(Dis)embarking Hyperloop

Design of process and infrastructure for passengers

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COLOPHON

(Dis)embarking Hyperloop: Design of
process and infrastructure for passengers
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A screen shot from Hardt test facility unveiling movie: sketching for the project (dis)-embarking hyperloop. Filmed by Wim Geuzendam.

Abstract

A proposal of the hyperloop was announced by Elon Musk in 2013. It is a new mode of transportation where vehicles travel in a low-pressure tube to minimise air friction. Hardt Global Mobility is one of the companies developing this new transportation system. One of the main challenges for Hardt is to attain a highly efficient system that also provides a pleasant passenger experience. To this end, this project aims at designing a passenger-centered embarking and disembarking process for Hardt's hyperloop system, including a relevant passenger environment both in the station and in the vehicle.

The project follows the method Vision in Product Design (ViP). Literature study on pedestrian flow, interview on crowd behaviours and a field study on (dis)-embarking efficiency contribute to insights on (dis)embarking in the past and current context. An observational study and interviews on passengers' behaviour with their belongings have been carried out in different modes of transportation. Key values for passengers concerning the luggage are discovered. Afterwards, a future vision of global public travel in 2027 is mapped by extensive literature research. Four possible categories of future public travellers are defined as chaser, passionater, criticizer and adapter. The mission of the project is to let criticizers adapt to the unexpected.

With various ideation techniques, four concepts are presented. The Shift concept is chosen to be elaborated further. It is a concept that divides the passenger compartments from luggage space and influences the (dis)embarking flow by the positioning of doors. Multiple doors on both sides of the vehicle allow passengers to embark and drop the hold luggage on one side and disembark and pick up the luggage on the other side.

An iterative testing process is performed to evaluate 12 aspects of the design in terms of concept performance, user experience and feasibilities. By keeping the valid aspects and reshaping the invalid aspects, a final design is presented. Comparing to the traditional (dis)embarking process, the design saves 40% of the time for vehicles to stay on the platform and 50% of the (dis)embarking time for each passenger. A concept video is shown to 13 passengers at Schiphol Plaza for final evaluation. They liked the simple and clear overall process, the efficient and transparent passenger flow and the smooth and safe luggage system. Boarding tolerance, luggage connection for transfer passengers, the height of the luggage belts and preventing luggage from being stuck can be improved.

Recommendations on the other touch points for hyperloop passengers are listed, including guiding passengers to platforms and doors, the interior, facilities for passengers with reduced mobility, the emergency exit and the door-to-door potential of the hyperloop concept. ■

A photo from the session within Hardt to come up with the desired interactions: some lively discussions. Photographed by Marinus van der Meijs.

Acknowledgements

I would like to extend my gratitude to a number of people who have helped to make this project possible and complete. Wilfred, thanks for your enthusiasm from the beginning to the end, your support at any time and your guidance on an academic level. Suzanne, thanks for sharing all your knowledge, experiences and connections in the related fields and your encouragement throughout the process.

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The greatest thanks to my dad, mom and grandparents for giving me the opportunity to study at TU Delft and supporting me to live in this unfamiliar country. I am grateful for all you did for me. Last but definitely not the least, thank you Nyckle, and your lovely family for all the provoking discussions, for your insightful advice, for your loving support, for being there for me and for being the most patient and caring person that I could ever ask for. ■

Contents

Introduction

Hyperloop concept

The hyperloop concept was proposed by Elon Musk, CEO of Tesla and SpaceX in 2013. The main feature of this mode of transportation is that the vehicle move through an environment with minimal air friction, which is made possible by a low-pressure tube. The hyperloop can reach the speed of 1200 km/h, faster than most of the commercial aircraft.

There are two main elements in Musk's hyperloop concept: the tubes and the vehicles. Two tubes will be welded side by side on pylons allowing vehicles to travel both directions. The tubes provide a low pressure (near vacuum) system which minimises the drag force on the vehicle, while maintaining the relative ease of pumping out the air from the tube. Solar arrays on top of the tubes will provide power to the entire system (Musk, 2013).

In Musk's design, the 'floating' vehicles, carrying 28 passengers travel along the tube departing every 2 minutes from a station. As illustrated in *Figure 1*, each vehicle is supported by air bearings via an air compressor at the front, which also prevents the air being blocked between the tube and the vehicle. Linear accelerators are placed at multiple points along the tubes to accelerate the vehicles.

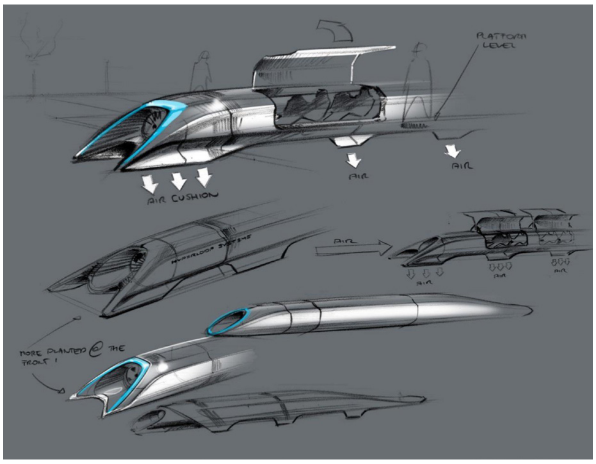

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Figure 1. Hyperloop passenger vehicle conceptual design sketch by Elon Musk (2013).

Hardt is one of the companies (and the only European company by 2017) creating and developing this high-speed tube transport system (hyperloop). It was founded in 2016 by four students from Delft Hyperloop, a student team from TU Delft that won the overall prize at the SpaceX Hyperloop Pod Competition (SpaceX, 2017) in 2017 (Pieters, 2017).

Problem definition

Hardt focuses on proving the technical feasibility and economic feasibility of the hyperloop concept. It is also what their competitors have been doing. In order to have a holistic view of their system, draw social attention and attract investors, Hardt plans to step into the field of passenger experience and develop the human aspect next to technology and business. In their system, each vehicle has the capacity of 20 to 200 passengers and departs from each station every 20 seconds during rush hour (Hardt, 2017b). Due to high departure frequency, the passengers' perception of embarking and disembarking becomes an interesting aspect to investigate.

Assignment

The assignment of this project is to design a passenger-centered embarking and disembarking process for the hyperloop system, including a relevant passenger environment both in the station and in the vehicle.

Stakeholders

The project aims to balance the expectations of all stakeholders. The stakeholders and their roles and expectations in this project are explained in the next paragraphs:

Hardt - the client

Hardt is the problem owner and they provide the original assignment in the beginning and give the approval to any adjustments of the assignment and final deliverables. During the project, they provide internal information and relevant expertise in the field. They, together with the designer, play an important role during concept decision. They expect a concept of the embarking and disembarking process that focuses on passenger experience as well as system efficiency.

TU Delft - the academic support

TU Delft being the academic support is the main party for the examination of the project. The university expects sufficient academic research that makes use of the Industrial Design Engineering (IDE) design philosophy and academic contributions to the current knowledge are a plus. They give feedback and support to the designer during the whole project and mainly focus on the research and design methods.

The author - the project manager and designer

I am the manager of the project responsible for the process management and quality of the outcome. I am the connection between the other stakeholders and make sure to balance their needs. As a graduating student, my aim is to apply the knowledge gained during the master program, seek and learn new methods and challenge myself to output new knowledge and a novel design.

Reading guide

This report consists of 8 chapters. Chapter 1 introduces the approach of the project. Chapter 2 discusses the project scope to set boundaries to the following parts. Chapter 3 and 4 analyse the current situation and state a future vision for conceptualization. Chapter 5 is the conceptualization phase and introduces a preliminary design. Chapter 6 elaborates the design and the final design is described in Chapter 7. Discussions and recommendations are in Chapter 8. ■

A photo taken in the office of Hardt: working hard at Hardt. Photographed by Felix Wong.

01.

Approach

This chapter introduces the theory of the main methodology in the project: Vision in Product Design and describes how the methodology is applied and how the project is structured based on the characteristics of the assignment.

1.1 Vision in Product Design

The research and design follow the design method Vision in Product Design(ViP) by Hekkert and van Dijk (2014). ViP is a user-centered and future-oriented design method which instead of solving present-day problems, looks for opportunities in the future context. Products are means of accomplishing actions, interactions and relationships. Products are meaningful only in the interaction with users and certain interactions are appreciated only under certain context. *Figure 2* explains the ViP method that consists of deconstructing the past and designing the future. In the deconstruction/preparation phase, designers analyse the current context by looking at current interactions and specific products. Designing is the synthesis part of the domain. It starts with defining a domain[1] and a time in which the design will be applied. In the domain, the future context will be formulated with collecting context factors[2] (principle, state, development, and trend) and later structuring the factors[3]. The next step is for designers to take responsibility for that future and state whether he/she wants to support or make a change of that future, which leads to a mission statement[4]. This will then be translated into an interaction vision, what users should feel when using the product so that the statement is fulfilled[5]. From there, product qualities[6] can be formulated as a brief for ideation, what the product should be like in order to accomplish the desired interaction. The conceptualization[7] phase follows the direction of the product qualities. Then the concept will be detailed[8].

This is selected as the main approach for the project because it fits the human-centered design assignment. Furthermore, the goal of the project is not to solve any present-day problems but to seek what the problems and opportunities of the future could be and what can be designed to fit in the future scenario. ViP is an ideal method for this project because hyperloop does not exist yet and everything will be designed for the undefined future. ■

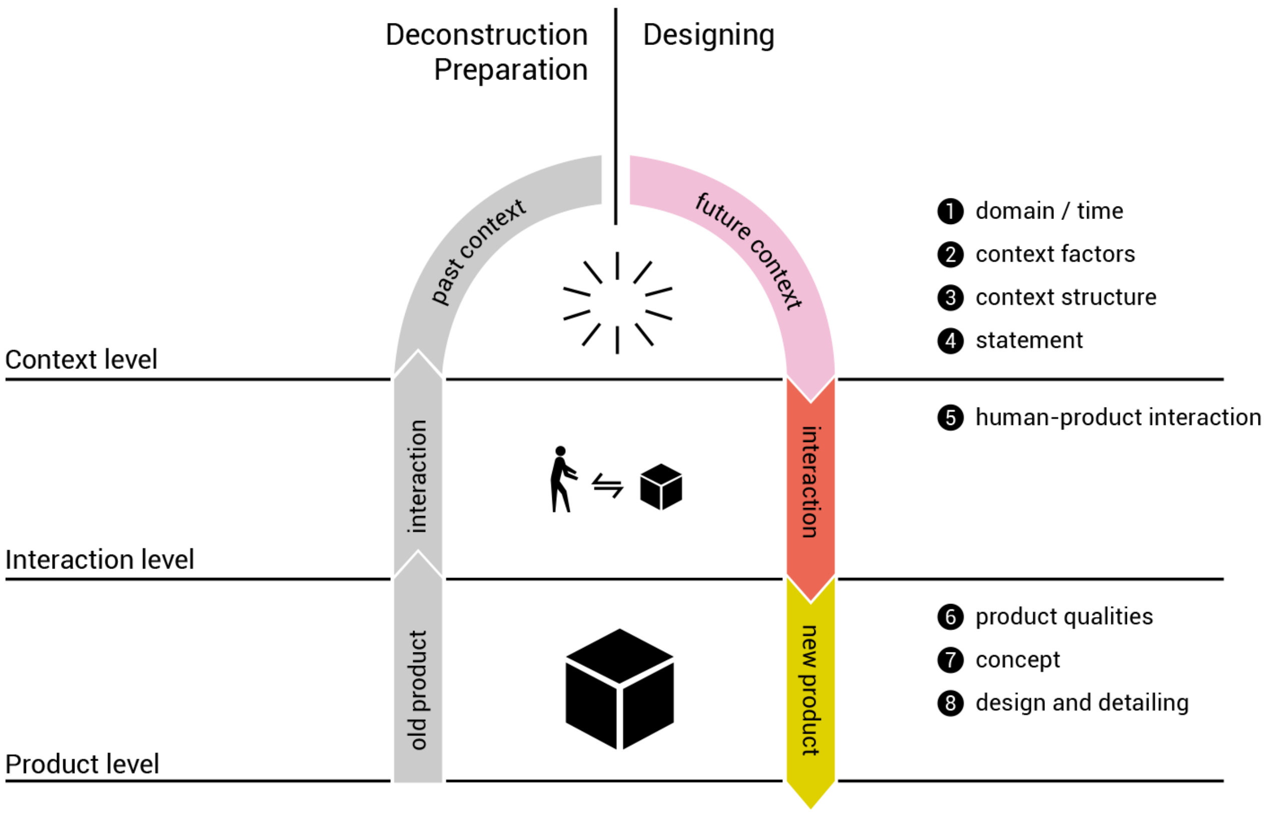

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Figure 2. Vision in product design method overview (Hekkert, & van Dijk, 2014).

1.2 Project Structure

Figure 3 shows the structure of the project. The given assignment 'embarking and disembarking hyperloop' is part of the entire passenger flow, which is undefined at this point. The project starts with defining the hyperloop passenger flow based on hyperloop characteristics, the company vision and analysis on passenger handling in existing transportation systems. This gives necessary preconditions to the assignment. A scope is defined afterwards, which will be the focus of the rest of the project. (Chapter 2)

Following the ViP process, the project goes into the deconstruction stage. Field research on existing transportation means has been carried out to understand the current context on embarking and disembarking flow and the luggage solutions. A list of criteria was generated from the aforementioned process. (Chapter 3)

Then, an extensive literature research is performed to construct the future domain. It starts with defining a domain, followed by collecting and clustering context factors. A future context is structured with two dimensions and four possible futures. At this point, a vision statement is made as the goal of the design. By formulating the interaction vision and interaction qualities, the key quality of the product is clarified. (Chapter 4)

After establishing the goal, the conceptualization phase starts. Two ideation sessions with twelve designers have been organised leading to hundreds of ideas. By clustering and developing the ideas in depth, a morphological chart is made. Considering various combinations, four concepts are developed. Based on the criteria, the method 'Weighted Objective' is applied and the concept decision is made. (Chapter 5)

The elaboration of the concept follows an iterative testing process originated from Osterwalder (2015) and developed by myself to fit the project. Instead of testing the complete concept, this method breaks down the concept to each individual hypothesis about the end-user experience, functional performance and technical feasibility.
The validations are done by quantitative and qualitative research with potential customers, expert interviews, an ergonomic study, calculations and a literature study. By keeping the valid features, learning from the invalid hypotheses and further developing the details, a final design is developed.
After computer modelling and rendering, the complete 'final' concept is tested with potential customers for final evaluation. (Chapter 6 & 7)

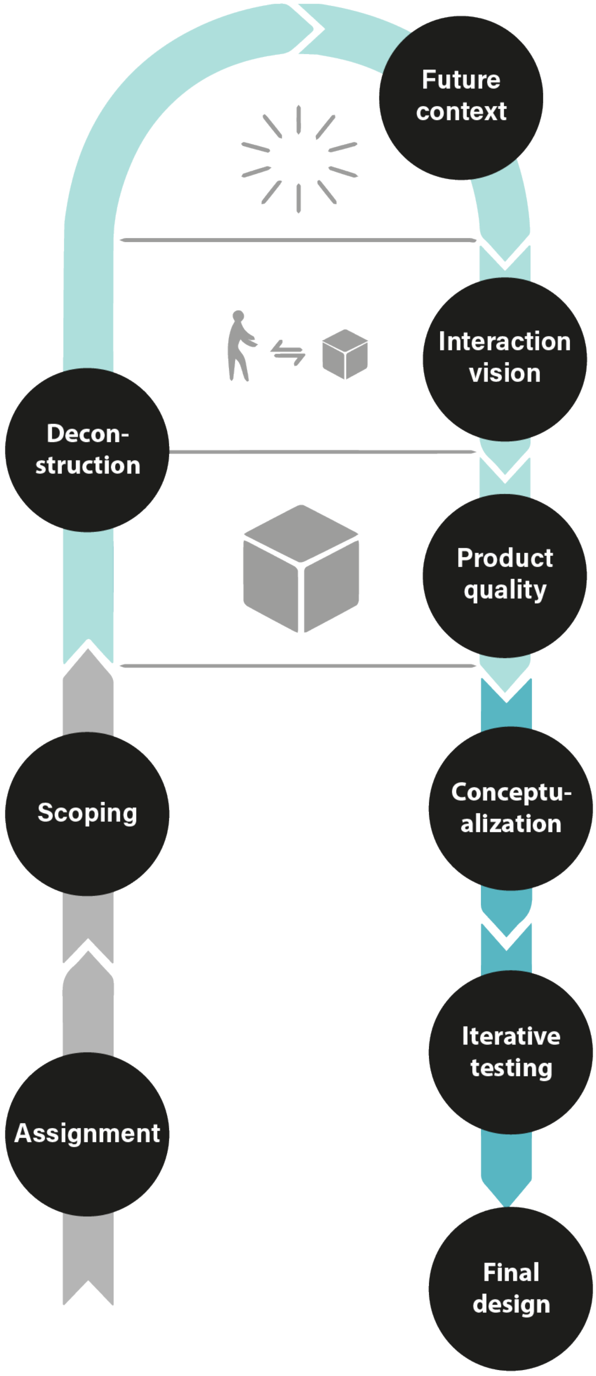

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Figure 3. Project structure.

The final evaluation gives insights to improvement space and directions for future development. Also, some valuable out-of-the-scope insights are generated during the project. Both of them will be discussed in the recommendation. (Chapter 8) ■

A photo from the session within Hardt to come up with the desired interactions: what are the interactions we want to avoid?

02.

Project Scope

The embarking and disembarking process is the original assignment. However, this is not the only undefined process within the entire passenger handling. Since each touch point will be interrelated, this chapter first defines the overall passenger process in station by analysing the company vision, the existing passenger handling process and its development. Then the project is scoped and the conditions are stated.

2.1 Company analysis: Hardt

In this part, the hyperloop system of Hardt is analysed. It helps to understand the goal of the company and serves as a context to fit the future design in the system. The technology, business scope and strategies of Hardt are analysed with internal literature research and internal interviews. In combination with literature research on competitors, the strengths, weaknesses, opportunities and threats of the company are mapped.

Hardt's hyperloop system

Hardt Global Mobility aims at providing a high-speed tube transportation system that is, in comparison to current modes of transportation, safer, faster, lower cost, more efficient, more convenient, more resistant to weather and less disruptive to those along the route. It is an origin to destination system where vehicles do not have stops in between. It is ideal for travelling between the distance of 50 to 2000 km in 5 to 120 minutes (Hardt, 2017b). Hardt's system consists of four elements: tube and track, vehicle, station, and service.

Figure 4 illustrates the separate elements and their interrelations. Information in the info-graphic comes from internal documents. Tube, track and vehicle (the top part) focus on the feasibility of high-speed travelling, routing, safety solutions and sustainable power system. Pylons are placed every 20 to 40 meters to support the tubes with 0.1% to 1% atmospheric pressure in both directions. Solar panels are placed on top of the tube over the entire length. Expansion joints along the tube absorb the thermal expansion. Near stations, the tube splits up into the main tube where vehicles that do not stop stay at full speed and off/on-ramps through which vehicles can decelerate and stop at the destination stations. Safety ramps are located every 5 km to provide an emergency exit.

Travelling in the tubes are passenger vehicles carrying 20 to 200 passengers and cargo vehicles. Passenger vehicles depart from a station every 20 to 120 seconds for an hourly throughput of 3600 to 36000 passengers. ►

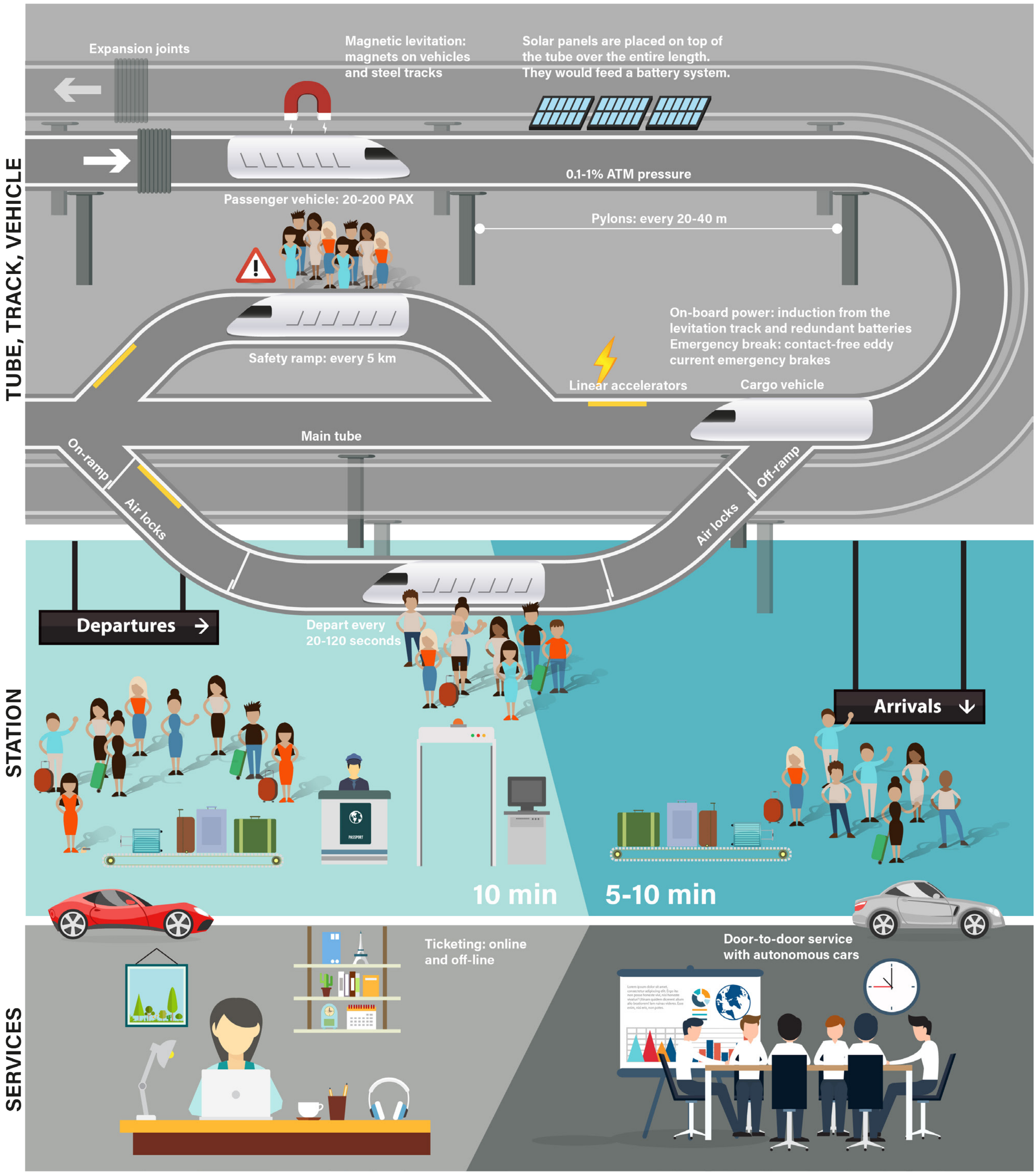

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Figure 4. Hardt's hyperloop system, illustrating tube, track and vehicle (top), station (middle) and services (bottom)

The vehicles are supported by electromagnetic levitation which requires permanent magnets as well as control coils on vehicles and laminated steel in tracks. Linear accelerators are integrated into the rail to accelerate the vehicles along the track.

Another part of the system is the station (the middle part) which is the context of this assignment. It includes the transition between low pressure and atmospheric pressure environments and the seamless passenger flow. Vehicles from the tube travel through air locks to reach and leave the open station with atmospheric pressure. Passengers can board the vehicles in parallel on different platforms in the station. The passenger flow is currently undetermined in the system but Hardt aims at 10-minute in-station time for passengers at the departure station and 5-to-10-minute in-station time at the arrival station.

Service (the bottom part) contains ticket service and door-to-door service with autonomous cars. The ticketing system is still under definition and it should be at least as accessible as metros, buses and trains. "Buying a ticket will be as easy as ordering an Uber taxi" is mentioned in the internal document. The company also sees the future of autonomous cars and has been in contact with external companies to make use of it to complete the hyperloop system.

Hardt strategy

Tim Houter, CEO of Hardt and Mars Geuze, one of the other founders, are interviewed for an overview on the strategy and the long-term planning of Hardt.

Hardt's mission is to connect main cities in Europe (later globally) with their hyperloop system *(Figure 5)*. It is an origin-to-destination travel solution, which means passengers sharing the same origin and destination get into the same vehicle saving the hassle of stopping in between. It is supported by the concept that all vehicles share the main tube during high-speed travel and they get on and off from their departure or arrival station through the ramps explained earlier.

Hardt positions itself as the owner of the intellectual property and the actual construction and production will be outsourced to other companies once the system is ready for it. To begin with, the test tracks will be built in the Netherlands to prove the concept from a technical point of view.

In order to build up to the goal, a 30-meter track is being built to test the suspension and the propulsion of the linear motor; in 2018, a test track of 1 km will be built to test the vehicle at a speed of 200 kph, in which acceleration, the braking system and the vacuum system will be tested; in 2019, a test at top speed, 1000 kph will be conducted on a 3 km track; a full-scale vehicle will be designed and tested in 2019 to 2022 and in the meantime, a 15 km track will be built to test top speed at corners and switches with the vehicle. From then on, the technology should be thoroughly proven and be ready for commercial use.

Competitor analysis

Two main competitors of Hardt are Hyperloop One and Hyperloop Transportation Technologies (HTT). They are both vying to build the world's first hyperloop by 2020 (The Wall Street Journal, 2016). A comparison among Hardt and its competitors is presented in *Table 1* (full analysis in Appendix A) and a brief SWOT analysis is presented in *Table 2*. ►

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Figure 5. Hardt's strategy of connecting Europe (image provided by Hardt).

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Table 1. Company analysis overview (updated April 2017).

	HARDT	HTT	HYPERLOOP ONE
COMPANY REGION	NL (2016)	USA (2013)	USA (2014)
EMPLOYEES	<10	700 (incl. crowd source)	200
LEVITATION	Electromagnetic suspension	Passive magnetic levitation with permanent magnets	Passive magnetic levitation with permanent magnets
TESTING	30 m test track planned in 2017	Vehicle prototype built in Mar 2017; 8 km test track planned in 2017	Propulsion tested in May 2016; building 500m test track in Mar 2017
FUNDING	$3 Million (incl. in-kind funding)	$100+ Million (incl. in-kind funding)	$160 Million
GOVERNMENT COOPERATION	The Netherlands (under discussion)	Slovakia (Mar 2016)	United Arab Emirates, Finland and The Netherlands (Nov 2016)

** Other two start-up companies in the hyperloop field Arrivo, from America and TransPod, from Canada are founded this year. They are also competitors of Hardt but there is not enough information to make a comparison at this point since little has been published.*

The strength of Hardt is the people. All founders of the company and most of the employees are from the Delft Hyperloop team. They have the experience and capability of making the best hyperloop vehicle in the global competition. Having a team with young people will possibly result in more out-of-the-box solutions. Originating from TU Delft, Hardt has the support and resources from one of the best technical universities in the world. Moreover, the winning mentality and a never-quit mindset of the team also build up to its strength.

The weaknesses mainly result from the later establishment of the company. Hardt has a small and unitary team with less experienced experts from different fields; it has not yet shown any technical feasibility through tests because of the late start; with a relatively small amount of press articles on the company and its development, there is not enough public attention globally, which also leads to lack of funding sources.

An opportunity for Hardt is to build a holistic system with the multidisciplinary resources from the TU, including a technical overview, station infrastructure, user experience and services; also, the Dutch government is interested in testing the technology, which is a huge opportunity for this Dutch company. From the Netherlands, the influence will grow to the rest of the EU opening international market for Hardt.

Threats are that the other companies will finish proving their technology first and win the deal with the Netherlands; the good infrastructure of the existing public transportation systems in the Netherlands might be of threat to the development of hyperloop; the Netherlands is also a difficult place to start the development since it is not a large country and the routes within the country will be relatively short. With most of the time accelerating and decelerating,

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Table 2. SWOT analysis for Hardt.

Strengths	Weaknesses
• People from Delft Hyperloop team • Experience and capability of making the best hyperloop vehicle • Support and resources from TU • Winning mentality and never-quit mindset	• Small and unitary team composition • Technical feasibility tests • Lack of public attention • Source of funding • Lack of experienced professional experts in different fields
Opportunities	**Threats**
• A complete system combining technical overview, station infrastructure, user experience and services • The Netherlands is interested in building Hyperloop with a Dutch technology • International influence in EU	• Other companies finish testing first might get the opportunity • The good infrastructure of existing public transportation system • The short distance in the Netherlands is not the most beneficial route to start with • Lack of trust among citizens

the average speed will not be desirable. Lastly, because of the lack of proof of the technology and little communication with the general public, some people are against the hyperloop concept for safety issues or the NIMBY(not in my back yard)-attitude might oppose the implementation because it might affect their lives or require sacrifice on their part. ■

2.2 Passenger handling

In the following part (2.2 to 2.4), analysis on the current passenger handling for existing transportations is made. The trends for future passenger handling in the aviation industry are gathered by literature study and interviews with aviation experts. Taking both into consideration, the overall passenger flow for hyperloop is pictured and the scope and conditions for the assignment are defined.

The existing four modes of transportations are air, rail, road and water transport and they all have different systems for passenger handling. *Figure 6* is a bar chart showing the overall passenger process for aeroplane, railway and road travel and a vision for hyperloop from arriving at departure station to departing from the arrival station (water transportation is less comparable in its throughput and travel speed, thus it is not mentioned here). The travel between Amsterdam and Paris is chosen as an example because it is a potential route for the Hardt hyperloop system and the travel time (of 38 to 45 min) has been estimated. The aeroplane travels the fastest among all existing transports while it has a longer and more complex passenger process; trains have very short process time and it handles a sufficient amount of throughput (numbers of passengers leaving the station in a certain time) at a time. Cars are more private and flexible with travelling and loads quickly because of fewer passengers. Hyperloop directly travels from Amsterdam to Paris with no stops like planes, aims at handling large numbers of passengers in a short time just like the trains and has the opportunity to become a fully door-to-door system like the cars.

Since having a station is a condition in the Hardt system, it is reasonable to analyse airport and train station passenger handling and predict a hyperloop system based on that. *Figure 7* shows the passenger process in most of the airports for domestic flights and the passenger process in most of the train stations in EU (the Netherlands for example). Here we only analyse the process before departure and the arrival process will depend mostly on it.

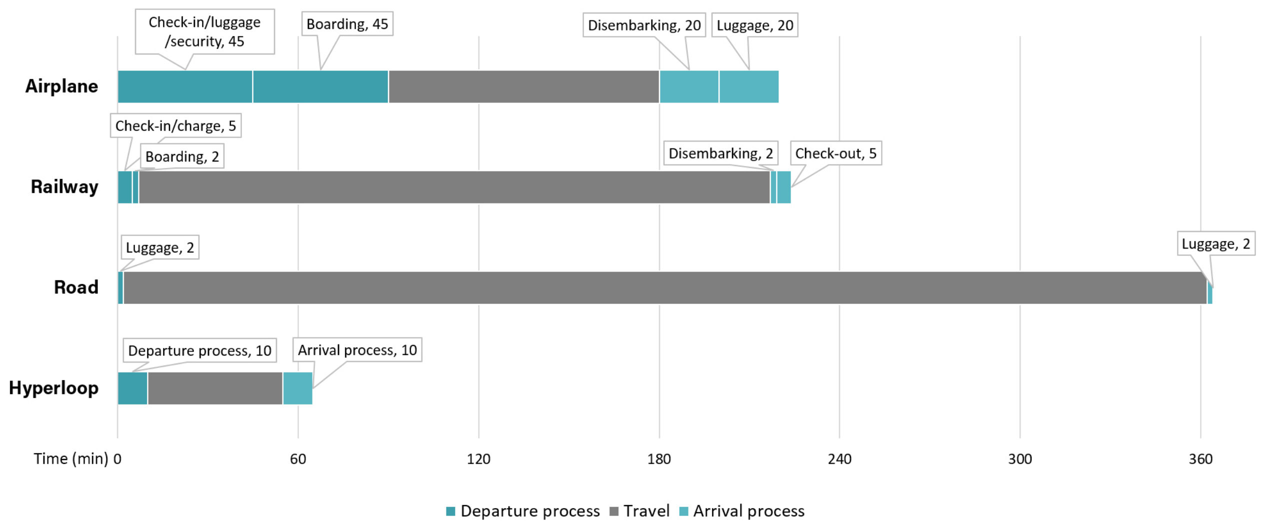

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Figure 6. Travel time (grey) VS process time (blue) for different transportations travelling between Amsterdam and Paris.

Airport

For air travellers, they plan the trip and finish the payment at home. Passengers plan ahead to make sure that they have a spot on the plane and that they arrive at the airport at the right time because of the low frequency of flights to the same destination every day. Check-in, for identification and seat arrangement, is done online most of the time to save in-airport time. In the airport, there are three main touch points: baggage drop, security check (and passport control for non-domestic flights) and boarding. Large luggage is checked in for the convenience of passengers, to optimise luggage placement and to increase boarding time. Security check for passengers and their belongings is for the safety of the flight. Boarding gates are set up to confirm that passengers get on the right flight and to control the boarding flow. After that, passengers and checked luggage board the plane separately. In the plane, passengers need to find their seats, place their belongings and be seated before the plane takes off.

Airport experience has been a problem, especially for EU passengers. For a short flight, nearly half of the trip time is spent on a process like baggage check-in, security and boarding (PASSME, 2017a). Projects like PASSME (Personalized Airport Systems for Seamless Mobility and Experience) have been working in cooperation with airports, airlines and many other companies to make the future airport process more efficient and enjoyable (PASSME, 2017a). Literature research, observations in Schiphol and an interview with Peter Vink and Suzanne Hiemstra-van Mastrigt, leading researchers in PASSME project in TU Delft, is conducted on the trends and possibilities for future airports.

Biometric identification is one of the solutions to the complex touch points. Biometric enrollment has been implemented in Aruba airport in 2015 by Vision-Box, a ▶

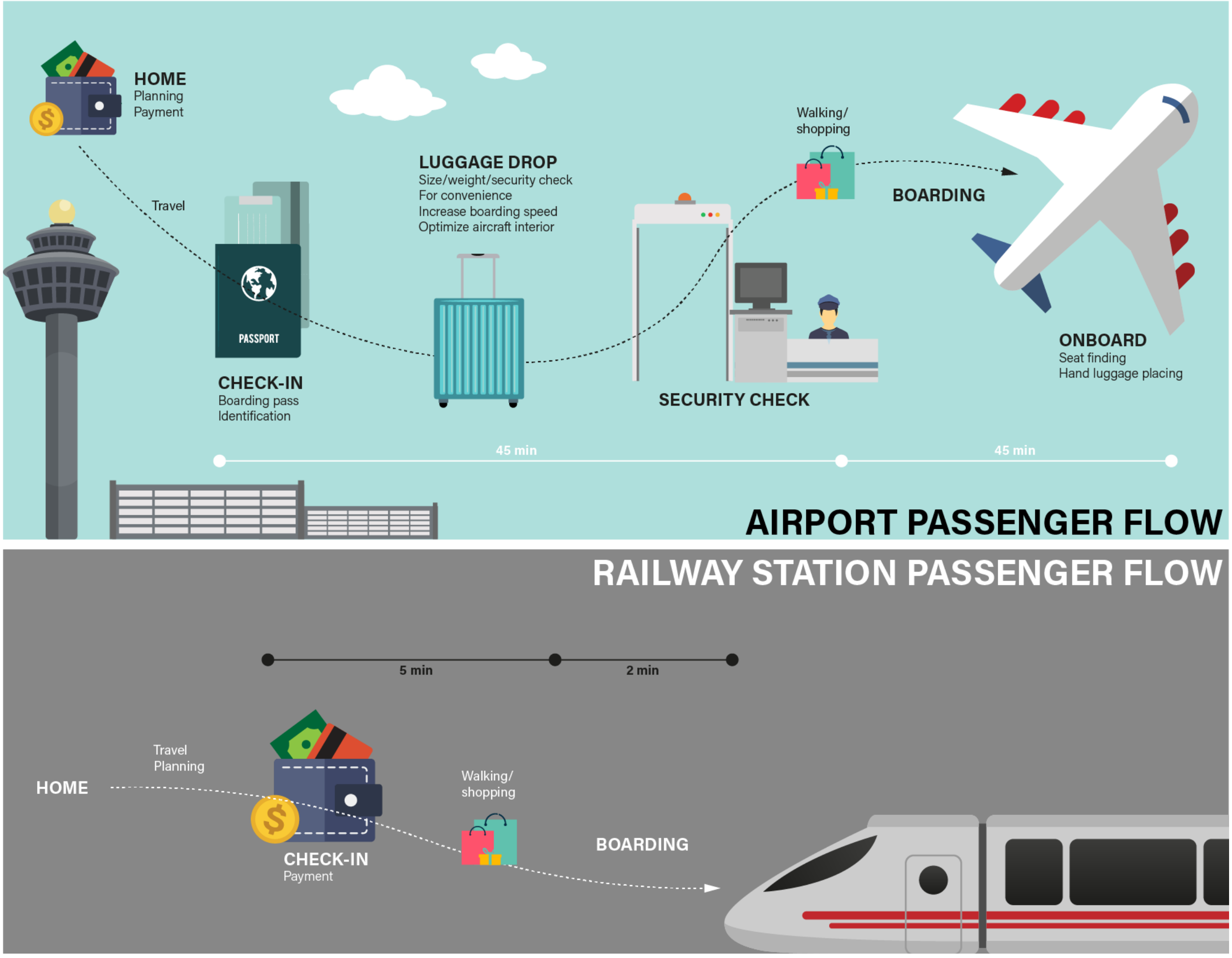

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Figure 7. Passenger process in airports and railway stations.

provider of end-to-end passenger solutions (KLM, 2015). In Schiphol, passport control with facial recognition and check-in with iris scan have been implemented. With biometric identification, touch points can be combined and simplified with one simple scanning.

Luggage has always been a hassle for passengers. Check-in luggage takes too long while bringing cabin luggage slows down the boarding process. PASSME has been experimenting with the Origin to Destination (O2D) luggage solution, in which third-party companies take care of the check-in luggage from door to door (PASSME, 2017b). However, it is required for passengers to prepare the luggage in advance. The company Airportr is providing a similar service that brings luggage from your doorstep to London airport and the other way around. Solutions for cabin luggage have also been researched in TU Delft in collaboration with KLM and one possible solution is to place cabin luggage under seats instead of the overhead cabin which saves time and reduces the effort for passengers.

Walk-through security is developing rapidly. Passengers will no longer have to open their bags or waiting at the security door for a body check. Companies are also testing the new security system where everything can be checked in movement (Peter Vink, interview, March 20, 2017).

Smart boarding sequence is taken into consideration by many of the airlines. According to the research of Vox (2014) with a 170-seat aircraft, the most efficient way of boarding is not assigning seats and let passengers board and choose a seat they like. Other research stated that the Steffen method is the fastest in theory, where passengers board separately in a given order to maximise the utilisation of the aisle (Jaehn & Neumann,2014). KLM has introduced a board-by-seat smart boarding system since 2013 using this knowledge (KLM, 2013) and the pilot was carried out in 2016 (Suzanne Hiemstra-van Mastrigt, personal contact, July 27, 2017).

Railway

For railway travellers in the Netherlands, most of the passengers plan the trip on their way to the station or even in the station because of high departure frequency. In the station, people check in and finish the payment with a chip card (OV-chipkaart in the Netherlands for example), phones or even bank card (X-CEPT, 2017). Passengers board the train faster because of more doors and the seat-finding process and the baggage-placing process does not influence the departure time. There is no security check (or simpler security check comparing to airports in other countries) because of the lower safety risk, namely, it is easier to evacuate people and generally, there is less damage than in an aircraft during emergencies. Neither is there a baggage drop because there is no time for passengers or the system to load luggage due to high departure frequency and there is enough space for luggage inside the train.

In conclusion, what influences the passenger process are the departure frequency of vehicles, the level of safety risk, regulations, baggage placement, seat arrangements and the business model. ▪

2.3 Hyperloop passenger handling

With the information from analysis on the company vision and the existing passenger handling, the future hyperloop passenger flow (in 5 to 10 years) from origin to destination is explained in *Figure 8*. It includes travelling from origin to departure station, identification and security, passenger and luggage embark, travelling, passenger and luggage disembarking and travelling from arrival station to destination.

First of all, there will be a station where passengers get on and off the hyperloop vehicle. It can be centralised stations like an airport or decentralised stations like train stations. The process of travelling to and from station mostly depends on the location of the stations and the infrastructure of other modes of transportation. At places where other transportation cannot (yet) easily reach, autonomous car services can provide passengers with a convenient transit.

With the development of biometric identification and walk-through security technology, identification, payment and security can be combined into one non-stop touch point. It can be done at the station, at home or even on the way. Passengers no longer have to stop or wait for any process before boarding if of course, they pass the standard security requirements.

Because of the high throughput and departure frequency of the hyperloop system, preparing and planning in advance is not necessary. People can be fluid and the system will be (nearly) on demand like a bus or a train in the Netherlands. Therefore, any kind of luggage pre-collecting before the boarding process is not necessary for this system. Passengers will be guided to one of the platforms with their luggage and get on a vehicle that is almost ready to depart. The embarking and disembarking process will include both passengers and their luggage (if they have any) right in front of the vehicle. ■

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Figure 8. Suggested hyperloop passenger flow.

2.4 Project scope and conditions

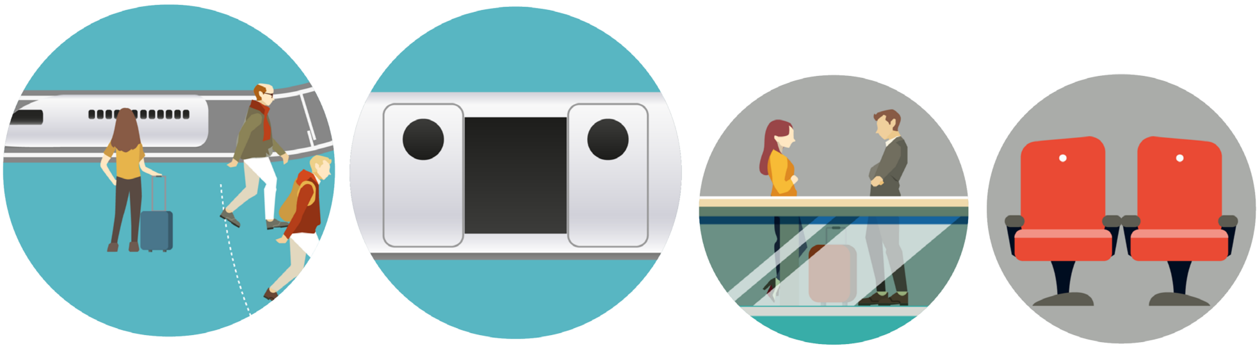

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Figure 9. Scope of the project.

Scope

Having mapped the passenger process within hyperloop station, the scope of the project *(Figure 9)* can be defined as follow:

1. The process for passengers and their luggage to get in and out of the vehicle.

2. The entrance/exit design of the vehicle for passengers (and luggage if separated).

The design should include the form, size and possible interaction (opening direction for example) of the entrance/exit with proved feasibility. While the structure and specified mechanism is out of the scope because the company has not yet decided on the structure of the vehicles and it does not make sense to structure the doors at this point and it is less important for the assignment.

3. Supporting interior including seat configuration and aisle specifics (if exist).

4. Supporting platform including the waiting area and platform flow management.

** 3 and 4 are not the focus of the project but are aspects that are needed to support the designed embarking and disembarking process.*

** Emergency exits are not part of the project.*

Conditions

Conditions of the project are described below, deriving from internal documents and discussions with the company mentors.

The target group is all passengers, taking disabilities, all age groups and all travel purposes into account. The design should be for vehicles with the capacity of 50 passengers each with a departure frequency of every 30 seconds. However, the design should have the potential to fit different capacities of vehicles from 20 to 200 passengers. The vehicle travels from origin station to destination station without stops in between. It travels at a cruising speed of 1000 kph, with the top longitudinal acceleration/deceleration of 0.3G (comparable to the acceleration/deceleration of a car at traffic lights in the most common situations), travelling between places that are 100 to 2000 km away in 10 to 120 minutes. The radius of the vehicle is 1.9 meters, comparable to the size of a single-aisle aircraft.

Furthermore, the vehicle activities at a station are mapped *(Figure 10)* and the time for each activity is estimated together with the company. Activities for disembarking passengers and embarking passengers are also listed separately. An overview is shown in the flow scheme *(Figure 11)*.

After the main deceleration, vehicles go through the first two airlocks, drive to the platform and stop for disembarking. This takes less than 1.5 minutes. The vehicle stops three times during the process and due to this constant change in movement, passengers should be recommended to remain seated. When the vehicle stops at the platform, passengers can get ready and disembark. For the embarking passengers, the vehicle has to stop at the platform until passengers get seated because it only takes around 1.5 minutes before the main acceleration starts (after airlock 4 opens). In that time, safety instructions need to be given. Therefore, the stopping time for a vehicle includes (dis)embarking process and the time for passengers to get ready. ■

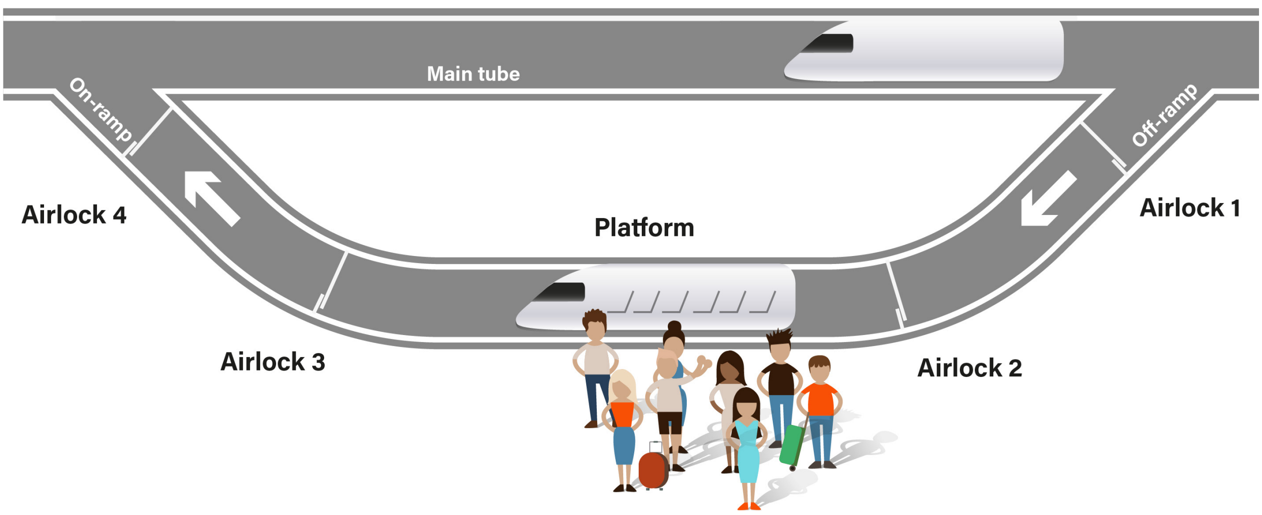

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Figure 10. Vehicle flow in station.

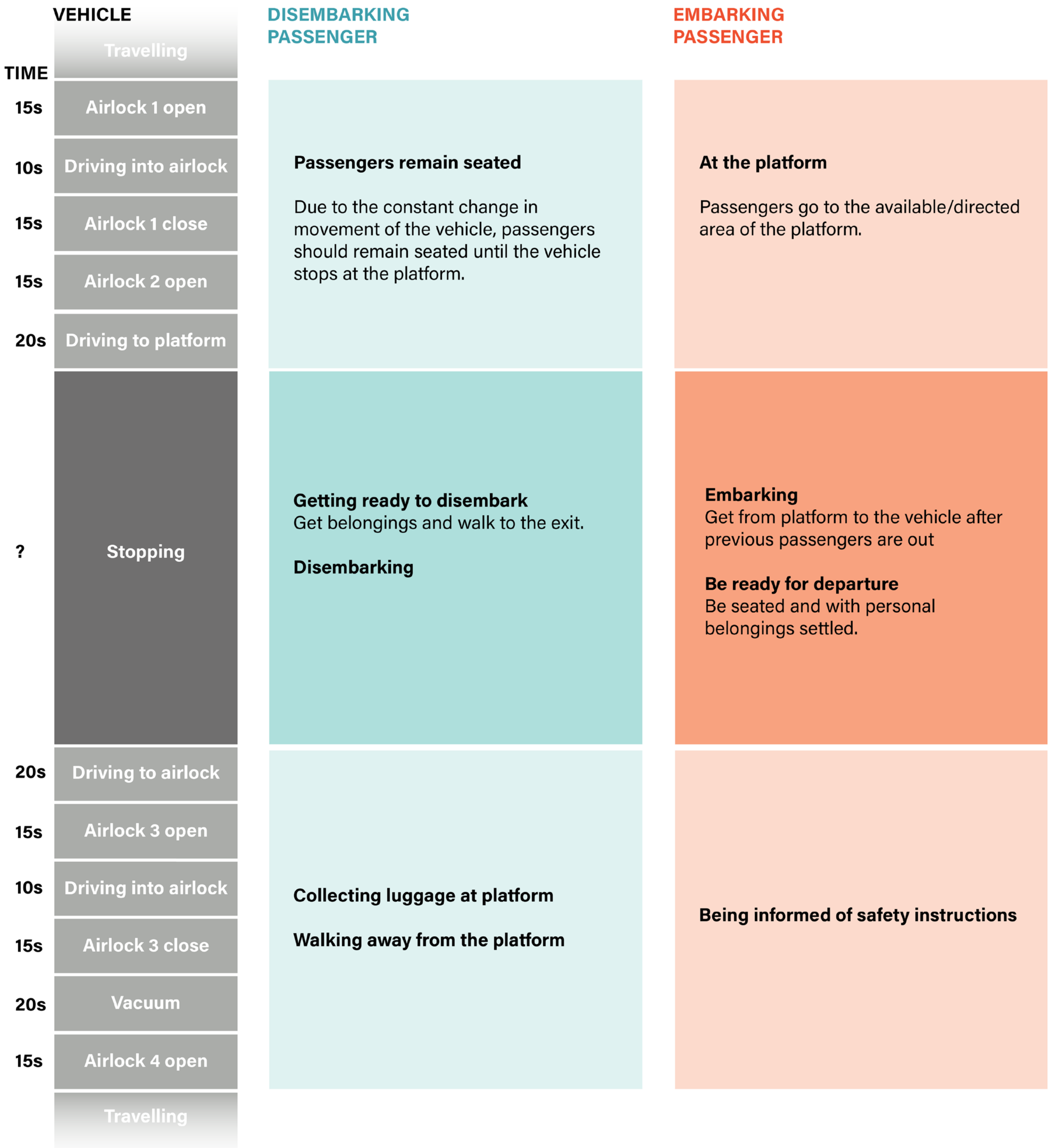

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Figure 11. A flow scheme for vehicles and passengers.

2.5 Conclusion

The overall passenger process for a hyperloop system is shown in *Figure 12*: passengers will travel from home to departure station; at the station, or even before arriving at the station, identification, security check and payment of the ticket can be done. Passengers will be guided to one of the platforms with their belongings and the embarking begins. Luggage will either be handled directly at the platform or integrated with the boarding procedure.
At the arrival station, passengers disembark with their belongings and can head to their final destination. This project will cover the process for passengers and their luggage to get in and out of the vehicle; the entrance/exit design of the vehicle, supporting interior and supporting platform.

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Figure 12. Storyboard for the suggested hyperloop passenger flow (coloured parts are within the scope).

A photo from the Sprinter during the field study: having some personal space in the face-to-face seats.

03.

Decon-struction: Analysis

In the deconstruction/preparation phase suggested by ViP, the current context is analysed by looking at the current designs. In this chapter, two studies have been done to understand the current context. Literature studies and expert interviews on pedestrian flow and crowd behaviour in combination with an observational study on the train platforms lead to insights on the embarking and disembarking flow; observations and interviews in different modes of transportation are done to understand the important factors for passengers regarding their belongings during travel.

3.1 (Dis)-embarking flow for trains

Literature study on pedestrian flow and an interview with an expert on crowd behaviour were done. Insights on pedestrian flow and evacuation flow were found but there was not any previous research to be found on the passenger (dis)embarking flow. A field study was carried out to answer the following questions: what is the (dis)embarking efficiency for trains? What are the factors that slow down the (dis) embarking process?

Literature and interview review

Studies on self-organizing phenomena in pedestrian crowds have been done by Dirk Helbing, a professor at ETH Zurich, revealing dynamic crowd behaviours in different ingress and egress environments. (Dis)embarking vehicles is a special form of 'pedestrian dynamic' therefore the findings in Helbing's papers are of great value to understand the (dis)embarking flow. Besides the literature study, an interview on crowd dynamics with Jie Li, an expert on crowd behaviour at IDE, TU Delft, also leads to insightful results.

Helbing et al. (2005) discovered that high interaction frequency and necessary braking or avoidance manoeuvres slow down the average velocity in the desired direction of motion. Li agreed with the statement and stated that any kind of hesitation in the crowd will cause a chain of reaction delay and slow down the flow or even create conflicts and stampedes in the crowd.

The bottleneck is another factor that reduces the pedestrian flow and the longer the bottleneck, the slower the flow. A widening in a narrow route also slows down the efficiency and the wider the area is the lower efficiency it has (Helbing et al., 2002). Li mentioned in the interview that getting into

▲

Figure 13. A snapshot of the video recording for data analysis.

a bottleneck is dangerous in an overcrowded situation because the unawareness of what is happening in the bottleneck causes pressure and anxiety among the crowd. Therefore, eliminating bottlenecks or smart design of bottlenecks will be beneficial to the embarking and disembarking process.

Field research

In this study, I observed passengers getting in and out of 11 trains at Schiphol and 15 trains at Utrecht Centraal with video recording. Passengers (dis)embark trains with all their belongings and this is the most similar situation to the defined hyperloop (dis)embarking. At Schiphol train station, most of the passengers are travellers with large luggage; at Utrecht Centraal, the busiest train station in the Netherlands, most of the passengers are commuters with only personal bags. At both stations, three types of trains were observed. By a frame-to-frame analysis of video recordings *(Figure 13)*, the efficiency of passenger flow (number of passengers passing through the door per minute) was calculated for both scenarios. By comparing the variables, circumstances that influence the flow were concluded. (Full research set-up and results, see Appendix B) ►

Result

One passenger per second without large luggage

15 trains were observed in Utrecht Centraal station during rush hour and passengers were mostly commuters with only personal bags. The average embarking and disembarking time was calculated. The average passenger flow was 60 passengers per minute, regardless of the train type (door size, stairs/no stairs), total passenger number and the difference between embarking and disembarking.

Large luggage slows down the flow

By analysing the videos of (dis)embarking 11 trains, the relationship between suitcase/ large travel bag rate (suitcase per passenger) and passenger flow Q (passenger per minute) was concluded. The suitcases/large travel bags slowed down the passenger flow under the same condition (train type, embark or disembark etc.). Through making stair charts (Appendix B), suitcases and large strollers were the main luggage that influenced the passenger flow. Passengers with backpacks and travel bags did not stand out from passengers with no luggage; passengers with suitcase(s) took approximately twice as long to embark and passengers with stroller took three times as long.

People hesitate to give way to 'the inconvenient'

Observation showed that passengers hesitated to (dis)embark when they saw other people with large suitcases, strollers or disability. Sometimes people with inconvenience took the opportunity to go first while more times they just waited untill

▲

Figure 14. Two types of trains observed (A: narrow doors and stairs; B: wide doors and no stairs).

the other passengers went on/off the trains. This created delays in the passenger flow and inconvenience and confusions to the crowd.

Narrow doors or stairs only make it slower when luggage is involved

Calculations were made on the average passenger flow of two different trains *(Figure 14)*, Train A with narrow doors and stairs and Train C with wider doors and no stairs. When passengers did not have suitcases or large travel bags, the passenger flow was similar; while in the situations with suitcases or large travel bags, the flow for Train C was faster (depending on the number of large luggage). This shows that narrow doors or stairs only make it difficult for passengers with luggage.

Reflection on literature and expert interview

Some findings from the field study correspond to the result of the literature study and the interview with Li.

More people passing the door at the same time does not mean higher efficiency

Passengers disembarked one by one while embarked with more people at the same time. However, more people passing the door at the same time did not result in a faster flow. This corresponded to the bottleneck theory by Helbing stated in his researches on self-organizing phenomena in pedestrian crowds (2005). High interaction frequency and necessary braking or avoidance manoeuvres slow down the average velocity in the desired direction of motion. Therefore, the embarking flow became slow when two or more flows joined (Helbing, 2005).

More choices result in hesitation

Results of the observations also showed that the more choices people had the more time they spent making decisions, which proves Li's theory. For example, people changed between two train doors and hesitated to go left or right, up or down when entering the train. Decision making requires environmental information (for example, which part of the train has more seats left) and providing this information at the right time in the right form will help reduce the time it takes for each decision (Glastra van Loon, 2017). ■

3.2 Passengers and their belongings during the trip

This research aims at finding out what concerns people with the current luggage solutions in different transportations. In some degrees, those concerns should also be considered when designing luggage handling for hyperloop.

Observations were carried out at five different locations, namely on the train to and from Schiphol Airport, on the airplane between Schiphol Airport and Olbia Airport in Italy, on the buses travelling between Schiphol Airport and Amsterdam city centre, in the taxi from Leiden to Schiphol and on the shuttle bus transiting people between Schiphol Plaza and Long Parking area *(Figure 15)*. I observed the placement of passengers' luggage quantitively and their conscious or unconscious behaviours towards the luggage during the journey. During the research, 15 passengers from different locations were interviewed. (Full research see Appendix C)

Key values for passengers concerning the luggage resulted in their behaviour and preferences towards luggage. Discussions on each value are in the next paragraphs with quotes.

Loss concern

Luggage Security is the number-one concern for passengers. In general, passengers feel secure when the luggage is close to them or in contact with them and in their sight. Other variables also influence the perception of security. In a closed environment where nobody is able to get in or out, namely

▲

Figure 15. Observation on shuttle bus luggage solution.

vehicles that do not stop in between, people are less concerned about luggage security; it feels safe when no one can see or reach the luggage like the overhead cabin in an airplane; the easier the accessibility to the vehicle is, the more insecure people are. For example, it is very cheap and easy to jump on a bus and anyone can do that without any effort; while boarding an airplane, you need to get a relatively expensive ticket, go through all the identification, security and boarding process and spend at least 40 minutes before you can be on an airplane. Of course, it is more likely for theft to happen on an easily accessible bus rather than on an aeroplane.

"I think it's very safe here (because) I'm keeping an eye on it."

- A man standing by the luggage rack in a shuttle bus

Accessibility

There are always some belongings that people would like to keep by their hand not for safety reasons but for easy accessibility. Items like water bottles, books, headphones, phones, cameras and jackets are necessary during the trip and passengers would like to have access to it throughout the trip. These items or luggage containing the items are required to be placed within the reach of the passengers.

"I never place luggage in the overhead cabin, I don't have access to it easily."

- A traveller on the plane ▶

Personal space

Passengers appreciate personal space for them and their luggage. In the trains and buses, passengers prefer to sit in a four-person seat alone with their luggage or a one-person where there is a luggage place next to the seat. Or people stand with their suitcases in the corner between train coaches, or the standing zone in a bus to avoid sharing space with others.

> ***"Would be nice if I have my own cabin for me, my friends and luggage."***
>
> *- A traveller in the train*

Avoid damage

People avoid damage to their luggage, including valuable belongings like laptops, shopping items and suitcase itself (the wheels for example).

> ***"I'm holding it because it's valuable and it might be damaged on the rack."***
>
> *- A father of the family placing suitcases on the shuttle bus rack but holding his personal bag between his legs*

Seek for clear use cues

Most of the people in the train do not even recognise there are luggage racks when the train is not so full. They intuitively place the luggage next to them on the floor and consider it comfortable and convenient.

> ***"Oh, I haven't thought about it (placement), I just put it there as I sat here."***
>
> *- A businesswoman with a suitcase in the area next to the single seat*

Influence on other passengers

Most of the passengers take other people's convenience into account. They do not like bothering other passengers to give way to their luggage. Or they do not use the overhead cabin on the plane when they sit next to the window because it interrupts others when they need to reach anything from the cabin during the flight.

> ***"I would place it on the rack if it fits so that other people can sit next to me."***
>
> *- A man travelling along with his travel bag on the seat next to him*

Convenience

People choose convenience over comfort for short trips that last less than half an hour. It is inconvenient when moving with big luggage in a narrow or crowded aisle, bringing large luggage up and down the stairs, placing heavy luggage on the rack or placing/collecting luggage at/from different locations. On the contrary, staying with luggage by the door, keeping everything in one place or not having to carry luggage by themselves are considered convenient.

> ***"It's definitely more convenient to put it by the door than travelling in that narrow aisle."***
>
> *- An old lady sitting by the train door, watching the rest of her group going into the aisle*

Comfort

Comfort is valued more when people are not in a hurry. When luggage takes up the passenger space, for example on the lap, between legs or in front of the legs, it reduces the comfort. Comfort is more important when people travel together than alone.

> ***"If I'm not in a hurry, I would value comfort more."***
>
> *- A student placing his travel bag between legs in a taxi hurrying to the airport*

Time efficiency

Time efficiency is a requirement mainly for business travellers and passengers having a connecting trip. In this circumstance, check-in luggage is not preferred despite the comfort or convenience it might bring. Also, taking one big luggage is more time efficient than bringing multiple small luggage.

> ***"I won't check-in luggage, it takes at least 20 min to have it back."***
>
> *- A businessman in the train*

Loss concern, accessibility, personal space, avoiding damage, seeking for clear use cues and influence on other passengers were the values for most of the travellers; convenience, comfort and efficiency were the values that differed per person/trip. ▪

A screen shot of one of the concept video materials: departing with luggage. Filmed by Nyckle Sijtsma.

3.3 Conclusion

In the deconstruction part of ViP, I have analysed the current context of the dominating part in the scope: embarking and disembarking with luggage. Literature study on pedestrian flow, interview on crowd behaviour and a field study on (dis)embarking efficiency contributed to many insights on the traditional way of (dis)embarking in the past and current context. On average, it takes only one second per passenger to walk in or out of the train door without large luggage. The more choices people have during the process, the more people hesitate. Hesitation, large luggage and stairs at the entrance are the factors that make the (dis)embarking flow slower. Since solving the luggage solution is included in the scope, an observational study and interviews on passengers' behaviour with their belongings were performed in different modes of transportations. As a result, loss and damage concern, availability during the trip, convenience and clear use cues of the luggage placement, comfort during the trip, time efficiency for luggage handling and the influence on other passengers are the aspects people struggle with their belongings during trips.

These are the findings from the current world that help to understand the current context and give a general direction and inspiration for the ideation phase. The result of Chapter 2 and Chapter 3 contribute to a list of requirements and wishes that need to be taken into account during the design phase.

List of requirements

1. Embarking and disembarking

1.1. The designed embarking and disembarking process should be a self-service procedure for passengers without the help of personnel. (Chapter 2.1)

1.2. The design should allow vehicles to stay on the platform for less than 2 minutes for embarking and disembarking. (Chapter 3.1)

1.3. The design should allow passengers with reduced mobility to embark and disembark independently. (Chapter 3.1)

1.4. The design should not ask passengers to arrive more than 10 minutes earlier than the departure time. (Chapter 2.1)

1.5. The design should enable passengers to leave the station within 10 minutes after arriving the destination platform. (Chapter 2.1)

2. Luggage handling

2.1. The designed luggage handling should be a self-service procedure for passengers without the help of personnel. (Chapter 2.1)

2.2. Passengers should be able to bring baggage up to the size of the average standard of air travel, which has the maximum dimensions of 78*45*30 cm. (Hardt)

2.3. The designed luggage solution should be able to handle strollers, wheelchairs and other odd-sized luggage. (Hardt)

2.4. The designed luggage solution should enable passengers to access the needed belongings during the hyperloop trip. (Chapter 3.1)

2.5. The designed luggage placement should not take up passenger seating space or aisle space during the trip. (Chapter 3.1)

2.6. The designed luggage handling process should not take more than 2 minutes extra for passengers before embarking. (Hardt)

2.7. The designed luggage handling process should not take more than 5 minutes extra for passengers after disembarking. (Hardt)

3. Ergonomics

3.1. The measurements of the design should work for P5-P95 of the international population. (Hardt)

3.2. The measurements of the design should work for passengers with reduced mobility. (Hardt)

Wishes for concept decision

1. Concept performance

The designs are better when a better performance is achieved, including high space efficiency for passengers, more luggage space per passenger, high operational time efficiency for vehicles and high inclusiveness for passengers with reduced mobility.

2. User experience

The designs could have a better user experience in terms of clear use cue, comfort during waiting, (dis)embarking and travel, and convenience for (dis)embarking, luggage management and during travel.

3. Complexity and cost

The designs could have low complexity and cost in vehicle design, interior design and station infrastructure.

4. System integration

The designs could integrate well with the rest of Hardt's hyperloop system, including suspension, propulsion, ventilation system and the possibility to integrate cargo transportations.

5. Emergency safety

The designs could consider on board safety equipment and evacuation flow during emergencies.

6. Innovative selling point

The designs could be original and have unique selling points (USPs) for the company to stand out among its competitors.

In the ideation and conceptualization phase, the criteria will be taken into account. The list of requirements will be used to filter out ideas that do not have the potential to meet all requirements; weights will be applied to the wishes in the concept decision part and potential concepts will be scored based on how well they meet the weighted wishes. This chapter also functions as a guideline for concept evaluation. ■

A photo from the session within Hardt to come up with the desired interactions: the more post-its the better. Photographed by Marinus van der Meijs.

04.

Designing a future vision

This chapter is the design phase in the ViP process. It starts with defining a domain; then a literature study is performed to collect future context factors; afterwards, the factors are structured with clusters and dimensions and finally, a future vision will be formed and a design brief will be stated as a direction for the conceptualization phase.

4.1 Domain and context factors

Domain

As explained in Chapter 1, formulating the future context starts with defining a domain, the area where the designer chooses to make an influence. The domain for this project is global public travel in 2027. In the next paragraphs, the domain will be explained.

Global public travel

"In most cases, and preferably, this domain can be defined more broadly, without specifying the function (or user) of the product." (Hekkert, & Dijk, 2014). In this case, the 'product' Hekkert referred to is already defined in the scope: the embarking and disembarking process of hyperloop and its supporting infrastructures. Zooming out from that 'product', it is in the context of global public transportation. 'Global travel' means travelling domestically and internationally and it is part of the concept of Hardt hyperloop, connecting main cities all over the world. 'Public travel' meaning travelling with forms of transport that are available to the public, charge set fares and run on fixed routes.

2027

This project aims to develop a system that is meaningful in the context in which it will be used. Referring to the strategy and planning of Hardt, the testing of technology will be done around 2022. The commercial route planning, governmental agreement, investment and partnership and constructions need to be settled and that will take at least 5 more years. Approximately around 2027, the first commercial track will be built and passengers will be involved. This is the year in which first-time hyperloop users are involved. Therefore, in this domain, the focus should be on the first-time travellers instead of frequent travellers.

Context factors

In order to shape the future of global public travel, an extensive literature research has been done on patterns of change and stability are found in relevant areas. They are context factors including the following four types according to ViP method.

Principles

A natural law or a given in human or in nature that will not change over time.

States

Something is frozen for a short period of time but is able to change in the future.

Developments

A phenomenon that is changing or in transition at the moment.

Trends

A human reaction to the change, including behaviour, value and preferences.

Over 100 context factors have been collected, covering six fields. Technological factors on how technology developments and how that changes people's lives and work especially in terms of mobility; psychological factors on how people think, feel and behave; sociocultural factors about how people deal with others in public environment; biological factors about the different physical needs of different demographic groups; economic factors about people's financial concerns and political factors that might influence legislations for future public transportation. All context factors are based on literature, without moral judgements or interpretations. A complete list of context factors can be found in Appendix D and the variety of the factors is listed in *Table 3*. ■

▼

Table 3. Numbers of context factors found in different fields.

	TECHNOLOGICAL	SOCIALSOCIO-CULTURAL	PSYCHOLOGICAL	BIOLOGICAL	ECONOMICAL	POLITICAL	ECOLOGICAL	TOTAL
PRINCIPLE	/	9	17	5	1	/	/	32
STATE	4	7	6	3	5	1	/	26
DEVELOPMENT	11	1	/	/	7	4	4	27
TREND	8	6	4	/	1	/	7	26
TOTAL	23	23	27	8	14	5	11	111

4.2 Context structure

A list of factors is comparable to building blocks. They are the key elements for building the future context yet do not form a context on their own. The next step is to add designer's interpretations and seek for the relationship among factors. In this part, the factors are grouped into a manageable number of clusters based on the two cluster types distinguished by the ViP method: a 'Common-quality' cluster which concerns a combination of factors that all point to the same (underlying) direction and together form a 'meta-factor' or an 'Emergent-quality' cluster that brings together various factors and a new factor emerges. The outcome of the clusters reflects the designer's value upon what is original, appealing and domain-related. After clustering, two dimensions are found which determine the future context.

#1 Machines are taking over the hassles

Machines are gradually taking over human labour and emerging service companies are assisting people with all aspects of their life. Less physical struggles means more time for experience. During global travel, there are fewer processes to go through and fewer belongings to take care of, just walk out of the house and experience the journey.

#2 Human interaction is needed on an emotional level

Although machines and robots are used everywhere and they are probably doing a great job with managing tasks. People still need interactions with other people to get an emotional understanding which cannot yet be replaced by other forms of interactions in the near future. In the travel industry, autonomous systems will be efficient but people will be treated as freights being moved around. How to provide an emotional interaction will be the biggest challenge.

#3 People only spend time on what they think is meaningful

People hate wasting time and want to spend every minute on valuable things. Valuable time means different things to different people, getting new information, making progress, spending time with families, or simply being engaged. But all that points to a rewarding result. While most of the things are taken care of, being inspired or being creative might be the new reward of travel.

#4 People are bored of the plain reality

The reality is not stimulating enough and people have been trying to involve digital to the analogue. After a few decades of the ‘smart devices’ hype, upgrades are required on the level of digitalization. Virtual reality and augmented reality are the new hype of stimulation. This will definitely be a big opportunity for transportation upgrade and a way to bring inspiration and creativity.

#5 People realise their value through others

Most of the people, as part of the society, are living under the ‘judgement’ of others. Some people like it because they build their own value upon the value to others while some people are stressed because it conflicts their own interest. In terms of public transportation, passengers are in a ‘community’. How to make use of their social conventions and how to make it comfortable for different people?

#6 People are spoiled with on demand services, any delay will make them complain

The collaborative consumption and sharing lifestyle requires accurate and efficient on-demand services and companies will have been working towards that for a decade in 2027. The services are almost optimised and users are used to being treated ‘on-demand’. With the 2027 transportation system, they will also expect it to be perfectly matching their needs and wishes in all dimensions and any undesired results will make them complain publicly.

#7 People want to be in control with the help of confirmation

People like to be in control literally but they cannot anymore in the context of systematic and robotic future. Instead, they want information and confirmation towards their current situation and the future events so that they know what’s going on and they can be prepared mentally. The conflict requires transportation systems to manage the process carefully while still providing people with the feeling of being ‘in control’.

#8 People need their ‘personal space’ when transparency takes over privacy

In order to feel secure, people want to know everything and require transparency in all industries. The growing level of transparency in organisations and systems also require transparency in the people in the organisation or system. People’s privacy will be a big social issue and will always conflict with transparency in public transport.

#9 Independency is important to the ‘weak’

People want to be respected. When they are treated respectfully they don’t think it as a big parameter in life. On the contrary, people who are less confident about themselves physically, social-status-wise or educational-wise wants to show their independence and abilities to gain respect. In global travel systems, it mainly regards elderly passengers, illiterates and handicapped people. They don’t want things to be done for them, instead, they want to manage things to show their capability to others.

#10 Everyone wants special treatment

In the sharing future, people can share almost all consumptions but they do not want to share the attention. People want to feel special and be treated as their very self and that is the experience they would appreciate in any services.

#11 Intuitive thinking is fast and effortless

People have two thinking mechanisms in their brain, the logical part and the intuitive part. Intuitive thinking is fast and effortless, people follow their intuition and even don’t notice what process they’ve been through. This can be used in transportation industries, by making use of intuition, guide people through necessary processes. No over-thinking, no complaints. ■

4.3 Future context

Some clusters together formulate a coherent story while some conflict with one another. Analysing the underlying connections among the eleven clusters again, four possible future mindsets of travellers are extracted following two dimensions: initiative and collectiveness.

Dimension 1: Initiative

This dimension is about people's initiative towards taking control during global public travel. People with high initiative are always trying to be in control of everything, "arrange it myself". This future is mainly caused by the massive information and data explosion that makes people insecure and lose trust towards anything other than themselves. The supporting clusters are #7 People want to be in control with the help of confirmation, #3 People only spend time on what they think is meaningful and #9 Independency is important to the 'weak'.

On the other hand, people with low initiative are system-dependent, "tell me what to do". This originates from the highly autonomous future and mechanism in general, which makes people more dependent or even 'addicted' to the convenience that can be achieved effortlessly. Supporting clusters include #1 Machines are taking over the physical hassles, #6 People are spoiled with on demand services and #4 People are bored of the plain reality.

Dimension 2: collectiveness

This dimension describes people's orientation in the society. High collectiveness leads to social orientation, "help each other out". Collective people appreciate the human interactions and realise their personal value through a society in a sharing future with the increasing sharing economy and collaborative consumption. The clusters that give shape to this future are #2 Human interaction is needed on an emotional level, #5 People realise their value through other people and #7 People need constant confirmation.

Opposite to that, people with low collectiveness are individualists who are goal-oriented, "get what I want". They tend to have a clear goal of things they do. Spoiled by personalization and on demand services, they avoid any disruption in their way. This is supported by the flowing clusters: #6 People are spoiled with on demand services and any delay would make them complain, #8 People need their 'personal space' when transparency takes over privacy and #10 Everyone wants special treatment.

Placing the two dimensions into a matrix *(Figure 16)*, the structure of the future context is established. The structure describes four mindsets that will appear in the domain of global public travel in 2027.

Chasers are confident and isolated from the rest of the society. They are travellers who are confidently going after their own goals and are not aware of the environment around them.

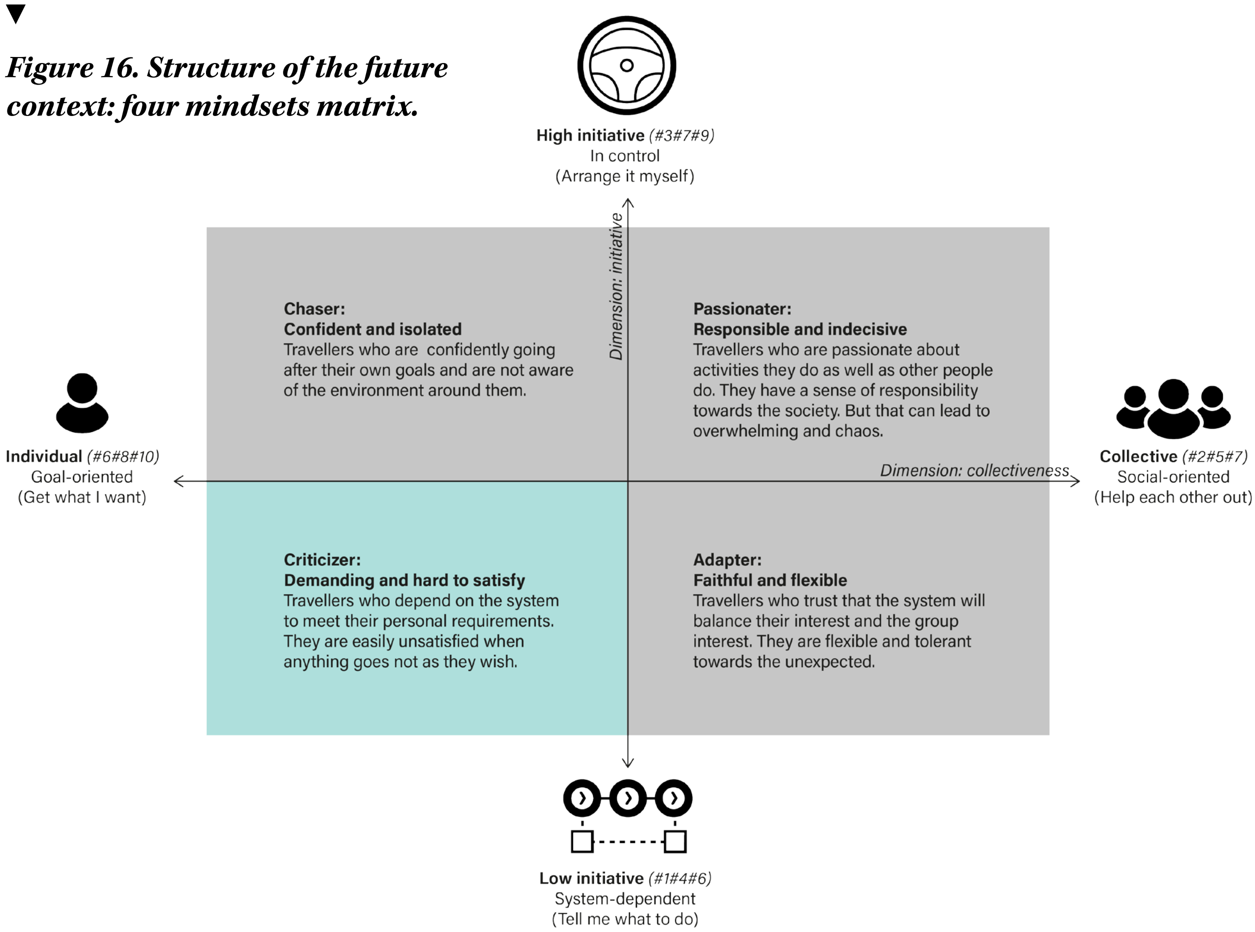
Passionaters are responsible and indecisive. They are travellers who are passionate about activities they do as well as other people do. They have a sense of responsibility towards the society. But that can lead to overwhelming and chaos.

Criticizers are demanding and hard to satisfy. They are travellers who depend on the system to meet their personal requirements. They are easily unsatisfied when anything goes not as they wish.

Adapters are faithful towards the environment and flexible to any changes. They are travellers who trust that the system will balance their interest and the group interest. They are flexible and tolerant towards the unexpected. ■

▼

Figure 16. Structure of the future context: four mindsets matrix.



4.4 Vision

Now that a future context is structured, the next step is to decide the designer's response to this new context. This decision is beyond what people want, about understanding what people do, how people think and help them figure out what they need in the future.

Target: criticizers

With mobility, on-demand services, more convenience, chances are that more people in the future will be 'spoiled' and become the criticizer as defined in the highlighted box of *Figure 16*. The newborns will be used to get what they want immediately and take it for granted. People with such mindset will be extremely efficient with their life and work. With their critical attitude, they can be of great value for the hyperloop system, especially during the pilot. Since they are goal-oriented and system-dependent, when problems appear in the hyperloop system, they will not easily adapt to them or try to solve things themselves, problems in the system will be easily spotted and solving them at the beginning saves trouble at later stages.

Behaviour change

However, with mobile services, internet connection, food delivery, the trend is that they will become even more demanding and behave as a group that only complains about the hyperloop system. Predictably, they are unwilling to depend on themselves or work things out with the society around them.

During the unexpected in the systematic future, which will happen, they will have the highest stress level and their behaviour arises negative emotions among the crowd. They are the target that needs help the most among travellers with other three mindsets. The 'complaining' behaviour of these people will neither help improve their experience nor improve the system, therefore as a designer, I want to make a change. I would like to design to influence their behaviour in the future context so that they are more adaptable to the unexpected.

Mission statement: In the domain of global public travel, I want demanding people (criticizers) to adapt to the unexpected.

The design should make them realise that they need to appreciate those services they receive, and act more understanding and contribute to the unsatisfying factors. So instead of complaining the environment when they are unsatisfied, they should negotiate with the environment and contribute to the situation with their critical mind.

Inclusiveness

Regarding the inclusive nature of public transport, the design on the 'product' level, (dis)embarking process for hyperloop, should not exclude any travellers. Solutions that are designed for criticizers will also apply for adapters, chasers and passionaters.

Adapters, with low initiative and high collectiveness, are flexible and tolerant originally in their mindset. A design that accomplishes the previously mentioned mission (willing to adapt) will be the comfort zone for adapters. In terms of the high-initiative travellers (above the axis in *Figure 16*), chasers and passionaters, they are less dependent on the system and likes taking control over the situation. Although the design might not focus on their needs of feeling in control, they will still be able to use the designed system and define for themselves what they can be in control of. While the other way around does not work (a design that requires initiative makes it impossible for system-dependent people). ■

4.5 Design brief

Interaction level

I want people using the product to realise the goal presented in the statement. Products realize their value through interactions. Therefore, before deciding what the product should be like, it is best to design the human-product interaction. The interaction qualities should evoke criticizers' new behaviour of being adaptable to the unexpected. In order to define the desired interaction qualities, I started by formulating an analogy in a different domain that serves my goal *(Figure 17)*:

(Dis)embarking hyperloop should feel like eating at a local's home during a road trip.

In the analogical situation, during a road trip to an unfamiliar place, a critical and demanding person is invited by a local family to have dinner in their house unexpectedly. At the host's, he might encounter some inconvenience and satisfaction. As a demanding person, he will kindly negotiate with the host (about food flavour for example) to reach his goal instead of complaining. The analogy captures the essence of the desired interaction for the

▲

Figure 17. An analogy for the interaction vision.

stated mission in global public travel. In other words, if the travellers feel the same way as 'eating at a local's home' when (dis)-embarking hyperloop, our goal is reached.

Three interaction qualities are extracted from the interaction vision: enjoyable excitement, grateful negotiation, and unconscious adaptation. The interaction qualities will be explained in the domain context.

Enjoyable excitement

Enjoy the excitement in the environment. Demanding travellers are hard to satisfy in general, but when they are overwhelmed by excitement, like in the case of the analogy, they will enjoy the moment and that opens the possibility of changing their behaviour.

Grateful negotiation

Be grateful and appreciate what they are experiencing and negotiate with the environment when sensing any satisfaction. This is the next stage of their experience, sharing their inconvenience in a negotiable way.

Unconscious adaptation

Accept the result of negotiation and understand that not all their demands can be met in a public surrounding. If this interaction is triggered in the final design, the mission is completed.

Product level

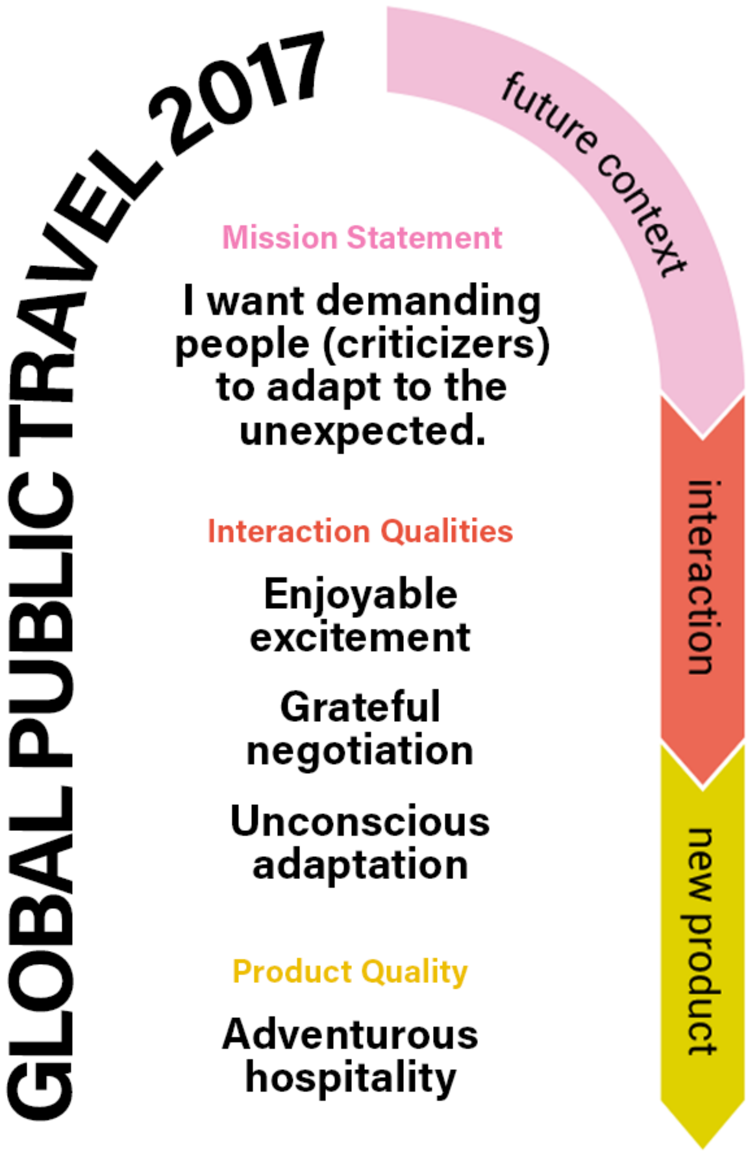
Determining the appropriate quality of the product to be designed is the last part of formulating the vision. The (dis)embarking process of hyperloop should have the quality of adventurous hospitality.

Adventurous responds to the interaction quality 'enjoyable excitement'. The final design should be unconventional, exciting and surprising; hospitality evokes the other two interaction qualities 'grateful negotiation' and 'unconscious adaptation'. The design should be welcoming, inviting and warm. Since this is a design for 2027, when hyperloop is in its beginning stage, these qualities should mainly apply for first-time travellers. The design brief for the conceptualization phase will be: ►

To design an adventurous hospitable embarking and disembarking process and supporting infrastructures for hyperloop passengers in 2027. ▪

▼

Figure 18. An overview of the ViP result.



4.6 Conclusion

This chapter formulated a future vision of Global public travel in 2027. With extensive literature research, four future mindsets in the domain are chaser, passionater, criticizer and adapter. My mission is to let criticizers adapt to the unexpected like eating at a local's home during a road trip. Three interaction qualities, enjoyable excitement, grateful negotiation and unconscious adaptation leads to the product quality: adventurous hospitality. *(Figure 18)*

ViP is a method for designing for the future context, therefore the mission and vision cannot be evaluated in the present context. The method only serves as an inspiration during the ideation and conceptualization phase in the next chapter.

A screen shot from Hardt test facility unveiling movie: making a morphological chart. Filmed by Wim Geuzendam.

05.

Conceptu-alization

This chapter describes the process from idea generation to a preliminary concept decision. The ideation starts with the stated design brief from the ViP method. Creative sessions are done to enlarge the solution space and come up with a lot of ideas. Then the ideas are organised, further developed and selected, resulting in a morphological chart. Given thought on all possible combinations of ideas from the morphological chart, four combinations stand out and are developed into concepts. The concepts are compared by the method Weighted Objectives and a concept decision is made.

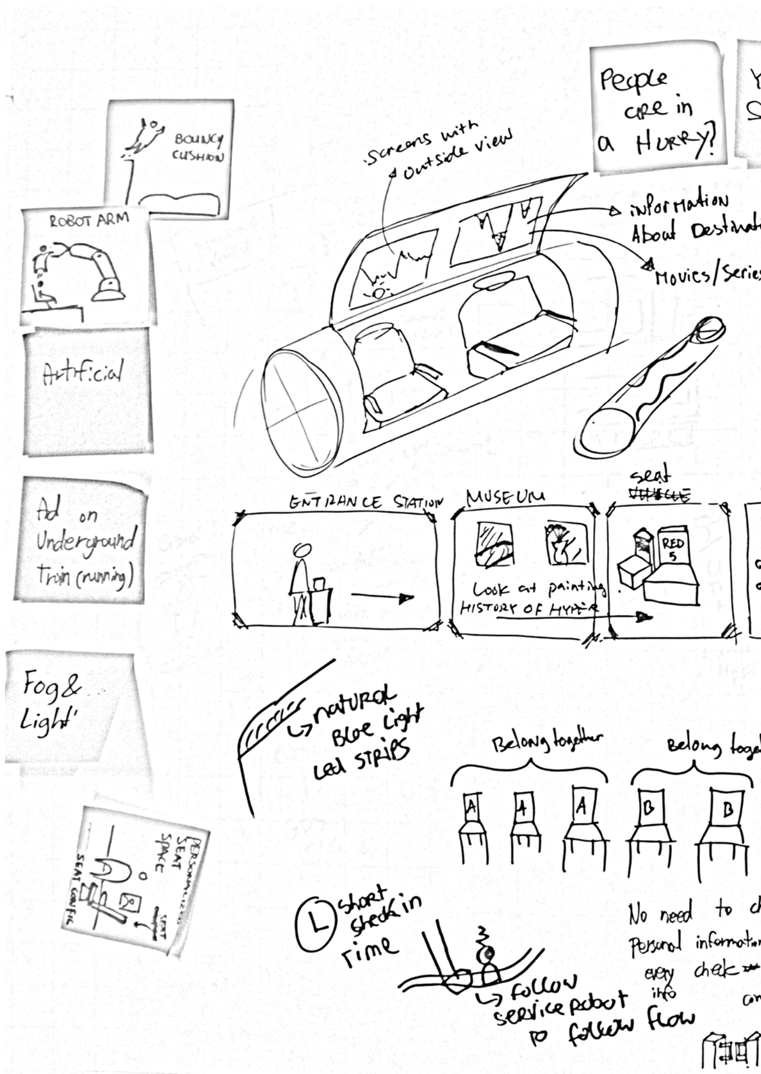
5.1 Ideation

Step 1: Exploring solution space

Two ideation sessions were carried out with twelve participants (both from Industrial Design Engineering and Hardt) in two days. The aim of the sessions was not only to come up with a large variety of ideas but also to enlarge solution space as much as possible. This ensured that we have covered nearly all possibilities in the ideation phase providing a well-grounded base for the next steps. Various diverging techniques, suggested by Marc Tassoul (2009), Jan Buijs and Han van der Meer (2013) in their books, were used to facilitate the sessions.

Free brainstorming: listing first ideas

At the beginning of the creative sessions, the design brief, “to design an adventurous hospitable embarking and disembarking process and supporting infrastructures for hyperloop passengers”, was presented to the 12 participants and all first ideas were written on ‘post-it’. All ideas that popped into my mind throughout the whole project were also listed. Based on each other’s ideas, the second round, the third round of ideas came out.

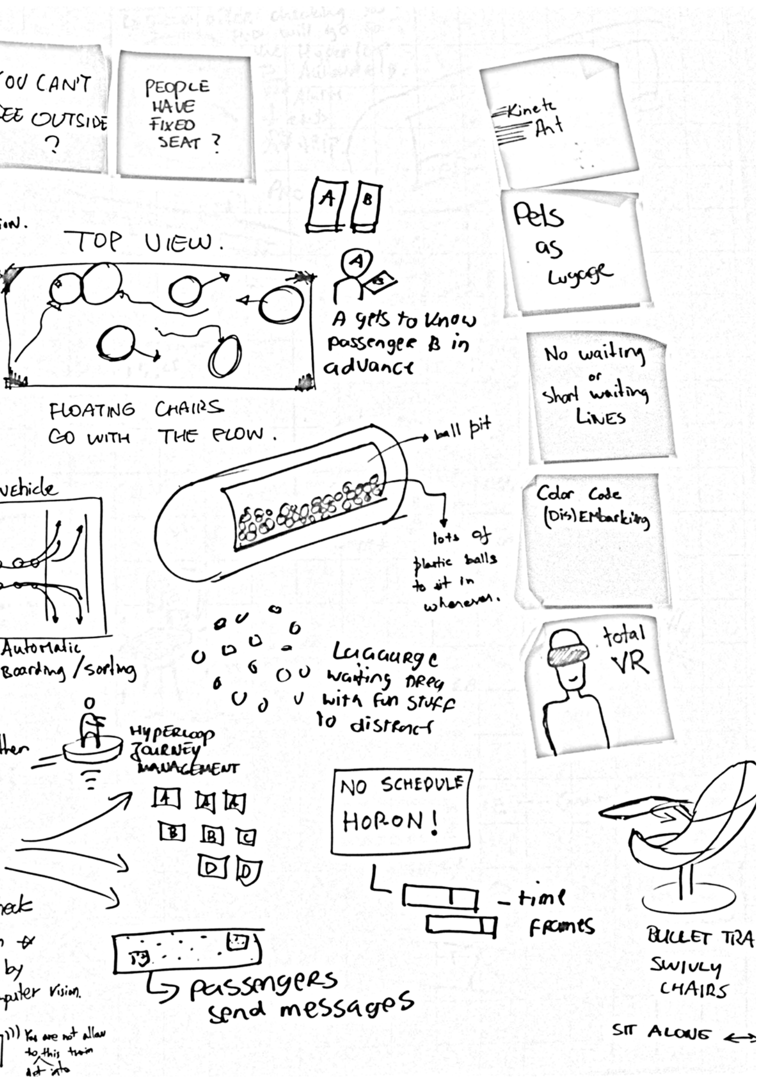


▲

Figure 19. An example of results from the creative sessions.

Breaking assumptions

Having an overview of the ideas coming out of brainstorms, I noticed that people were constrained by assumptions of previous experience. For example, we assumed that people are sitting in chairs; people walk into the vehicle; the vehicle is round; everything is made from solid materials; people want to be settled as soon as possible etc. In this step, we break the assumptions to get fresh and original ideas by asking questions like “what if there are no doors?” “What if all passengers get in at the same time?” “What if people can’t walk?” “What if all people are blind?” “What if there’s no platform” ...



Attribute listing

Attribute listing is a technique for ensuring all possible aspects of a problem have been addressed. This technique breaks the problem down into smaller and smaller bits and solves them one by one. “What does the platform look like?” “Where do people wait for the vehicle” “How do people get in and out?” “What about luggage?” “How do people find their place in a vehicle?” “How will they travel during the hyperloop journey?” ...

Inspirations from the research

The results of the field research in Chapter 3 (conclusions and quotes) and part of the context factors from Chapter 4 were printed out during the sessions to inform the participants and remind me of what users think now and what the future scenarios will be. Plenty of new and relevant ideas appeared.

Hundreds of ideas came out during this step and it was a joint effort of me and the twelve other designers. *Figure 19* is an example of the results from the sessions.

Step 2: Clustering and developing ideas

After the idea diverging sessions, all ideas were bunched together and validated rapidly with the criteria to prepare for converging. The ideas were clustered in order to check the variety and explore new categories if needed. Within each cluster, similar ideas were integrated and new ideas came out. Then the ideas were evaluated based on the relevance to the design brief, the potential to meet all requirements and on what level they meet the wishes. In the end, the potential ideas were sketched out in Figure 20. ►

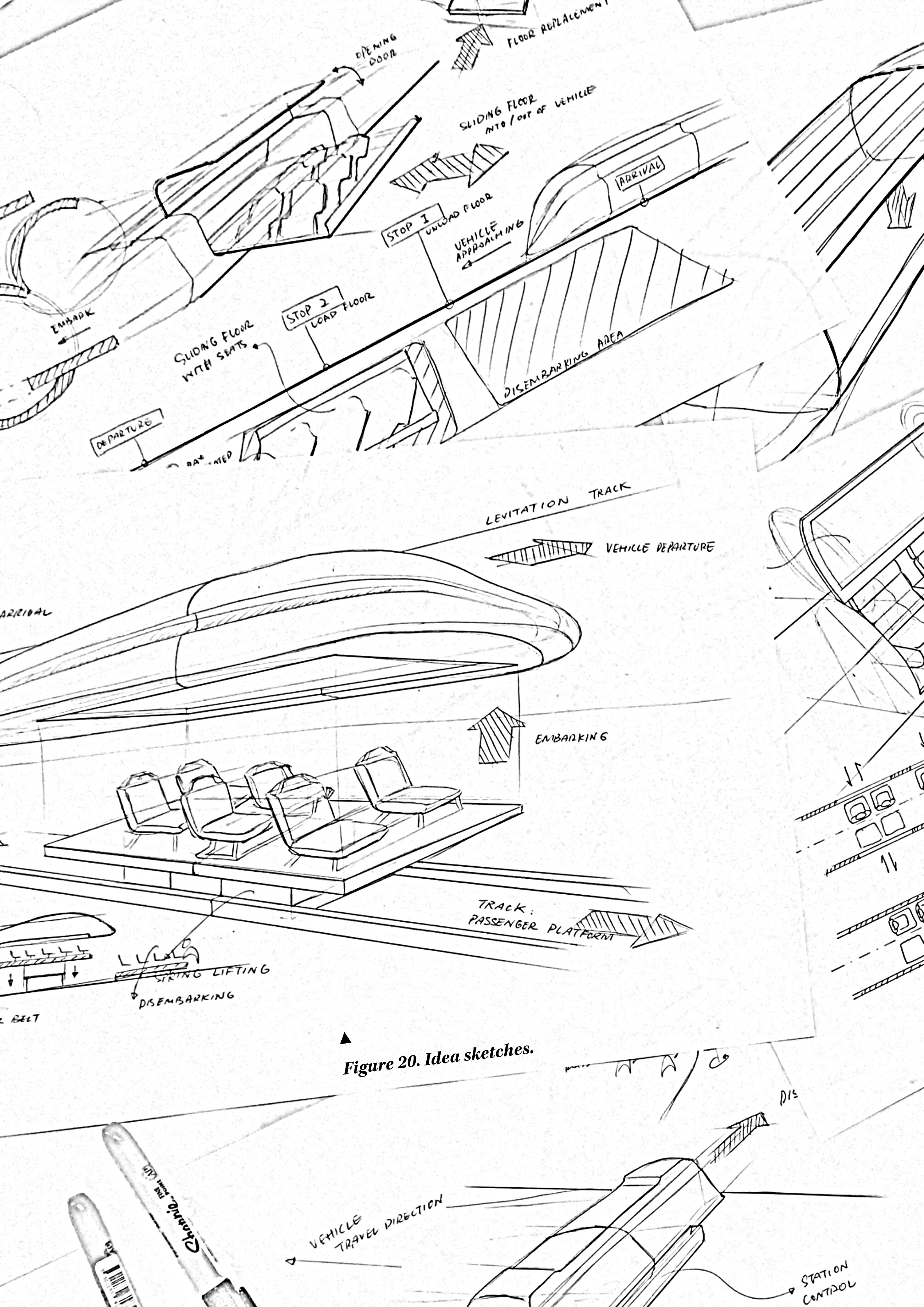
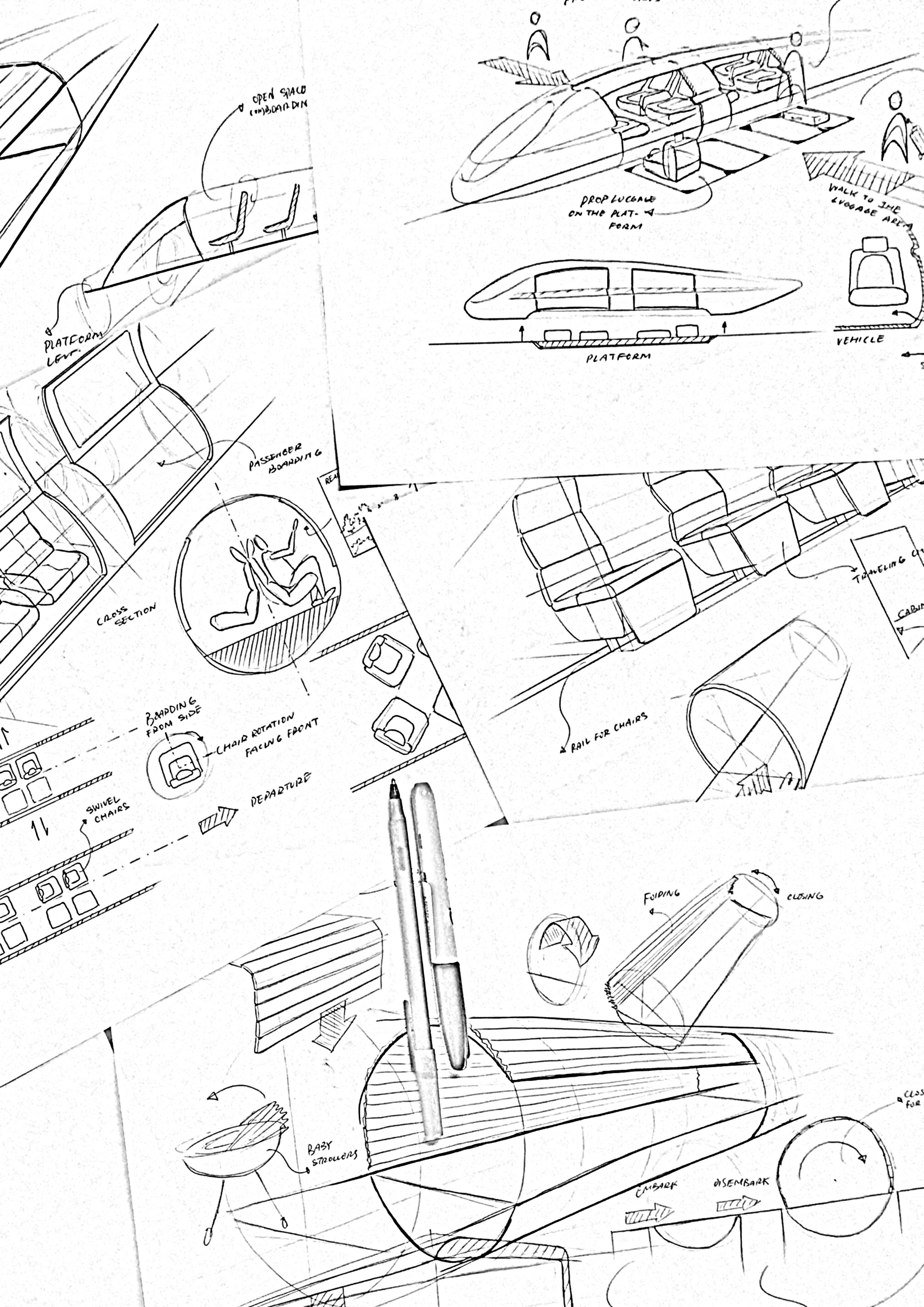
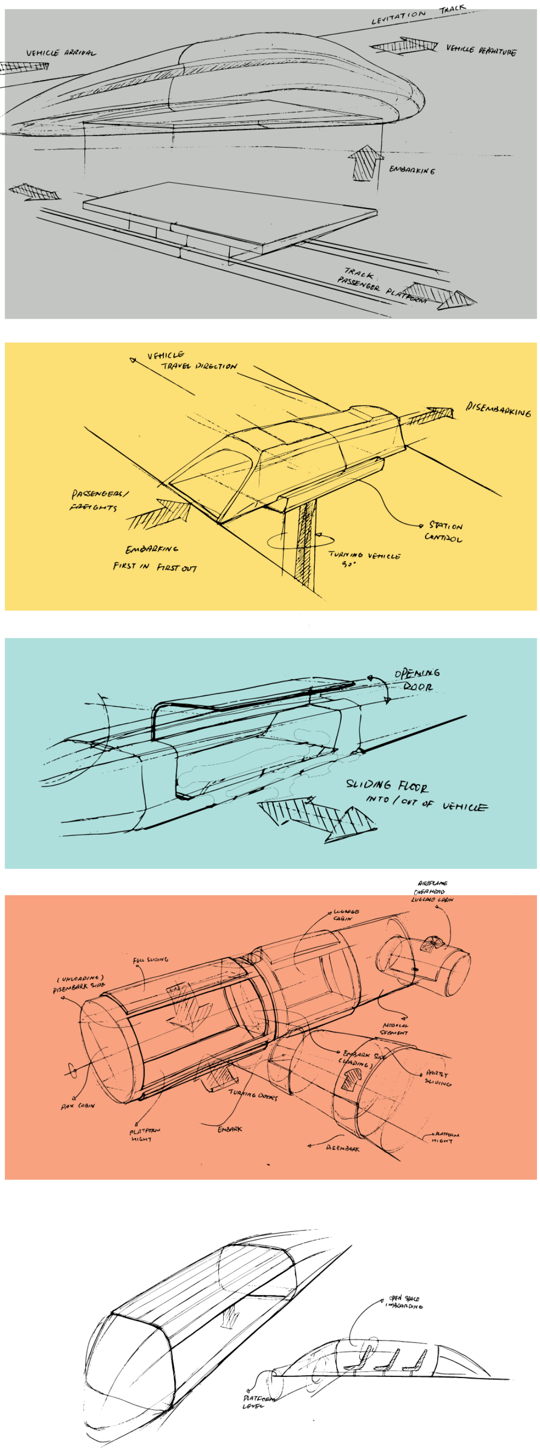


Figure 20. Idea sketches.

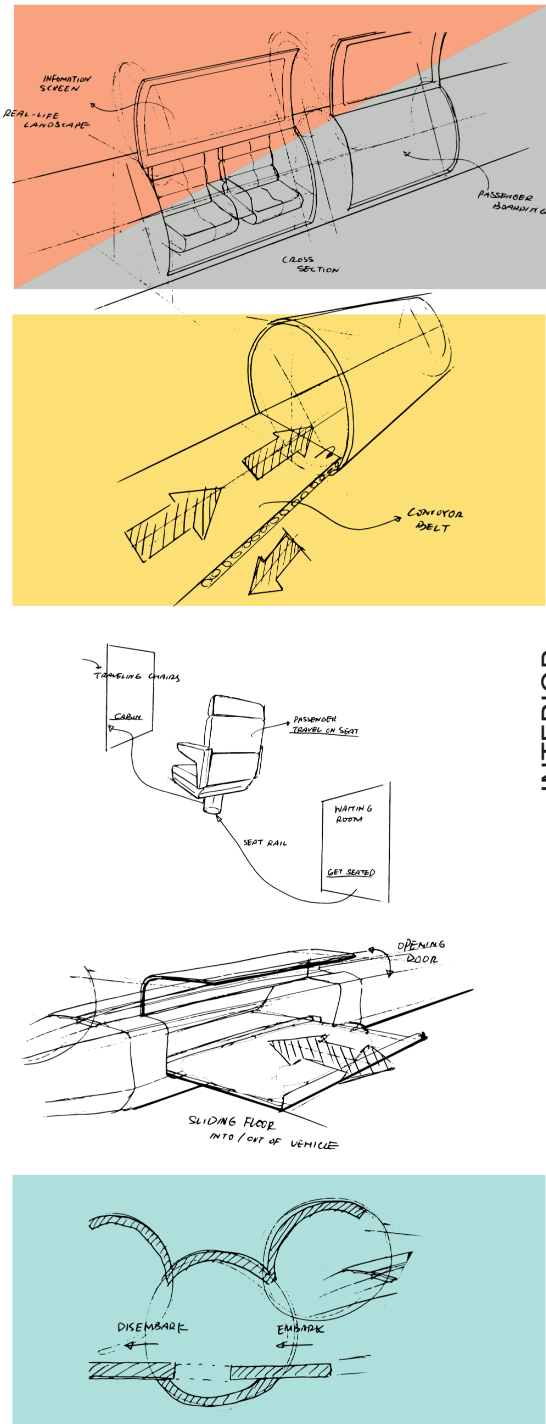


DROP LUGGAGE ON THE PLAT-FORM
WALK TO THE LUGGAGE AREA
PLATFORM
VEHICLE
PASSENGER BOARDING
CROSS SECTION
BOARDING FROM SIDE
CHAIR ROTATION FACING FRONT
DEPARTURE
SWIVEL CHAIRS
RAIL FOR CHAIRS
FOLDING
CLOSING
BABY STROLLERS
EMBARK
DISEMBARK

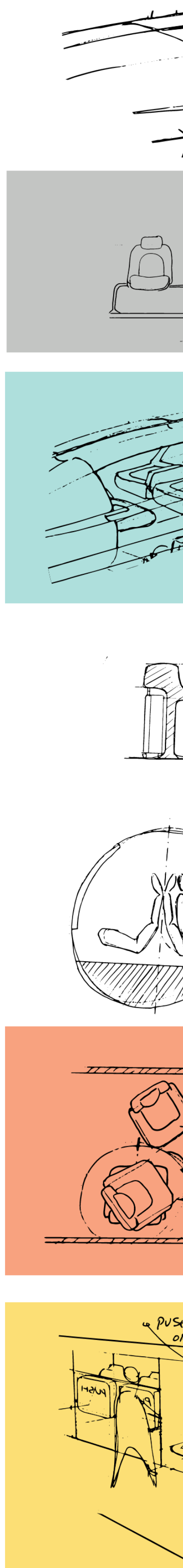
VEHICLE EXIT



(DIS)EMBARKING



INTERIOR



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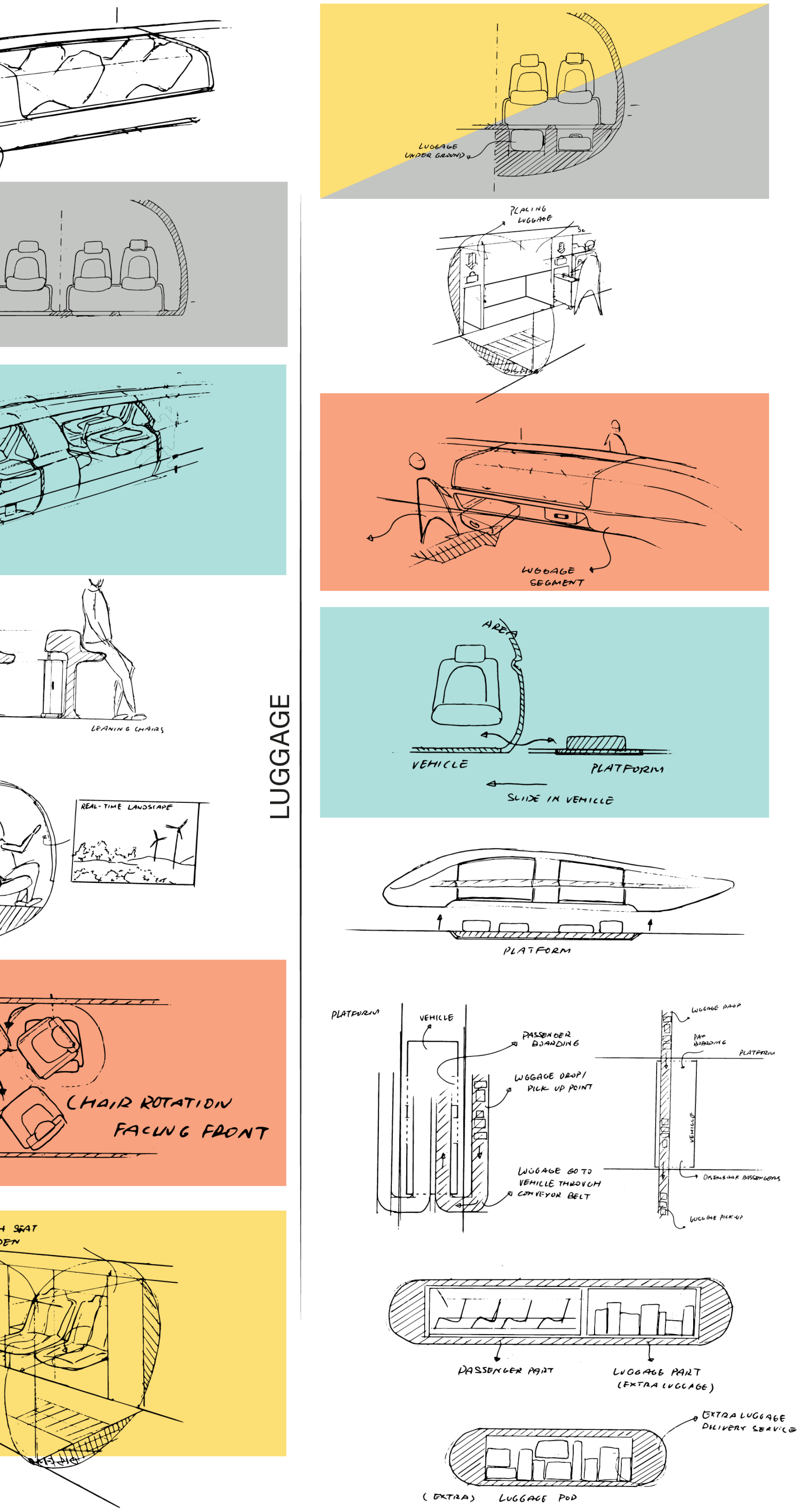


Step 3: Ideas to concepts

This is the converging part of the ideation phase. Concerning the design brief and scope of the project, the design concepts will be a system with different elements/functions: vehicle exit, embarking and disembarking process for passengers, the interior design of the vehicle and the luggage solution. A morphological chart was used to list all alternatives of each element/function.

All possibilities of combination from the morphological chart were thought of. In the end, four best combinations stood out shown in four different colours in *Figure 21*. In the next step, they were developed into concepts. ■

◀

Figure 21. Morphological chart with concept combinations.

5.2 Concept development

(Step 4: Concept development)

The four concepts suggested in the last step were developed further to the same level by means of computer sketching. Each concept was presented in a poster explaining vehicle exit, passenger embarking and disembarking process, luggage solution, interior and station infrastructure. Making use of the conditions and requirements, passenger capacity for each concept was also estimated.

Concept 1: Shift

Description

(Figure 22) The vehicle is divided into segments by rows of seats. Every passenger segment consists of two rows of seats facing each other and doors on both sides of the vehicle. Passengers embark from one side and disembark from the other side. (Large) luggage cabins are under the passenger floor with one cabin every two rows positioned right under the back-to-back seat rows. On the platform, conveyor belts are placed on both sides for each luggage cabin to transfer luggage from platform to vehicle for embarking passengers and the other way around for disembarking passengers. At each station, unloading luggage and loading new luggage, passenger disembarking and new passenger embarking can happen at the same time on both sides of the station.

Passenger journey

The passengers are guided to the right segment of the platform. Passengers stand in the waiting area and place their large luggage beside them on the conveyor belt. When vehicles arrive, their luggage will be delivered to the luggage cabin while they walk to their seats. Personal belongings can be placed under seats. When passengers are seated and ready for departure, the vehicle will depart. At the arrival station, the door on the other side will open while the luggage is transferred from the cabin to the arrival platform. Passengers can get out of the vehicle in sequence and their luggage will be waiting for them placed in the same sequence (first in, first out). They can simply take their luggage and leave the platform.

USPs

The unique selling point of concept Shift is the efficient operating system and the effortless passenger flow. Vehicles do not have to stop for long because of the embarking and disembarking process, luggage loading and unloading happen simultaneously. Passengers can drop their luggage right next to them at departure station and collect it while walking onto the arrival station. The short aisles and seat placement make it easy to get seated and be prepared for departure.

Relevance to design brief

The segmentation of passenger area makes the boarding process friendly and inviting because passengers only see a small group of people, unlike other public transportations. The luggage loads and unloads itself in the same sequence as passengers, like it is following you on and off the vehicle, which adds to the adventurousness.

Concept 2: Turn-in

Description

(Figure 23) Turn-in is a design based on rotating seats. The seats will face outwards to the platform for easy disembark and embark. During acceleration and deceleration, the seats turn to the direction of acceleration so that the backrest can always support passengers during acceleration and deceleration. It assures passengers a safe and comfortable journey. During cruising (or with little acceleration rate) passengers can personalise their orientation. On both sides of the vehicle, there are doors and luggage cabins underneath the passenger floor. Two passengers share one door and the matching luggage cabin. The platform is connected on both sides.

Passenger journey

Passengers enter the platform facing the vehicle travelling direction. Depending on the given information, they go to one side of the track and wait for the vehicle. When the vehicle arrives, previous passengers get out of the vehicle first and new passengers may place their luggage in the cabin and go on board to their seats. Right before departure, the seats will rotate facing the direction of movement. When the travel speed is relatively stable, passengers can control the rotation of their seats depending on what they want to do or where their companions are. When the vehicle is decelerating near the destination, the seats face backwards. At the platform, the seats rotate again facing the exit for easier disembarking.

USPs

Turn-in is a luxurious and personalised design. Passengers embarking and disembarking experience is comparable to a private transportation. During travel, passengers have the large personal space and the freedom to customise their journey by adjusting their seats.

Relevance to design brief

During embarking, the seats are facing towards the passengers 'inviting' them to be seated; during disembarking, seats are facing the exit and doors are open like a host holding the door for you and showing you the way out. Adventurousness is achieved by the automatic rotation of seats during travel.

Concept 3: Walk-through

Description

(Figure 24) The entrance and exit are placed in the front and rear of the vehicle. ►

During embarking and disembarking, the vehicle floor is connected to the station floor seamlessly on both sides. New passengers embark with their luggage from the front door and previous passengers disembark from the back. Seats with luggage room underneath are placed on the sides facing the aisle so that passengers do not have any corners like in the current aeroplanes or trains. Instead, they only need to 'walk through' the aisle. When all passengers are seated, the seats turn to the front for better comfort during acceleration and deceleration. Finally, the vehicle turns 90 degrees and runs perpendicularly to the boarding direction. It is the opposite situation for disembarking.

Passenger journey

Passengers will first wait at the station hall in front of their boarding gate. They will see the vehicle approaching, turning 90 degrees to have the entrance facing the gate. The gate opens and passengers can walk into the vehicle, find a seat, place their luggage beneath their seats and be ready for departure. The seats will all turn two by two towards the moving direction. At the destination, the seats move back and the aisle is wide and clear again. Passengers disembark from the rear while new passenger embark from the front.

USPs

The unique selling point of Walk-through is the simple and clear one-way passenger flow and the optimised structural solution. No confusion for passengers at all. There is only one door for embarking connected to the waiting area and the other door for disembarking. With wide doors and aisle without any corner, the passenger flow is optimised. Since the vehicles need to withstand the pressure difference in the tube, such cylindrical shape without any openings (doors) on the sides makes it a stiff structure with the least amount of materials.

Relevance to design brief

The design shows hospitality with large doors and a wide aisle. Passengers can walk through the vehicle without any obstacles. It is adventurous for passengers to enter a 'tunnel'-like vehicle and to see and feel the entire vehicle turning like being on a turning bridge while it opens and closes.

Concept 4: Carry-on

Description

(Figure 25) This concept includes three elements, carriers, passenger pods and the rising platform. The carriers always suspense on the track and they are the parts that provide propulsion (it is integrated into the vehicles in other concepts). Passenger pods are not only part of the vehicle to transport passengers but also function as the waiting rooms on the station. The carrier and the pod together form a vehicle. The platform is where the pods will be located when not travelling. When a pod is ready to go, the platform rises to enable a connection between the carrier and the pod. Then the vehicle is ready to depart. The same works for arriving vehicles. In this concept, fewer carriers are needed because they are always 'on the go' while more pods are needed making sure that there are always waiting rooms for passengers.

The embarking and disembarking process is similar to trains and the number of doors depends on the length and capacity of the pod. Under each seat, there is a personal underground luggage cabin and the seats are designed to be foldable like cinema seats to make the luggage placement more convenient.

Passenger journey

Passengers are directed to their pod, which is already at the station waiting for them. They walk into the pod with no time pressure, find a seat, places their luggage underground and unfold the seat. Once they are seated, they can chill and work on their own things until a carrier 'picks' them up. At arrival station, they stand up and the seats are folded again, which makes it easier for getting the luggage and walking out of their rows.

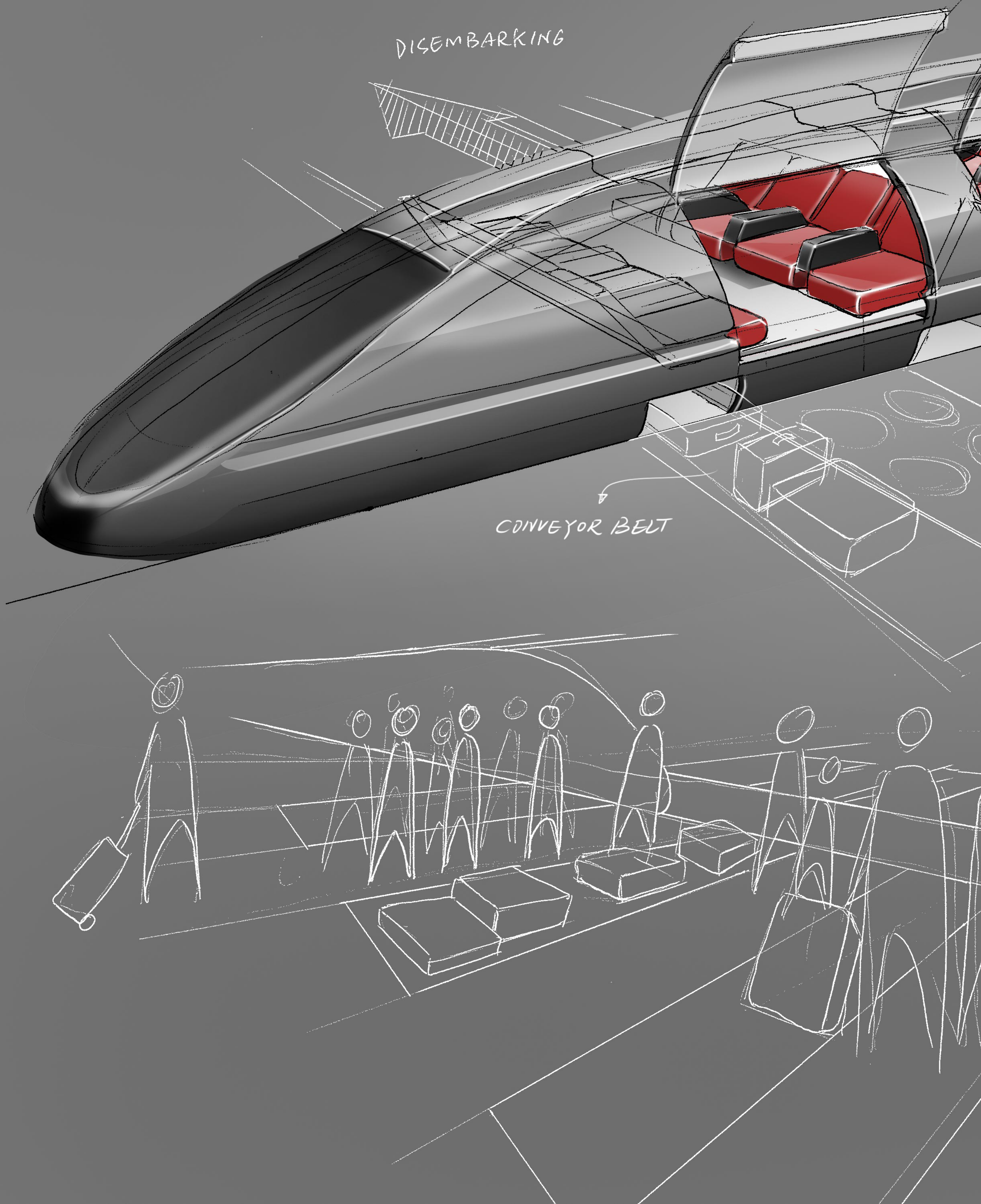
USPs

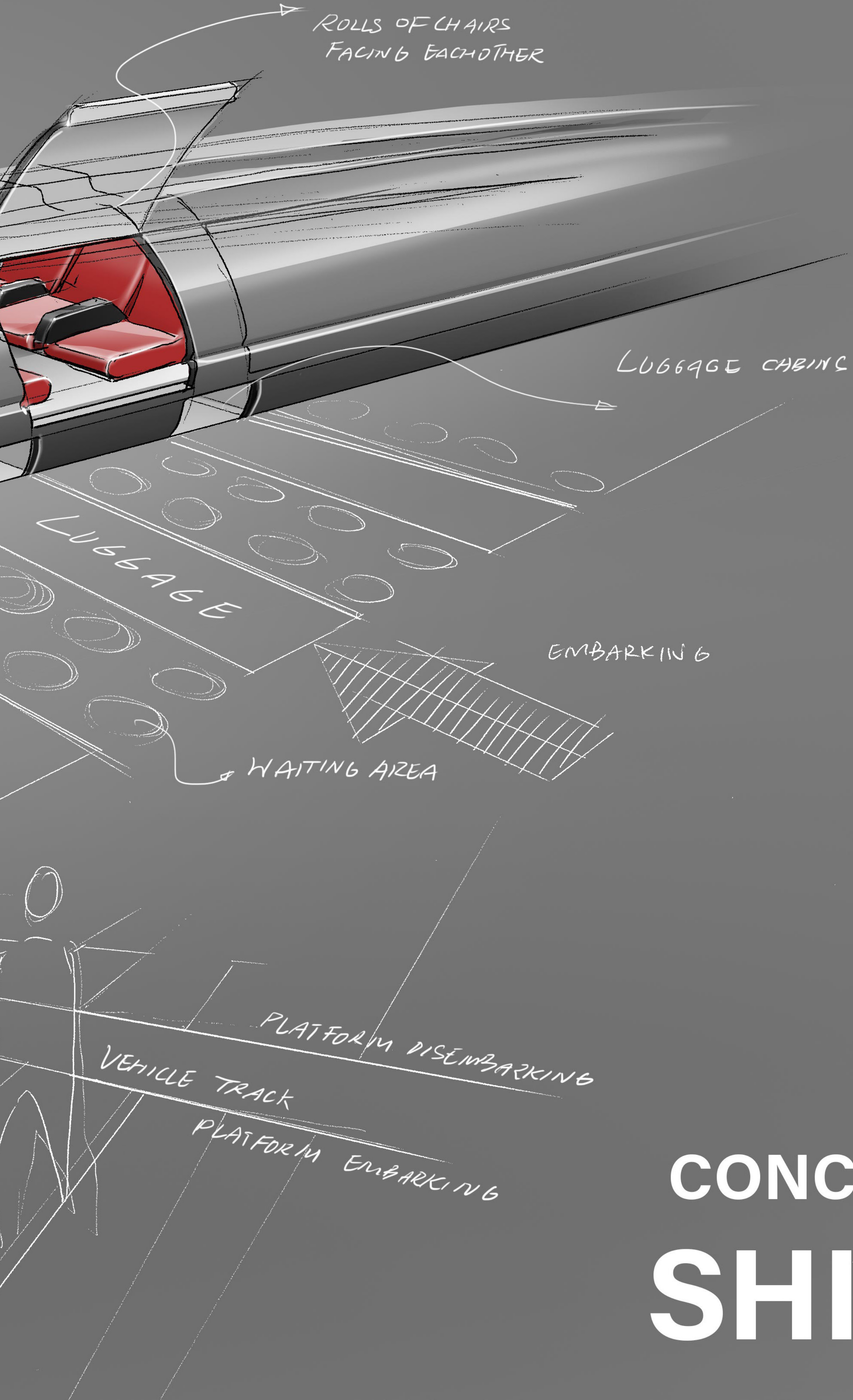
Unlike all other concepts, Carry-on concept allows passengers to take their time during embarking and disembarking. Because the pods do not have to be connected to the tracks, it does not matter where the passengers embark and disembark. A door-to-door service can be developed with multimodal transportation and modularity. Pods can be of small size like for example a personal pod. The personal pods can pick passengers up at their door and transport them to an hyperloop station propelling by road carriers or by itself. The carrier at the station will take over from there on, bringing pods through the pressurised tube.

Relevance to design brief

It allows passengers to embark and disembark on their own pace and it eliminates the time wasted on waiting on platforms, therefore shows hospitality. The fact that a carrier will pick you up at some point like a huge eagle carries you on its paws makes it adventurous. ■

▼
Figure 22. Concept 1 Shift.

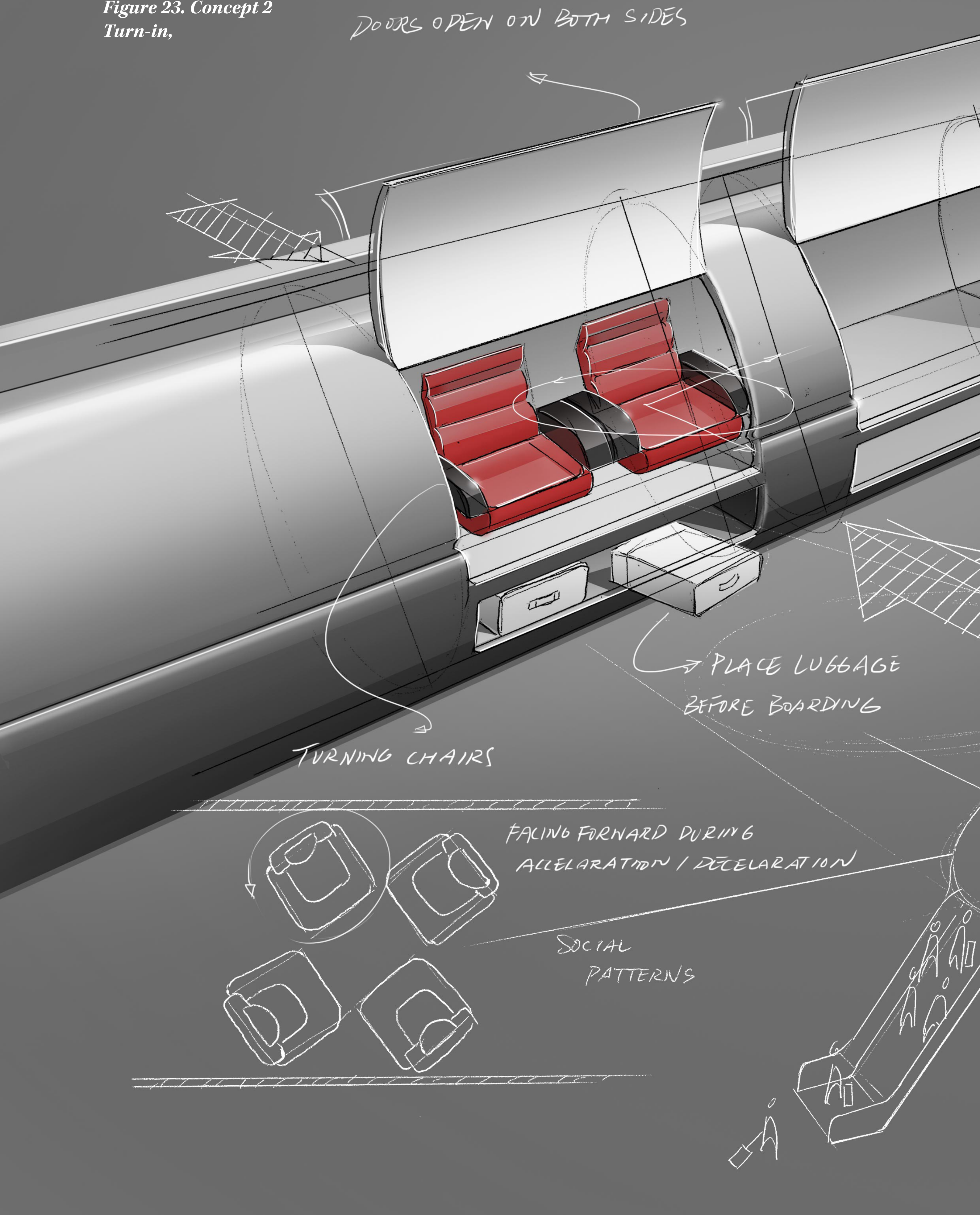




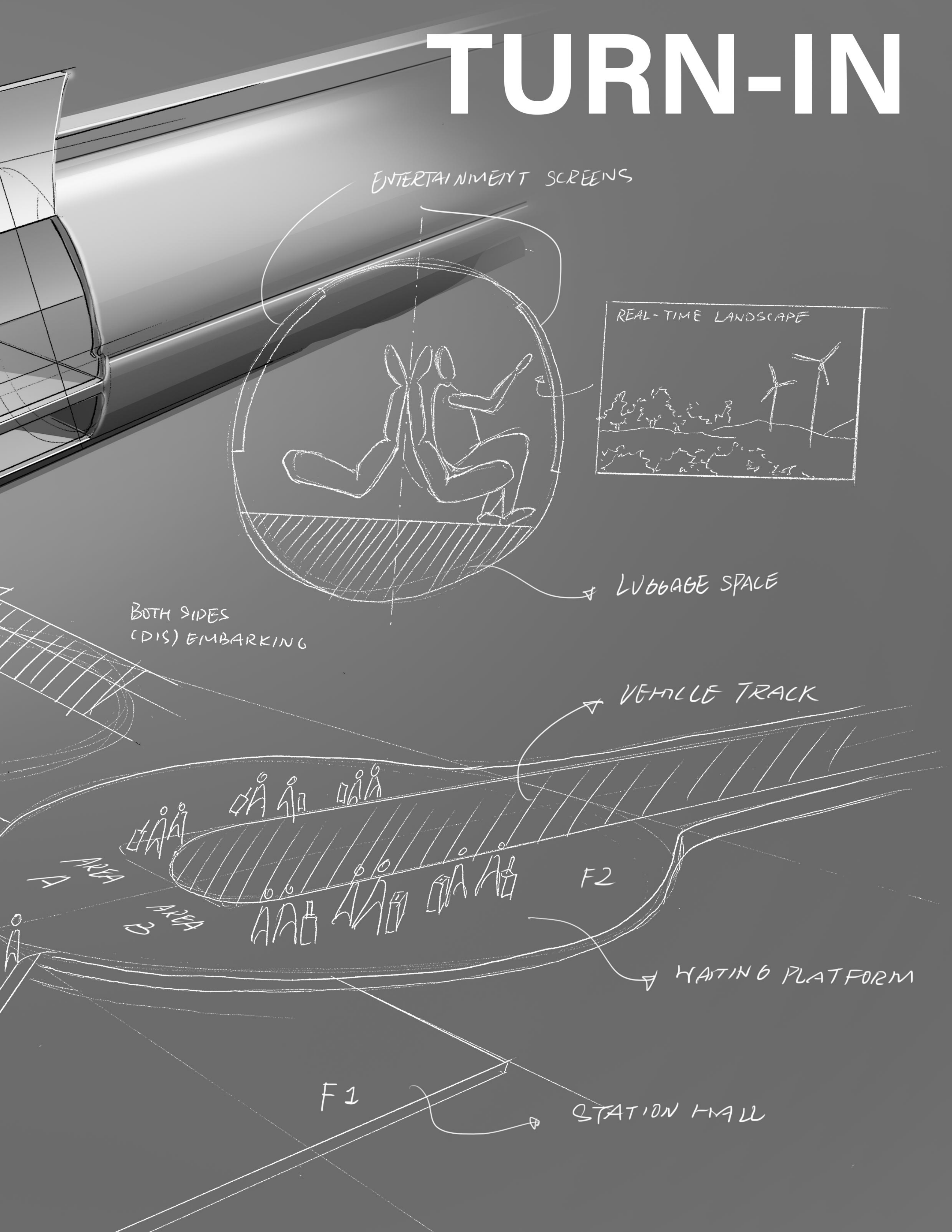
CONCEPT 1
SHIFT

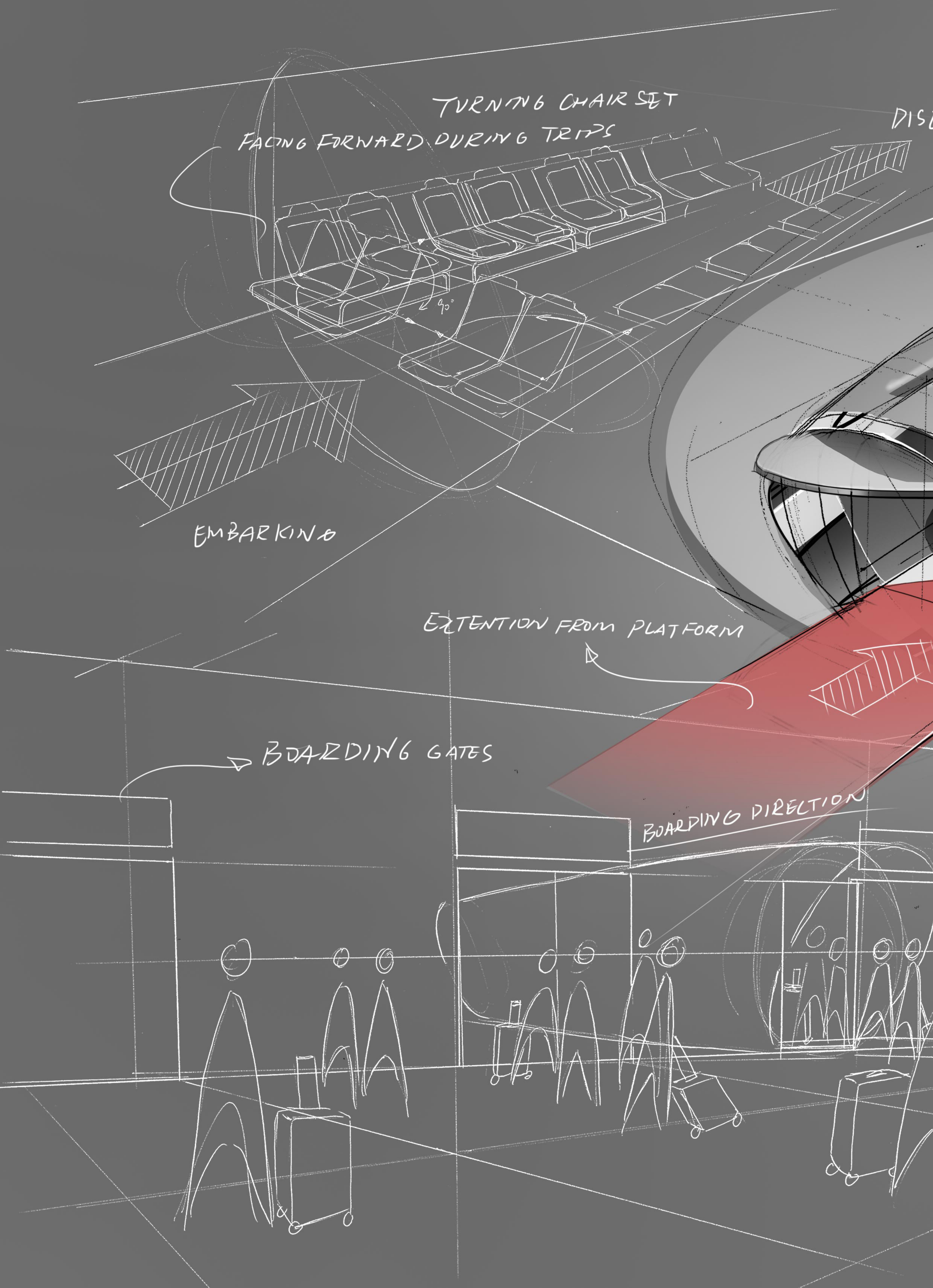
▼

Figure 23. Concept 2 Turn-in,



CONCEPT 2
TURN-IN




TURNING CHAIR SET
FACING FORWARD DURING TRIPS
DISE
EMBARKING
EXTENTION FROM PLATFORM
BOARDING GATES
BOARDING DIRECTION

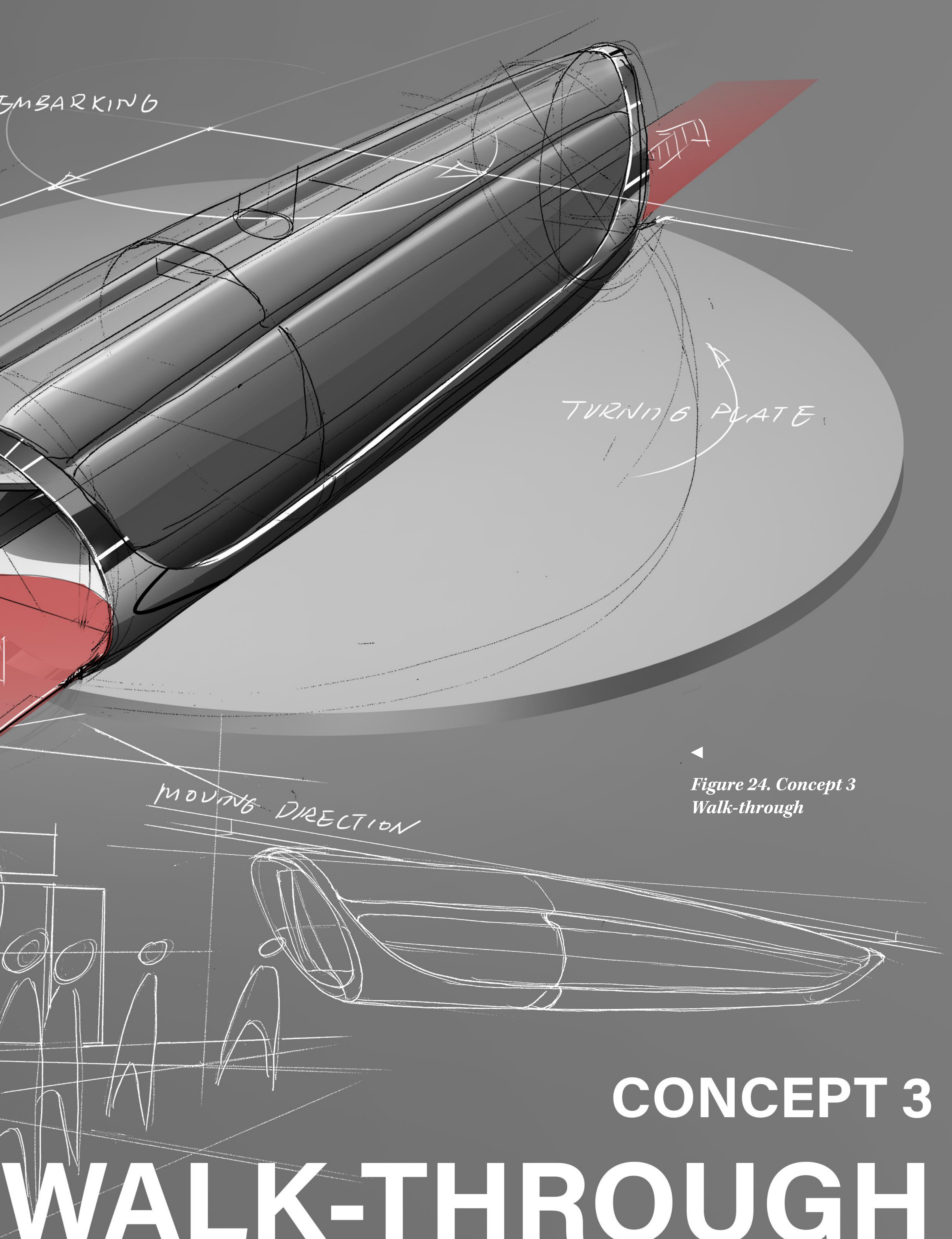


Figure 24. Concept 3 Walk-through

CONCEPT 3 WALK-THROUGH

CAR

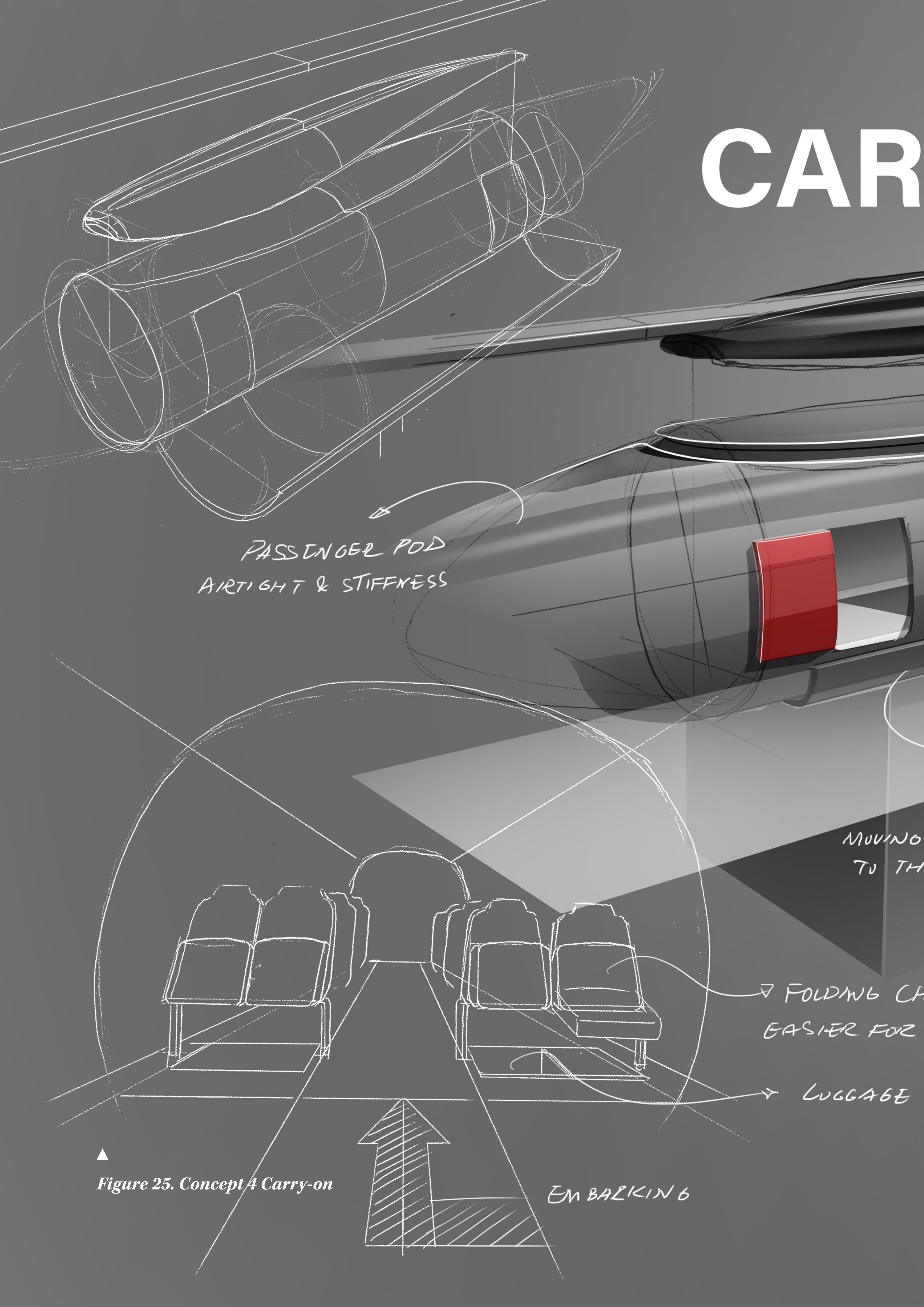
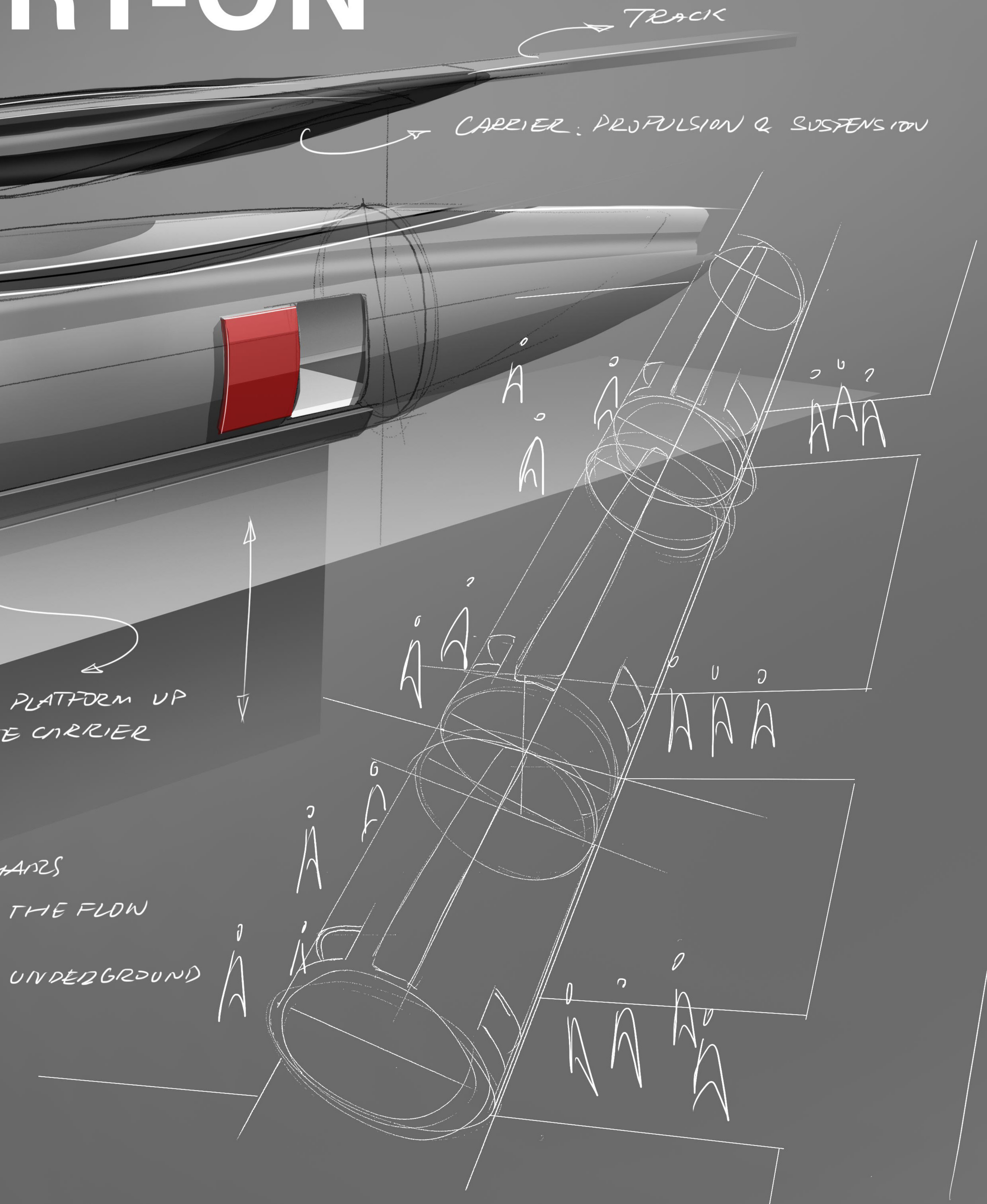


Figure 25. Concept 4 Carry-on

CONCEPT 4

RY-ON



5.3 Concept decision

(Step 5: Decision making)

In order to make a decision on which concept to develop further, the method Weighted Objectives (Boeijen et al., 2014) was applied in this step. Weight factors are attributed to the wishes in Chapter 3.3 according to the importance of the criteria. It was a result of the discussion with the company. In *Table 4*, values were assigned to each concept on a criterion from 1 to 10. The given values were based on estimation, interviewing potential users, discussions with the development team and hypotheses made according to the research results in the deconstruction chapter.

Traditional (dis)embarking solution was also scored in the table as a benchmark. The traditional concept is a combination of train and aeroplane (as the worse case): passengers wait on the platform until the vehicle arrives. For a 50-passenger vehicle,

CONCEPT DECISION SHEET		
Category	**Weight**	**Sub category**
1. Concept performance	**25**	Passengers capacity
		Luggage space/pass
		Time efficiency for s
		Inclusiveness for pa with reduced mobil
2. User experience	**50**	Hospitable
		adventurous
		Use cue clarity
		Comfort
		Comfort waiting
		Comfort (dis)emb
		Comfort travelling
		Convenience
		(Un)boarding con
		Luggage convenie
		During travel conv
3. Complexity and cost	**10**	Vehicle
		Station infrastructu
		Interior
4. System integration	**5**	
5. Emergency safety	**5**	
6. Innovative selling point	**5**	
Total	**100**	

there is one door in the front and all passengers embark/disembark from there. Inside, there are four seats in a row with an aisle in between. Appendix E explains how the scores were defined.

The overall result shows that Shift has the biggest potential regarding performance, user experience and feasibility (complexity and cost). Therefore, the preference of both me and the company goes to this concept. Shift concept will be elaborated and evaluated in the next chapters. Additionally, Carry-on scores the second best in general with the highest integration and innovation points. The company also sees great value in the idea of having 'carriers' and 'pods' due to its high originality and the ability to holistically reach the ultimate vision of a door-to-door service. However, since this is an idea more on the operating level than on passenger flow (the focus of the assignment), we reached the agreement that it will not be developed in this project but will be a valuable recommendation to the company. ■

		01 Shift		02 Turn-in		03 Walk-through		04 Carry-on		Traditional	
	Weight	Score	Sub total	Score	Sub total	Score	Sub total	Score	Sub total	Score	Sub total
y efficiency	**8.0**	10.0		4.2		5.0		6.7		6.7	
senger	**4.5**	8.0		10.0		5.0		5.0		10	
system	**8.0**	9.0	**224.0**	8.0	**160.3**	5.0	**147.5**	10.0	**182.8**	4	**148.6**
ssengers ity	**4.5**	8.0		4.0		10.0		6.0		4	
	11.3	8.0		7.0		5.0		4.0		2	
	11.3	6.0		8.0		7.5		8.0		2	
	7.5	8.0		4.0		8.0		10.0		10	
	10.0										
	2.5	*3.0*		*3.0*		*7.0*		*10.0*		3	
arking	***5.0***	*10.0*	**368.8**	*8.0*	**355.0**	*7.0*	**339.4**	*5.0*	**338.8**	3	**196.25**
g	***2.5***	*6.0*		*10.0*		*7.0*		*8.0*		7	
	10.0										
venience	***3.8***	*9.0*		*10.0*		*8.0*		*6.0*		2	
nce	***3.8***	*8.0*		*7.0*		*5.0*		*5.0*		3	
venience	***2.5***	*6.0*		*8.0*		*8.0*		*7.0*		7	
	5.0	2.0		2.0		6.0		5.0		5	
re	**4.0**	6.0	**41.0**	7.0	**39.0**	2.0	**41.0**	1.0	**34.0**	8	**64**
	1.0	7.0		1.0		3.0		5.0		7	
	5.0	2.0	**10.0**	2.0	**10.0**	8.0	**40.0**	10.0	**50.0**	2	**10**
	5.0	6.0	**30.0**	7.0	**35.0**	9.0	**45.0**	5.0	**25.0**	5	**25**
	5.0	6.0	**30.0**	6.0	**30.0**	9.0	**45.0**	10.0	**50.0**	1	**15**
	100	**703.8**		**629.3**		**657.9**		**680.6**		**458.85**	

▲

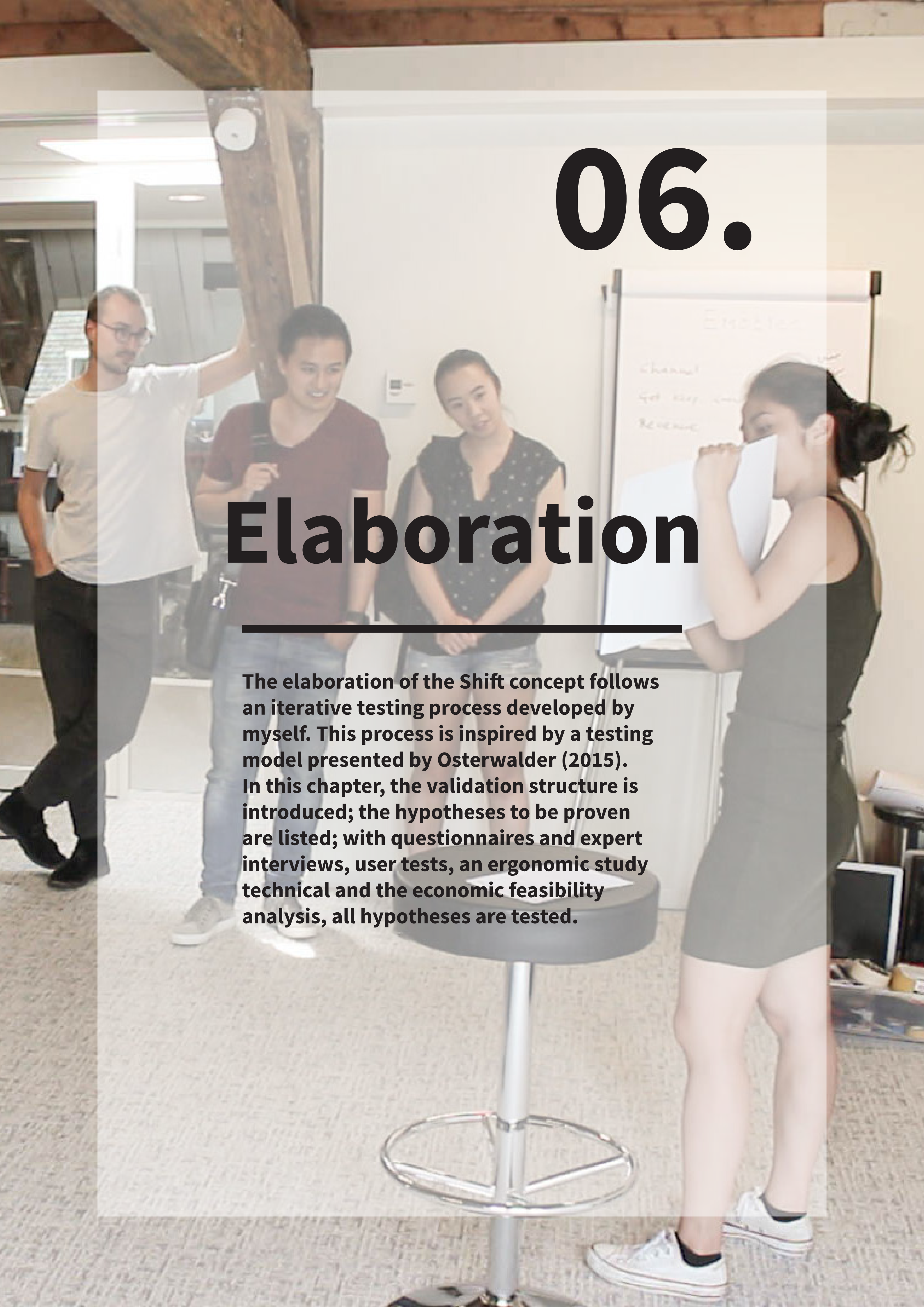
Table 4. Weighted objective concept score.
(Yellow=highest score in the category; green=highest score in total)

A photo from the ideation session: good ideas never come out without sweets.

5.4 Conclusion

Hundreds of ideas came out the ideation sessions with 12 other designers, four concepts were made out of the ideas. Using the Weighted Objective method, the Shift concept was chosen to be elaborated further in the rest of the project. Positive aspects of other concepts will also be taken into account when detailing the Shift concept and other interesting ideas for the company that are less relevant to the assignment will be recommended in Chapter 8.

A screen shot from the user test movie: introducing the concept and preparing for the experiments.

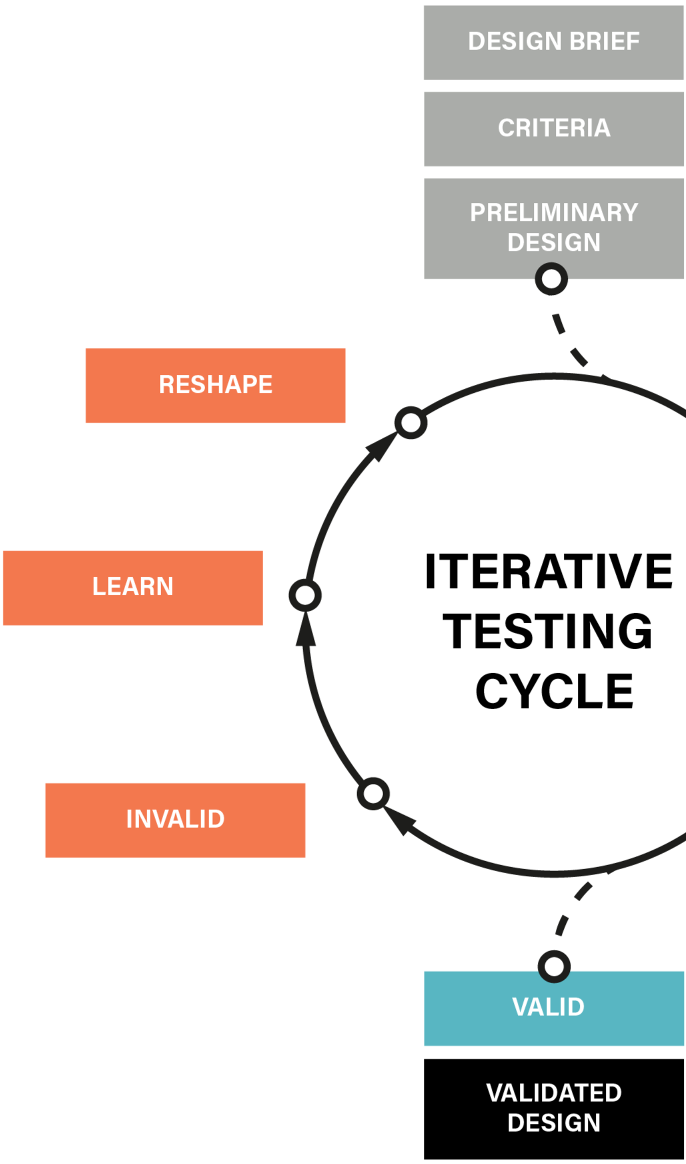


06.

Elaboration

The elaboration of the Shift concept follows an iterative testing process developed by myself. This process is inspired by a testing model presented by Osterwalder (2015). In this chapter, the validation structure is introduced; the hypotheses to be proven are listed; with questionnaires and expert interviews, user tests, an ergonomic study technical and the economic feasibility analysis, all hypotheses are tested.

6.1 Validation structure



▲
Figure 26. Iterative testing cycle.

The design brief, a result of ViP, is the starting point of the design. Among all ideas and concepts, a preliminary concept stands out based on argumentations of how much it meets the criteria. In the argumentation process, some assumptions (mostly about passenger acceptance and experience), are made with my own belief and experience. They are 'reasonable assumptions', hypotheses that need to be validated. Tests are designed and carried out to validate the hypotheses. The valid hypotheses go to the final design and invalid ones go back to the cycle. I will learn from the invalid ones and reshape the concept. Then extract new hypotheses from the reshaped design and test again until all important aspects of the concept are validated.

The elaboration part of the project follows the cycle *(Figure 26)*. In this chapter, 12 hypotheses of the concept are listed first. They are then grouped based on the way of testing/evaluation. Through questionnaires, interviews with experts, user test, ergonomic study, technical feasibility study and economic feasibility analysis, all hypotheses are tested.

Hypotheses

Concept performance

- Shift way of (dis)embarking is more system efficient than traditional (dis)embarking model

- The concept works ergonomically for P5 to P95 and people with reduced mobility (including aisle width and height, door width and height and seat width)

User experience

- Shift achieves a better user experience than traditional models

- Reducing door width from two-person width to one-person width will slow down the process significantly and cause negative experience for passengers

- Sitting facing backwards during the trip is acceptable for the majority

- It is more preferred to have large luggage loading separately into the luggage cabin

- People do not need lavatory for short-time trips

- Assigning seats (either in advance or on platform) is needed for boarding

- The designed process of (dis)embarking is clear to passengers

Feasibility (complexity and cost)

- The door (number and way of opening) design is technically feasible

- The luggage solution design is technically feasible

- The economical aspect is acceptable

The validations were done by quantitative and qualitative research with potential customers, an expert interview, ergonomic study, calculations and literature. Keeping the valid features, learning from the invalid assumptions and further developing the details, a reshaped concept (it is named final concept for this project) appeared. In this reshaped design, there are new hypotheses to validate but due to the limited time and resource, the second cycle of validation was done with the reshaped design as a whole in the final design chapter. ■

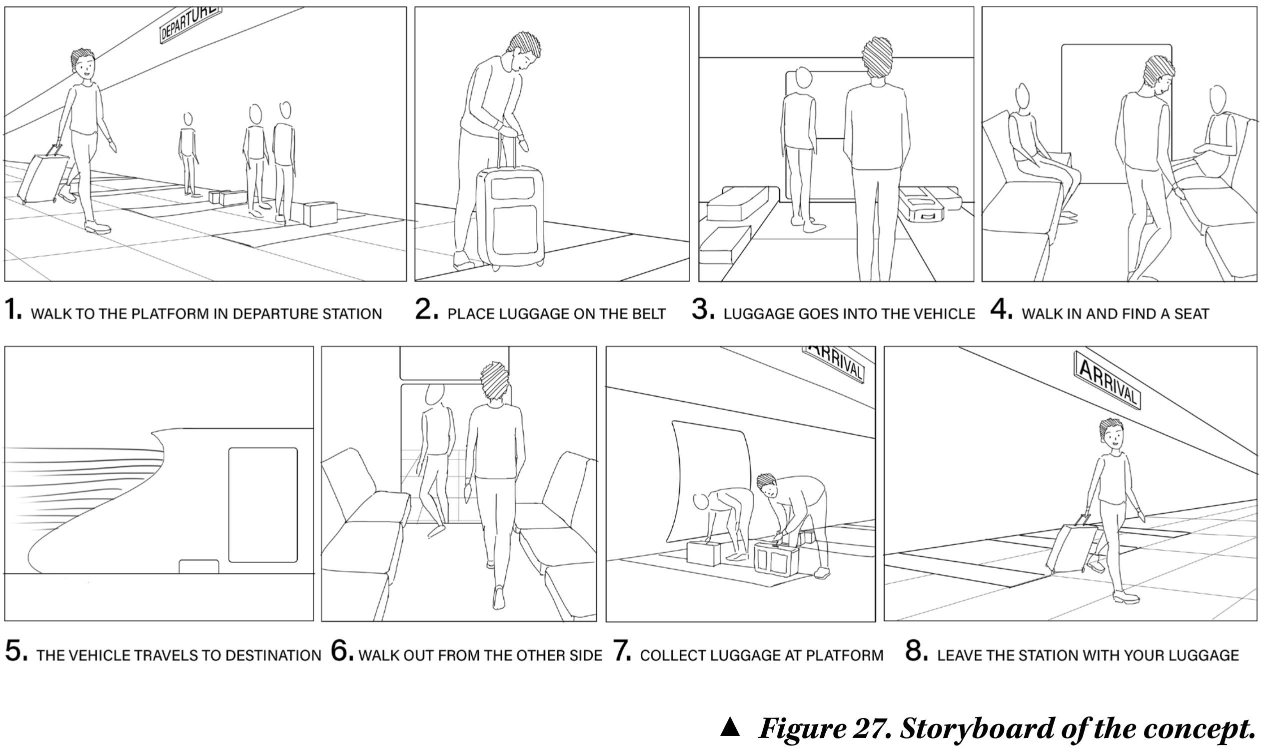
6.2 Questionnaire and expert interview

Hypotheses

1. Sitting facing backwards during the trip is acceptable for the majority

2. It is more preferred to have large luggage loading separately into the luggage cabin

3. People do not need lavatory for short-time trips



▲ ***Figure 27. Storyboard of the concept.***

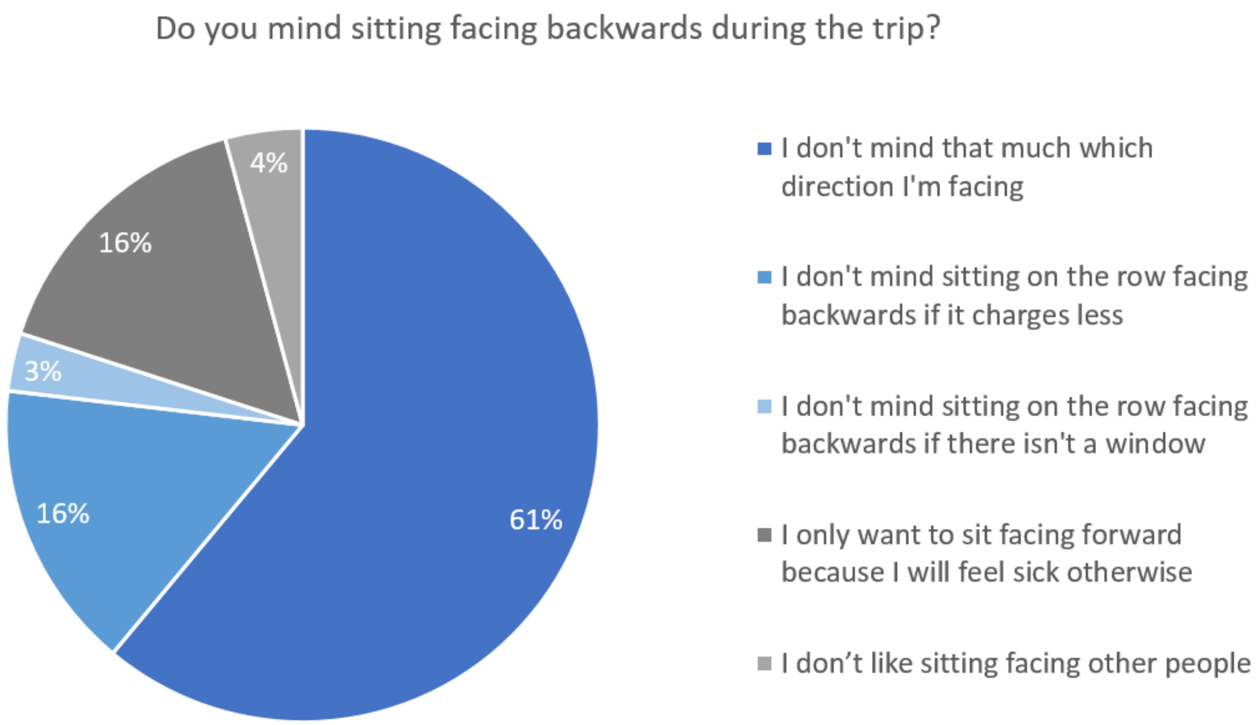
Validation

To validate these hypotheses, quantitative data is necessary to determine whether large groups share certain values. An online questionnaire was designed based on the above-mentioned validation points. The concept sketch *(Figure 22)* and a storyboard *(Figure 27)* were given in the questionnaire to help them understand the context (full questionnaire design is in Appendix F). It was filled in by 101 people from age 20 to 40, of which 64 participants are from Europe (others are from Asia, North America, South America, Africa, Australia, Middle East and the Caribbean). The result of the questionnaire was analysed to evaluate each hypothesis. Interestingly, there was hardly any difference among people with different nationalities. Therefore, the result will be discussed based on the responses of all participants (n=101).

#1. Sitting facing backwards during the trip is acceptable for the majority

If more than half of the participants can accept sitting backwards during the trip, the hypothesis is valid.

Participants were asked if they would like to sit on the row facing backwards in a vehicle and the result is as follows. 61% of the participants do not mind at all, 16% do not mind if it charges less and 3% do not mind if there isn't a window. 16% of them choose "I only want to sit facing forward because I will feel sick otherwise" and 4% of the participants commented, "I don't like sitting facing other people". In general, 80% of the participants (blue parts in the pie chart in *Figure 28*) thinks it is acceptable to sit facing backwards and motion sickness is the main reason for those who do not want to face backwards. ►



▲

Figure 28. Questionnaire result: do people mind sitting facing backwards? (n=101)

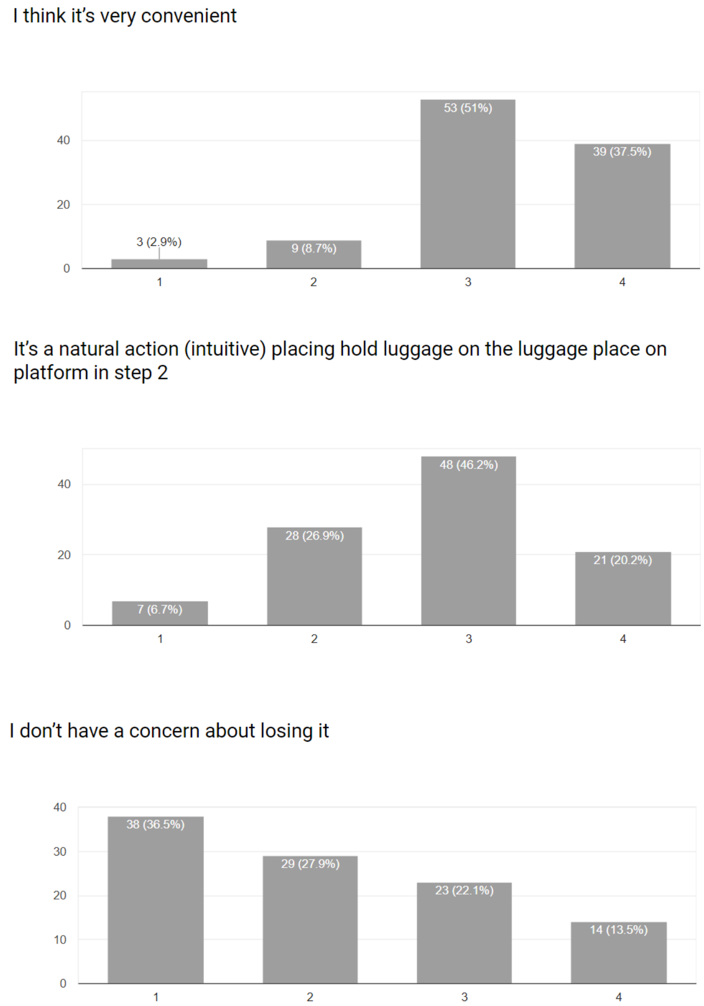
The hypothesis is validated by this result. Regarding motion sickness, literature shows that people get motion sickness when there is a conflict between one's senses. One part of their balance-sensing system (your inner ear, eyes, and sensory nerves) senses that their body is moving, but the other parts sense conflicting motion cues. For the hyperloop journey, the vehicles will be running in tubes which means no views can be seen out of the window. Passengers will not see movement yet their vestibular system will feel the acceleration. This can be solved by providing different virtual views for passengers facing forward and facing backwards to provide the most corresponding view for their vestibular system. This will not be elaborated in the final design and but will be an interior recommendation in Chapter 8.

Few participants commented that they do not like the fact that the seats are facing each other and think that "it's awkward seeing into a stranger's face for the whole trip" or "there might not be space for me to stretch my legs". It could be a potential problem of the design, but no conclusions can be made now because it was not in the options of the questionnaire. This will be further elaborated in the user test.

#2. It is more preferred to have large luggage loading separately into the luggage cabin

If more than half of the participants prefer to have large luggage loading separately, the hypothesis is valid.

Participants were asked to compare preloading hold luggage (hold luggage being automatically transferred to luggage cabin) to taking all luggage on board, in terms of convenience, intuitiveness, loss concern, efficiency and accessibility. 87% of the participants thought preloading hold

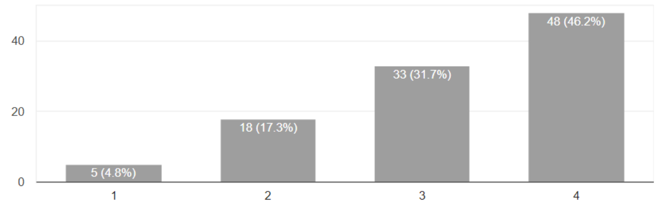


▲

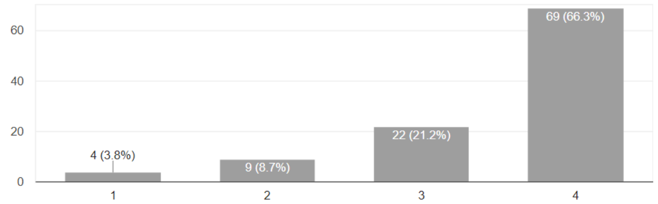
Figure 29. Questionnaire result: questions concerning luggage. (n=101)

luggage is more convenient; 76% of them agreed that it this makes their journey more efficient; 87% of them did not need access to their hold luggage; 66% of them thought it was intuitive to have luggage loading at the station. However, over half of the participants had concerns about losing their luggage especially on the platform of arrival. In general, 70% of the participants preferred preloading hold luggage separately at the platform *(Figure 29).*

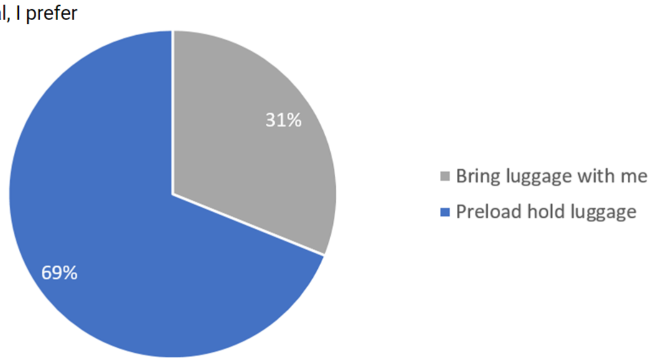
It makes boarding time-efficient



It's fine not having access to my hold luggage for a trip less than 2 hours (personal bags are always with you on-board)



In general, I prefer



The concept of loading and unloading luggage on the platform is proven but the loss concern of the luggage can be minimised by letting passengers disembark first and luggage unloads slightly after.

#3. People do not need lavatory for short-time trips

If over 90% of the participants do not need lavatory for a certain amount of time during travel, the hypothesis is valid.

An interview was carried out with Marian Loth, a PhD candidate who has done plenty of research on train toilets. Loth said in the interview that research shows that the borderline for healthy people not to use a toilet is 30 minutes. So theoretically for trips less than 30 minutes, the lavatory is not a must.

However, Loth stated that using the toilet is a natural thing, it cannot always be planned for healthy people, let alone people with bladder and bowel dysfunction. Unlike cars and buses that can stop anywhere, transportations like trains and aeroplanes have fixed stops and people do not have an 'escape' during travel. According to her, the NS Sprinters (with an estimated average trip time of 17 minutes), where no toilets are on board, "turned out to be a disaster" not only because of the at ethical issue mentioned above, but also because passengers sometimes stay on board longer than expected (for example emergencies). Furthermore, failing to manage passengers' expectation is another reason that evokes negative public opinions. In the NS train system, there are Intercitys with toilets and Sprinters without toilets. Without a clear communication, Intercity travellers who are used to have toilets on board will expect the same from Sprinter since they are both in the same railway system. This confusion happens a lot with first-time travellers making a negative first impression of the train service.

According to Hardt, the hyperloop trip will be 5 minutes to 2 hours. This means that for trips over 30 minutes, the lavatory is needed. If Hardt does not provide lavatory for trips within 30 minutes, it will be a similar case to NS. Considering the ethical issue, emergency cases and confusion problems for NS, it is best that hyperloop has a consistent lavatory service in all vehicles. The hypothesis is invalid. ■

6.3 User test

▲ ***Figure 30. Mock-up A: traditional (dis)embarking experience.***

▲ ***Figure 31. Mock-up B: Shift (dis)embarking experience.***

Hypotheses

4. Shift way of (dis)embarking is more system efficient than traditional (dis)embarking model

5. Assigning seats (either in advance or on platform) is needed for boarding

6. Shift achieves a better user experience than traditional models

7. The designed process of (dis)embarking is clear to passengers

8. Reducing door width from two-person width to one-person width will slow down the process significantly and cause negative experience for passengers

Validation

Two setups with mock-ups were performed in Buccaneer Delft, a joint working place for small-scale companies where Hardt is located. Ten people between the age of 24 and 53 participated in the user tests. Observations, questionnaires and interviews were done to validate the hypotheses.

Setup 1

Both traditional aeroplane/train setup (mock-up A: *Figure 30*) and the Shift concept (mock-up B: *Figure 31*) were simulated with mock-ups. Both mock-ups only represented part of the vehicle and the real performance for a 50-person vehicle was estimated based on the test result. Participants were asked to embark and disembark both mock-ups.

Mock-up A simulates a traditional boarding process. This is part of one compartment with one door for boarding and disembarking. There are four chairs in a row with an aisle in between for embarking and disembarking. Luggage cabins are overhead like in the aeroplane and most of the trains.

Mock-up B is part of the concept Shift, the bar chairs simulate doors on both sides of the vehicle, one for embarking and the other for disembarking. In front of the embarking door are the boxes representing conveyor belts for hold luggage. Instructions on the right luggage position are notified next to the belts. A dashed line in the middle of the waiting area tells people that they could stand 2 by 2 and place their luggage on both sides. (Testing process see *Figure 32* and *33*) ►

▼ ***Figure 32. The process of the experiment with mock-up A.***

1. Passengers walk into the vehicle and find a seat

2. Early passengers place their luggage and late passengers wait

3. Late passengers place luggage over other passengers

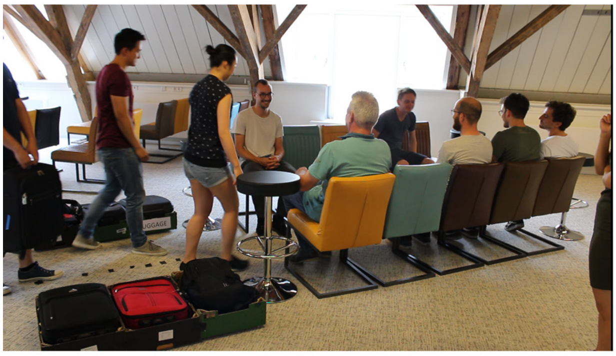
4. All passengers seated and the vehicle leaves

5. Passengers collect the luggage before disembarking

6. Passengers get out of the vehicle through the aisle

1. Passengers place their luggage on the belt before the vehicle arrived

2. Passengers start to walk to their seats



3. Later passengers fill up the available seats.

4. The luggage load into the vehicle while passengers are boarding

5. Passengers start to disembark while their luggage are unloading

6. Passengers get out and collect their luggage on the platform

▲

Figure 33. The process of the experiment with mock-up B.

#4. Shift way of (dis)embarking is more system efficient than traditional (dis)-embarking model

If the embarking and disembarking time for mock-up B is more efficient than mock-up A, the hypothesis is valid.

From the condition (Chapter 2.4), the time for each vehicle to stay on platform includes all disembarking passengers get from their seats to the arrival platform and all embarking passengers get from the departure platform to their seats with their luggage well placed. For comparison, it is assumed that a vehicle of 50 passengers consists of 5 compartments of mock-up A or B. This means that 5 compartments of 10 passengers embark and disembark at the same time. The time it takes for all passengers to embark and disembark is the same as in the mock-up experiments. The videos of the test were analysed and the time it took for each step was noted. *Table 5* shows the comparison between A and B.

For embarking, it took the traditional model (A) 29 seconds and Shift concept (B) 15 seconds from the first passenger stepping into the door till the last passenger getting ready for departure. B reduced the embarking time by half mainly because it saved 75% of the time on average for passengers to get from the door to being seated. For disembarking, it took A 26 seconds and B 18 seconds from passengers standing up to the last passenger getting out of the vehicle.

In total, the time for each vehicle to stay on the platform will be 33 seconds for the Shift concept which saves 40% of the time comparing to traditional (dis)embarking model. The hypothesis is valid. Apart from that, the average time for each passenger to embark and disembark (individual level) is 15.7 seconds for Shift, saving 50% of the time comparing to the traditional model. The hypothesis is proved both from a system point of view and a passenger point of view.

#5. Assigning seats (either in advance or on platform) is not needed for boarding

If not assigning seats (ask passengers to sit in the same sequence as they embark) does not cause noticeable inconvenience to passengers or inefficiency to the flow, the hypothesis is valid.

The result of experiment B showed that passengers tend to pick a seat they like during embarking instead of sitting in the same sequence as the board. The result of the interview showed that this did not cause inconvenience to the overall experience. However, the luggage collecting took more time when passengers did not disembark in the same sequence as the luggage was loaded. Therefore, the hypothesis is valid but it will be a recommended for passengers with hold luggage. ►

▼

Table 5. Time comparison for setup 1.

		A Traditional (Second)	**B Shift (Second)**
Embarking	Total embarking time	29	15
	Embarking time per passenger (average)	13.1	3.3
Disembarking	Total disembarking time	26	18
	Disembarking time per passenger (average)	18.9	12.4
Embarking and disembarking	Total vehicle on-platform time	55	33
	Total time per passenger (average)	32	15.7

#6. Shift achieves a better user experience than traditional models

If B scores higher in comparison to A in user experience, the hypothesis is valid.

#7. The designed process of (dis)embarking is clear to passengers

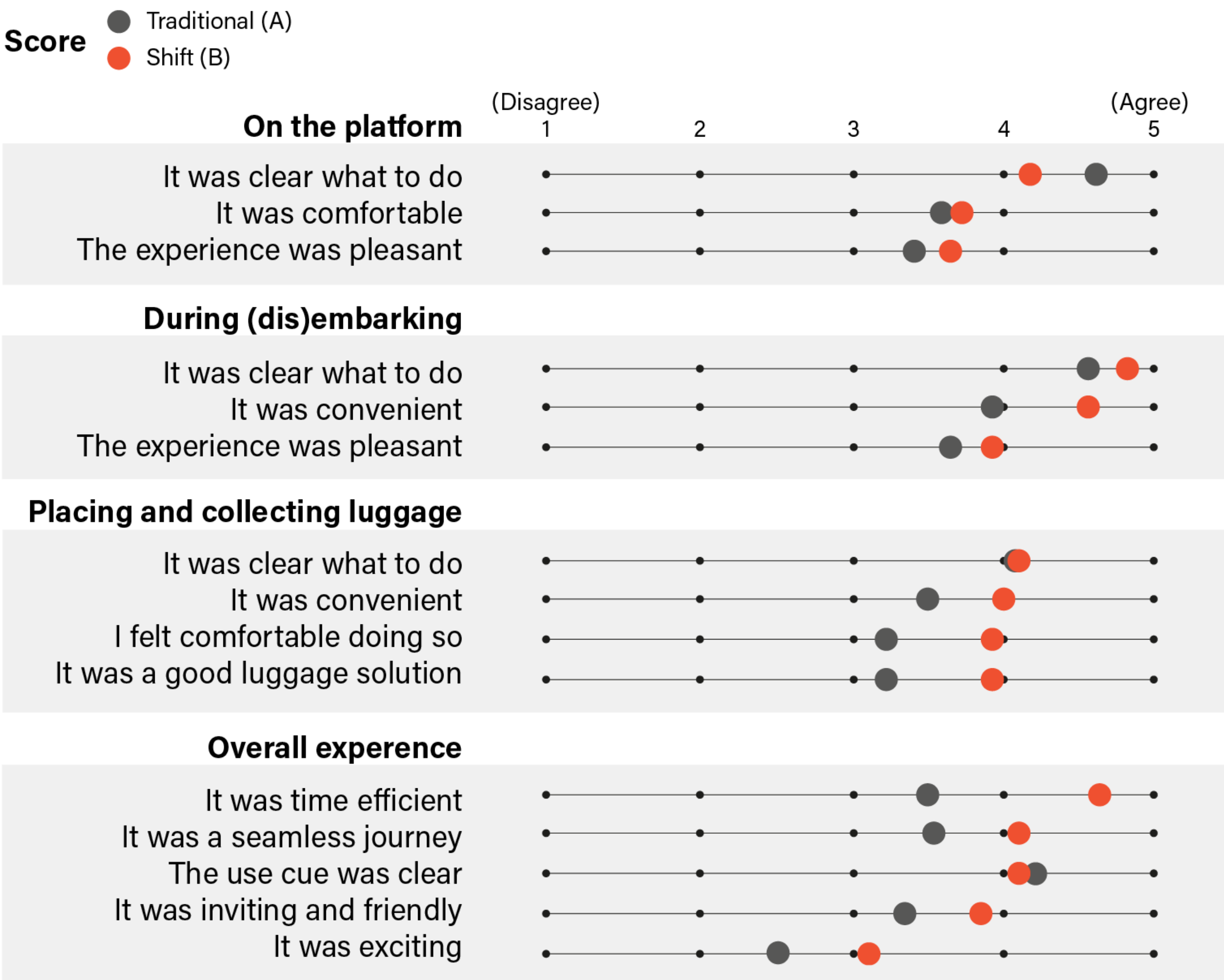
If the clearance of B scores higher than 4 out of 5, the hypothesis is valid.

Participants were asked to fill in a questionnaire (Appendix G) after the test. The experience of the concept (B) was scored on multiple aspects in comparison to the traditional model (A) and the average score is illustrated in *Figure 34.*

Overall, B was considered a lot more time efficient, more seamless, inviting and exciting. The use cue of B was quite clear (4.1/5) yet slightly less clear than A (4.2/5). Since A was a (dis)embarking experience that everyone was familiar with, it is logical that it scores high in the clarity of use. B, scoring nearly as high as A, can be considered a very clear design. The conclusion is that the concept Shift achieves a better user experience than traditional models. The designed process of (dis)-embarking is clear to passengers. Hypotheses 4 and 10 are valid. However, the process on the platform can be explained better in the final design for first-time users.

▼

Figure 34. Average experience score of A and B. (n=10)



Setup 2

In the next experiment, mock-up C was made by reducing the door size of mock-up B by half and having only one side with luggage belt *(Figure 35)* while the rest stayed the same as B. Participants were asked to embark and disembark C. The (dis)-embarking flow and the efficiency of B and C were compared with the observation and participants were interviewed to compare the experience of both experiments.

In the experiment, participants first placed their luggage on the luggage belt like with mock-up B and stood in a line to wait for the vehicle. When the door opened, they entered one by one and picked random seats. Comparing to B, participants had more choices in where they sit because they were not restrained to which row they are sitting in. Early passengers chose to sit in the seat that was neither next to anyone nor opposite to anyone like a zigzag *(Figure 36)*. When the vehicle arrived, participants walked out of the vehicle and picked up their luggage. People in the back had to wait long for the first ones to pick up their luggage like the situation of setup B but even slower because there was only one belt for luggage. ▶

▲

Figure 35. Mock-up C: Shift (dis) embarking experience with small doors.

▼

Figure 36. The first few passengers in experiment C.

#8. Reducing door width from two-person width to one-person width will slow down the process significantly and cause negative experience for passengers

Since smaller doors cut down the manufacturing cost and weight of the vehicle, narrow doors are preferred cost wise. If the embarking and disembarking time is increased by 20% when the door size is reduced and passengers have negative experience towards the smaller door size, the hypothesis is valid.

Analysing the video recording of the experiment, narrow doors did not have an influence on the embarking time *(Table 6)*. However, the disembarking time doubled (34 seconds while B took 18 seconds) because of the participants who disembark first were blocking the door when collecting luggage. In total, the time for the vehicle to stay on platform was 49 seconds, comparing to 33 seconds for B. However, this problem can be solved by moving the luggage collecting belt few meters away from the vehicle exit so that people collecting their luggage can get out of the way and the disembarking time will not be a big difference.

According to the interview, participants were not opposed to the smaller doors and stated that it was not too much of a difference regarding the overall experience. However, two inconveniences were brought up by the interviewees. The large luggage line before boarding looked like it would take a long time; the luggage belt could be shorter to look less stressful and passengers arrive later can make use of the belt when the previous luggage is loaded. Another inconvenience was that with smaller doors, passengers who were picking up their luggage at the door completely blocked the disembarking door. This could be solved by relocating the luggage collecting place on the disembarking platform as mentioned in the last paragraph.

The conclusion is smaller doors will not make a large difference in time efficiency when the luggage collecting location is adjusted and passengers do not sense a negative experience with smaller doors. Therefore, the hypothesis is invalid and the final design should have most of the doors with one-person width and few larger doors for people with wheelchairs.

▼

Table 6. Time comparison for setup 2.

	B Wide (second)	C Narrow (second)
Total embarking time	15	15
Total disembarking time	18	34
Total vehicle on-platform time	33	49

Discussion

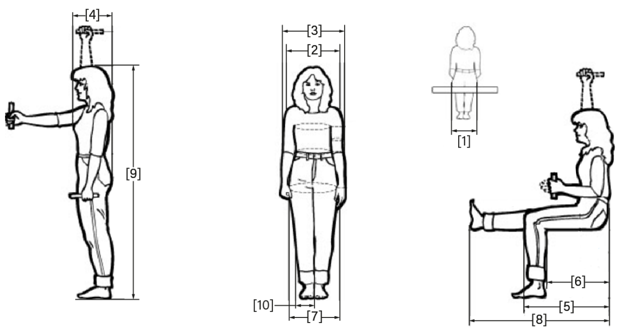
The user test was to compare the Shift concept to the traditional model and compare smaller doors with larger doors. With observations and interviews, the comparison was made and the above hypotheses were tested. However, since it was a test with only 10 people for one time each experiment, the exact time for embarking and disembarking mentioned in this chapter only serves as a reference. In terms of the luggage solution, participants were given empty suitcases in the test while in reality, heavier luggage could cost more time and effort. Also in the setup, participants walked in the vehicle without any concern about losing their hold luggage so they walked directly into the vehicle when the doors opened. While in the public area, passengers might be more cautious about their belongings and may stay on the platform (blocking the flow) until they see the luggage being placed into the vehicle. The perception of door width was tested with two bar chairs instead of solid walls and this might have an influence on the test results. The aforementioned aspects are recommended to test in a more authentic environment and these should also be taken into account in the final design. ■

6.4 Ergonomic study

Hypothesis

#9. The concept works ergonomically for P5 to P95 and people with reduced mobility (including aisle width and height, door width and height and seat width)

If all the required measurements from the anthropometric database can be applied to the concept without conflicting the conditions (size of the vehicle for example), this hypothesis is proved.



Standing, length/depth   Standing, width   Sitting length/width/depth

▲ ***Figure 37. Relevant measures of the human body (instructions).***

Validation

The literature study was done making use of DINED anthropometric database, a database developed by the faculty of Industrial Design Engineering, TU Delft, to prove the ergonomic feasibility of the concept. Hardt defined the seat width of 510 mm, this was evaluated with ergonomic data. Other undefined dimensions including (dis)embarking aisle width between seats, lavatory aisle width and height and door width and height were defined.

Nine measurements of the human body are relevant to the project and they are illustrated in *Figure 37*. The values of the P95 (P5 is not the restraining value here) for international adults (both male and female) are used. However, due to the limit of the database, some values for international adults are missing. The values of P90 for Dutch adults are used instead because it is comparable to most of the measures of P95 for international adults. The values are listed in *Table 7* for further analysis.

Measurement decisions for P95

Seat width: 510 mm

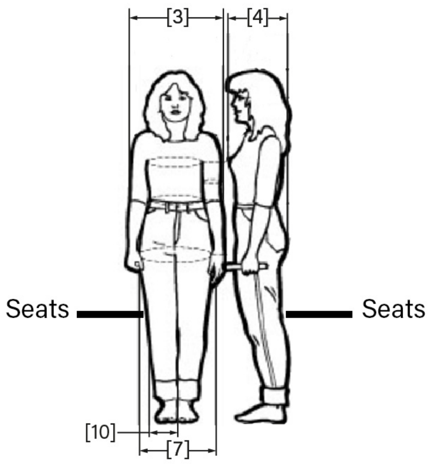
The seat width is defined by Hardt referring to the average width of aeroplane seats for first class. Two relevant measurements are hip breadth while sitting [1] and shoulder

populations	International International, mixed	Dutch adults 20–60, mixed
measures	P95	P90
Hip breadth, sitting (mm) [1]	436	
Shoulder breadth (bi-deltoid) (mm) [2]	496	
Breadth over the elbows (mm) [3]		537
Chest depth (mm) [4]		343
Buttock-knee depth, sitting (mm) [5]	665	
Buttock-popliteal depth (mm) [6]		542
Hip breadth (mm) [7]	410	
Buttock foot length, sitting (mm) [8]	1183	
Stature (mm) [9]	1900	

▲ ***Table 7. Relevant measures of the human body.***

▼

Figure 38. Two passengers of P95 passing through the aisle.



breadth [2]. Both values are smaller than 510 mm, meaning that the defined seat width is ergonomically acceptable.

Aisle width for (dis)embarking: 800 mm

In the concept, the requirement for the (dis)embarking aisle is that one person can pass through the aisle in the direction of the doors while another person is sitting/ standing facing the direction of the front/ rear of the vehicle like in *Figure 38*. The distance between two rows of seats is the width of the (dis)embarking aisle which is defined by value [3][4][10]. However, the value of [10] is not in the database. Using the value of [7], the width of the aisle should be 816.5 mm. This calculated value is slightly larger than the actual value, so the aisle width for (dis)embarking can be reasonably estimated as 800 mm.

800 mm is also the legroom for each passenger when sitting in a zigzag (suggested in the result of the user test). Theoretically, the maximum legroom people need is the distance between [8] and [6] in *Figure 37*, which is 641 mm for P95. It is smaller than the aisle width meaning that passengers will be able to stretch their legs completely with the defined aisle width.

Lavatory aisle width: 410 mm

The lavatory for a 50-passenger vehicle is placed in the front or rear of the vehicle. The lavatory aisle is placed along the length of the vehicle. The lavatory aisle is not used during embarking and disembarking and only serves as an 'escape' for passengers with lavatory needs. Therefore, the aisle only needs to fit one person passing through. The minimum width of the aisle (distance between seats) should fit the hip breadth [7] of one person of P95, which is 410 mm. ►

Door width: 737 mm

The minimum door width for the vehicle should allow P95 to walk into the door without any inconvenience. The width of the doors should be the breadth over the elbows [3] plus 200 mm (estimated) for their belongings. Therefore, the door width should be 737 mm.

Height for walking areas: 1900 mm

The height for doors and aisles for passengers to walk should be at least 1900 mm according to the stature of P95. The door height will be 1900 mm and most part of the aisle height will be larger than that due to the shape of the chassis.

Measurement decisions for passengers with reduced mobility

Airlines use an internationally recognised code system to identify the seven different types of passengers with reduced mobility (Vueling, n.d). Two types of passengers are relevant for the ergonomic measurements in the vehicle: WCHS, passengers who need a wheelchair or other means for moving between the aircraft and the terminal but who are self-sufficient for moving around inside the plane; WCHC, passengers who are completely immobile who can only move around in a wheelchair or other similar means.

The measurements below follow the guidelines of The Americans with Disabilities Act (ADA), a list of international standard for designing for disabilities. The minimum clear floor or ground space required to accommodate a single, stationary wheelchair is 760 mm by 1220 mm *(Figure 39)*. *Figure 40* shows the minimum required areas for a person in a wheelchair to make a T-shaped turn, similar to a three-point turn in a car. The minimum width of the entrance/exit for wheelchair accessibility is 810 mm.

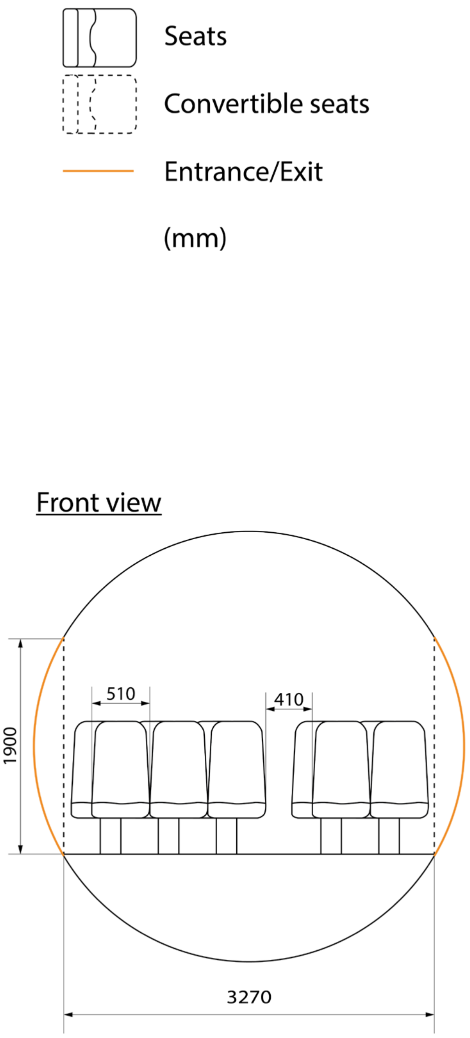
Passengers with wheelchairs should be able to embark and disembark with their wheelchairs. They should be able to sit in their wheelchair and be able to use the lavatory during the trip. Therefore, the compartment at the front or rear, depending on where the lavatory is, should be designed for wheelchair users. According to EU railway regulation, for units (or vehicles) less than 30 m (true in this case) there should be one wheelchair space per unit (or vehicle). In the same compartment, some of the chairs should be convertible for more wheelchair users when necessary. The (dis)embarking aisle of the unit should meet the minimum requirements for T-turn space in *Figure 40*. Door width of the wheelchair compartment is 810 mm.

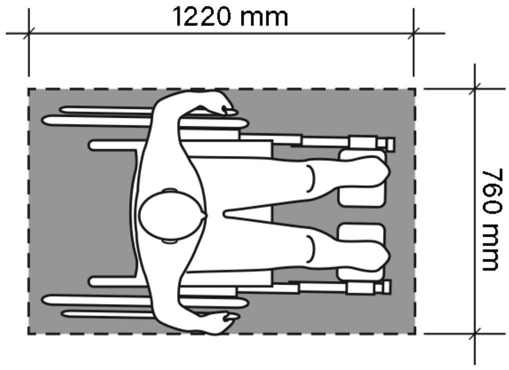
Result

Figure 41 is the top, front and side view of the interior planning of the passenger cabin (excluding lavatory) that supports the embarking and disembarking concept. The hypothesis is valid. ■

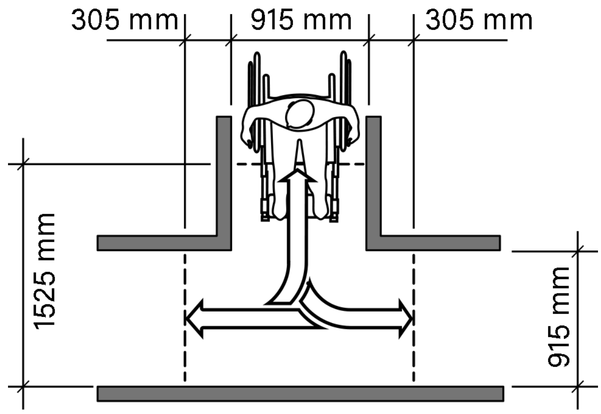
▼

Figure 41. Top, front and side view of the interior regarding (dis)embarking.

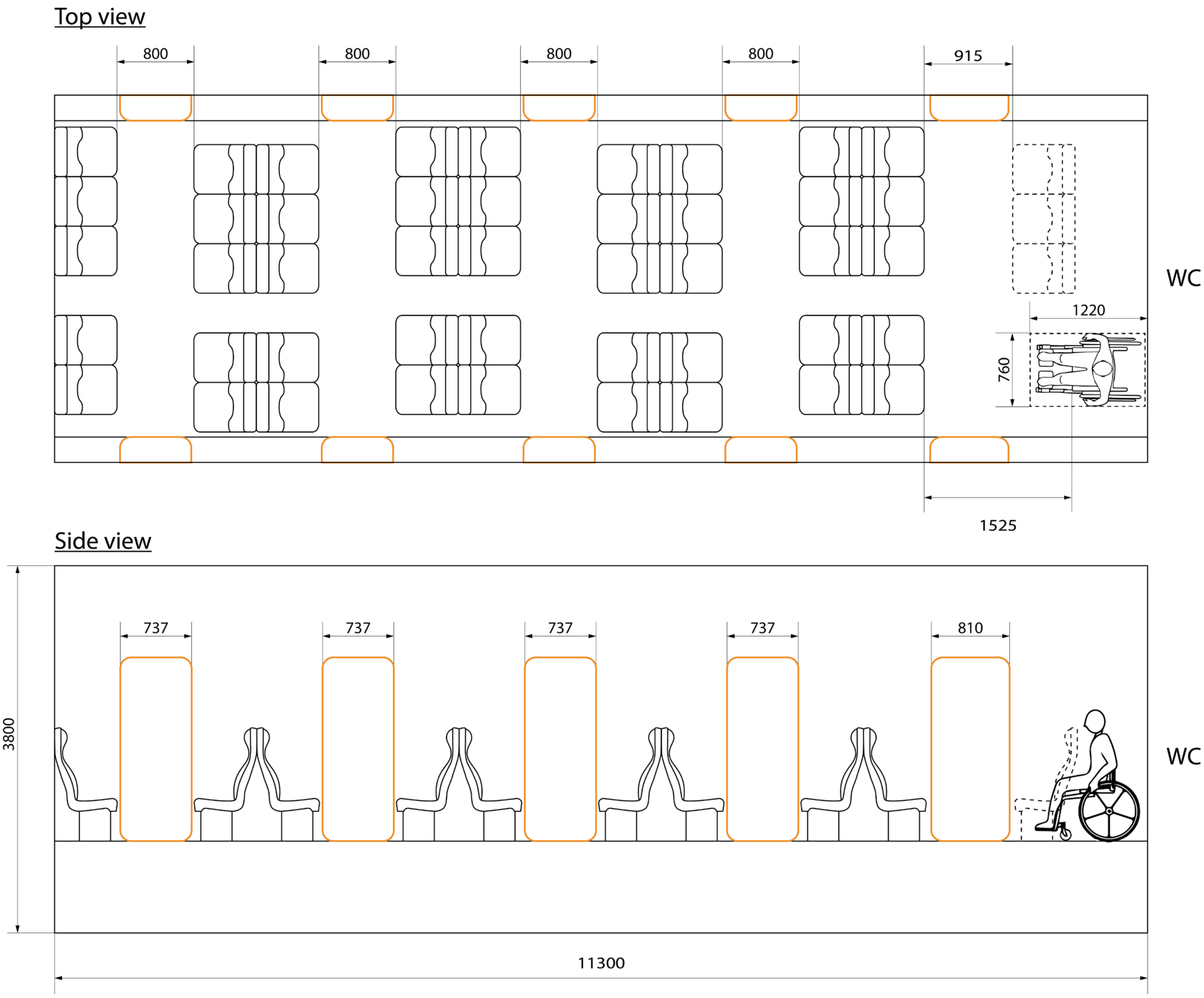




▲ ***Figure 39. Minimum clear floor space for wheelchair.***



▲ ***Figure 40. Minimum requirements for T-turn space.***



6.5 Technical feasibility

In this concept, the main technical doubts are the feasibility to have the number of doors in the concept and still maintain the strength and stiffness of the chassis in the pressurised environment and the way to tackle the designed luggage interaction.

Hypotheses

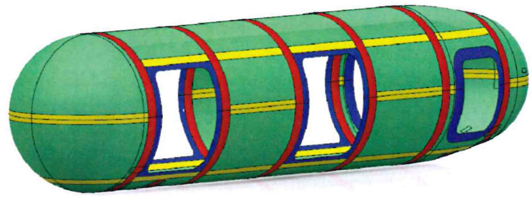
10. The door (number and way of opening) design is technically feasible

11. The luggage solution design is technically feasible

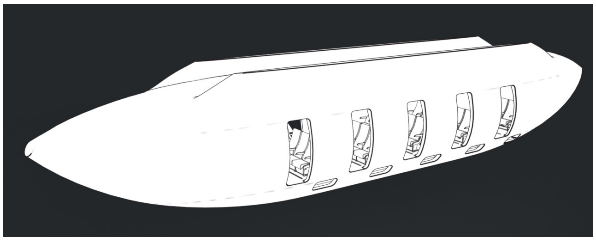
Validation

#10. The door (number and way of opening) design is technically feasible

In Shift concept, there are multiple doors on each side of the vehicle for embarking and disembarking. Since the vehicles are operating in the pressurised environment, each door added to the chassis needs reinforcement around it to maintain the desired strength and stiffness. Although more doors mean more complex structural design and more materials in the vehicle, it is technically feasible to have multiple doors on both sides. A more similar example is the chassis design of the Delft Hyperloop *(Figure 42)*. The chassis is designed for the pressurized environment in the tube which is comparable to this project. Simulation has been done by Delft Hyperloop Team (2017) to prove that by designing the stiffeners as in *Figure 42*, multiple doors on both sides of the



▲ ***Figure 42. Chassis Design of the Delft Hyperloop. (Delft Hyperloop, 2017)***

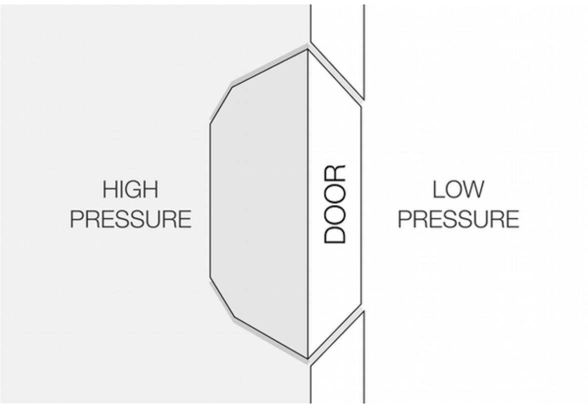


▲ ***Figure 43. Render of the chassis without doors.***

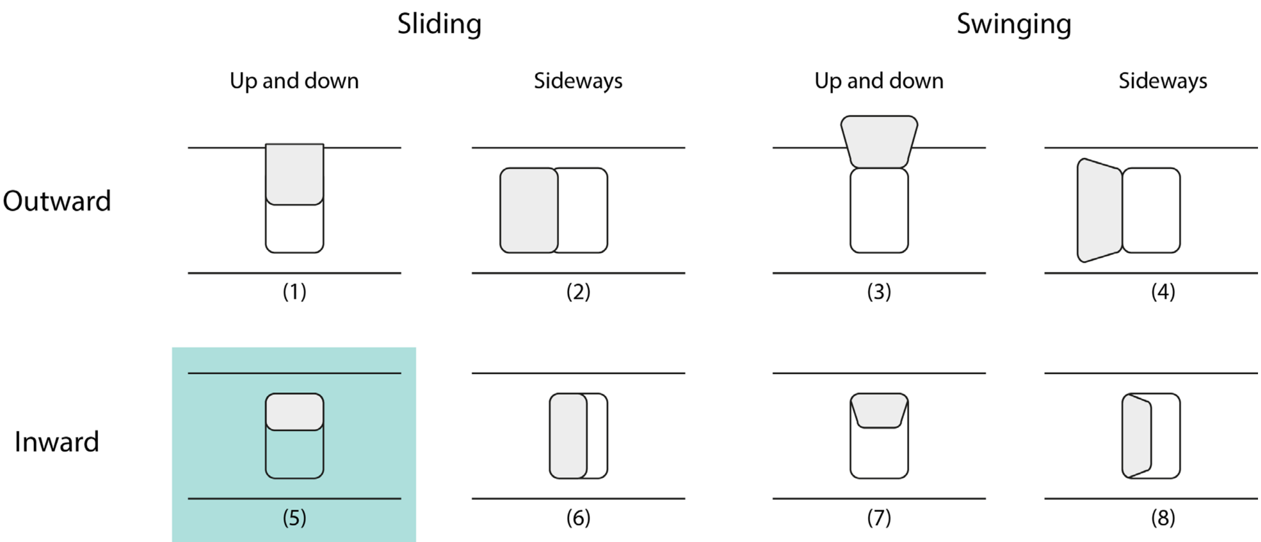
chassis can be able to withstand the pressure difference in the tube. Comparing the opening area and position of *Figure 42* and *Figure 43* (design of this project), the ratio of solid area to opening area of my design is larger than the model simulated by Delft Hyperloop, meaning it is possible to make the reinforcement.

Plug doors can be used in the concept. A plug door is designed to seal itself by taking advantage of pressure difference on its two sides and is typically used on aircraft with cabin pressurization (Wikipedia, 2016b). The higher pressure inside the vehicle pushes the door outwards, applying pressure on the seal, and the door seals itself when the pressure differential increases. Plug doors are designed to unseal only towards the inside, towards the area of high pressure when the vehicle is pressurized *(Figure 44).*

An overview of different ways of opening a plug door is illustrated in *Figure 45*. The door can open and close by sliding (up and down or sideways) or swinging (up and down or sideways). Swinging doors need more space when opening and closing. It takes up more space on the platform and in the vehicle. Regarding sliding structure, sliding up and down like (1) and (5) is preferred; structural wise, it is easier to open inwards because of the structure of plug doors. Therefore, (5) is chosen for the final design. ▶



▲ ***Figure 44. A plug door demonstration.***



▲ ***Figure 45. Ways of opening a plug door on the side view of the vehicle (blue is the chosen way).***

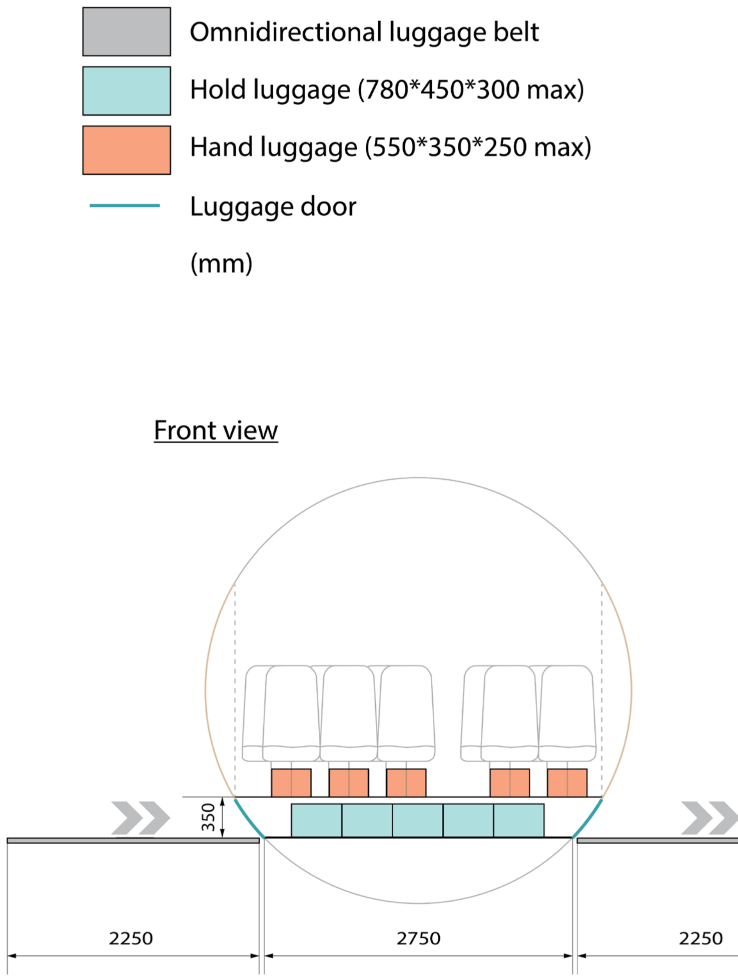
#11. The luggage solution design is technically feasible

The luggage solution in the concept is that passengers place their hold luggage on the embarking platform and it will be transferred into the luggage cabin automatically. On arrival, passengers will get out of the vehicle approximately in the same sequence as their luggage. Passengers then can collect their luggage on the disembarking platform. Hand luggage can be taken on board and placed underneath the seats. In this part, the mechanism of moving the hold luggage between platforms and the vehicle and the feasibility of hand luggage placement will be discussed.

Hand luggage within the limit of 55*35*25 cm (the average limit for air travel hand luggage) can be brought on board and be placed under seats (red areas in *Figure 47*). Larger luggage of the maximum dimensions of 78*45*30 cm (the average limit for air travel check-in luggage) should be placed in the hold luggage cabin. There will be omnidirectional conveyor belts connecting the hold luggage cabin with the platforms. Instead of using a traditional band to transfer objects around, the omnidirectional belt system uses small, fully rotational wheels giving the system more freedom to handle the movements of goods in all directions *(Figure 46)*. These are individually controlled by a computer that is connected to sensors that recognise objects and decides where they need to go. This technique has been used in factories to sort and transfer products and in the postal industry to sort and pass on parcels. The units together with sensors can smartly put the luggage into place and transfer them in and out in desired order.

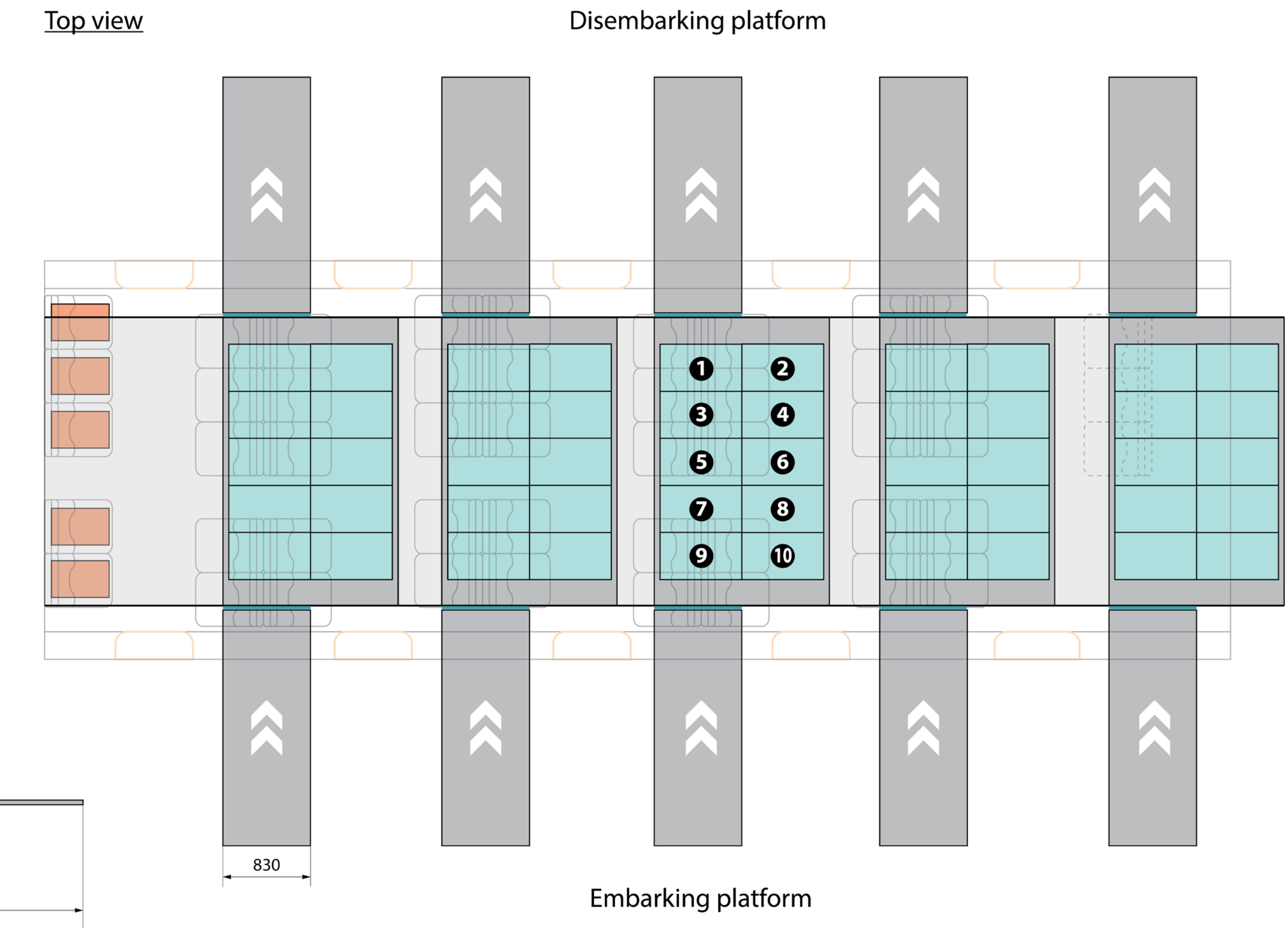
Figure 47 shows the layout of the omnidirectional luggage belt in the vehicle and on the platform. Passengers will place

▲ ***Figure 46. Omnidirectional conveyor belt units.***



▲ ***Figure 47. Top and front view of the luggage cabin.***

their luggage on the belt of the embarking platform while waiting for the vehicles to arrive or the passenger doors to open. The omnidirectional belt will recognise the size and location of the dropped luggage and apply movements to place it nicely for loading. The belt on the platform is 2.25 meters long and fit a minimum of 5 luggage at the beginning. When It started loading, passengers in the back of the line can place their luggage on the belt again. Luggage will load into the vehicle in the sequence described in the figure and unload in the same sequence in the condition that passengers will disembark almost in the same sequence as they embark. Once a compartment has more luggage than its capacity, the omnidirectional conveyor units in the light grey area between two compartments will be activated and luggage can be sorted in the whole luggage floor, creating more luggage space. Passengers with odd-sized luggage are suggested to go to the special compartment in the front or rear where there is more space for luggage. ■



6.6 Economic feasibility

Hypothesis

#12. The economical aspect is acceptable

Validation

The economical aspect of the concept is analysed. Due to the fact that the company is in the process of defining the technical specification, logistics and business model, only part of the cost be estimated at the moment. The advantages and disadvantages in terms of cost are listed, using the traditional (dis)embarking solution as a benchmark. Afterwards, the economical acceptance is discussed with Mars Geuze, Marinus van der Meijs and Sascha Lamme, three of the founders of Hardt.

With 40% higher (dis)embarking efficiency, the time vehicles spend on the platform significantly decreases. Providing the same throughput or departure frequency, fewer vehicles are needed in the whole system. Also, fewer platforms are needed because there are fewer vehicles boarding at the same time. The infrastructure cost of each station decreases.

On the other hand, because of multiple doors designed on both sides, more materials will be added to each vehicle, resulting in a higher production cost per vehicle. Heavier vehicles need more energy to propel. A calculation is done in Appendix H and the electricity cost for Shift concept (10 doors) is 3.2% more than the traditional concept (2 doors), which is 0.19 Euros more per trip per vehicle and 0.004 Euros more per ticket. However, the calculation is only an estimation with limited assumptions.

Because of the uncertainty of the vehicle structure, there is not a conclusion for the entire cost of the system and the profit depends on the business model that is under development. However, what can be concluded from the tests is the customer satisfaction of using the system is much higher with a fluent and effortless boarding solution. This will potentially attract more customers. It is also what the company wishes to accomplish through this assignment: to find out the best solution for the customers and from there, they will build towards that best scenario with engineering solutions and new technology. “Cost is not the deal breaker, we will always find a way to make it affordable”, says Mars Geuze. In general, the company believes the concept can be economically acceptable. ■

6.7 Conclusion

All 12 hypotheses are tested or elaborated in this chapter, the result is shown the table below. The valid hypotheses will be kept while the invalid ones will be adjusted in the final design.

Hypotheses	Status
1. Sitting facing backwards during the trip is acceptable for the majority	Valid
2. It is more preferred to have large luggage loading separately into the luggage cabin	Valid
3. People do not need lavatory for short-time trips	Invalid
4. Shift way of (dis)embarking is more system efficient than traditional (dis)embarking model	Valid
5. Assigning seats (either in advance or on platform) is not needed for boarding	Valid
6. Shift achieves a better user experience than traditional models	Valid
7. The designed process of (dis)embarking is clear to passengers	Valid
8. Reducing door width from two-person width to one-person width will slow down the process significantly and cause negative experience for passengers	Invalid
9. The concept works ergonomically for P95 and people with reduced mobility (including aisle width and height, door width and height and seat width)	Valid
10. The door (number and way of opening) design is technically feasible	Valid
11. The luggage solution design is technically feasible	Valid
12. The economical aspect is acceptable	Valid

A screen shot from Hardt test facility unveiling movie: discussions with Jose. Filmed by Wim Geuzendam.

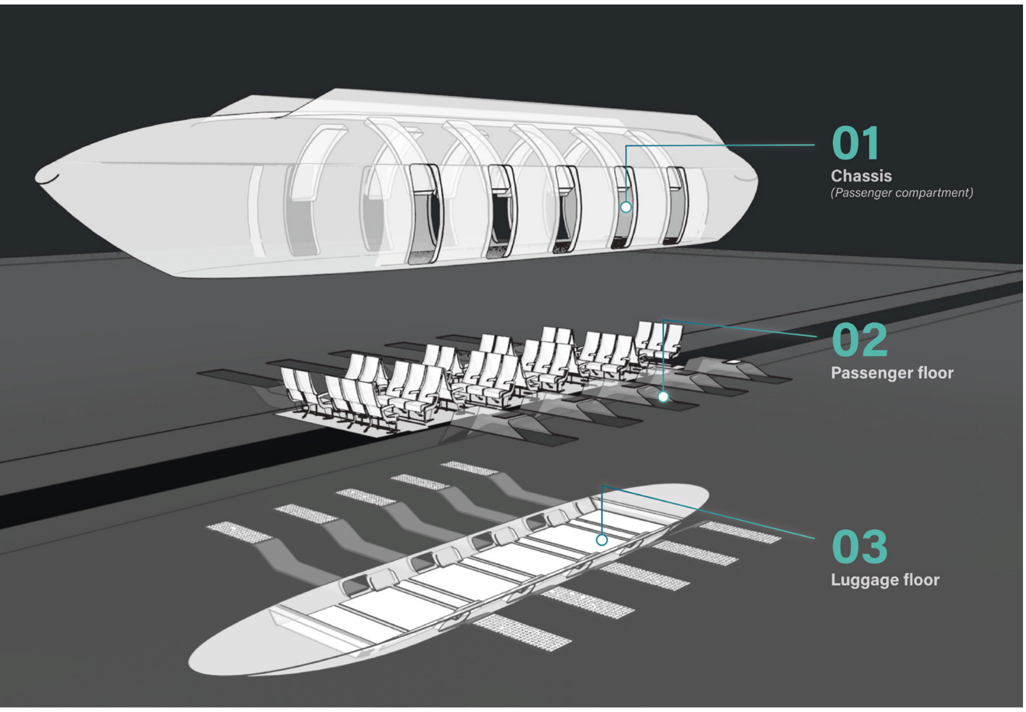
07.

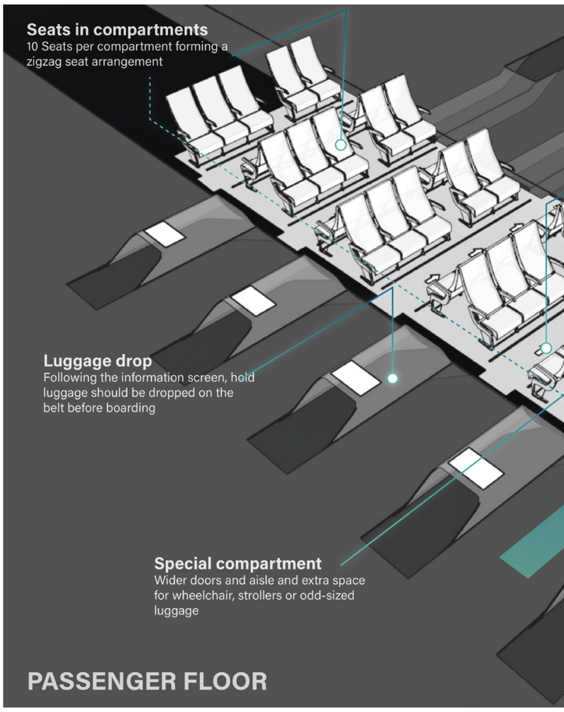
Final design

After validating and elaborating the preliminary concept, the final design takes shape. The final design includes all aspects in the scope: the process for passengers and their luggage to get in and out of the vehicle, the entrance and exit design, a supporting interior including seat arrangement and aisle specifics and the supporting platform infrastructure for trip planning and ticketing. In this chapter, I will introduce the final design with computer renders of the CAD model and explanatory illustrations. The final evaluation is done by checking the fulfilment of the requirements as well as interviews with potential customers with the concept movie.

7.1 Design description

Embarking and disembarking platforms are separated on the two sides of the track for a consistent flow direction and the possibility of handling the embarking and disembarking process at the same time. Each vehicle has five passenger compartments, including a special compartment with space for wheelchairs, strollers and odd-sized luggage. As shown in the exploded view (*Figure 48, Figure 49, Figure 50*), each compartment has an entrance on one side, a symmetrical exit on the other side, an aisle connecting the entrance and exit and two rows of chairs facing the aisle. The design of the entrance and exit avoids bottlenecks (Chapter 3.1), creating an environment for efficient passenger flow. A lavatory is placed next to the special compartment





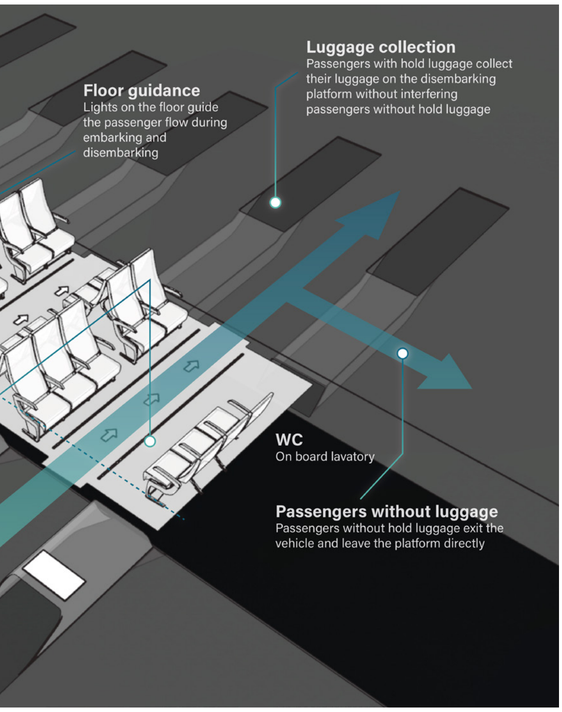
and the lavatory aisle is created along the length of the vehicle. Passengers are directed by floor lights during embarking and disembarking to walk through the aisle in each compartment.

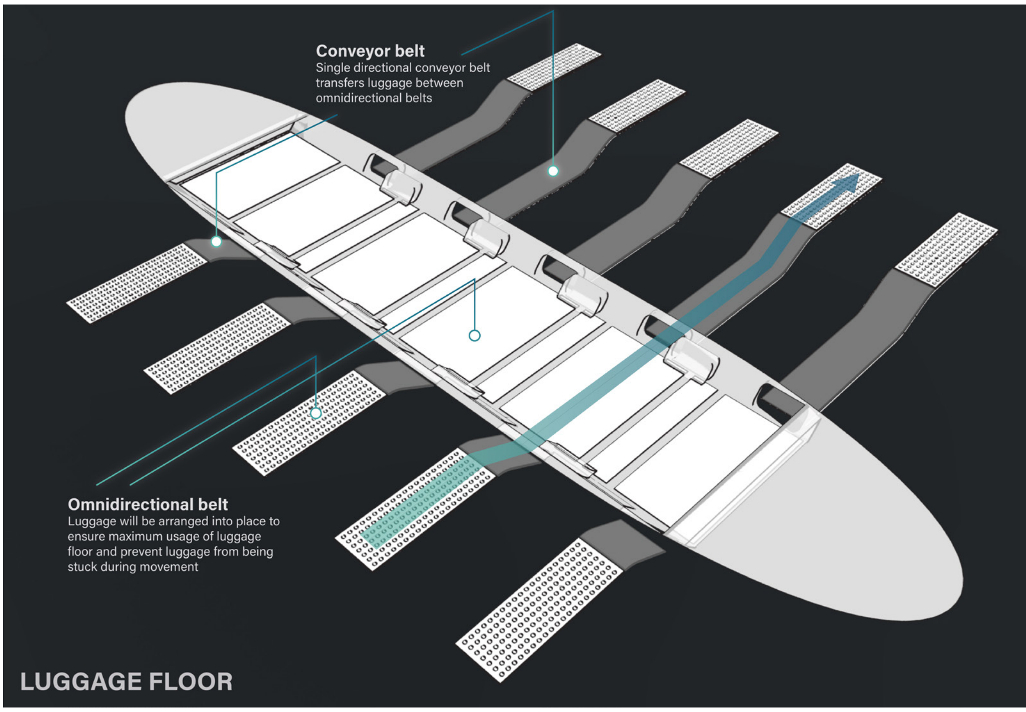
Hand luggage will be placed under seats for ergonomic convenience during placement and accessibility during the trip. Luggage that does not fit under the seat will be dropped on the luggage belts in front of doors as hold luggage right before boarding. Hold luggage will be loaded into the luggage floor and will be transferred out when reaching the destination automatically making use of the combination of omnidirectional belt and traditional conveyor belt. Instruction screens are placed at each luggage drop point, providing guidance and confirmation. On the disembarking platform, luggage is well sorted by doors and the sequence of boarding. The luggage pickup points are aligned with the doors and 2.5 meters away from the vehicle. In this way, passengers without hold luggage can exit directly from the sides and other passengers can easily find their luggage by walking to the matching luggage belt reducing the time and pressure of luggage collecting. New luggage can be loaded as soon as unloading starts.

*For technical feasibility of the doors and the luggage belts and specific measurements for the interior, see Chapter 6 Elaboration. ■

▼

Figure 48, Figure 49, Figure 50. Exploded view of the final design.





7.2 User interface

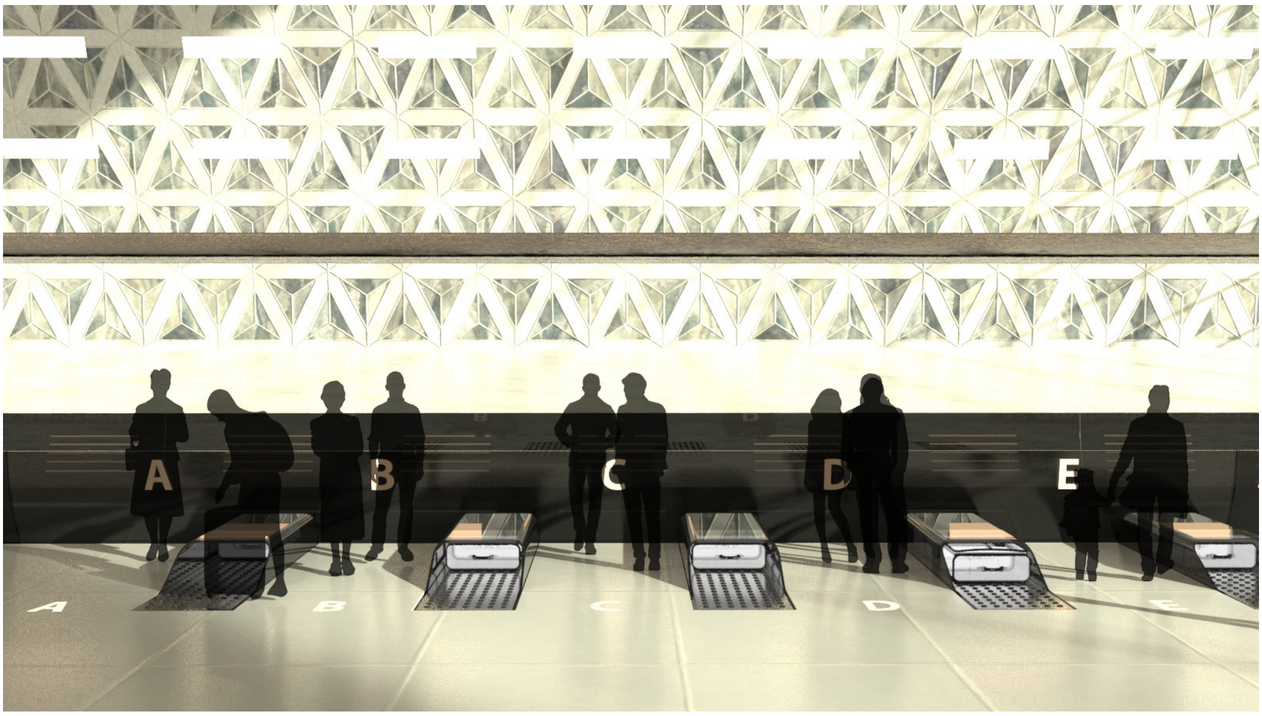
This part introduces the user interfaces chronologically from a passenger's point of view, making use of and the computer renders of the CAD model.

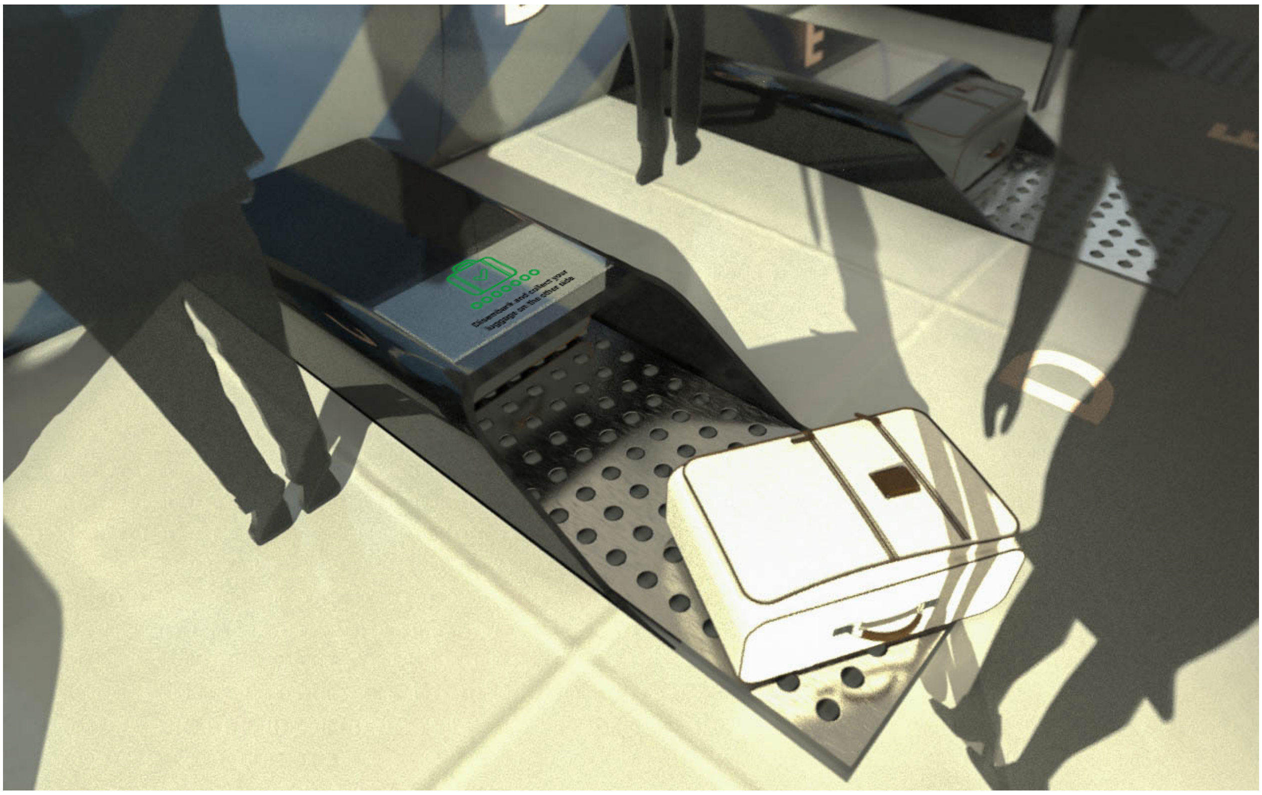
▼

Figure 51. Render of the embarking platform.

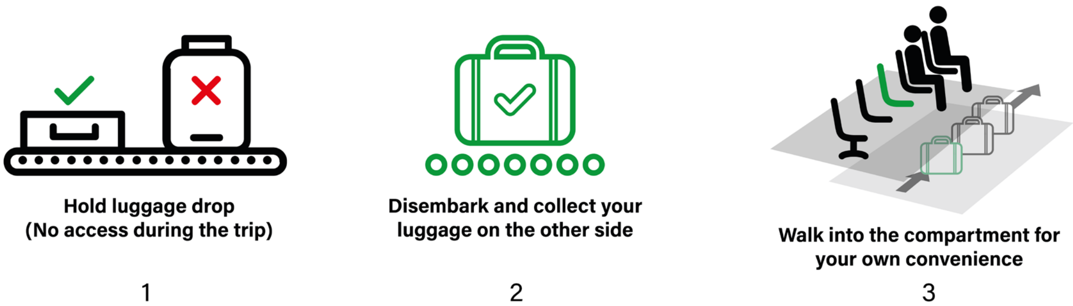
On-platform preparation

Passengers walk to one of the doors on the platform *(Figure 51)*. Guiding them towards the right platform is out of the scope but it will be discussed in the recommendation (Chapter 8). If they do not have hold luggage, they simply wait at (or close to) their





▲ ***Figure 52. Render of baggage drop.***



▲ ***Figure 53. Displays on the information screen.***

door until the vehicle approaches; if they need to drop hold luggage, they will place their luggage on the belt beside the door *(Figure 52)* following the instruction on the information screen *(Figure 53)*. They get a confirmation when their luggage is well placed. Passengers are asked to walk into the compartment and sit in the boarding sequence because their luggage will be transferred onto the disembarking platform in that specific sequence. Then the luggage is delivered forward until it reaches the end of the platform and it will start loading when the vehicle comes. If the belt is full for special connections such as airport connection, passengers arriving later will be able to drop their luggage when former luggage starts loading. ▶

Embarking

After the hold luggage is loaded into the vehicle, the doors on the embarking platform will open *(Figure 54)*. The arrows on the floor light up to guide passengers to walk into the aisle for their own convenience as well as the convenience of other passengers. Passengers will follow the floor lights and find a seat *(Figure 55)*. Hand luggage can be placed under seats *(Figure 56)*. Passengers will then be informed of the safety instructions, for example wearing seat belts if necessary (depends on the acceleration rate and jerk of the vehicle which cannot be decided yet).

▲

Figure 55. Render of walking into the vehicle.

▲

Figure 54. Render of embarking.

▶
Figure 56. Render of the hand luggage place.

During the trip

Because of the zigzag arrangement of seats, passengers will have sufficient space for their legs during the trip. The lavatory is accessible during cruising *(Figure 57)*. ▶

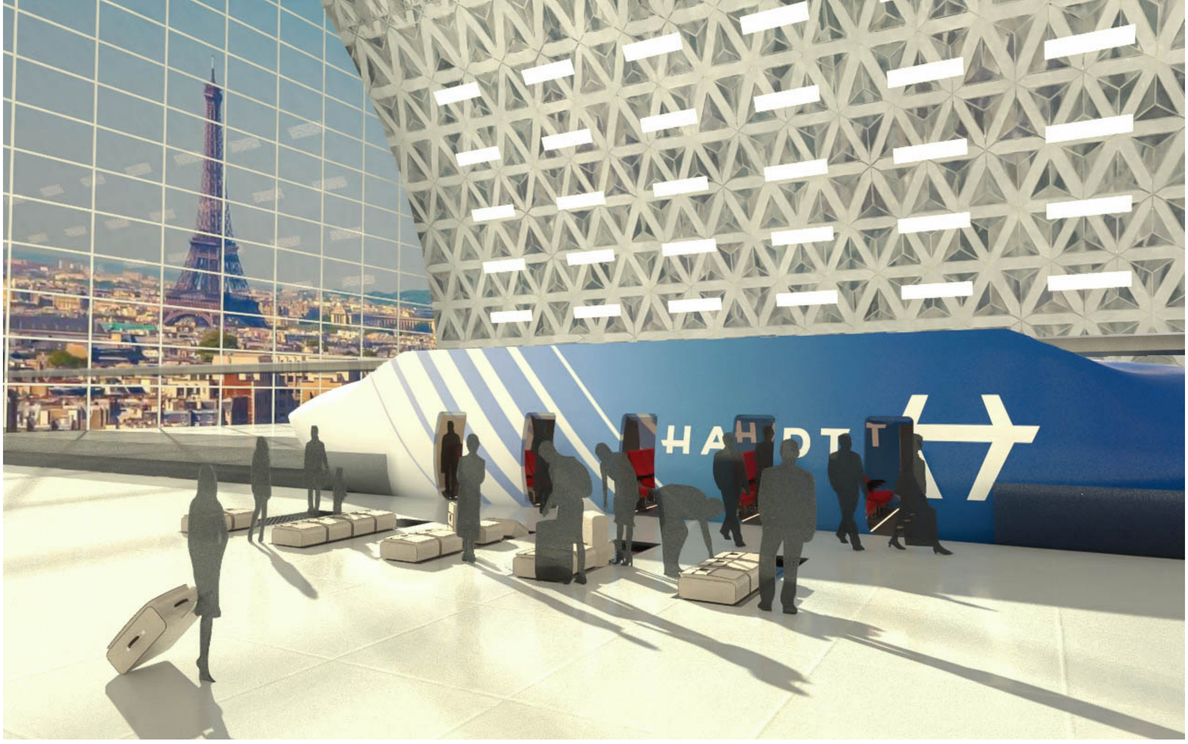
▲
Figure 57. Render of the interior.

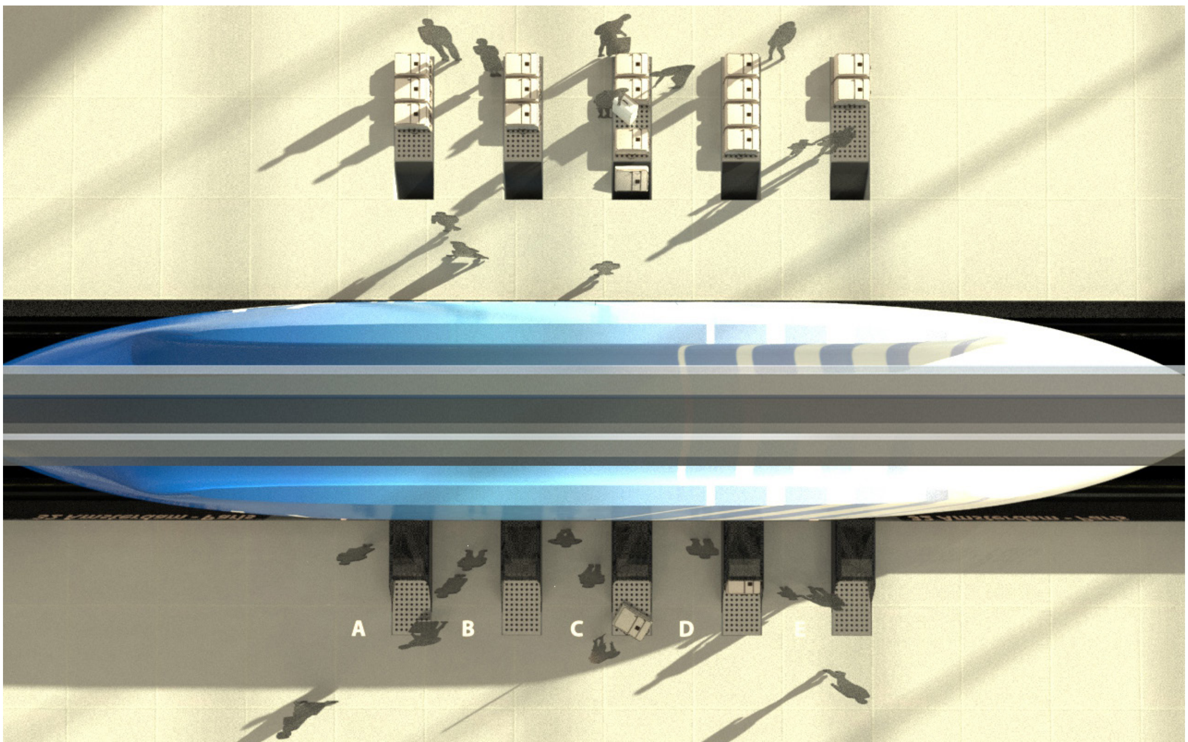
Disembarking

When the vehicle reaches the final destination, doors on the disembarking side will open. Passengers with hold luggage will spread around the luggage belts positioned a few meters from the doors and wait for their luggage to be unloaded. This also leaves empty space near the exits for passengers without hold luggage to walk out of the platform quickly without being blocked by the crowd *(Figure 58)*. Shortly after, the luggage will be unloaded to the belts in sequence and passengers can easily find and collect their luggage *(Figure 59)*. At the same time, new luggage will be loaded and new passengers can embark from the other side *(Figure 60)*. ■

▶

Figure 58, Figure 59, Figure 60. Render of disembarking.




A
B
C
D
E

7.3 Final evaluation

The final design meets the requirements of the embarking and disembarking process, the luggage solution and ergonomic requirements listed in Chapter 3.3. Since this is a design addressing passenger experience, the final evaluation was done with the potential end users. A concept video explaining the designed embarking and disembarking process was shown to 13 passengers (from age 16 to 65) at Schiphol Plaza. They were interviewed afterwards on their opinions on the design regarding the embarking and disembarking flow and the luggage solution (two main design elements in the scope) comparing to the current public transportation systems. The interviews were recorded (the transcript is in Appendix I). Results are explained in the following paragraphs with quotes.

Simple and clear overall process

All of the 13 interviewees thought the overall process was clear and they immediately knew what to do as a passenger. All interactions seemed simple and logical and they would not have trouble proceeding independently. Centralized check points, namely boarding and luggage drop happen at the same place and the other way around when disembarking, makes the process easier and more user-friendly.

> ***"I could understand where to place the luggage and pick it up. It was quite easily laid out. I found it more attractive because it didn't seem like you need to be in different places. In airports, you have to travel quite far distance between different check points. This is pretty central."***

Efficient flow

In general, passengers liked the fact that there are more exits in the design because it makes the process more efficient and less time is wasted on waiting in queues.

Knowing where to wait before the vehicle comes also makes the process more organized and efficient.

> ***“I also like the fact that there are several different exits, not just one. I think it’s just more efficient. Probably works better because you don’t have to stand in queues for ages to get there.”***

Transparency and being in control

An interviewee also mentioned that the flow gives passengers a clear and transparent overview of the process. With a simple aisle, passengers will immediately know where to get in, where to sit and where to get out, which gives a sense of control compared to in the trains and aeroplanes where people are not able to see the situation in and out of the train while embarking and disembarking.

> ***“Comparing to a normal train, you see immediately what is about to happen to you and what is expected from you. It’s very clear and structured like this. You don’t have to take any corners. You can just immediately see when you walk into that door where you can sit and where you will go out again.”***

Smooth and safe luggage system

12 out of the 13 interviewees pointed out that the luggage solution attracted them the most. Having hold luggage separately allows passengers to go on board luggage-free and saves the hassle of moving inside the vehicle with large luggage and finding a place for it. It was also considered safer because nobody could have access to the luggage during the trip. The automatic luggage belts make the luggage drop and pickup process efficient and smooth because the luggage goes out right in the same strip as it goes in. The interaction of placing it on the floor was considered more ergonomically pleasant than placing things in the over head cabin as in the trains and aeroplanes.

> ***“(I like) the fact that you could go on luggage free. You don’t have to worry about your luggage and you know it’s safe.”***

Suggestions for improvements

Boarding tolerance

Some passengers might get confused which door to go to when they are on the platform or they simply do not have enough time to walk to the right/recommended door. Possibilities are that they walk into a random door and it should still be possible that they find a place to sit. This could be solved by using the lavatory aisle during embarking.

> ***“I already see people getting confused. My mother, for example, she would just read it wrong and go to the wrong door.”***

Luggage connection for transfer passengers

For transfer passengers at most of the airports, their hold luggage transfers automatically to their connecting flights. It should also be possible for transfer passengers travelling with hyperloop. This means that at the disembarking platform, luggage should be sorted. Transfer luggage will be directly transferred to the connecting vehicle. ►

> ***"(For transfers) you should have a system where like in the airport ... the system takes the bag from one flight and go underground and come up at the next flight."***

Higher the luggage belts for better comfort

In the concept, luggage belts are placed on the floor. It could be difficult for passengers to pick up their luggage because they need to bend over like picking up something from the floor. Instead, the luggage belts can be on a higher platform than the floor with a ramp for trolley suitcases.

> ***"It seems a little uncomfortable when you pick up the luggage from the floor."***

Prevent the luggage from being stuck

The automatic luggage belt system has a height limit for hold luggage. however, for luggage that is flexible in shape, for example backpacks, it is possible that they get in the vehicle in the right shape but changes shape during the trip. The luggage might get stuck in the luggage exit. The design of the luggage doors should be a certain percentage larger than the limit of the luggage dimensions or mechanisms should be designed to keep the luggage in place.

> ***"What if the luggage is like a big bag that changes volume easily and it doesn't fit into the luggage belt."*** ■

7.4 Conclusion

A final design is described in this chapter. Passengers drop their hold luggage at the platform in front of the doors; the luggage will be loaded when the vehicle arrives; passengers will embark from several doors each accesses one compartment; passengers sit in rows facing their embarking aisle; when arriving at the destination, they disembark from the doors on the other side; their hold luggage will be unloaded to the disembarking platform in front of each door; passenger can collect their luggage at the same strip as where they dropped it.
A concept video is made for final evaluation. Thirteen Passengers at Schiphol watched the video and gave their opinions. They liked the simple and clear overall process, the efficient and transparent passenger flow and the smooth and safe luggage system. Boarding tolerance, luggage connection for transfer passengers, the height of the luggage and preventing the luggage from being stuck can be improved according to the interviewees.

A screen shot from Hardt test facility unveiling movie: discussions with Jose. Filmed by Wim Geuzendam.

08.

Discussion / Recommen-dations

This chapter discusses contributions to new knowledge, limitations and recommendations for further research and design.

8.1 Discussion

8.1.1 Contributions to new knowledge

Embarking and disembarking flow of trains

The embarking and disembarking flow of trains has not been discussed in the published literature (by April 2017). Field research on this aspect was done in this project and the results added new knowledge to the relevant field. The method of the research is repeatable and can be used for researching the embarking and disembarking flow of other means of transportation or general crowd behaviours of ingress and egress.

Future traveller mindsets

Through the the ViP method, four mindsets of the future public travellers were discovered by extensive literature research. This could be a starting point for designs and research regarding public travel in the future. The collected context factors and the interpreted clusters in this thesis can be of use in domains other than public travel.

Validation method

The iterative testing process proposed in this thesis can be a useful method for evaluating concepts and convincing clients in the design process. By questioning all aspects of the design based on the criteria, a list of hypotheses can be created. Iteratively validating the hypotheses and reshaping the concept lead to a validated design.

8.1.2 Limitations

User Testing

The user test in this project was carried out with 10 participants and each set of the experiment was done once with the same participants. The result, especially the time comparison between different settings is not scientific due to the non-repeated test with a limited number of participants. Setups of the experiment, for example, the empty luggage and the 'open' walls might have an influence on the test results.

Ergonomic data

The ergonomic data used in the ergonomic study was from the database of 2004 and 1989. The measurements may not be accurate anymore. Although Molenbroek, Author of Design Tool DINED compared DINED students ergonomic data from 2004 with the data from 2014 and it turned out to be of little difference. It is still recommended to check the latest ergonomic data base before implementation.

Evaluating in the current context

The validations and evaluations of this project were mostly done with potential end users. It could only reflect on how people perceive the design in the context of today. However, since the design was based on a future vision in a future context, the mission statement and interaction vision cannot be evaluated in the current context. Therefore, the vision and mission of this project are more of an inspirational purpose than for evaluation. ■

8.2 Recommendations

This project is unique in the sense that the context around the assignment is not determined. This leaves me with a large design space. While defining the embarking and disembarking process, I have also given a lot of thought to other passenger touch points that are out of the scope of this project. In this subchapter, I will address recommendations on guiding passengers to platforms and doors, the interior, facilities for passengers with reduced mobility, the emergency exit and the door-to-door potential of the hyperloop concept.

8.2.1 Guiding passengers to platforms and doors

One of the system conditions is that each vehicle can only allow a fixed number of passengers on board like an aeroplane situation (one person per seat). Therefore, for safety reasons, the number of passengers on the platform should not exceed the capacity of each vehicle. In general, there are two ways of guiding a fixed number of passengers to the platforms, both in combination with environmental way finding information. Either compartment of each vehicle are reserved before boarding process (reserving and assigning seats are not necessary as discussed in Chapter 6.3), or passengers are directly guided and limited by station infrastructure without any reservations. The advantages and disadvantages of both possibilities are stated and examples are given for both situations.

Table 8 compares the two ways of guiding and limiting passengers. Reserving makes sure that group travelers can travel together in the same vehicle or even the same compartment; passengers with special needs can book the special compartment; with reservation service, information on hold luggage can be collected making sure that the amount of luggage does not exceed the limit per vehicle and passengers can be assigned to different compartments accordingly. For passengers who need to transfer, luggage can be transferred automatically to the reserved connecting vehicle saving the hassle of picking up and drop the luggage again at the transfer station. However, reserving has the disadvantage of passengers not showing up on time because of the high departure frequency, which will result in empty seats in the vehicles. The non-reserve way makes the system more flexible. Passengers do not need to plan their departure time and can

▼ ***Table 8. Comparison between two ways of guiding and limiting passengers: reserve and non-reserve.***

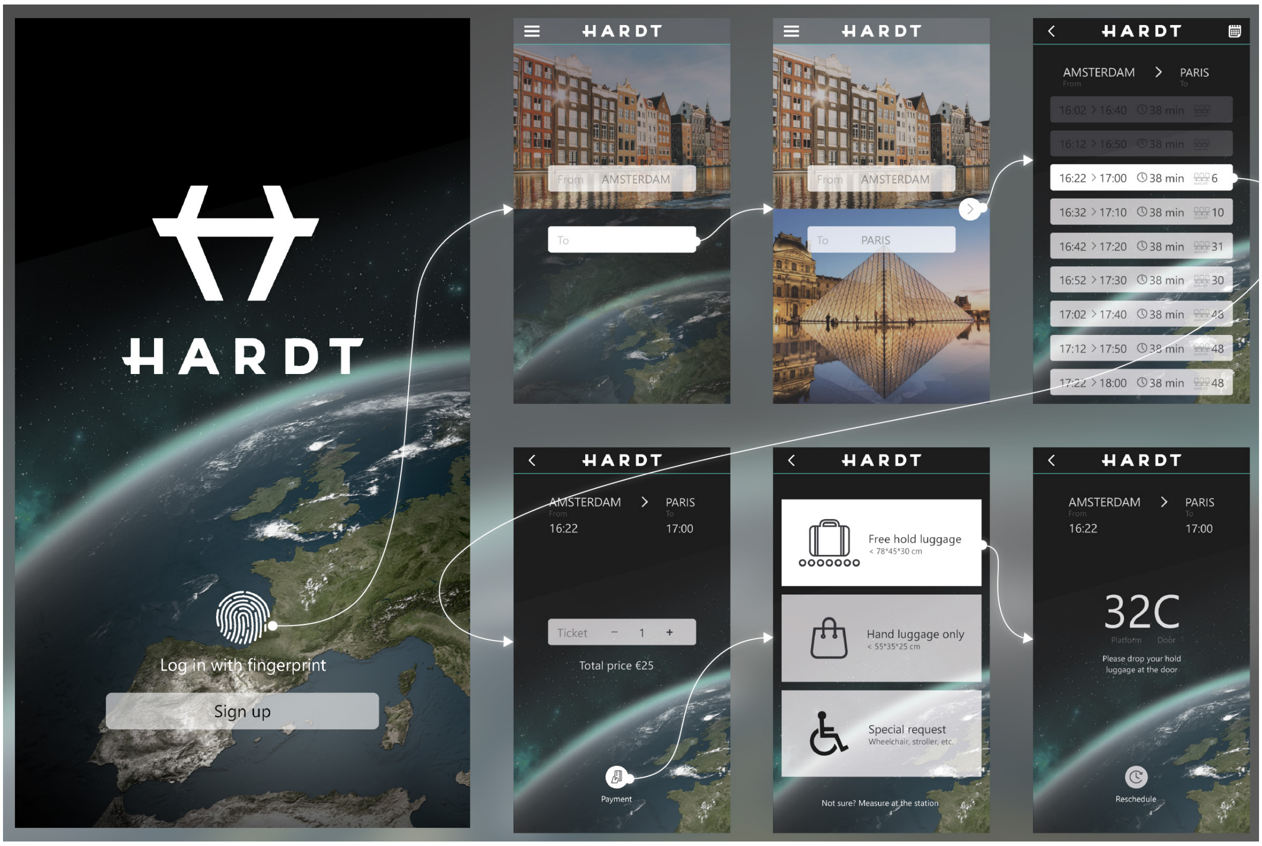
	Reserve	Non-reserve
Advantages	• Group travellers can travel together • Passengers with special needs can be sure to sit in the special compartment • Information on hold luggage can be collected before hand • For transfer passengers, luggage can be transferred automatically to the reserved connecting vehicle	• Flexible system where passengers do not have to plan • Opens the possibility of on-demand schedule instead of fixed schedule
Disadvantages	• Passengers not showing up on time will cause empty seats	• Extra station infrastructure • Causing conflicts among passengers about who to enter first

arrive at the station and leave when there is a vehicle available similar to a metro interaction; it also opens the possibility of creating an on-demand schedule – the vehicles depart when they are full. On the other hand, the non-reserve way will require extra station infrastructure to limit the number of people going on the platform or on board; there is also the possibility that passengers will argue who should enter first, causing unnecessary conflicts especially during rush hours.

Ideas in both directions will be explained in the next paragraphs. The ideas need to be further detailed and evaluated to make a decision. A combination of both is also a possible solution.

Quick Reservation

An integrated ticketing and trip planning service will support the embarking and disembarking process (interface will be explained in the following subchapter). Through a mobile application, webpage or kiosks at the station, passengers can plan their trip, reserve a ticket (or more tickets as a group) and finish the payment. The service also asks for the luggage information of each passenger and give guidance on whether they need to drop their luggage at the door. After that, the information about the boarding platform and boarding door will be given. With this information, passengers will go directly in front of the door and are ensured that they have a seat in this compartment. Passengers travelling with companions can travel in the same vehicle or the same compartment. Passengers with reduced mobility or special requests can reserve the special compartment for their convenience. For the system, it makes sure that each vehicle will not be overloaded both with passengers and luggage. ►



▲

Figure 61. Illustration of the mobile prototype.

When passengers want to plan a trip, they can either do it through a mobile application, on the web page or on a kiosk at the station. Take mobile application, for example, *Figure 61* shows the interface for passengers in case a mobile application is considered. Frequent passengers can have their own account with biometric information and payment details for a fast and safe planning and ticketing experience. After logging in, they will choose their departure and arrival station. Real-life timetable from the moment on will show up with the information of departure time, arrival time, trip duration and the number of tickets left for each vehicle. Passengers can also schedule a trip for other dates by clicking the calendar icon. Passengers can choose the number of tickets they want and the system will calculate the total price. Passengers can then pay through the app.

After payment, passengers will be informed of the different luggage solutions and be provided with the opportunity to request for the special compartment. If passengers are not sure about their luggage size, the station also provides luggage scanning machine where it tells them whether they need to drop their luggage. Finally, passengers will get their boarding information. If for multiple tickets, the seat arrangement is not desired (for example, passengers are not in the same door as their companions) or passengers failed to catch the planned vehicle, it is possible to reschedule the trip. For web page and kiosks at the station, the procedure is similar.

* See interactive prototype of the mobile application here: https://xd.adobe.com/view/afd66265-4b9d-4a2a-aa85-1fea8a96e8c8

Arrive and go

Turnstiles, like in most of the metro stations and airports, are used to let passengers through one by one *(Figure 62)*. The gates will calculate the number of people on the platform. The gates will be closed once the number of passengers on platform reaches the limit. There is also a countdown screen at each gate indicating how many passengers can still get through. Passengers travelling in groups can check if they could all be in the same vehicle before entering *(Figure 63)*. Luggage size scanning machines are available both before and after the gates so that passengers can make sure whether they need to drop their luggage at the doors.

Once entering the platform, passengers can wait at the doors and drop their hold luggage. In front of each door, there are sensors (for example photoresistors) sensing the number of passengers at each door. When the number of passengers is less than the number of seats in the door, a green indication light will be on to direct passengers to the door; if not, the light will turn red. With the colour cues, passengers will be guided to an available door on the platform (Glastra van Loon, 2017).

The gates can be integrated with other passenger process, for example, payment. Depending on the way of payment, the gates can be activated by different means: biometric information, chip cards, bank cards or mobile phones (X-CEPT, 2017). ►

▼

Figure 62. One of the swing turnstiles design by DaoSafe.

▲

Figure 63. Turnstiles with a countdown screen before entering the platform.

8.2.2 The interior

Virtual views

Many passengers suffer from motion sickness during travel and it needs extra attention when designing the interior of the hyperloop vehicles. Motion sickness is caused by incoherence between what people see and what they feel in their balance system. Since hyperloop vehicles will be travelling in tubes, it is not possible for passengers to directly see the outside environment. If passengers only see the relatively still walls of the vehicle while feeling the acceleration and turning, they will suffer from motion sickness. Virtual views projected on the walls can provide visual information that matches the movement of the vehicle. It could solve the problem of motion sickness as well as an alternative to windows.

Entertainment and working space

In current public transportation systems, the entertainment is mainly provided by screens at the back of the seats. It was designed decades ago in the context where passengers enjoy the convenience of having access to entertainment provided by airline companies for example. Laptop tables are also common on flights and trains to enable passengers to work during travel. However, research needs to be done to discover what are the needs of people during travel in 10 years regarding entertainment and working habits. The next step will be how to integrate them into the seat configuration (or the way of embarking and disembarking) designed in this project.

8.2.3 Passengers with reduced mobility

Passengers with reduced mobility include wheelchair passengers, passengers who are blind or visually impaired, deaf or deaf without speech and passengers with intellectual or developmental disability. This project has only addressed passengers with wheelchairs because it is relevant to the design of embarking and disembarking process. For passengers with other types of reduced mobility, extra designs should be made both on the platforms (in the station) and in the vehicles to allow them to use the system individually and safely.

8.2.4 Emergency exit

There are two types of emergency situations in the hyperloop system: emergency situations in which vehicles are able to transport passengers to a safety ramp (like a platform at a station) and evacuate passengers from there and emergency situations where vehicles cannot move and passengers need to evacuate in the tube. In the former situations, evacuation can be done through the embarking and disembarking exits; in the latter situations, whether the embarking and disembarking exits can be used largely depends on the distance between the vehicle and the tube which has not been decided yet. If there is enough space in between, passengers can evacuate like the former situations; else extra emergency exits need to be added on the floor or at the front and rear.

8.2.5 Door-to-door potential

In Chapter 5.2, the concept Carry-on is described. By separating the carriers (propulsion and levitation system) and the pods (passenger compartment or cargo space), a door-to-door service can be developed with multimodal transportation and modularity. Pods can be of small size like for example a personal pod. The personal pods can pick passengers up at their door and transport them to an hyperloop station propelling by road carriers or by itself.
The carrier at the station will take over from there on, bringing pods through the pressurised tube. The same goes for cargo transportation or even an integration of passenger and cargo transport can be developed. ■

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