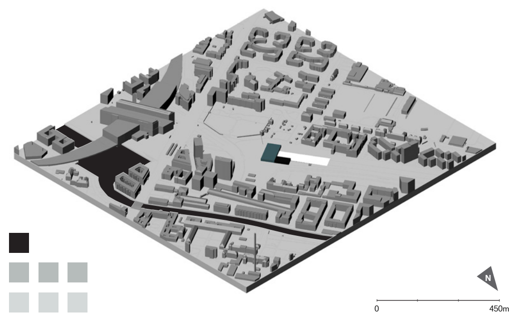
Aspects
+ Pickup reacts to context
+- growth possibilities limited
- Long terminal flow
- No central entrance

Area
Plot: **41.146 m²**
Footprint **12.203 m² (30%)**
GFA: **15.876 m²**

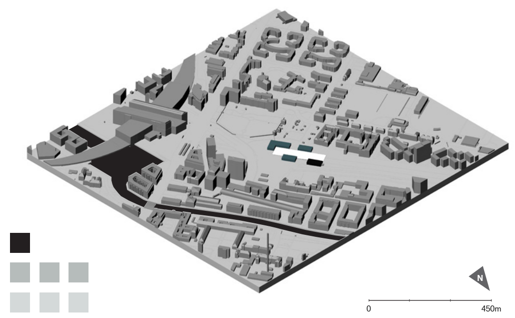
Legend
Terminal
Apron
Warehouse
Existing buildings
Water

Figure 63: Mass focus on warehouse.

Option 2.1
Main entrance area



Option 2.2
Entrances following urban context



Aspects
+ Entrance facing Hbf.
+ Warehouse near museum
+ Apron stretching over tracks
- Relatively large surface area

Area
Plot: **41.146 m²**
Footprint **11.061 m² (27%)**
GFA: **15.876 m²**

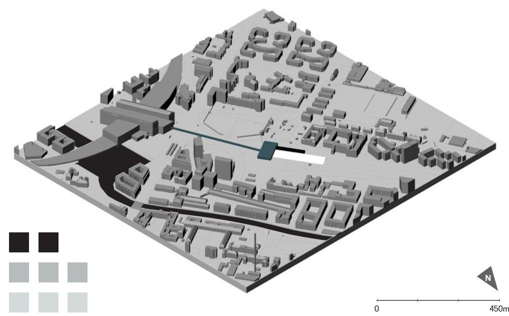
Aspects
+ Volumes react to urban context
+ Modular design
+ Allows public space
- Inefficient wayfinding

Area
Plot: **41.146 m²**
Footprint **11.061 m² (27%)**
GFA: **15.876 m²**

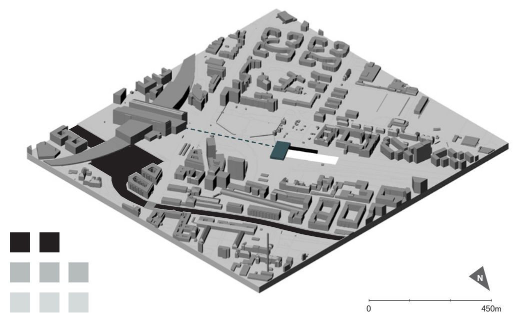
Legend
Terminal
Apron
Warehouse
Existing buildings
Water

Figure 64: Mass focus on public space.

Option 3.1
Bridge connection to main building



Option 3.2
Tunnel connection to platforms



Aspects
+ Direct acces to station
+ Beneficial cooperation
- Not connected to platforms
- Bridge may raise urban division

Area
Plot: **41.146 m²**
Footprint **11.061 m² (27%)**
GFA: **18.173 m²**

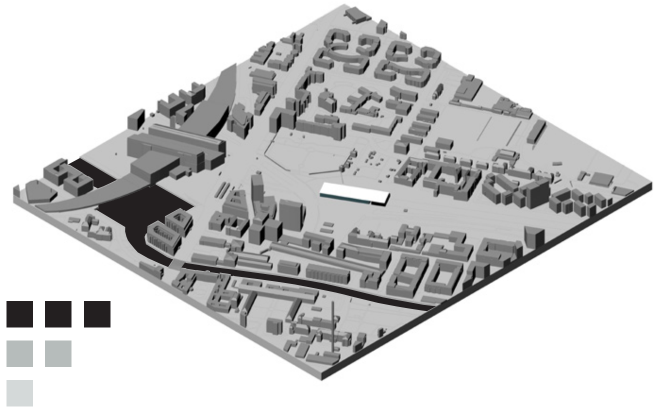
Aspects
+ Direct acces to platforms
+ Easy and dry transfers
+ Ground level remains walkable
- Tunnel size limited

Area
Plot: **41.146 m²**
Footprint **11061 m² (27%)**
GFA: **15.876 m²**

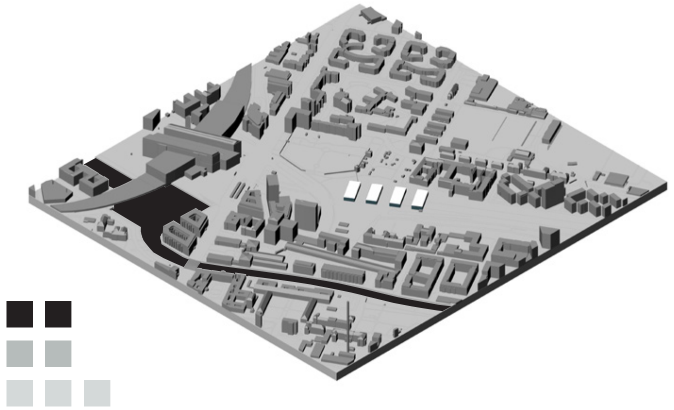
Legend
Terminal
Apron
Warehouse
Existing buildings
Water

Figure 65: Mass focus on relation Hbf.

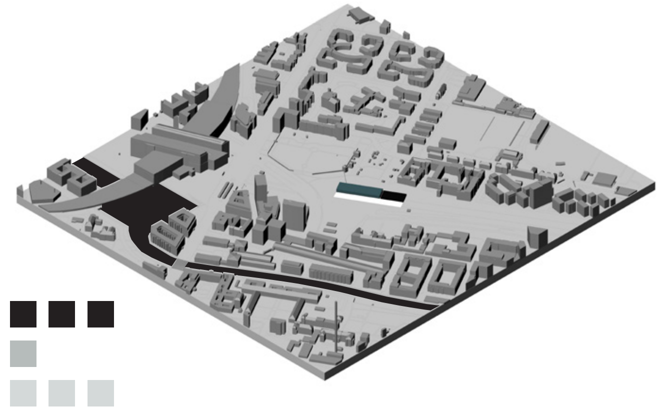
Option 1.1



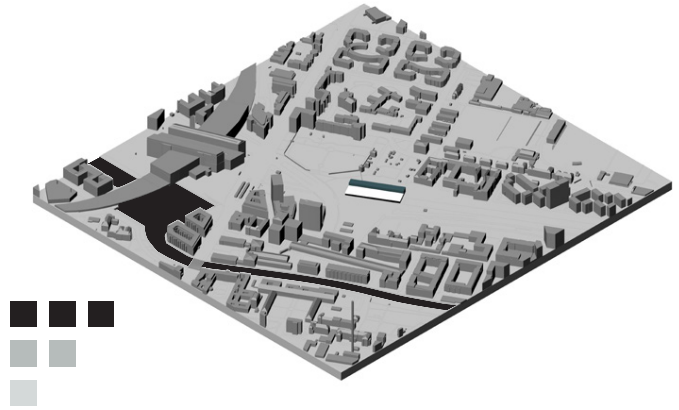
Option 1.2



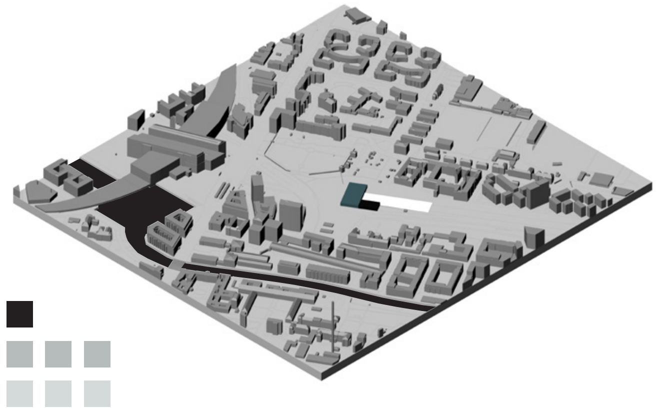
Option 1.3



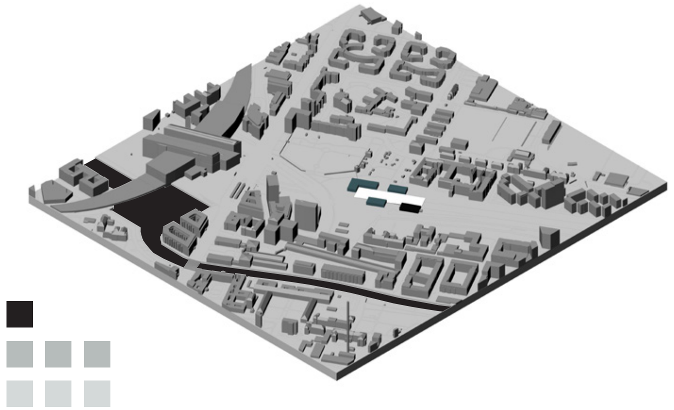
Option 1.4



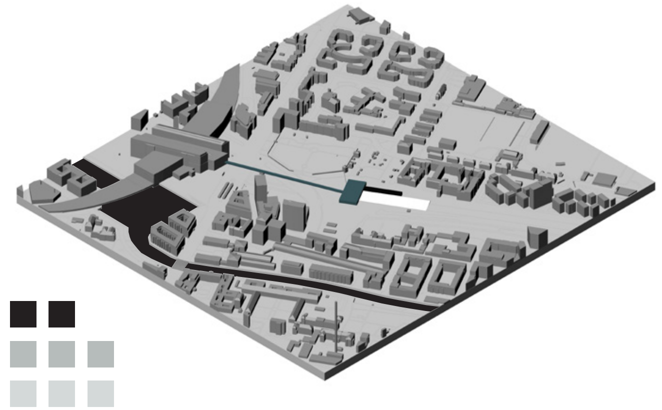
Option 2.1



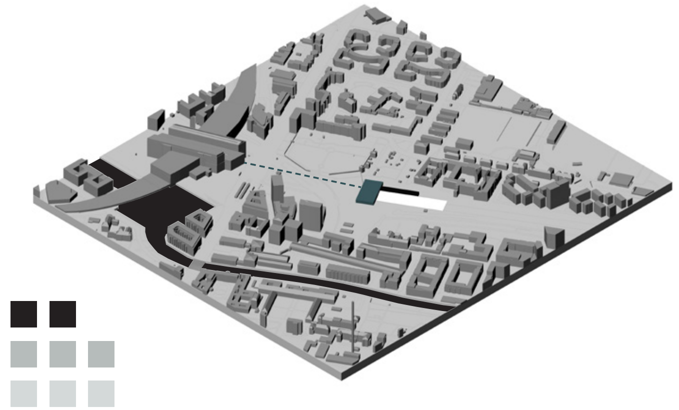
Option 2.2



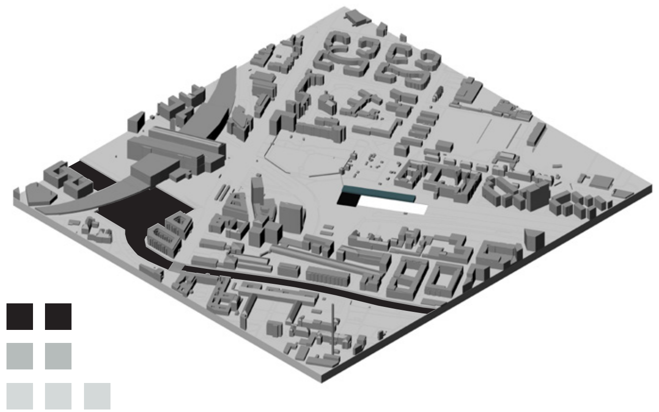
Option 3.1



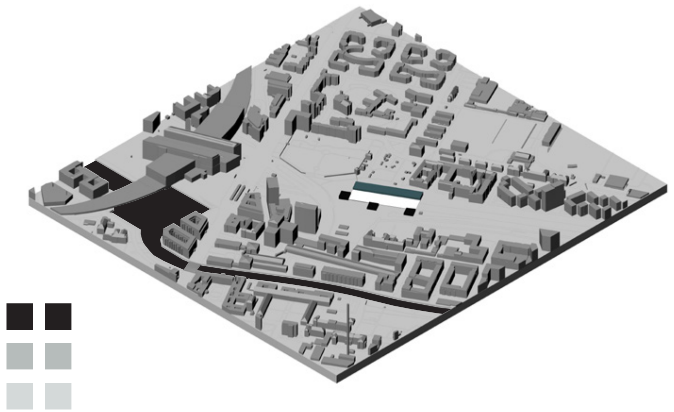
Option 3.2



Option 4.1

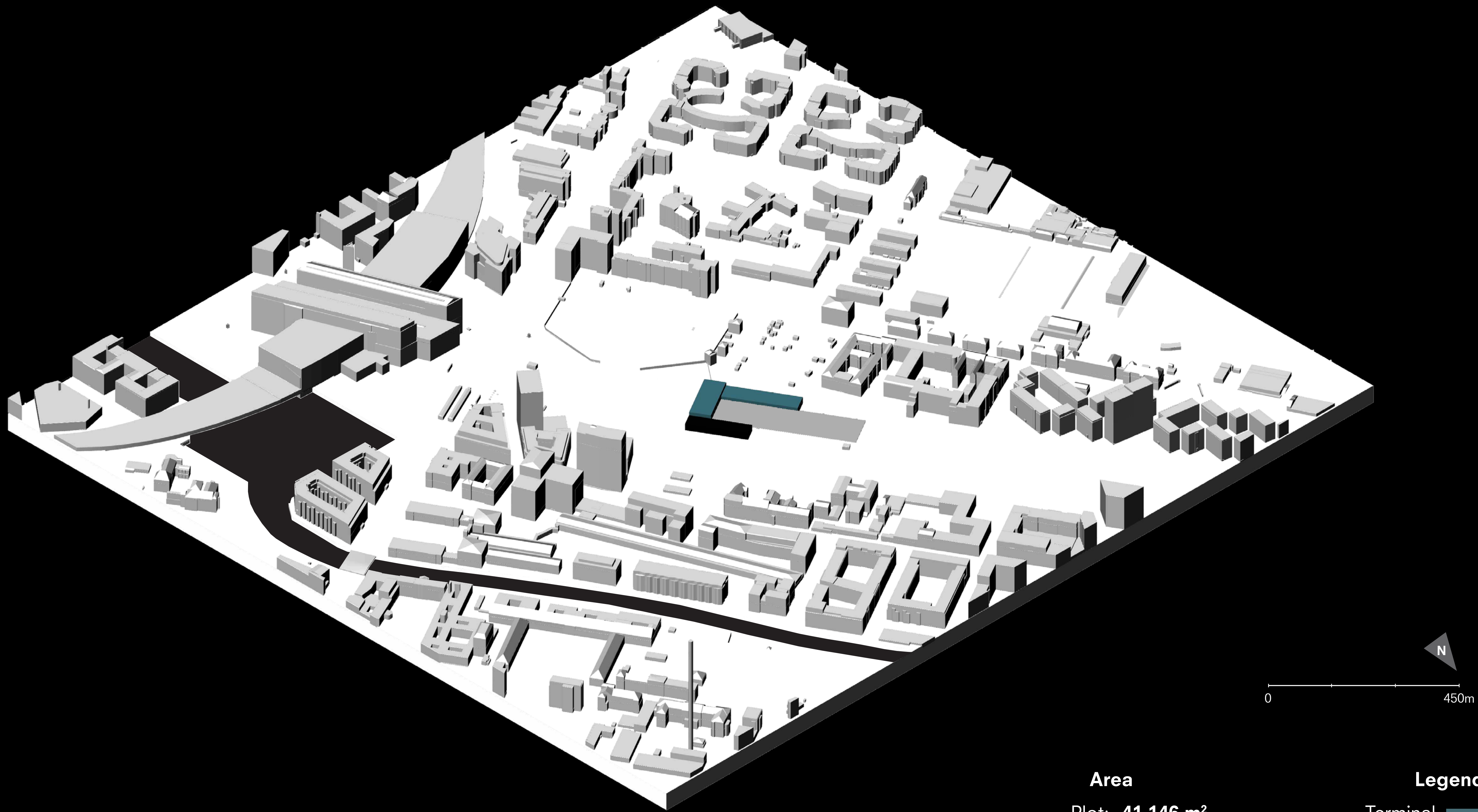


Option 4.2



1	User flow:	**Gate structure following apron**
2	Accessibility:	**Main entrance area facing Hauptbahnhof, including tunnel connection to platforms**
3	Growth opportunity:	**Apron deck over train trench**

Figure 66: Mass study conclusions.



Area

Plot: **41.146 m²**

Footprint **10.750 m² (26%)**

GFA: **21.500 m²**

Legend

Terminal

Apron

Warehouse

Existing buildings

Water

Figure 67: Preferable mass.

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05

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