

 24H COACH

A day and night train interior design for improved passenger comfort and improved train usage

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Master Thesis Industrial Design Engineering

Royal HaskoningDHV & TU Delft

February 2024



Master Thesis

Delft, February, 2024

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Abstract Executive summary

This project explores the prospects for interior design in a dual purpose train that can run both day and night for improved utilisation.

Contemporary trains are categorized as either exclusively for daytime or nighttime use. Their interiors limit them to specific temporal contexts. For instance, in daytime trains, passengers are confined to sitting positions and cannot lie flat, resulting in suboptimal sleeping comfort. Thereby the appeal of such trains for night (longdistance) travel is reduced. Conversely, in existing night trains, while passengers can lie flat, the fixed layout featuring compartments and beds makes the capacity of the train too low for daytime use. Moreover, night trains face strong competition from aviation, rendering their utilization challenging.

A solution to this problem involves designing a train interior that serves the dual purpose of accommodating both daytime and nighttime travel.

Drawing insights from research, and the existing coach geometry, four distinct design directions were developed. Emphasis was placed on striking a balance between coach capacity and passenger comfort, recognizing the inherent tension between these two factors in this context. One of

these directions was further refined into the final concept. In refining the final concept, the emphasis was on creating a passenger experience characterised by privacy, safety and comfort. Two Virtual Reality tests were conducted among other efforts to achieve this goal.

The final concept features a symmetrical coach with a centrally positioned entrance. The entrance aligns with the platform's height, facilitating easy boarding for passengers with reduced mobility. The central hall houses a self-service bar for acquiring food and beverages. Adjacent to the central hall are seats on both sides. During the day, passengers can occupy these seats, which are configured in sets of two facing each other. No ticket reservation is necessary for daytime travel, and the coach accommodates 72 passengers during this period. Capacity is thereby 10% lower than in daytime-only trains. At night, the seats transform into beds, offering passengers the option to lie flat. Privacy screens can be easily placed around the bed, and overhead lockers are available for secure luggage storage. The nighttime capacity is 36 passengers, which is the same capacity as in the sleeper accommodation in nighttime-only trains. Ticket reservation is obligatory for overnight travel. The coach incorporates two toilets and two washrooms. Distinct zones within the coach, such as a quiet zone, a socializing zone, and a women-only zone for nighttime travel, contribute to a tailored and comfortable passenger experience.

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Introduction Project

This report is part of a larger project consisting of two phases. In the first phase, the passenger experience in night trains with a focus on comfort was investigated in the form of a research elective. The research question was: "How do behavioural and (physical) environmental aspects influence a traveller's sense of perceived comfort when travelling in a night train?"

In the second phase, which is described in this report, additional research on privacy, the feeling of security and comfort is conducted and a proposal for a new train interior design for a 24h coach is made.

Mobility is undergoing a profound shift worldwide. Due to increasing urbanisation and the rapidly changing behaviour of new generations, transport systems are under pressure. Air travel has put Europe at our fingertips and has become one of our most favoured ways to travel around Europe. From a sustainability perspective, there is a great demand (Inspiratiegids Duurzame Mobiliteit, n.d.) for more sustainable mobility. The night train could be a suitable replacement for the plane for trips between 750-1500km (Zijlstra & Rienstra, 2021).

Royal HaskoningDHV is an expert on this Air-Rail transition. According to a recent study, the comfort level of the night train is a very important factor in the choice between plane and night train (Heufke Kantelaar et al., 2022). New night train interiors are already showing an improvement in terms of comfort level, e.g. more private travel options, modern design, etc (Nightjet of the new generation, n.d). However, it is still a dedicated train with separate compartments. This means that these trains are often used only once per day. To be able to use night trains more efficiently, and thus improve the business case, the interior needs to be suitable for both daytime and nighttime use.

In my graduation project from TU Delft together with Royal HaskoningDHV, I am trying to solve this challenge. The full research question is: "What would a train interior look like that offers a comfortable journey during the day as well as during the night while maintaining sufficient capacity?". The ultimate goal for this project is to attract more people to travel by train instead of using other less sustainable options such as an airplane or a car. This era, also called the 'Renaissance of the night train' (Geerst & Geerts, 2023), offers many opportunities for change.

The project structure and method is shown in figure 1 and is as follows: the project's design goal and further refinement of the project's scope will be elaborated on in chapter 1. Chapter 2 describes the research that was done before the coming up with ideas. Chapter 3 describes how through ideation four different concept designs were created and evaluated. In chapter 4, the chosen concept is further developed. Chapter 5 shows and explains the final proposed concept. Finally in chapter 6 an evaluation, recommendations and a reflection is given.

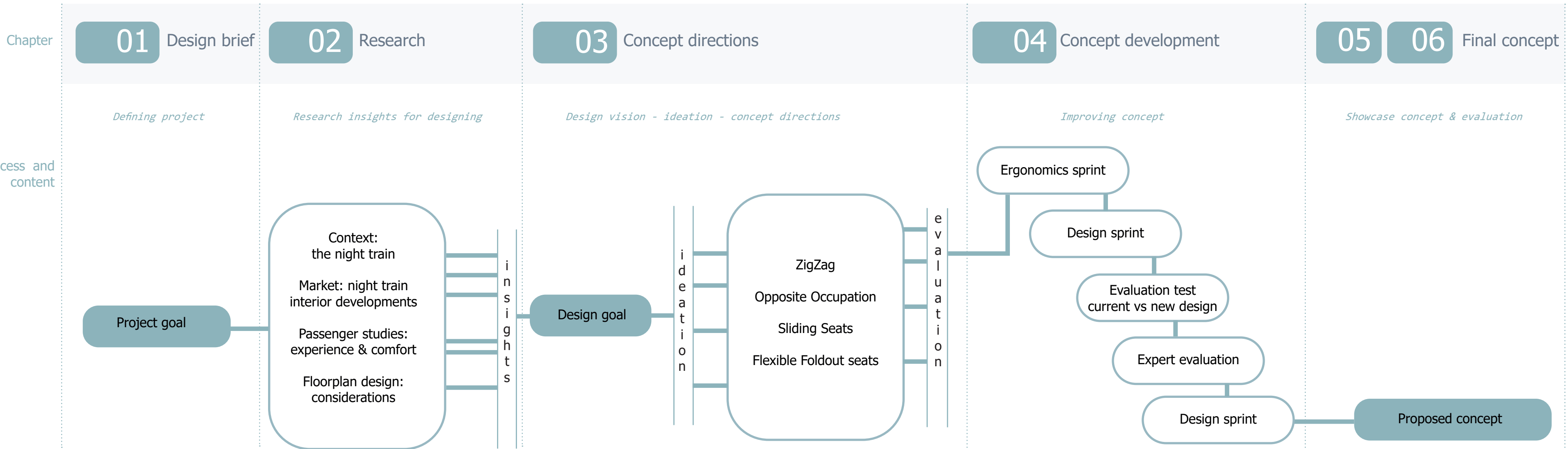


Figure 1. Design process

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Design brief Initial goals

- / 01 Why operating night trains is (still) challenging
- / 02 Project goals
- / 03 Stakeholders
- / 04 Opportunities and limitations



01 / Why operating night trains is (still) challenging

Under the leadership of the Austrian Railways (ÖBB), in cooperation with other European state-owned companies, a variety of night trains have been reintroduced recently (Hildebrand, 2021). Several private railway companies have also introduced and announced new night trains in the past few years. Therefore, there seems to be demand for night trains, but operating a night train profitably is no easy task (Roel, 2023).

This is because of a couple of reasons as shown in the visual overview in figure 2. First of all, a night train requires a relatively large amount of rolling stock. One Thalys train set easily makes four trips between Amsterdam and Paris in a day, but a night train can only make one trip a day. Moreover, special equipment is needed because people want to be able to sleep at night. A normal seat does not suffice for most travellers. It soon becomes more attractive to take the plane, instead of spending 12 hours in a seat (without being able to sleep properly). In addition, night train equipment is expensive, as much as €15 million per train and the same amount is often spent on renovations and maintenance over its lifetime (Hildebrand, 2021). Then there is another disadvantage. A seated coach

can accommodate 66-60 passengers but the sleeper and couchette coaches can accommodate far fewer. In practice, a sleeping coach can accommodate about 36-30 passengers (The Good Night Train | European Sleeper, z.d.). Because there is room for fewer passengers, the ticket price is significantly higher (Hildebrand, 2021).

The infrastructure charge also affects the ticket price. For each train kilometre travelled, a carrier has to pay an infrastructure charge. The exact amount varies from country to country, and can also vary based on time of day, weight and other factors (Ministerie van Infrastructuur en Waterstaat, 2019). Finally, a relatively large number of staff is needed on a night train because the passenger wants to be able to address a steward easily. Staff costs are high because the staff works at night and journey times are long (Hildebrand, 2021).

The fact that night trains are now experiencing a revival is partly explained by the fact that ÖBB and other railway companies are investing in night train travel. The challenge of railway companies will mainly be to reduce costs on the one hand and to offer sufficient comfort that suits passengers' wishes on the other. Whether this challenge will be solved will be seen in the future.

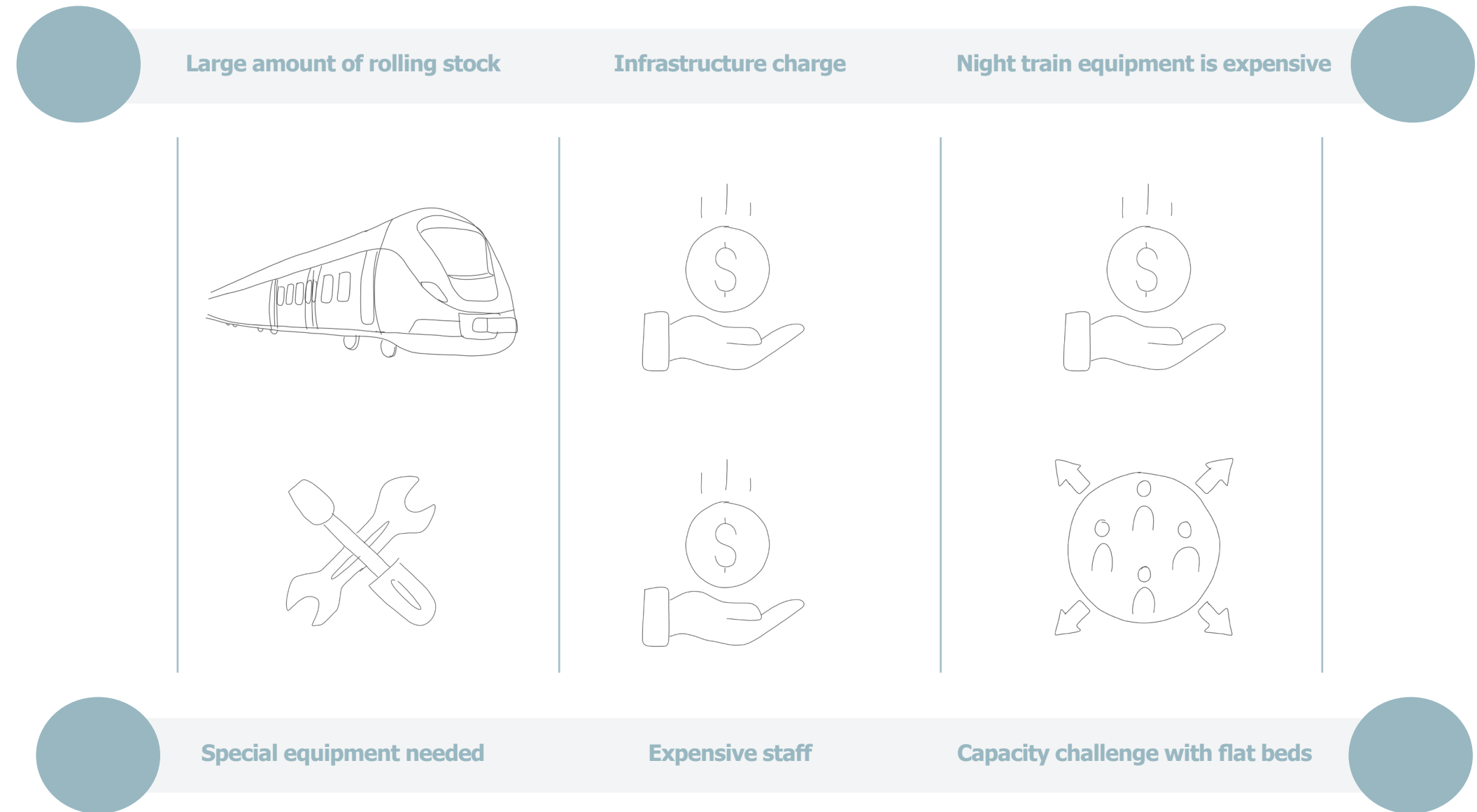


Figure 2. Why night trains are (still) challenging

02 / Project goal

This project concerns the design of the seats and floorplan of a day and night train coach. A new train interior design offers the opportunity to create a passenger experience that is different from current night trains. Passenger experience is influenced by several aspects such as environmental factors, seating characteristics and privacy factors. How these factors relate to the passenger experience will be explored during my research. Using these insights, a design vision will be created.

This project has two main goals to be incorporated into the vision. The first goal is to design a train interior that can be used during day and night travel. The second goal is to design an interior in which passengers will have a comfortable and differentiating travel experience.

'My project goal is to create a vision of how a comfortable and differentiating passenger experiences should be created. This vision can then be used to design a new seating design and floorplan that illustrates this new experience and is usable for day and night travel.'

03 / Stakeholders

Several stakeholders need to be considered when designing the interior of a day and night train. Firstly, the train operators. They are mainly concerned about the profitability of the train, therefore the passenger capacity is one of the main requirements to keep in mind. Secondly, the passengers are very important stakeholders as the project goal is to improve their travel experience. Furthermore, when designing the interior of a train, other stakeholders need to be addressed as well, such as manufacturers of interior elements, train crew, maintenance and service crews etc.

through the use of sustainable materials and production methods. In addition, safety regulations have recently been equalised within Europe, opening up opportunities for international (night) trains (European Rail Traffic Management System (ERTMS), 2023). With climate concerns higher on the public agenda, decarbonisation imperative beginning to take shape in European policy (Limb, 2023), changing behaviour and (travel) habits in the wake of the global pandemic (EenVandaag, 2021), the renaissance of the night train is in full swing (Geerts & Geerts, 2023). By responding to this, a major impact can be made in the field of sustainable mobility.

However, there are certain limitations to consider. Developing entirely new train interiors would incur substantial costs and resource consumption, making redesigning existing train interiors a more sustainable approach, although with design constraints imposed by the interior dimensions of the train. Passenger capacity represents a crucial concern, impacting profitability, yet maximizing capacity may compromise passenger comfort, necessitating a careful balance between these aspects (Maung et al., 2022). Furthermore, human adaptability poses a limitation, as we are accustomed to fast travel times of airplanes, necessitating a shift in preferences to align with sustainability goals ('Veel mensen vinden het ov maar gedoe', z.d.).

04 / Opportunities & limitations

The project offers several opportunities, including the potential for an interior that promotes efficient utilization and provides an enhanced comfort experience, encouraging travellers to opt for the train over less sustainable modes of travel. Additionally, the project allows for a fresh perspective on floor plan design and interior design which provides an opportunity to reflect the low-impact image of night trains

02
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Research Setting the scene

- / 01 Context: night trains
- / 02 Market studies: trends and developments
- / 03 Passenger studies
- / 04 Interior & floorplan design: what to consider

02
01

Context: night trains

- // 01 The start of night trains
 - // 02 Working principle night trains
 - // 03 Stakeholders
 - // 04 Current floorplan, interior & facilities
 - // 05 Night train interiors around the world
- Take aways context

01 / The start of night trains

George Mortimer Pullman (1831-1897) became famous as the designer of the eponymous sleeping car, which made its debut in 1865. He first made a name for himself as an engineer in Chicago but after an uncomfortable train ride the idea for his next venture, namely luxury railway carriages.

His first design was not a success but his second design, the Pioneer, see figure 3, was. The carriages had rubber springs to reduce bouncing and shaking, thick curtains and chandeliers hung from the ceiling painted with detailed designs. The walls were lined with rich dark walnut, the seats were covered with plush upholstery and the light fittings were brass. During the day, the sleeping car looked like an ordinary, albeit particularly luxurious, passenger car, but at night it transformed into a hotel on wheels. Chairs were unfolded into lower berths, and the upper berths were unfolded from the ceiling. Pullman porters installed sheets and partitions to complete the effect. The only problem was that the train did not fit on the existing platforms. Pullman said of this "My contribution was to build a carriage from the point of view of passenger comfort; existing practices and standards were secondary." In 1865 a national tragedy worked in Pullman's favour. After the assassination of President Lincoln, the government chose to use the luxurious Pullman wagon for the last leg of his funeral train, requiring the renovation of every station and bridge between Chicago and Springfield. The publicity made the Pullman sleeping car an overnight success (The Pullman History Site: The Pullman Company, n.d.).



Figure 3. Pullman night train interior



Figure 4 & 5. Interior night train

The first night trains were very luxurious, see figures 4 & 5, and only affordable for the rich. The night train was promoted as a romantic and comfortable way to travel. When after the second world war equality became more important in society, it was also reflected in the night train interior, see figure 7. A tourist class, the more economical berths (the couchette) and cheaper seats were created, making the night train available to all social classes. What was a great idea, making travel possible for all, unfortunately had negative consequences for the comfort level and image of the night train.

When it got competition from budget airlines (figure 6), high-speed train and the oil crisis,



Figure 6. Budget airline



Figure 7. Poster

the night train was almost extinct (Roel, 2023). Now that railway companies are joining forces (Burroughs, 2020), people are more aware of their impact on the environment (Public awareness inspires shift towards sustainability, n.d.) and the government is investing in night trains and rail (Augusteijn & Augusteijn, 2022), all these developments make that the night train is reviving.

However, in terms of interiors, service and comfort, the night train is a bit behind because there has been no investment and innovation for a long time. Besides that, people's standards have changed because we can all afford a (private) car, for instance. For the night train to become a real success, it might help if more attention is devoted to making a night train of this time, which means returning to the focus on comfort that made Pullman a success. See Appendix 1 for a cultural timeline of the nighttrain.

02 / Working principle night trains

What

A night train is a train that travels at night, usually with train cars that allow sleeping (sleeper, couchette). A night train allows you to travel while sleeping. A night train has different classes consisting of normal seats, couchettes and sleeping cars (Night trains in Europe, z.d.).

Why

Travelling by night train is a safe and efficient way to travel. You leave in the evening and travel throughout the night. In the morning, you arrive at your destination (often already in the city centre so no need to arrange extra transport). You arrive rested which means you gain a day compared to travelling by any day time trip. The night train has different accommodation options in terms of comfort and price making this way of travelling accessible to everyone (Night trains in Europe, z.d.).

How

Figure 8 explains the steps for travelling by night train.

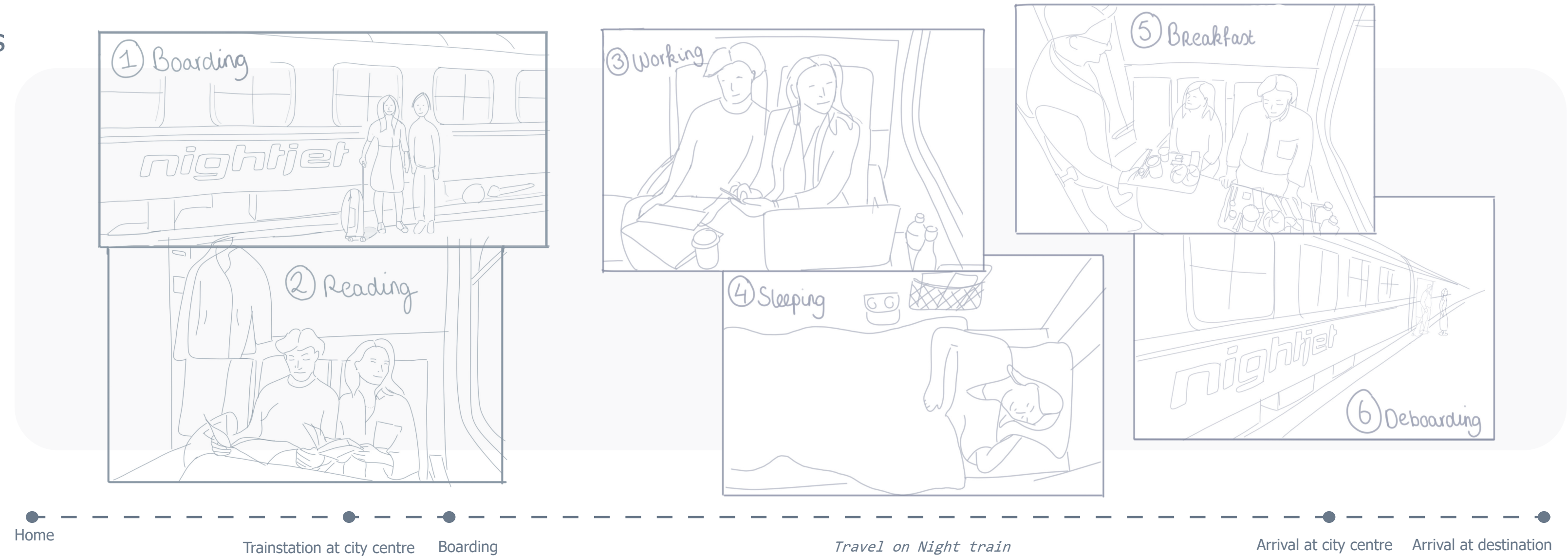


Figure 8. Storyboard travel by night train

03 / Stakeholders

Designing train interiors is a complex process that takes into account the needs and expectations of different stakeholders. Below are some of the key stakeholders involved in train interior design described and figure 9 shows how they relate to each other.

Passengers:

The most important stakeholders are the passengers themselves. Train interior design should meet the comfort and convenience needs of passengers. This includes seating, legroom, storage options, accessibility for people with reduced mobility, lighting, ventilation and overall aesthetics. Passengers should feel comfortable and safe during their journey.

Carriers and operators:

Train carriers and operators play a crucial role in train interior design. They want to make efficient use of available space, minimise costs while providing attractive and functional interiors to attract and retain customers. They also have maintenance and durability requirements.

Government and regulators:

Government bodies and regulators set standards and regulations regarding the safety, accessibility and environmental performance of train interiors. They must ensure that designs comply with applicable laws and regulations and assess the impact of train interiors on the environment.

Suppliers and manufacturers:

Manufacturers of train interior components, such as seats, flooring, lighting and other elements, are important stakeholders. They must provide high-quality products that meet the specifications and quality standards of the design agencies and operators.

Environmental and sustainability organisations:

Sustainability is becoming very important in train interior designs. Environmental and sustainability organisations monitor the environmental footprint of train materials and designs.

Network operators:

Network operators are responsible for managing the railway network and infrastructure, such as tracks, overhead lines and signalling equipment. They are important stakeholders in train interior design because they impose requirements on the dimensions and specifications of trains to ensure their compatibility with the railway network. Train interior design must take into account these technical requirements to ensure seamless operation and safety.

Train crew:

Train crews, including drivers, conductors, stewards and stewardesses, have daily interactions with passengers and are therefore an important stakeholder. Train interior design should take into account the ergonomic needs of the crew, such as controls, work areas and storage facilities. Moreover, design aspects, such as the layout of the train and the placement of emergency exits, should support crew safety and effectiveness.

Maintenance and service teams:

People responsible for maintaining and cleaning train interiors are also important stakeholders. The design should consider maintenance needs and easy cleaning to maintain a pleasant and safe environment.

Technology suppliers:

With the continuous advancement of technology, suppliers of infotainment systems, connectivity solutions and other technological components play an important role in train interior design.

Successfully designing train interiors requires balancing the diverse needs and expectations of all these different stakeholders. A holistic approach involving all stakeholders can result in attractive, comfortable and sustainable train interiors that satisfy both passengers and operators.

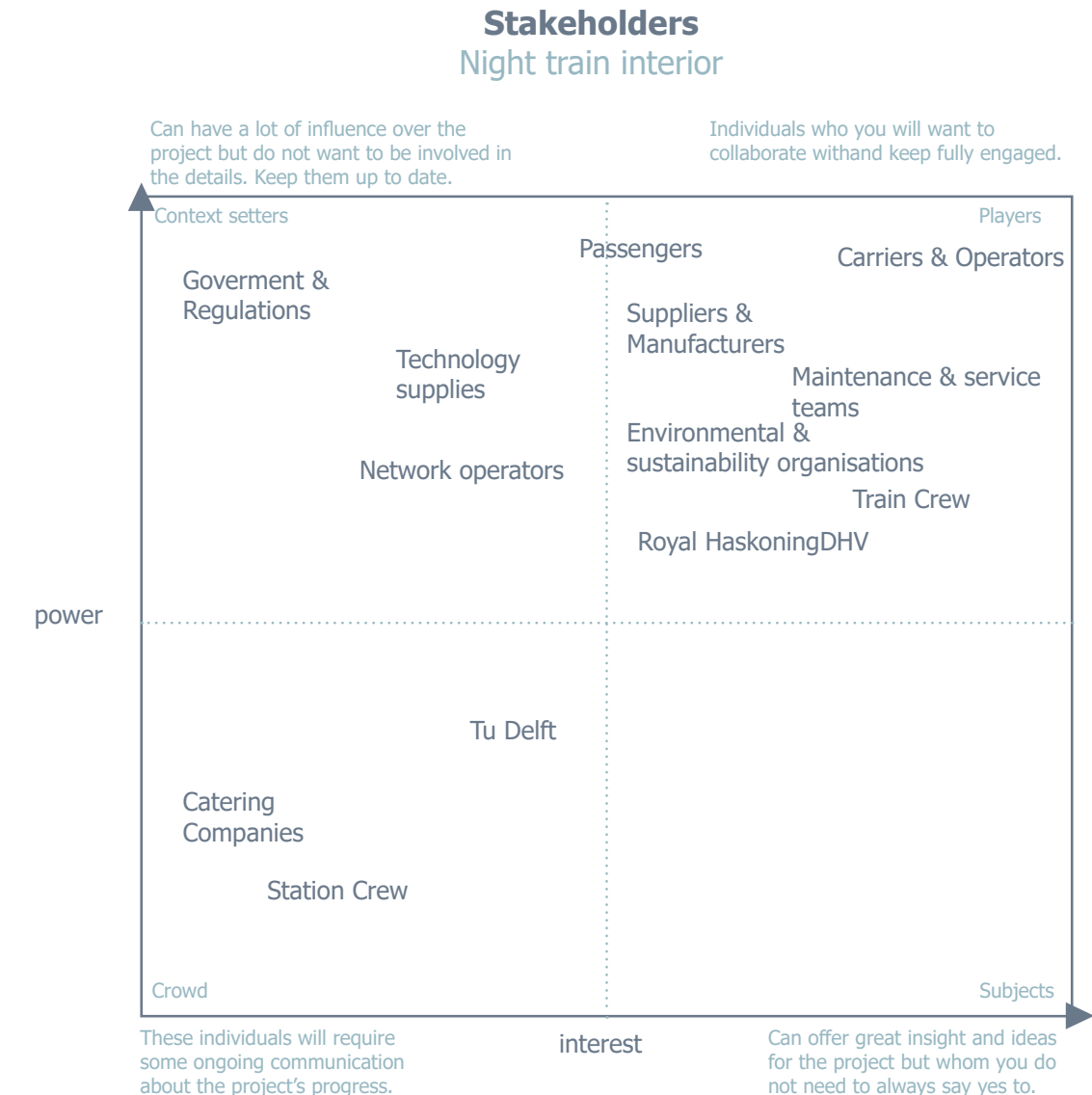


Figure 9. Stakeholdermap

04 / Current floorplan, interior & facilities

Seating carriage

This is the most economical way for people to travel on night trains, some services offer coaches with airline style reclining seats. Depending on the night train you are travelling on, coaches can be divided into compartments of around six seats each or can be open plan, see figures 10 & 11. In this coach there is a toilet on each side of the car (Hildebrand, 2021).

Facilities:

- Sockets
- Food & drinks for sale
- Toilets in the corridor
- Coat hooks
- Luggage area (+ overhead)

Facilities depending on operator:

- Wi-Fi
- Adjustable head/ arm/ foot support
- Adjustable backrest
- Sleeping kit
- Blanket
- Audio channel
- Free coffee & tea
- Reading lamp
- Folding tables



Figure 10. Seating coach open



Figure 11. Seating coach cabins

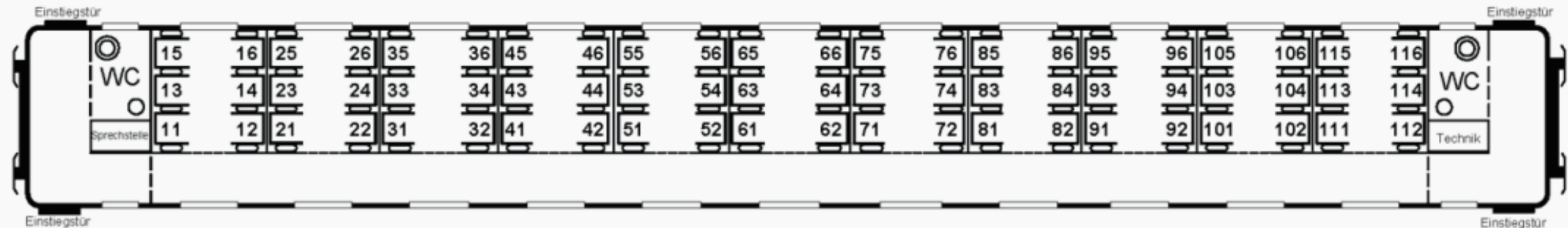


Figure 12. Floorplan seating coach

Couchette

This travel mode is usually available as either four or six berth coaches, see figure 13. Couchettes transform from ordinary seating during the day to padded bunks (two or three on top of one another) during the night. In this coach there is a toilet on each side of the car and there are two washrooms (Hildebrand, 2021).

Facilities:

- Sockets
- Food & drinks for sale
- Toilet in the corridor
- Coat rack
- Luggage area
- Curtain
- Blanket, sheet, pillow
- Table
- Lock inside
- Breakfast & water
- Magazine holder

Facilities depending on operator:

- Wi-Fi
- Mini travel set
- Staff on board
- Wake-up service
- Assistance with boarding & disembarkation

Bed size:

- Varies between 174 and 195 x 66 cm
- Bed is most of the time a bench



Figure 13. Couchette



Figure 14. Floorplan couchette

Sleeper

Sleeper cabins are almost like staying in a moving hotel, see figure 15. Available as one, two, three and sometimes four berth coaches, during the day these rooms can act as a sitting room with comfortable seating and a small table. At night, beds are freshly made with pillows, duvets or blankets. Sleeper cabins usually come with a sink, towels and toiletries so you can arrive at your destination as refreshed as possible. Some deluxe sleeper cabins even have their own shower and toilet for total privacy during your journey (Hildebrand, 2021).

Facilities:

- Sockets
- Sink
- Mirror
- Night light
- Curtain
- Seat & table
- Made up bed
- Inside lock/keycard
- Food & drink for sale
- Coat rack
- Toilet in corridor/room
- Shower on corridor/ in room
- Matress

Facilities depending on operator:

- Wifi
- Breakfast/ welcome drink
- Towel, slippers & toiletries
- Station lounge access
- Priority boarding
- Room service
- Temp control/ air conditioning
- Service button
- Wake-up service
- Films
- Staff present
- Assistance with boarding & disembarkation
- Restaurant close to sleeping compartments



Figure 15. Sleeper

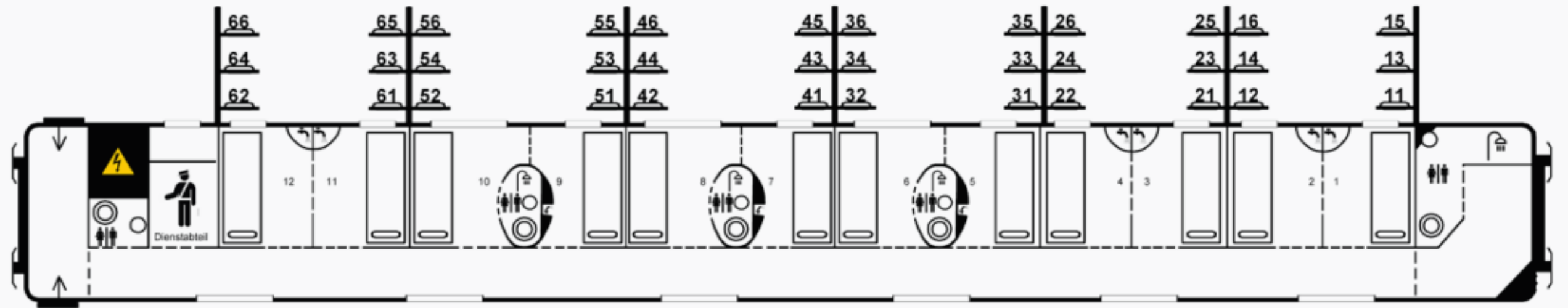


Figure 16. Floorplan sleeper

Special cabins

Prive cabins:

Night train organisation ÖBB Nightjet is currently testing night trains with private cabins on board, see figure 17. They are scheduled to enter service around 2023/2024. This is a small lockable bed in which you can lie flat.

Barrier-free coupé:

For passengers with mobility impairments (wheelchair), a special accessible compartment and adjacent sanitary facilities are available in many night trains. This compartment has 2 beds, a service button with tactile elements, space for a guide dog and boarding assistance on the platform, see figure 18.

Women's coupé:

Some night trains have special women's compartments. These are couchettes of 4 or 6 people that can only be booked by women.

Bicycle coach:

There is a bicycle coach on Nightjet trains between Germany and Switzerland/Austria. This requires a reservation. There are no bicycle coach on other Nightjet trains.

Vehicle-carrying coach:

A number of Nightjet trains have a vehicle-carrying coach for both cars and motorcycles.



Figure 17. Private cabins



Figure 18. Barrier-free coupé

05 / Night train interiors around the world

Night trains are available all over the world. To get a complete picture of night train interiors and innovations, this section looks at night train interiors from Europe, the USA and China.

Europe

There are a lot of night trains in Europe, see figure 19. For this analysis, the following night train organisations were considered: ÖBB (Austria), SNCF (France), Trenitalia (Italy), Renfe (Spain/ Portugal), European Sleeper, GWR (England), Caledonian sleeper (England), GoAhead (Norway), VY (Sweden), SJ Euronight (Sweden), VR (Finland), CD (Czech Republic), HZPP (Croatia), MAV (Hungary), BDZ (Bulgaria), TCDD (Turkey), ASTRA (Romania), ZSSK (Slovenia), UZ (Ukraine), PKP (Poland). All these night trains have the same kind of classes and interiors described in section 4.

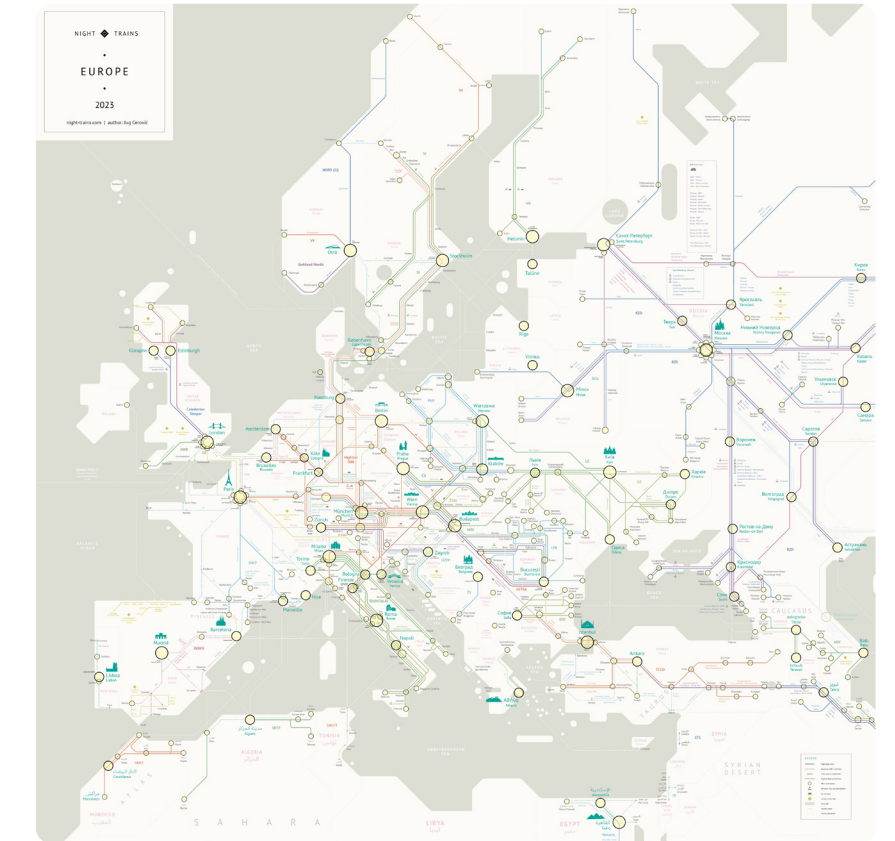


Figure 19. Night trains in Europe

USA

The operator Amtrak has night trains in the USA. Amtrak has two types of trains: the Superliner and the Viewliner. The main difference is that the Superliner offers two kinds of private rooms and the Viewliner one kind. The structure of the classes is slightly different from the EU. There are Seating options and First Class Private Room options, see figure 20. Within the seating options, there are three different classes: Coach, Business and First Class. The higher the class the more features and service.

The First Class Private Rooms exist in three different classes. The lowest class is the Roomette. This class is similar to the Couchette in Europe. The only difference is that this couchette is for 2 people instead of 4 to 6 as in Europe. One class higher is the Bedroom. This compartment is more spacious than the Roomette and including a toilet and shower in the compartment. The highest class is the Bedroom Suite. This is for 4 people and is 2x as spacious as the Bedroom as it consists of two bedrooms with an interconnecting door. Other than that, the facilities are the same. Both the Bedroom and the Bedroom Suite are similar to the Sleeper Cabin in Europe in terms of facilities.

Amtrak offers next to these classes, a Family compartment and an Accessible compartment for people with mobility impairments.

A dedicated First Class attendant will provide turndown service, assist with meals and help with luggage. All customers in private rooms receive complimentary lounge access at major stations, priority boarding and complimentary meals onboard (Amtrak, n.d.).

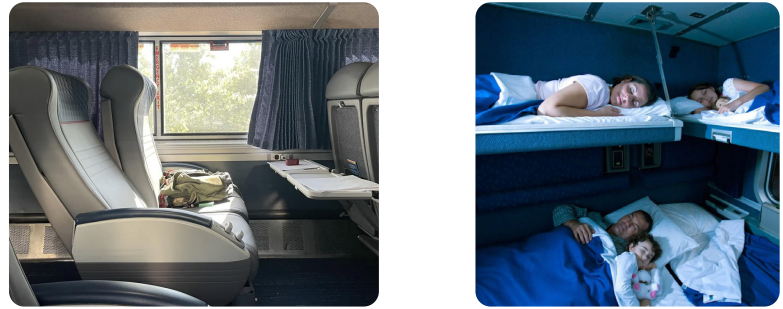
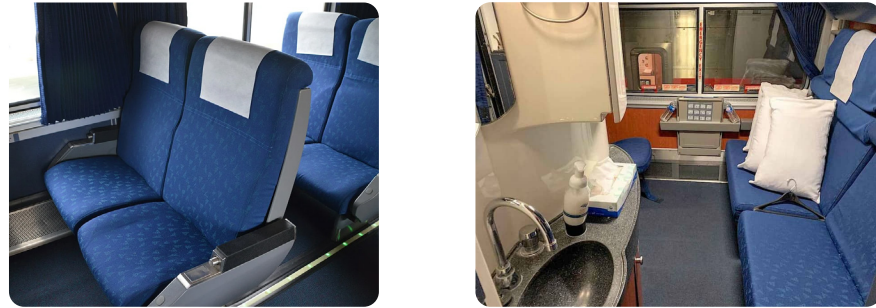


Figure 20. USA night train interior

China

In China, there are two types of night trains. High speed trains and ordinary trains. Both have different types of travel classes.

High speed trains

High speed night trains have the following seating classes: Second Class, First Class & Business Class, see figure 21,23 & 25. The higher the class, the more luxurious. In the First Class you can adjust your backrest to a certain angle and in Business Class your backrest can be come completely flat. In addition, these night trains also offer sleeping compartments, the Soft Sleeper (figure 24) and the Soft Sleeper Deluxe (figure 22). The Soft Sleeper is a compartment for 4 people, has a TV at each bed with headphones, a night light and the temperature is adjustable. There is a toilet and shower in the coach. Both Western-style and Chinese-style. The Soft Sleeper Deluxe is a compartment for 2 people with a lockable door. There is a sofa and a closet with pillows and slippers. Finally, a Western-Style toilet and shower are in the coach.

A new high speed train has recently made its appearance in China, the double-layer sleeper EMU. The train is also known as a mobile hotel and the train owes this name to its interior. The train consists of single rooms, with beds parallel to the corridor and parallel to the train's direction of travel, see figure 26. Each single room is equipped with sockets, USB sockets, a lamp above the bed, a reading light, books, a newspaper net, a wastebasket and disposable slippers. The single rooms can be closed off with a curtain and the back of the headboard of the bed can be adjusted at an angle. In addition, this train design further optimised vibration and noise reduction to make passengers' sleeping environment more comfortable. The luggage compartment in the lower bed can accommodate six standard size suitcases or two extra-large suitcases (Xiaoyuan, n.d.).



Figure 21. Second Class



Figure 23. First Class

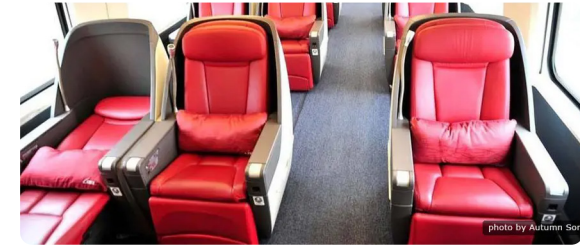


Figure 25. Business Class



Figure 22. Soft Sleeper Deluxe



Figure 24. Soft Sleeper



Figure 26. Private room close up

Ordinary trains

In ordinary trains, there are two seat classes: a Hard Seat (figure 28) and a Soft Seat (figure 29). Hard Seats are the cheapest and are often very crowded. Soft Seats are more comfortable. There is more space, they are cleaner and there is air conditioning.

Next to that are there three sleeper cabin classes: a Hard Sleeper (figure 30), a Soft Sleeper and a Soft Sleeper Deluxe. In a Hard Sleeper compartment, there are 3 beds one above the other and the space is open. Each bed has a fitted sheet, a blanket and a pillow. The lowest bed is the most expensive and the highest bed is the cheapest. The top and middle beds are the most cramped, tall people cannot sit upright in these beds. The Soft Sleeper and Soft Sleeper Deluxe compartments look the same as in high-speed trains (Fabio, 2023)



Figure 28. Hard seat



Figure 29. Soft seat

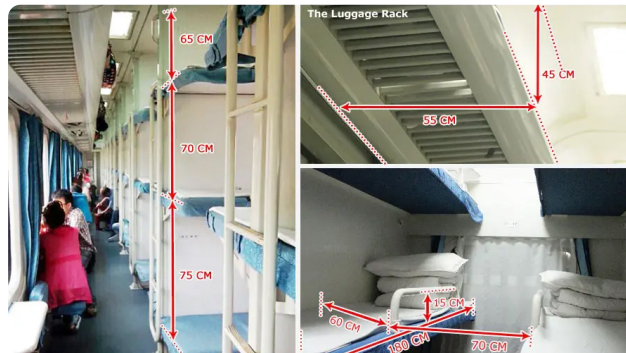


Figure 30. Hard sleeper



Figure 27. Chinese style toilet

Take-aways Context

01) A night train is a train that travels at night, usually with sleeping cars. It allows you to travel while sleeping and it is a more sustainable travel option than travelling by airplane or car.

02) Night trains had been operating since 1830, but were not a great success. In 1865, Pullman introduced a new luxury night train with passenger comfort as main focus. With this train, Pullman made night trains a success.

03) Night trains used to be only for rich people and were very luxuriously furnished. With the rise of equality, more economy options came on the night train. In addition, budget airlines and high-speed train emerged. This made the popularity for night train travel disappear. Now due to people being more aware of the environmental impact of travelling, investments of railway companies and the government, the night train is reviving.

04) There are many different night train operators around the world. The interiors and facilities of night trains in Europe, China and the USA are fairly similar. The different classes consist of seats, couchettes and sleepers, with seats being the cheapest travel option and sleepers the most expensive. The interior seems to have been standardised over the world.

05) The seat coach has a capacity of 66, the couchette has a capacity of 54 and the sleeper of 36 passengers.

06) The comfort level is a very important factor in choosing the night train over an airplane (Heufke Kantelaar et al., 2022).

02
02

Market studies: trends and developments

// 01 Future projection: current trends and developments

// 02 Benchmark: new nightjet

Take aways market studies



01 / Future projection: current trends and developments

This section describes an analysis of current trends and developments in the field of mobile interior design. This analysis has focused on concepts for airplane interiors, as a lot of innovation is taking place in this field and trends in the field of mobility interiors in general.

Comfort & personal space

Concepts are being developed that focus on improving personal space and passenger comfort. This relates to seat design, the design of cabin interior elements such as lighting, smell, temperature etc (Mile, 2023) & (Möller et al., 2023) and hygiene.

Social space

Alongside improvements in personal space, a shift in the design of social spaces can be seen. This relates to group travel areas but also dedicated social areas (Stahl, n.d.) & (Mark, n.d.).

Open cabin

With regard to the spacial perception of the cabin as a whole, a clear shift can be seen towards design that appears light, more spacious, and less cluttered.

The trends are clustered into 5 themes described below, see figure 31 for a visual impression. More information about the trends and cluster process can be found in Appendix 2.

Hybrid interior

A clear focus can be seen on the design of hybrid interiors. This relates to modules that define a larger space of the interior, as well as smaller interior parts, like seats (IAA Mobility 2021: Automotive Interior Trends of the Future | Accuride, 2021) & (Mark, n.d.). This shift can be explained by the desire to optimise the interior for the type of travel, by wanting to offer different quantities of seats number and by creating a possibility for passengers to choose different areas.

Integration of technology

Furthermore, it can be seen that more technology and electronics is integrated in interior concepts (Stahl, n.d.). Electronics will be integrated into the surfaces of the cabin and seats and speech may become the main input in vehicles (Möller et al., 2021).

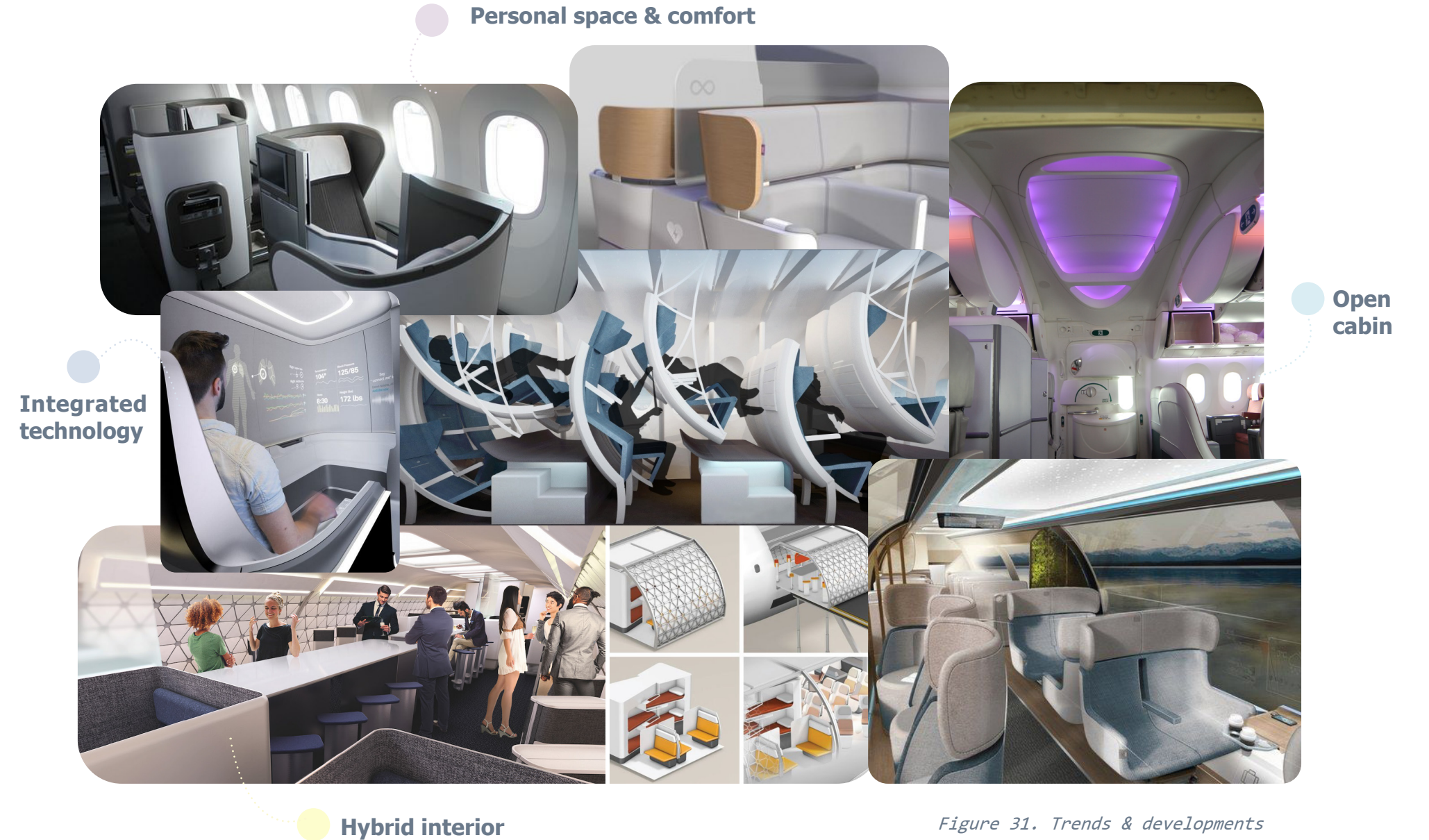


Figure 31. Trends & developments

02 / Benchmark: new Nightjet

This section describes a the interior improvements of the new Nightjet from the Austrian night train operator ÖBB. See figure 32 for a visual impression.

The new Nightjets consist of two seating, three couchette and two sleeping coaches. The maximum capacity is 254 passengers per train. The new interior design accommodate guests' wish for greater privacy by reducing the occupancy.

All compartments have their own toilets and showers. The fixed beds increase sleeping comfort and a cozy seating area allows passengers to relax, work, read or eat during the trip. New mini cabins are implemented which provide everything you need for undisturbed nighttime travel. Also the transport options of the train are improved by creating more space for bicycle parking spaces, more luggage and ski or snowboard equipment space.

Furthermore, technical improvements have been made. New features on board include free WiFi, a ÖBB Railnet portal will provide movies, shows and magazines. A modern information system is integrated which provides up to date information about their journey. Also conventional power outlets are implementend and a control panel with various convenience functions such as light control options and the possibility to call onboard staff are implemented in each compartment. Finally, the compartments are equipped with an electronic access system that makes use of NFC cards, and all cars have video surveillance to help passengers feel even safer (ÖBB and Siemens Mobility present the interior design..., n.d.).



Figure 32. New Nightjet

Take-aways

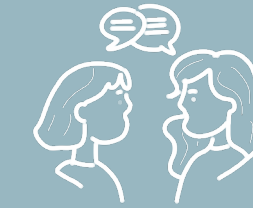
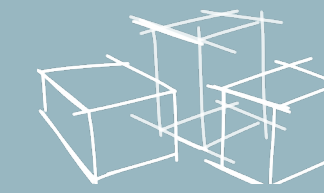
Market research

A couple of themes emerged from the analysis towards future vehicle interior concepts. These are described on the next page.

In addition, the benchmark of ÖBB's new Nightjet shows that the focus in new night train designs is very much on improving the passengers privacy and security experience.

Capacity benchmark & Hybrid interiors

A clear focus can be seen on the design of flexible and modular interiors. This shift can be explained by the desire to optimise the interior for long or short travels and to meet different capacity needs.



Social interiors

In addition to individual comfort, the comfort of group travellers is increasingly taken into account. To facilitate social interaction, group seating and social areas are being integrated into vehicles.

Personal space and comfort

Concepts are being introduced that focus on improving individual passengers' personal space and comfort.



Integration of technology

The integration of technology with regard to material use and assembly is becoming increasingly important.

Open Cabin

A clear shift in the design of the interior can be seen towards spaces that appear light and decluttered. Here, open compositions, lighting and materials are used that create the feeling of a more open cabin environment.



Passenger studies: opportunities to improve

// 01 Comfort in night trains

// 02 Types of travellers and travel choices

// 03 Group size and seat preference (regional train)

// 04 Sleep comfort in vehicles

// 05 Passenger experience research on comfort (survey - research elective)

// 06 Passenger experience research on comfort (interviews)

Take aways passenger studies

01 / Comfort in night trains

Travel time, cost and reliability of travel time are the main parameters influencing transport choice. However, factors such as convenience, comfort, quality of service and safety also deserve additional attention. Insights on comfort in night trains from Heufke Kantelaar et al. (2022) are as follows: comfort levels vary by travel class. It is argued that the perceived comfort of night trains is most influenced by the privacy of accommodation. Travellers do not like to share their surroundings with people they do not know. For highly educated people, this applies more strongly. In addition, the study showed that a night train with only basic facilities (i.e. no shower, no food/drink) but with private compartments (for 2 people) was rated as more comfortable than a night train with these facilities but with shared compartments for 6 people. Furthermore, offering food and drink on board increases comfort, but the form in which this is done (restaurant or kiosk) does not make a big difference. To increase comfort, on-board entertainment during a long journey is essential. Finally, comfort is more important for business travellers than for leisure travellers.

Since there is no study on comfort in night trains besides Heufke Kantelaar's (2022), I conducted a study to fill this research gap. The aim of the study was to find out how to provide night train travellers a comfortable travel experience. This research has collected data on different aspects of passenger comfort, such as seating comfort, environmental factors such as temperature and noise and the perception of privacy.

The key insights from the study and additional literature about comfort in transportation modalities are given in this chapter. For more details, see the research elective report 'Design Considerations for Night Train Passenger Comfort' (Out, 2023).

02 / Types of travellers and travel choices

Travellers make their travel choices based on a number of factors. These can be divided 'hard factors' and 'soft factors'. Hard factors can be quantified such as travel time, money and frequency. 'Soft factors' are qualitative such as, for example, comfort or convenience. In addition, people make travel choices based on what is possible for them. A person had three budgets according to Van Hagen & Exel (2012); money, time and physical/mental effort. People often choose the travel option with the least resistance. This means the option in which they can travel quickly, cheaply and with little effort. Contemporary travel trends are having the opportunity to spend your travel time usefully and creating a travel experience that triggers travellers' emotions (Van Hagen & Exel, 2012).

Travellers can be differentiated based on their experience, travel origin and travel purpose. Especially on travellers' travel purpose, night train operators could respond. 'Must travellers' demand fast and reliable travel and want to experience as few stimuli as possible. 'Lust travellers' mainly travel on night trains. They value ease and comfort of travel and want to be stimulated as much as possible to create a good experience (Van Hagen & Exel, 2012).

Environmental impact is clearly the main reason why people travel by night train. Furthermore, people travel by night train because of the departure and arrival times and the possibility of spending their travel time usefully. Out of 117 people in the survey, there was one person who would never travel by night train. This was because of the perceived comfort of the night train.

03 / Group size & seat preference (regional train)

From a heat map study by NS, using virtual reality, passengers could sit down in different concepts of a digital coupe. It revealed that intuitively people want to sit in the 'safest' place. These safe places are where you are as far away from others as possible, with your back against a wall and shielded from others preferably in a corner.

Passengers sought distance from other travellers but too much distance also turned out not to be ideal, because then they no longer felt secure (NS, n.d.) & (Out, 2023).

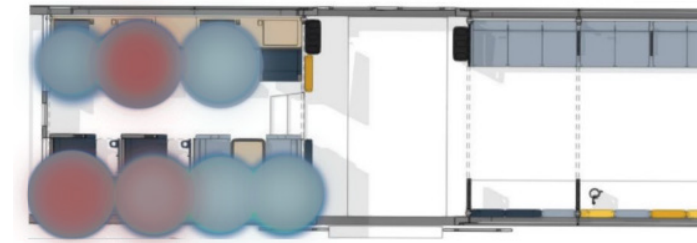
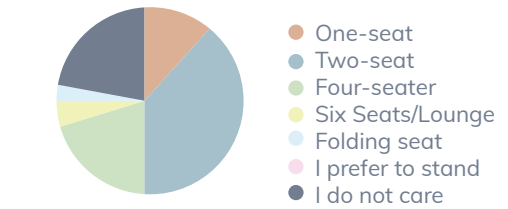


Figure 33. Example of heat map study - first class carriage

Preference seat



Travel company



Preferred seat relative to the driving direction

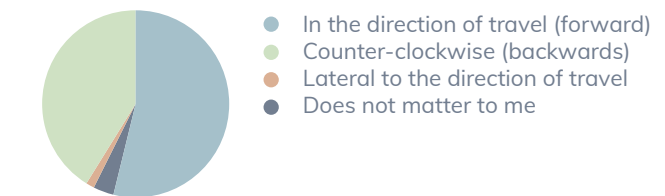


Figure 34. Research group size & seat preference

04 / Sleep comfort in vehicles

The train shows its competitive advantage over flying or driving by car by improving the perceived value of the efficiency of travel. Therefore, sleep comfort and quality on the night train is one of the keys in promoting the shift. A number of studies have been conducted on sleep comfort and sleep quality in vehicles. From these come interesting insights that can influence the interior design of night trains. This section explains the key insights from research on sleep.

Environmental factors

Research from Vledder et al. (2023) on environmental factors in relation to sleep quality and comfort in night trains shows that speed, temperature, humidity, noise and the ergonomics of the seat influence the sleep comfort during a night train trip. Especially, acceleration and sound can harm the sleeping quality. Abrupt changes in some factors, such as shocks or distinctive noises, should be avoided. Research from Caddick et al. (2018) states that all forms of noise in the sleep environment should be recuded to below 35 dB and that the optimal ambient temperature varies based on humidity and the bedding microclimate, ranging between 17 and 28 °C at 40–60% relative humidity. Complete darkness is optimal for sleep and blue light should be avoided during the sleep opportunity. Finally, sea level air quality, with ventilation is optimal for sleep.

Seating position (recline)

Caballero-Bruno et al. (2022) conducted two studies to improve sleep quality while travelling in automated vehicles. They conducted a sleep study and a pressure distribution study using two seat positions, a 60-degree recline and an 87-degree recline. The study found that sleepiness increased in the reclined position, while it decreased in the flat position. Also, the self-reported Wake After Sleep Onset parameter was higher in the reclined position. From the pressure distribution, it was possible to extract where the seat provided insufficient support which was related to discomfort. The passengers experienced a more fluctuating sleep timeline with more awakening episodes and less uniform sleep appearance in the reclined 60 degree seating position. This showed that the flat seat position was the most comfortable and effective to sleep in for in motion vehicles.

The areas where passengers felt the most discomfort were the head/neck and legs/feet areas, and the feeling of discomfort became worse over time. This is consistent with the research by Smulders et al (2019) and Zhang et al (2021) who state that the feeling of discomfort is due to the instability of the head during the ride due to vehicle movements and vibrations. Keeping your head balanced requires a lot of activity from the neck muscles and the feeling of discomfort comes from the fatigue of the neck muscles.

What was striking from this study is that 67% (10 out of 15 participants) of the women of this study prefered the reclined position while 72% (18 out of 25 participants) of the men preferred the flat position.

Sleeping quality and comfort in a minimal space

Sleeping facilities in vehicles often have limited space for economic and/or operational reasons. Smulders and Vink (2021) investigated the influence of a 2D minimum space envelope on sleep quality, sleep effectiveness and (un)comfort. They had 41 participants sleep in three different conditions: their normal bed space, in a confined space (170 x 70 cm), and in a participant-designed minimal space. This showed that sleep quality and sleep effectiveness were rated worst in the confined space, which offered 30% less space than an average single bed. However, no significant difference in sleep quality and sleep efficiency was found between the participant's own bed and the minimal space designed by the participant, although the space was reduced by 25% on average. This means that adjusting the dimensions of the reduced sleep space can increase sleep quality, sleep efficiency and comfort.

05 / Passenger experience research on comfort - Survey - Research elective

As mentioned before, a survey on the perception of comfort in night trains was conducted during my research elective. In total there were 117 respondents on the survey. The most important take aways for the design of a day and night train interior are given in figure 35 and table 1. For more information I refer to my research elective report.

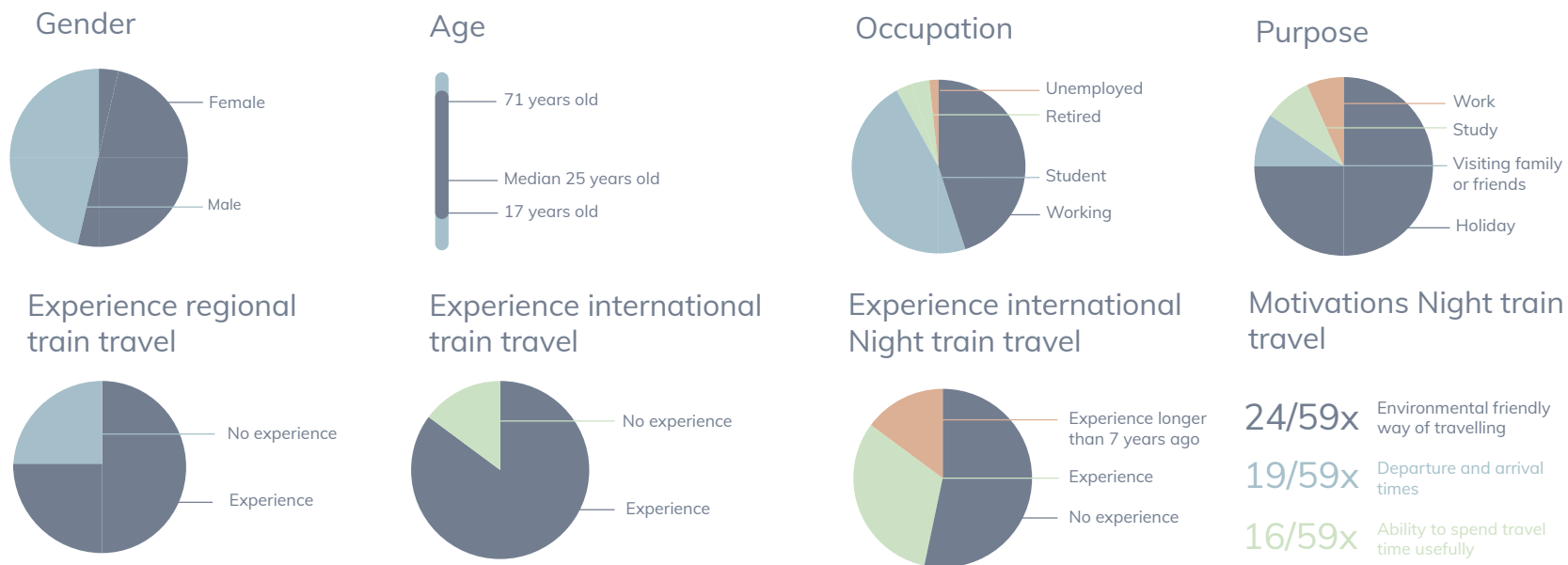


Figure 35. Results survey (Out, 2023)

Environment	Seat	Privacy
Comfort level is most important determinant for choosing an aircraft or night train (Heufke Kantelaar et al., 2022).	Seat most important for comfort (Bouwens, 2018), (Out, 2023).	Comfort level mostly influenced by privacy (Heufke Kantelaar et al., 2022).
Comfort levels vary by travel class (Heufke Kantelaar et al., 2022), (Out, 2023).	Different seat features do not equally contribute to overall comfort but are dependent on specific activities performed in the seat (Bouwens, 2018), (Hemstra-van Mastrigt, 2015) & (Out, 2023).	Privacy at nighttime is more important than at daytime (Out, 2023).
Noise should be minimised (max 35 db) (Vedder et al., 2023), (Meert et al., 2008), (Quehl, 2001) & (Out, 2023).	Working on a laptop requires a well-designed tray table, access to a power outlet, and adequate legroom (Out, 2023).	Importance privacy factors is different during nighttime and daytime travel (Out, 2023).
Vibration should be minimised (Vedder et al., 2023), Vink & Brauer, 2011), (Bouwens, 2018) & (Out, 2023).	Sleeping comfortable entails features such as reclining capability, the ability to lie flat, head support, head side support, and adequate legroom (Out, 2023).	Most important factors nighttime: locked & shielded environment (Out, 2023).
Light colour should be adapted to the activity (Clarkson, 2008) & (Out, 2023).	The use of smartphones or tablets requires considerations such as armrests, power outlets, and USB ports (Out, 2023).	Most important factors daytime: distance to others (Out, 2023), (NS, n.d.).
Temperature and smell should be personalized (Pasut et al., 2013) & (Out, 2023).	Engaging in social interactions calls for sufficient personal space, which encompasses factors like seat pitch, seat width, and armrests (Out, 2023).	Important during daytime & nighttime: smell (Out, 2023).
Ranking environmental factors: Noise followed by temperature as most important. Smell as least important.	Adjustable seat is best to support all postures while performing different activities (Groenesteijn, 2014), (Hemstra-van Mastrigt, 2015) & (Out, 2023).	Control over luggage/ safe stored luggage is very important for creating the feeling of security (Out, 2023).
	Seat elements that need improvement: lie flat, power outlets, bottom cushions, recline function, lumbar support, head support, head side support, legroom and the seat width (Out, 2023).	
	Seat characteristics that need improvement: accessibility, user-friendliness and hygiene (Out, 2023).	
	Seat should be oriented in the direction of travel or counter clockwise (Out, 2023).	

Table 1. Take aways research elective (Out, 2023)

06 / Passenger experience research on comfort - Interviews

During a journey with the night train, passengers experience different positive and negative emotions and different comfort levels. In this section the results from interviews held in the night train are given. The interview was made using the Open Interview Method (Turner, 2010). It was a structured interview with open ended questions and the same questions were asked to all participants. This allowed participants to give as much detailed information as they wished. Follow up questions were asked to get more into detail. The main advantage of using open questions was that participants were able to express their opinions and experiences. In addition to the interview, context observations were also made.

The participants were recruited on the night train itself, since the most important requirement was that they had experience with night train travel.

To map the comfort difference between travel classes, travellers from all 3 classes were interviewed. Figure 36 provides an overview of all participants. In total 8 interviews were conducted, including 2 with passengers from the seating coach, 4 with couchette passengers and 2 with sleeper passengers. Voice recordings were made to make the interview easier to analyse later. Before the interview started, the purpose of the interview was explained and participants were asked to sign a consent form.

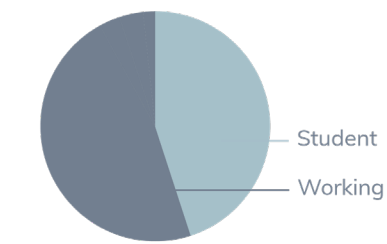
The constant comparison analysis method was used for the data analysis (Leech, 2007). With this analysis the whole dataset can be used to identify underlying themes. The data was grouped by similarity and subsequently themes were identified for clustering. In a later stage of the project these themes will form key drivers for the concept.

Data interviews on Comfort in Night trains
8 participants

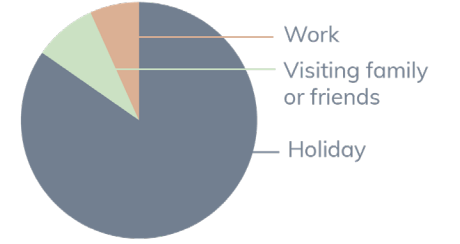
Gender



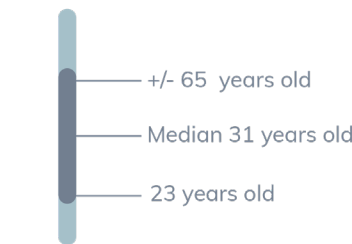
Occupation



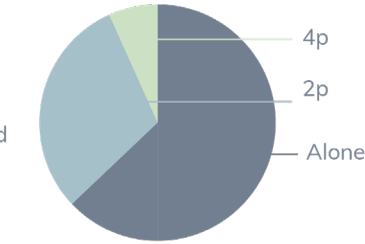
Purpose



Age



Group size



Motivations Night train travel

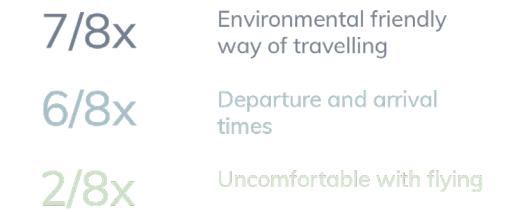


Figure 36. Results interviews (Out, 2023)

Seating carriage

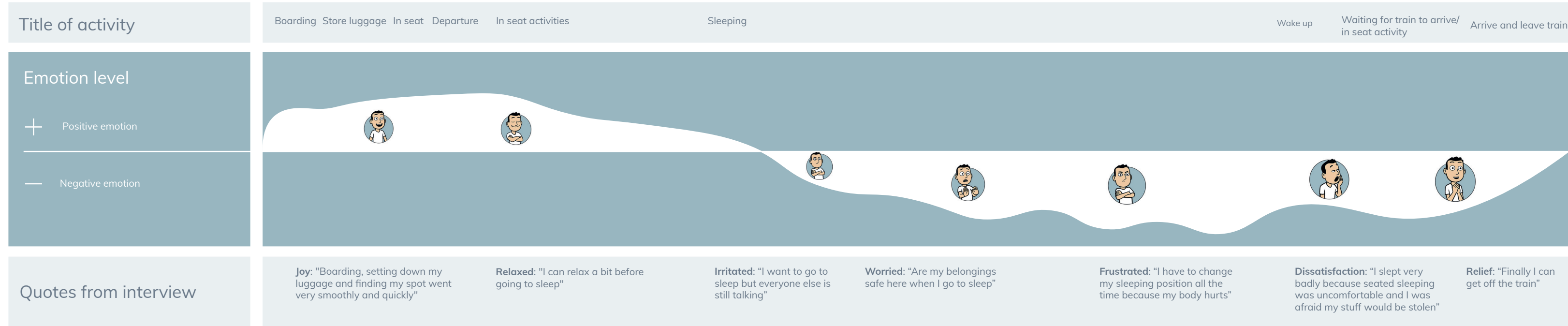


Figure 37. Journey map seating carriage

Seating carriage traveller
 Female
 25 years old
 Travels alone



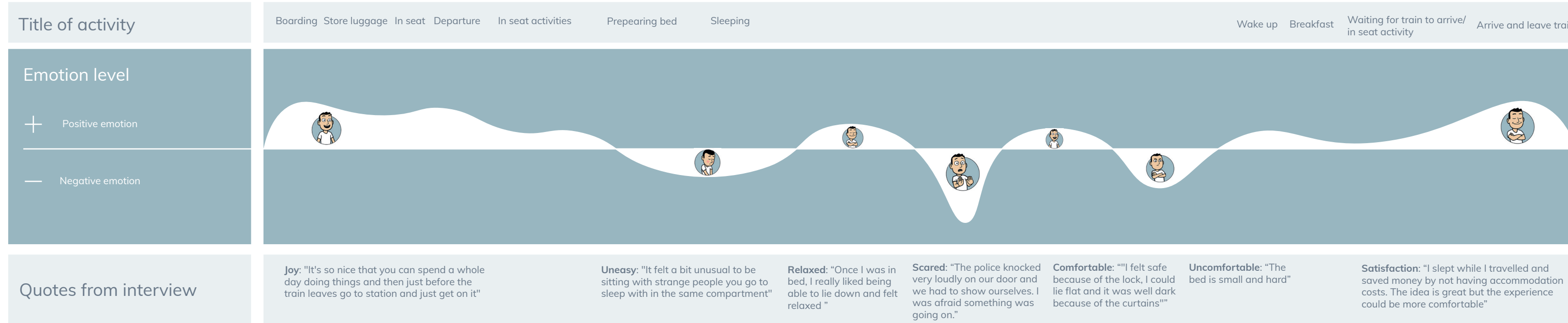
Travels in the seating carriage because the couchette and the sleeper are too expensive.

- No privacy
- Unsafe feeling
- Not lying flat
- Bright light during the night

+ Efficient way of travelling (quick boarding and deboarding)

Comfort rating **4,0**

Couchette



Significant changes in comfort

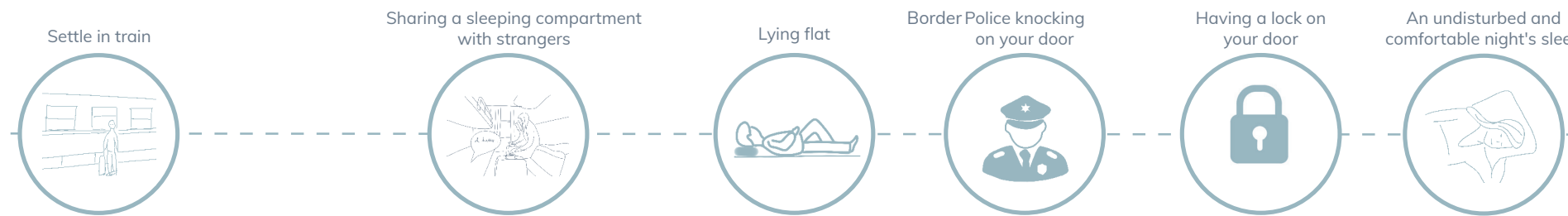


Figure 38. Journey map couchette

Couchette traveller
 Male
 33 years old
 Travels with a friend



Travels in a couchette because he wants to lay flat. Would want to travel in a sleeper but the sleeper is too expensive.

- Small & hard bed
- No full privacy
- Police in the middle of the night
- Old and worn-out interior

- + Lying flat
- + Lock on door
- + Travel while you sleep!
- + Departure & arrival time
- + Hassle free boarding

Comfort rating

7,0

Sleeper

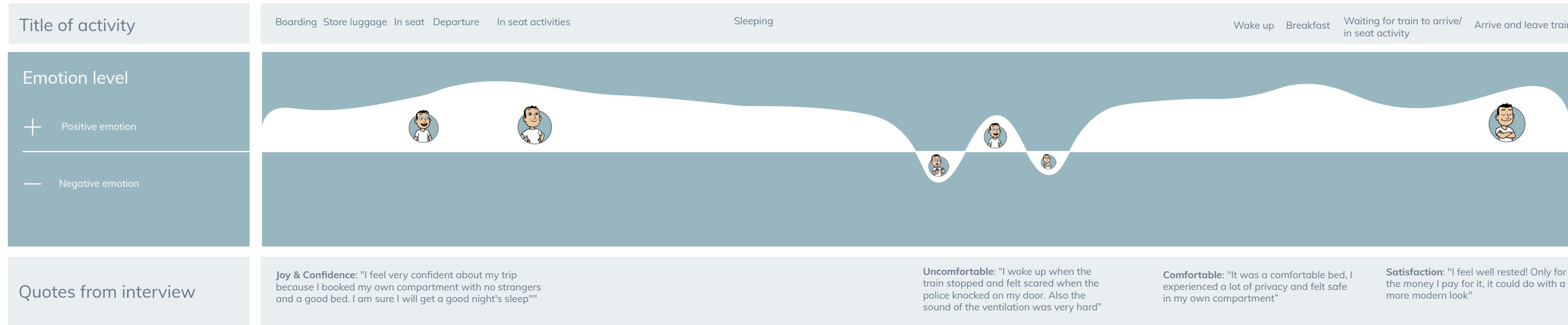


Figure 39. Journey map sleeper

Sleeper traveller
 Female
 43 years old
 Travels alone



Travel in a sleeper because she wants to be sure she will get a good night of sleep.

- No WiFi in the train
- Police in the middle of the night
- Sound of ventilation machine

- + Soft bed
- + Private compartment
- + Place to work
- + Lock on door
- + Breakfast with coffee

Comfort rating

7,8

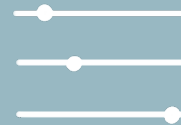
Take-aways

Passenger studies

Based on the literature review, the outcomes of my research elective and the results of the interviews with night train passengers, the following five themes emerged that contribute most to comfort in (night) trains. More information about how the five themes emerged is shown in Appendix 3.

Control

People want to have a sense of control over the journey. This can be in the form of travel updates, seat reservation, certainty about luggage and so on.



Personalisation

People want to feel that the travel is a personal experience. This can be in the form of personalised service but also personalisation within the interior.



Privacy & Personal space

Travellers want to have a sense of privacy while travelling. The feeling of personal space plays an important role in this. The most important privacy factors differ for day and night travel.



Safety

People want a sense of security. This is not about the safety of the means of transport but about the feeling of security in the interior and knowing that your luggage is safe.



Sleeping comfort

For good sleep, lying flat is the most comfortable. In addition, noise level, temperature and vibration have influence on the comfort level and sleep quality.



Interior & floorplan design: what to consider

// 01 Differences night trains and regular trains

// 02 Floorplan differences night trains and regular trains

// 03 Cabin interior - dimensions & geometry

Take aways interior & floorplan design

01 / Differences night trains and regular trains

A regular passenger train differs from a night train in several ways, mainly in its interior design, purpose and schedule.

Schedule

Regular passenger trains usually operate during the day and follow a timetable designed for short to medium distances. They are designed for regular commuting and journeys within a region. Night trains, on the other hand, are designed for long-distance journeys and usually operate at night (surprise). They allow passengers to sleep and are often considered a comfortable and efficient way to travel long distances while sleeping (Night trains | Travel Information | NS, z.d.)(source: own experience).

Interior

In regular passenger trains, there are mainly seats in different classes, such as first class, second class. Passengers usually sit upright during their journey. Night trains have, as already mentioned in chapter 2.1, sleeping accommodations, such as sleeping cars or couchettes, where passengers have beds to sleep in (Hildebrand, 2021)(source: own observations).

Travel time

Regular passenger trains are generally designed for relatively short journeys and offer limited facilities. Night trains are designed to cover longer distances while passengers sleep. They can last an entire night or even several nights, depending on the route (source: own experience).

Service & facilities

Regular passenger trains often offer limited to no services on board, sometimes there is a dining car or a snack bar on board. Night trains may offer more extensive services, such as meal service, toilets and showers, enabling passengers to fresh up before arriving at their destination (Facilities on the train | Travel information | NS, z.d.)(Hildebrand, 2021)(sourc: own experience).

Target group

Regular passenger trains typically target commuters and passengers travelling during the day. Night trains attract passengers who need to travel long distances and prefer to travel sustainable, at night to save time and/ or avoid the cost of hotel accommodation (source: interviews).

02 / Floorplan differences night trains and regular trains

The floor plans of a regular passenger train and an overnight train can differ significantly due to different purposes and interior layouts. Here are some typical differences in floor plans between these two types of trains:

Regular train:

Seats: In a regular passenger train, see figure 40 upper layout, floor plans consist mainly of rows of seats. These seats can be divided into different classes, depending on the train company and route.

Aisles: There are wide aisles between seats to allow passengers easy access to their seats and move around within the train.

Luggage space: Regular passenger trains often have special luggage racks above the seats or at the ends of the carriages to store luggage (Goedkoop treinkaartje, 2019)(source: own observations).

Night train:

Sleeping accommodations: The main feature of a night train is the presence of sleeping accommodations such as sleeping cars or couchettes. These floor plans contain cabins or compartments with beds or bunk beds where passengers can sleep, see figure 40 bottom layout.

Common areas: Besides sleeping cabins, night trains often have common areas, such as corridors with seats where passengers can sit and socialise when not sleeping.

Toilets and showers: Night trains are equipped with toilets and sometimes even showers to allow passengers to freshen up during long journeys.

Privacy: Depending on the type of night train and class, some sleeping cabins may be private while others have shared facilities (Hildebrand, 2021) (source: own observations).

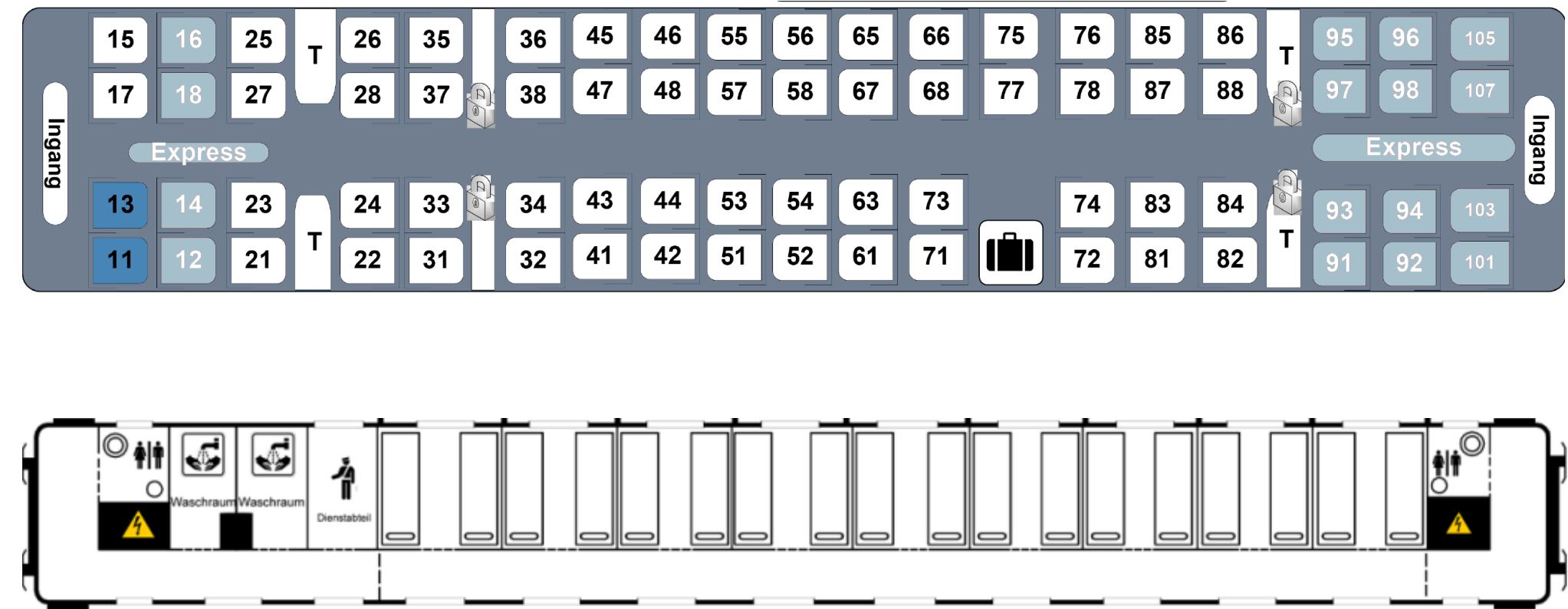


Figure 40. Floorplan 2nd class seating regular train and couchette night train

03 / Cabin interior - dimensions & geometry

When designing a seating concept for a train that runs day and night, it is important to achieve a certain passenger capacity per train coach. The interior dimensions of the train coach are therefore important. For this project, the border profile of the coach type G2 was used because this is an existing international train. The dimensions are shown in figure 41. The train is 3.15 m wide and 4.68m high. However, a 2.20m high ceiling has been assumed. The average length of a coach is 26 metres (How long are all NS trains if you put them on one track back to back?, 2021).

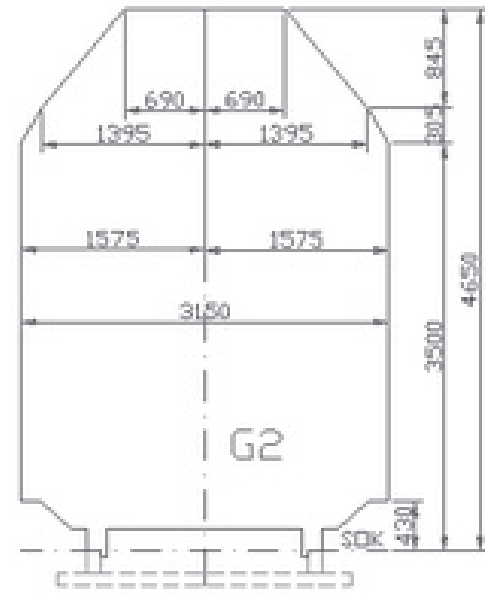


Figure 41. Boarder profile coach (EBA, 2013)

Interior dimensions

The dimensions of train seats vary by seat type (1st and 2nd class) but also by manufacturer. Figure 42 shows the dimensions of Grammar's IC3000 Comfort Seat. This dimensioning will be adhered to.

Bed couchette: 174 - 195 x 66 cm (own measurements)
 Bed sleeper: 183 - 200 x 70 - 75 cm (own measurements)

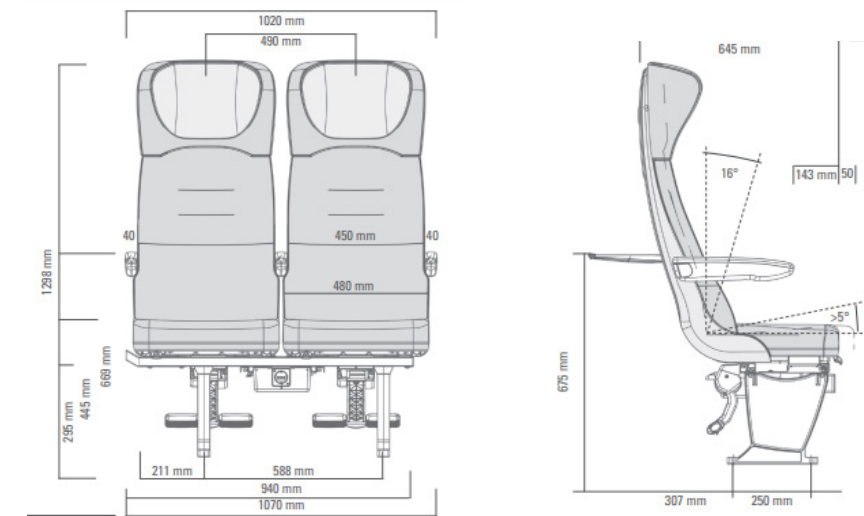


Figure 42. Dimensions Grammar IC3000 Comfort Seat

Take-aways Interior & floorplan design

There are a number of differences between regular passenger trains and night trains. Firstly, regular passenger trains are meant for short/ medium-long journeys and night trains are meant for long journeys. In regular passenger trains, there are only seats and in night trains there are also several options in which passengers can lie flat. In addition, night trains offer more service than regular passenger trains such as meal service and showers. As a result, the floor plan of both trains differs. Finally, the target group and their needs of both types of trains are different. A day and night train must therefore meet both needs.

A train coach is assumed to be 3.150m wide, 2.20m high and 26m long. The dimensions of the seat assumed are shown in figure 42.

03
00

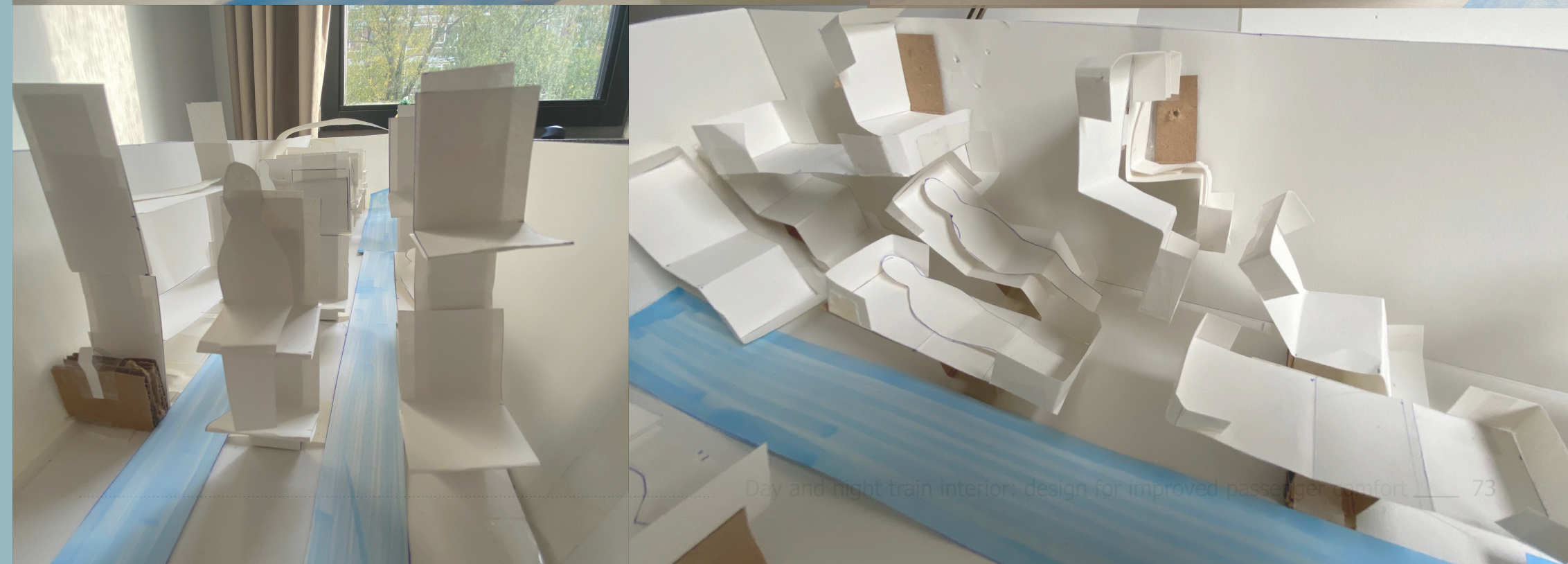
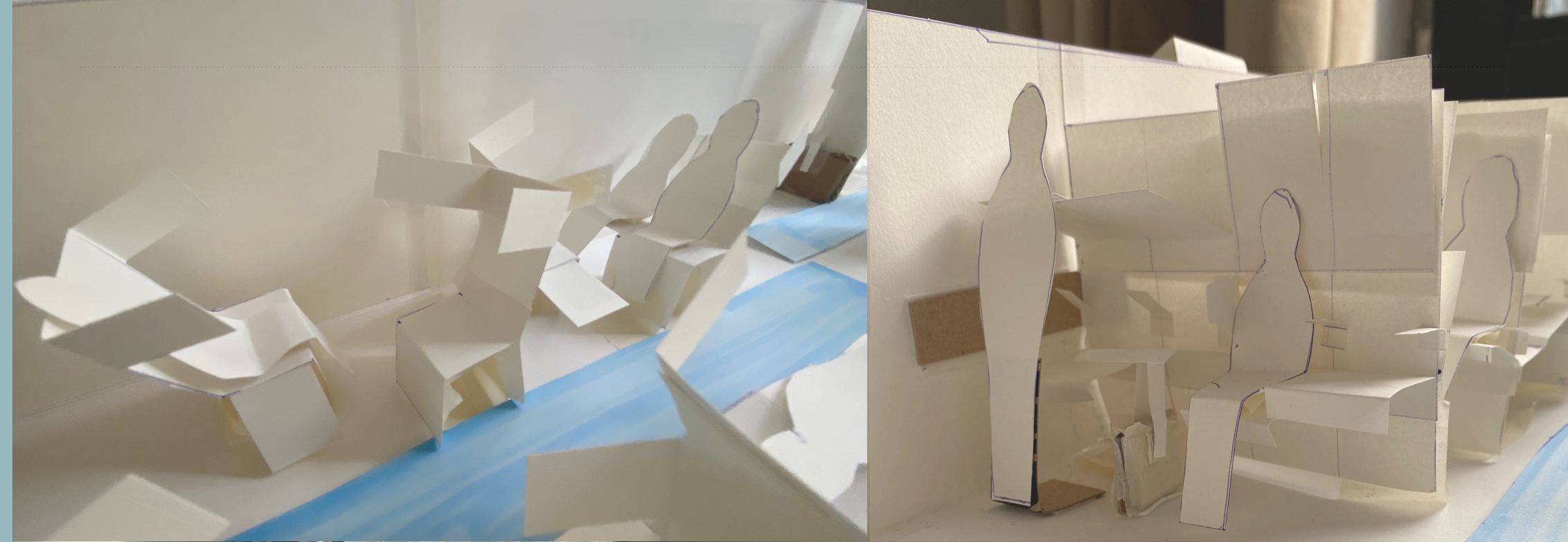
Design directions from vision to design directions

/ 01 Problem definition & design goal

/ 02 Ideation towards concept designs

/ 03 Concept ideas & capacities

/ 04 Concept assessment & choice



03
01

Problem definition

Design goal

// 01 Design scope

// 02 Vision & focus

01 / Design scope

The scope of this project is quite broad. The concept can range from detailed product design to more conceptual solutions and from a seat design to a full train interior design. Before starting the ideation phase, the scope of the project is narrowed down. The focus of this project is on the conceptual design of seats, in which passengers can sit comfortably on during the day and sleep on at night. It also considers how the seats will fill the space in the coach and takes into account space to enter the train, space for an aisle and space for toilets and washing facilities.

In addition, a specific target group was chosen, namely business travellers. This target group was chosen for a number of reasons; first, it is a group that does not currently travel by night train (Out, 2023)(Zijlstra & Rienstra, 2021). Currently, mainly holiday travellers travel by night train. Business travellers could be a suitable target group because

travelling by night train is more sustainable than flying and companies like to present themselves as sustainable to the outside world (Zijlstra & Rienstra, 2021). As night train tickets are unfortunately not (yet) as cheap as air tickets and the company often pays for the tickets, this could be a good solution (Source: interview with expert Thomas SauterServaes). Moreover, the company then does not have to pay for hotel accommodation. In addition, the (night) train has potential to take over a large segment of flying business travellers. More than 50% of business flights to or from Schiphol are shorter than 1,000 km. The night train would therefore be a good replacement for business trips of this distance. The business segment thus accounts for 30% of total passengers which means there is a lot of demand (Zijlstra & Rienstra, 2021). Business travellers mainly travel alone or in pairs, this will have to be taken into account in the proposed concept (CVO, 2018).

02 / Vision & focus

As already mentioned, literature research from Heufke Kantelaar (2022) has shown that the level of comfort the most important determinant for night train travel is and that the level of comfort is mostly influenced by the amount of privacy. In addition, my own research showed that privacy and security are considered more important on (night) trains than on airplanes. In particular, visual and auditory privacy and having a safe space for belongings were proved to be much more important in (night) trains. As my goal is to get more people to choose the train as their means of transport by designing a comfortable interior, the focus will mainly be on creating a feeling of privacy and security.

The definition of privacy is the degree to which a person is able to separate from or connect with other people. Privacy consists visual, olfactory, auditory and kinesthetic aspects (Omgevingspsycholoog, 2021). For a good sense of security, it is especially important that the environment is clear, manageable, predictable and attractive (Beïnvloedbare factoren veiligheidsbeleving, 2023). From the user needs and key drivers, the design vision emerged. This vision serves to guide the design process. It helps in setting goals, setting priorities and making decisions that are in line with the desired end result.

"I envision a new train interior design in which passengers feel comfortable during day and night travel by providing a sense of privacy and security".

Ideation towards concept designs

// 01 Approach

// 02 Ideation: search areas and how-to's

01 / Approach

Based on the design vision, one concept will eventually be developed. Figure 43 shows how this concept came about. Firstly, a brainstorm is performed in the ideation phase. 'How to's' were used to create ideas based on the conclusions from the research phase and by using the floor plan of a coach as the basis. We looked at what is possible within this space. In addition, the brainstorming is done from two perspectives: making a day train more comfortable for night-time travel and making a night train more comfortable for daytime travel. This total ideation yielded over 20 ideas, see Appendix 4. From these, the four most promising ideas were selected based on capacity, adaptability, flexibility, accessibility of the seat/bed, and spaciousness. Finally, these four concept ideas are evaluated on the basis of requirements. The concept that scored best on the evaluation will be developed further.

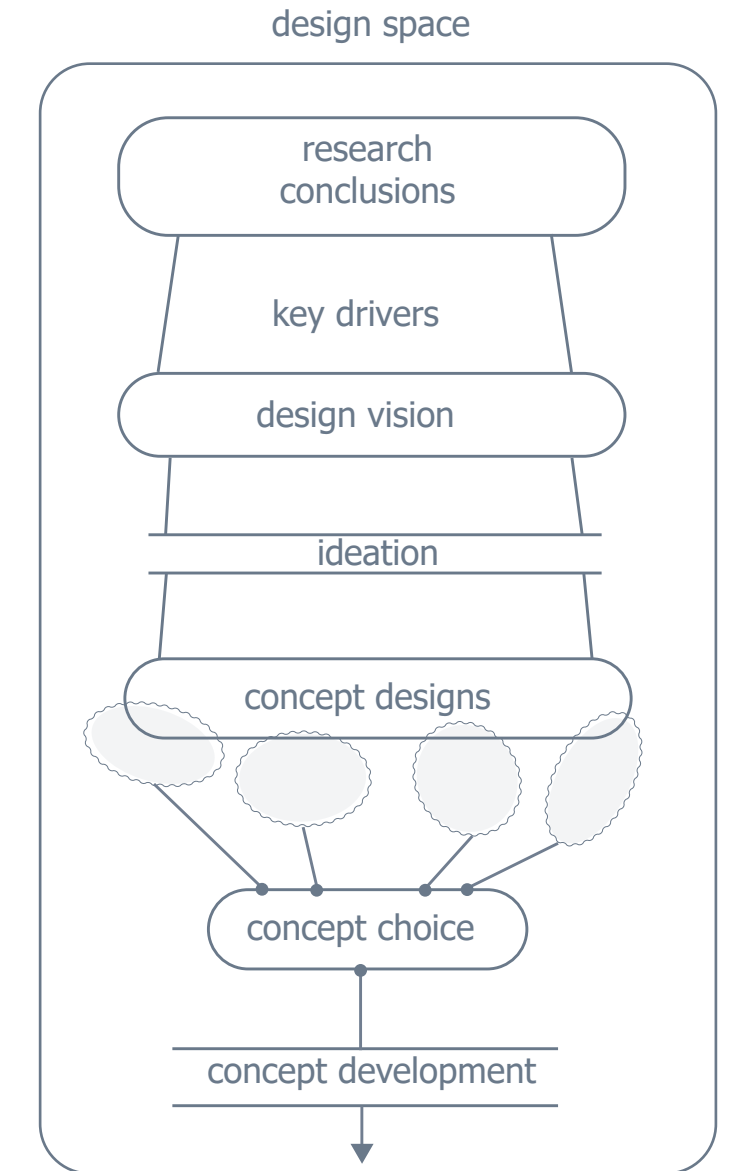


Figure 43. Design approach

02 / Ideation How to's & search areas

The conclusions from the initial research were the starting point for the ideation phase. An overview of the conclusions used can be found in figure 44. Using these conclusions, several solutions and opportunities for layout and interior design elements were ideated using the 'how to' and search area methods (Van Boeijen et al., 2013). Some ideas herein focussed more on overall floorplan design, where others were smaller solutions that could potentially be integrated into the different design directions.

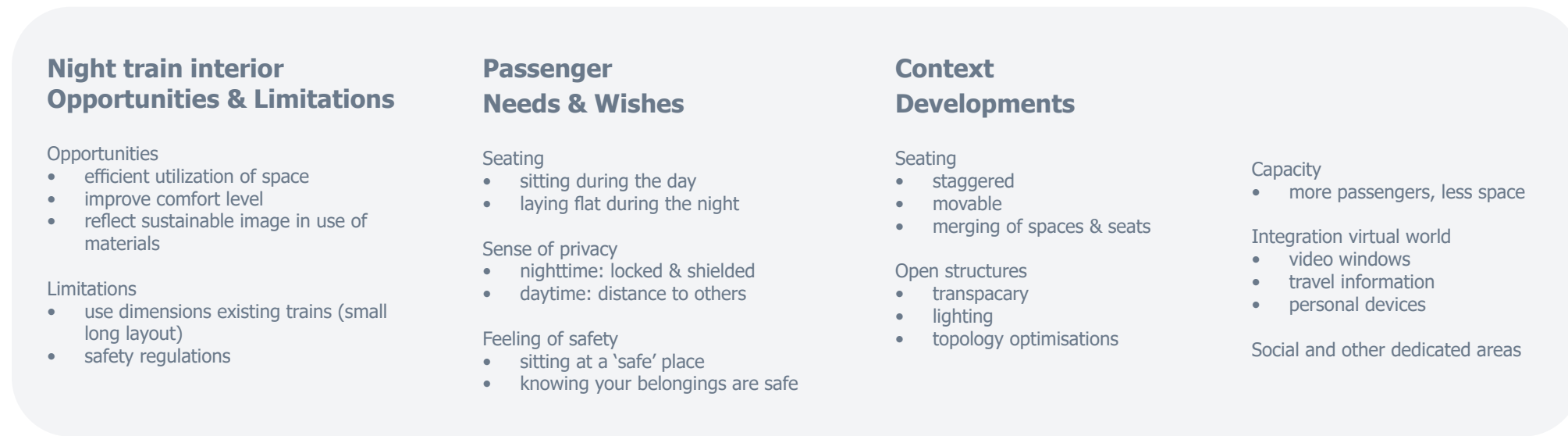


Figure 44. Conclusions research

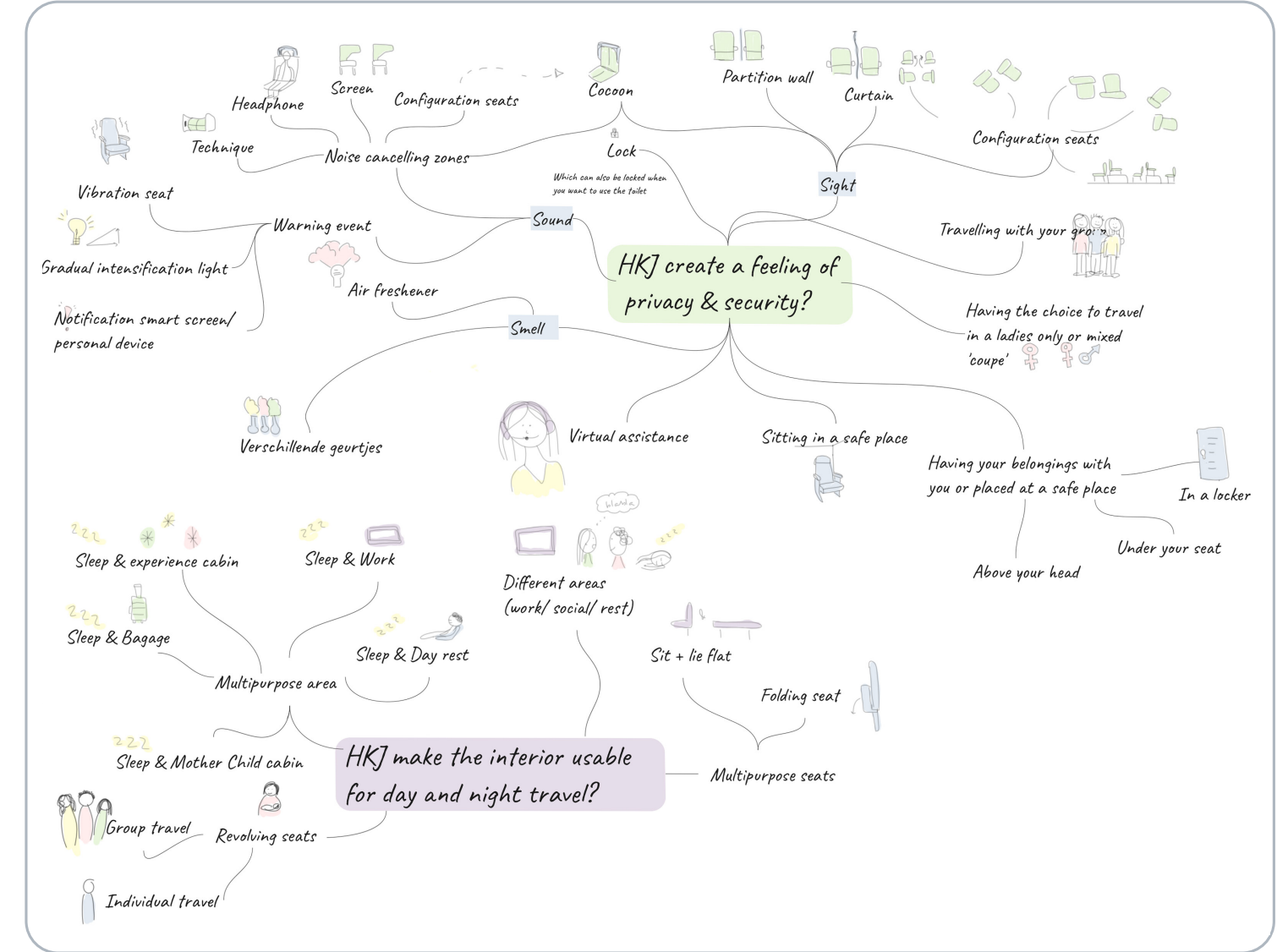


Figure 45. How to's

Table 2 shows different search areas. The table is composed of two axes: the horizontal axis lists external factors. These factors are not about the train itself but, for example, about passengers' wishes or operators' wishes. On the vertical axis, internal factors are listed. These are about the train coach. If interesting ideas arose when an external factor was combined with an internal factor, it is noted as 'search area' at the intersection of the factors the table. The ideas in bold are search areas with potential for further development.

As can be seen from the content of the search areas, some search areas are already real ideas and other search areas are somewhat more requirements on which further brainstorming is needed.

External → Internal ↓	Passengers want to sit during the day and lie flat during the night	Passengers want to sit as far away from others during the day	Passengers want to be shielded from others during the night	Passengers want their luggage to be safe during the night	People want to be informed on events during their travel	Some passengers travel in groups	Passenger do not want to be disturbed by others	Different passengers want to do different activities	Market trend: Less space, more capacity	Train has an environmental friendly image	Passenger want a comfortable ingress and egress	Passengers want to determine themselves when they want to sleep
Empty coach as starting point		Seats on both sides of the carriage	Use partition walls to create little private areas	Create safe spaces for luggage	Smart screens with information	Create group travel options	Improve the feeling of privacy by implementing more shielding options	Create different functional zones	Use all the available space in the coach	Use environmental friendly materials & natural colors		Design something were travellers can transition from day to night themselves
Windows on both sides of the train			Little private areas with window -> gives a feeling of space						Use windows to create a spacial feeling			
Passengers board on one side of the wagon			Sleeping hubs where people do not pass by often	Bagage lockers at entrance	Easy wayfinding in train	Social options at entrance	Make sure people do not get disturbed by others					
Unused height space	Sky lie flat cabins for during the night	Create height differences in the seats	Sky lie flat cabins	Sky bagage lockers	Place a smart screen somewhere high where everyone can see it		Silent sky cabins		Use the height in a functional way	Place plants or green art in the height		
High passenger capacity per coach	Make seat usable for both sitting and sleeping	Place the seats in different directions/ staggered to create a feeling of privacy	Keep open space during the day and create personal space during the night	Bagage lockers under seat/ above the seats		Create group areas	Use zones to create feeling of privacy				Use foldout seats to create space or use them as seats	

Table 2. Search areas

Concept directions

// 01 Concept directions

// 02 Capacities

01 / Concept direction

Each concept idea resulting from the ideation phase explores different opportunities for creating a train interior that is suitable for daytime and nighttime travel. The following pages explain the four concept designs resulting from the ideation phase (figure 46 - 49).

02 / Capacities

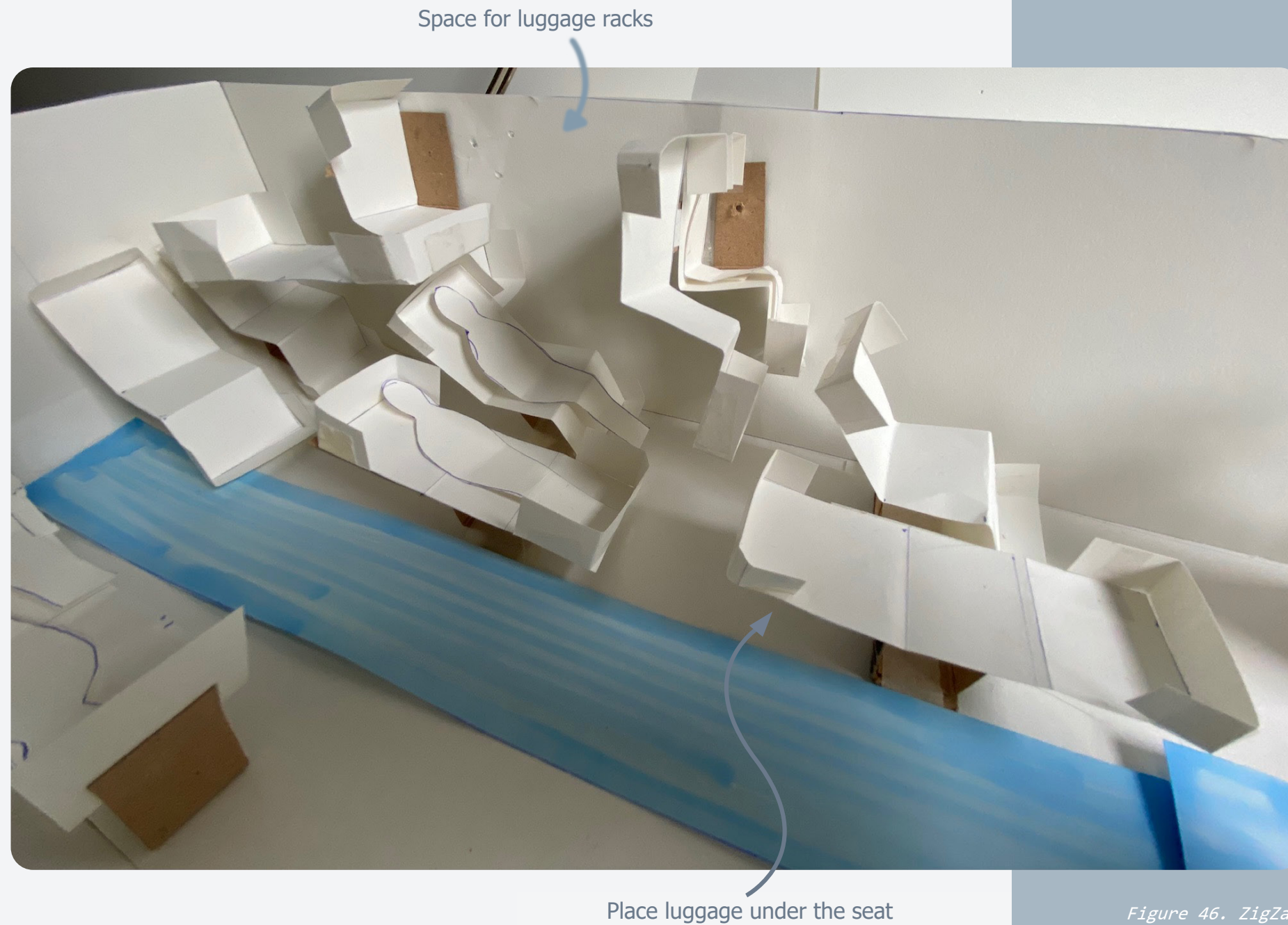
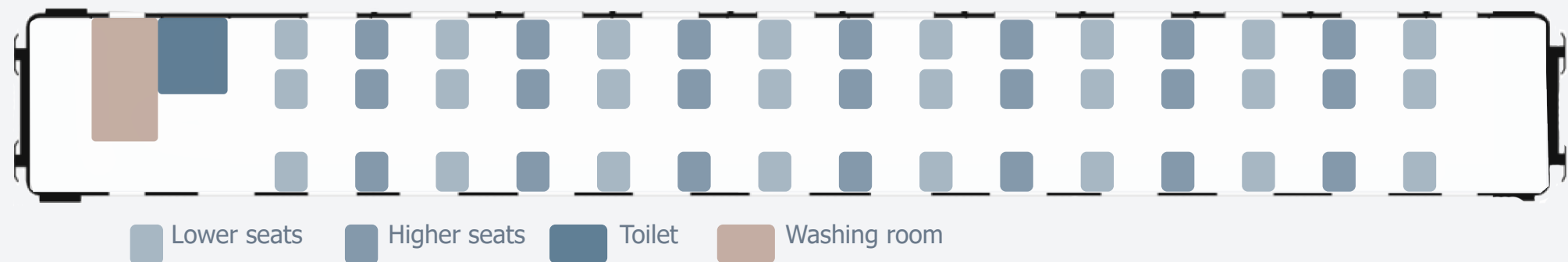
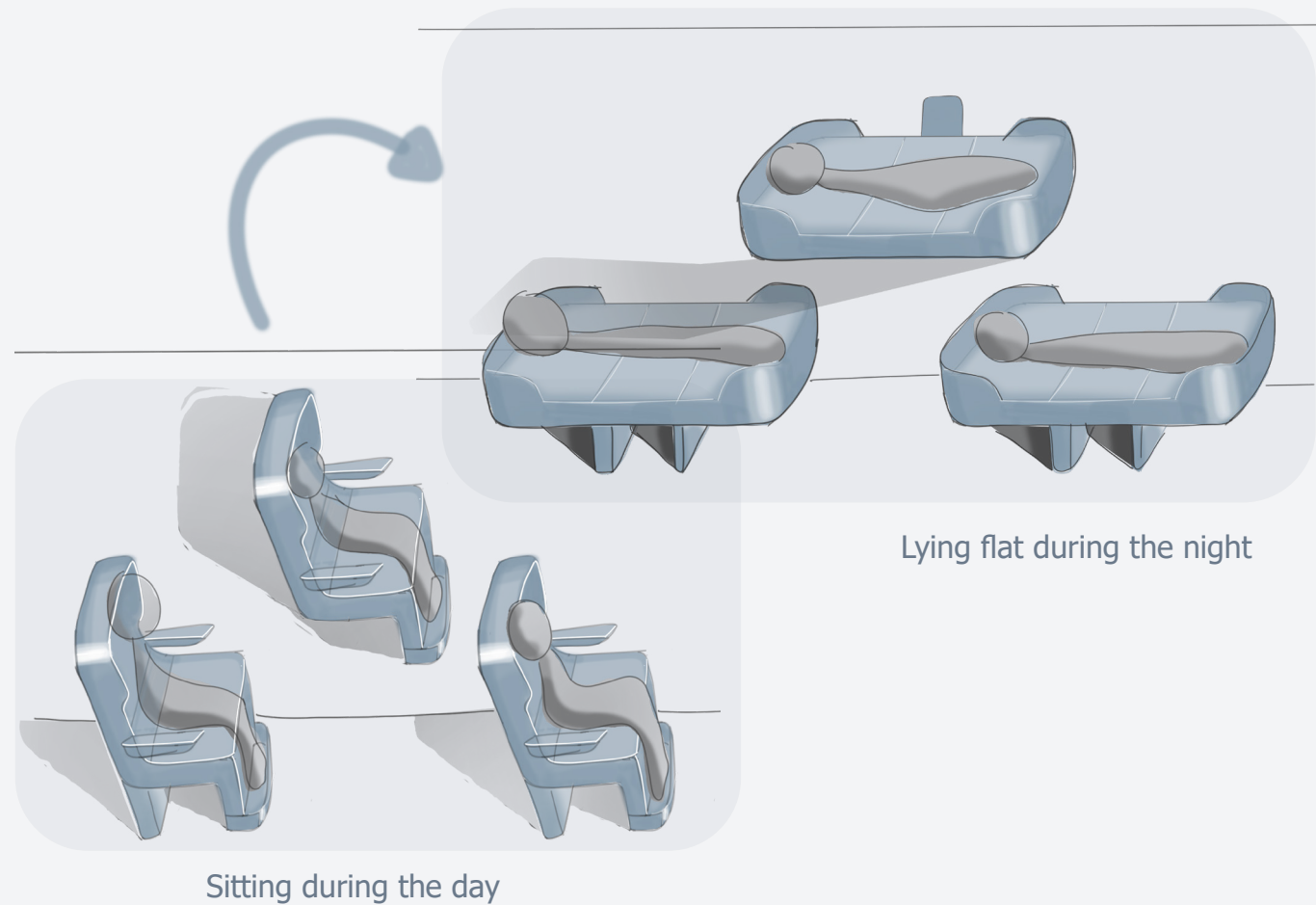
Capacity was calculated for each of the proposed design directions. These values can be found on the following pages. As a guideline, at least 36 passengers should fit on a train given that this is the lowest capacity per coach in current night trains. In all concepts, this number was met. However, a coach with a G2 boundary profile was assumed. As capacity depends on the dimensions of the coach, the amount passengers will vary per coach/operator.

For now, it is assumed that there will be 1 washroom and 1 toilet per coach. An airplane offers 1 toilet per 65 passengers. 2 of the 4 concepts meet this rule of thumb. The other two meet this rule of thumb only during the night, when the capacity is lower. However, the minimum capacity in all four concepts is more than 36 passengers per coach, meaning the capacity could also be reduced to make more room for sanitary facilities.

ZigZag

This concept consists of a 2 seats -aisle-1 seat arrangement. The seats are staggered in height to save space.

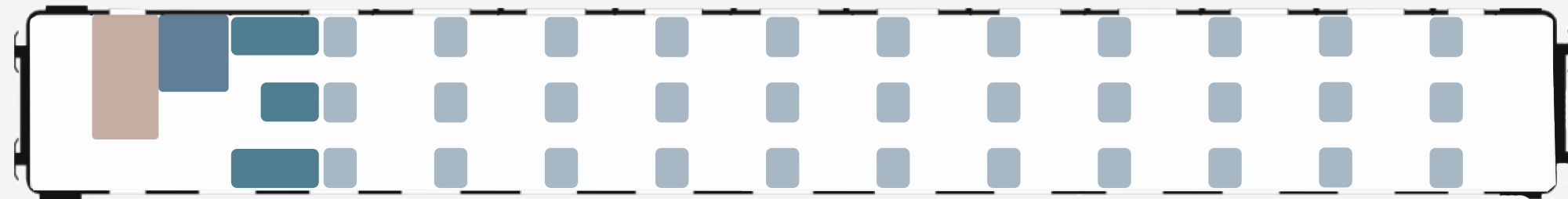
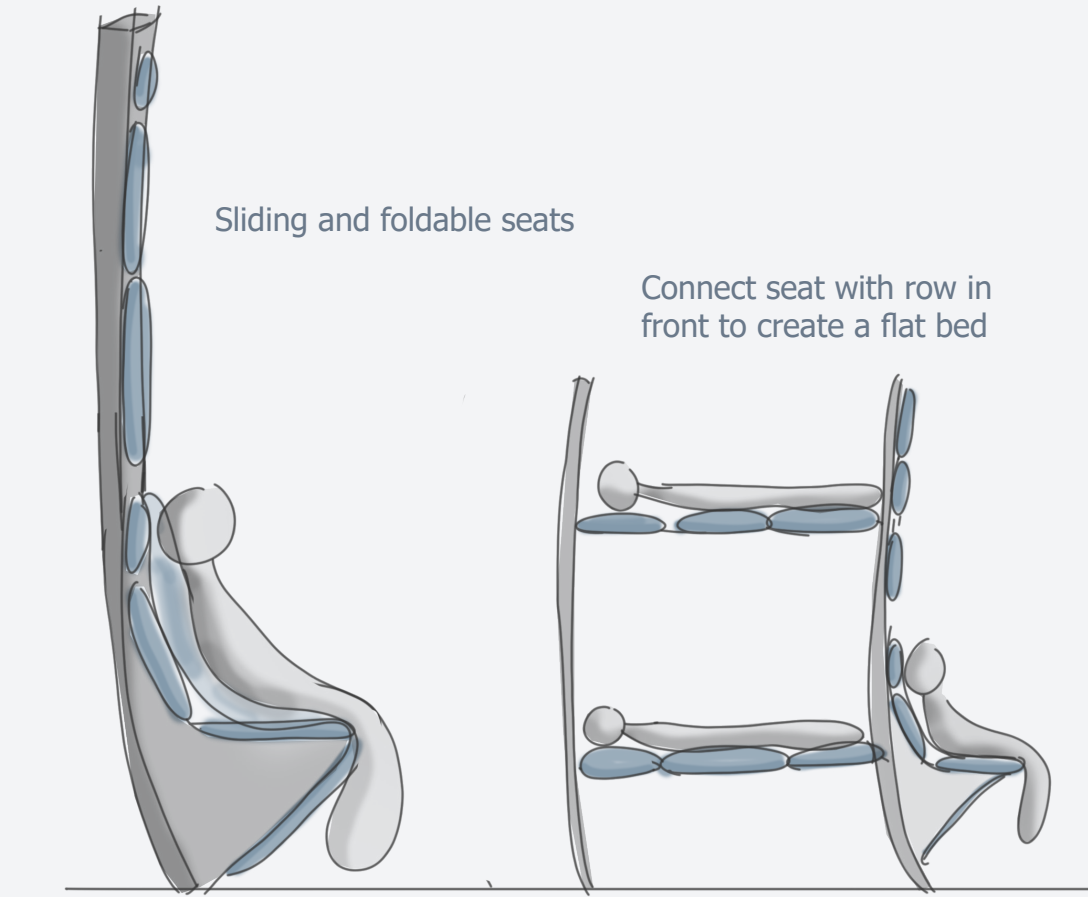
Passengers can sit and lie down in the seat. The seats include privacy screening at the head and a 'foot tray' where passengers can place their feet. On the side of the higher seats, there will be a small step so that passengers can easily reach the higher seats.



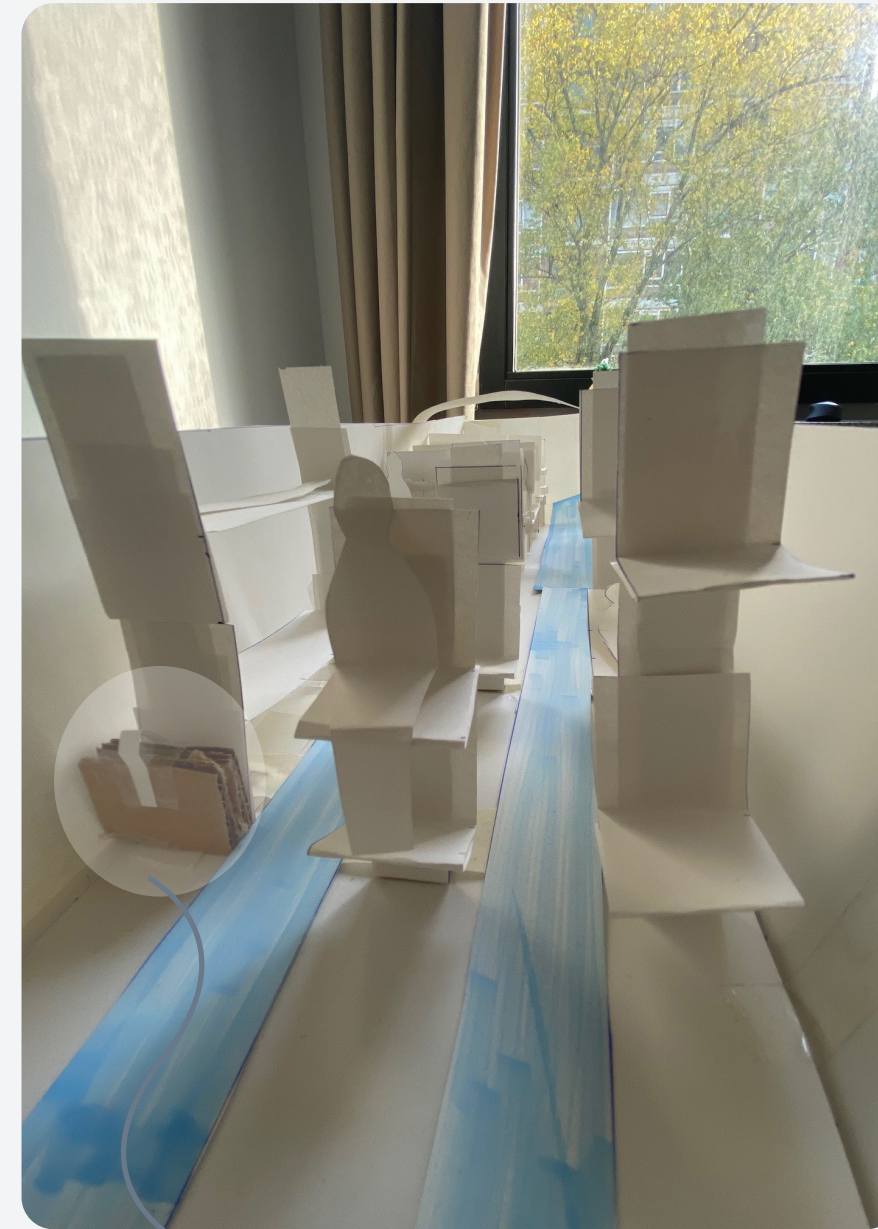
Sliding Seats

This concept consists of three rows with two seats one above the other.

The seats can be completely folded to make room to stand or put luggage, the seats can be partially unfolded to sit on and the seats can be completely unfolded and connected to the row in front to create a flat bed.



Luggage lockers
 Lower & higher seats
 Toilet
 Washing room



Fold the seats in to create luggage space or place it under the seat

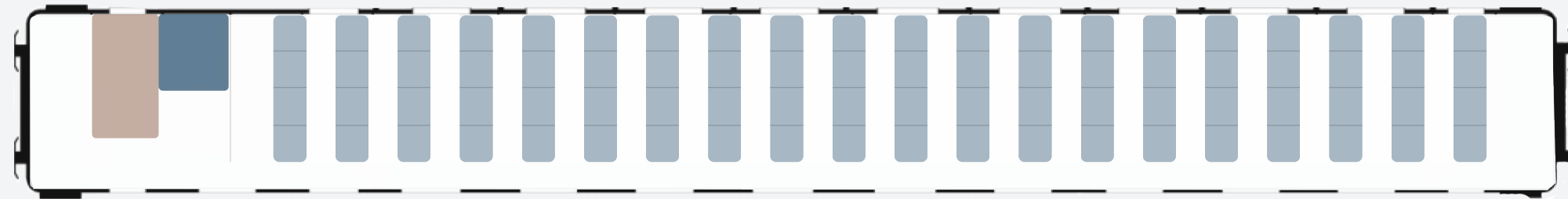
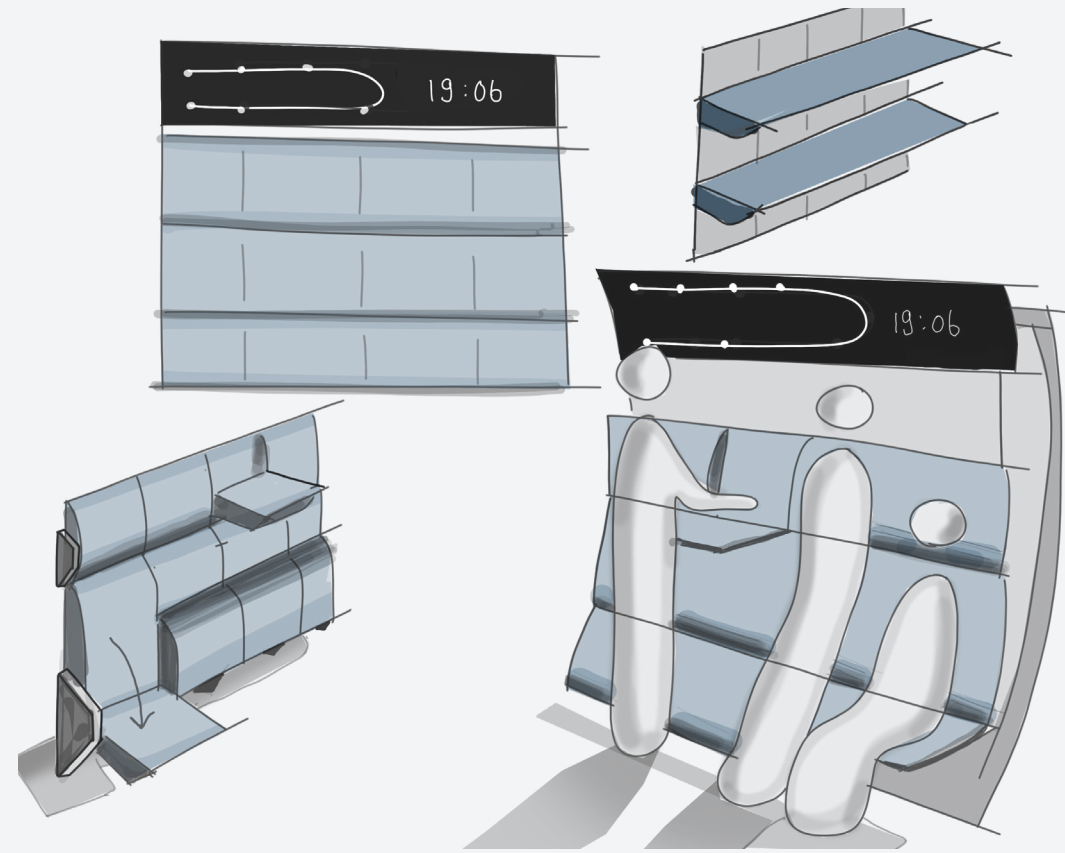


Figure 47. Sliding Seats

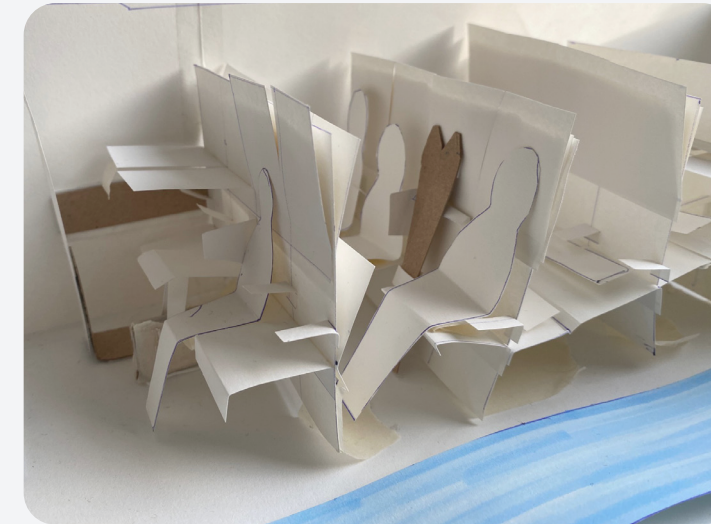
Flexible Foldouts

This concept consists of a row of four seats with an aisle next to it.

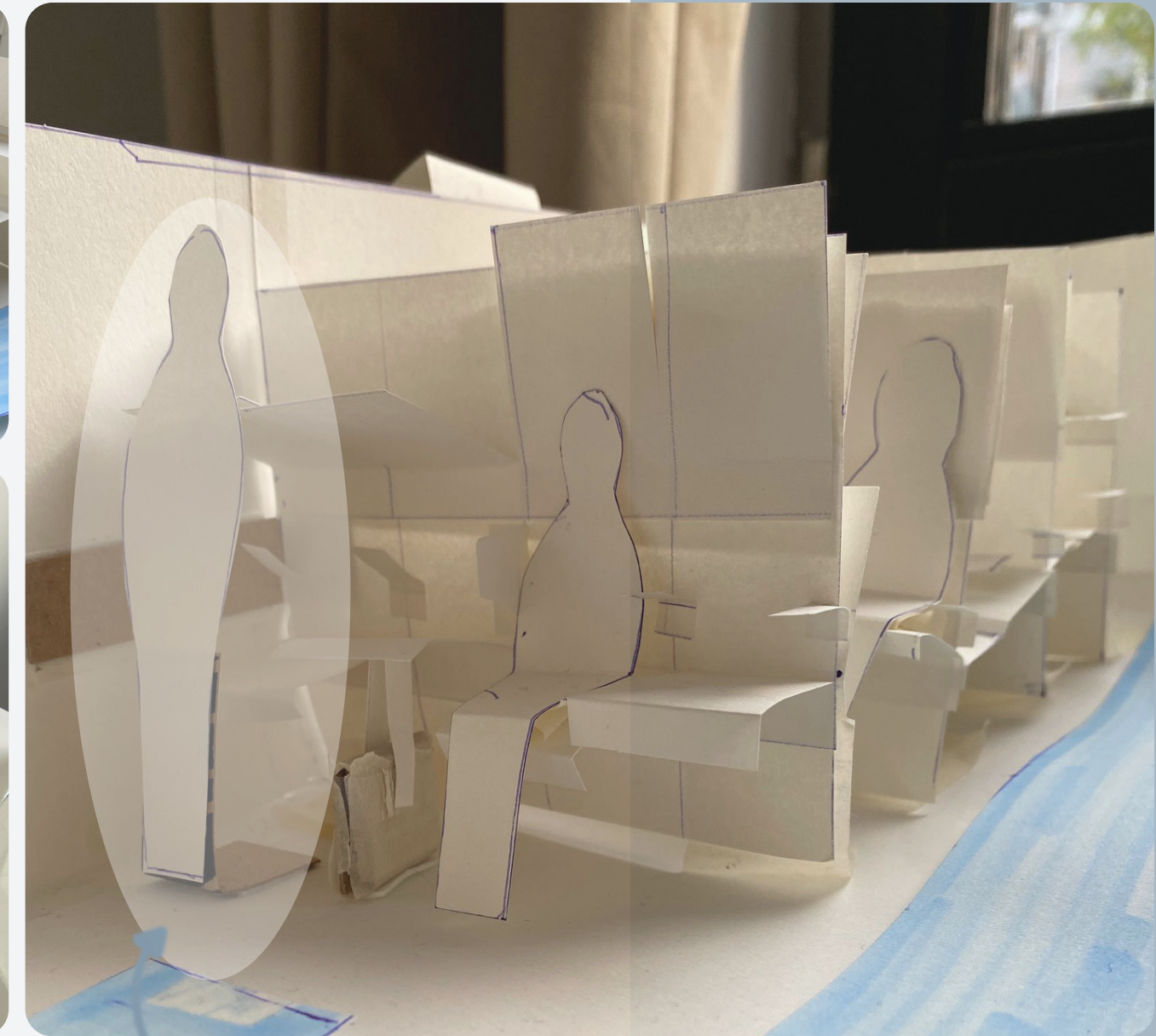
The seats are folding seats that can be folded to make room to stand or to place luggage. The headrest can also be folded out, allowing people work standing up.



Lower & higher seats
 Toilet
 Washing room



Double bed
 Luggage space
 Single bed

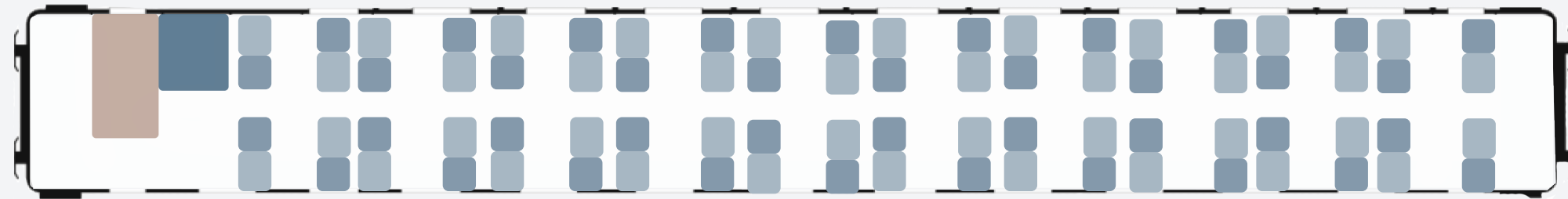
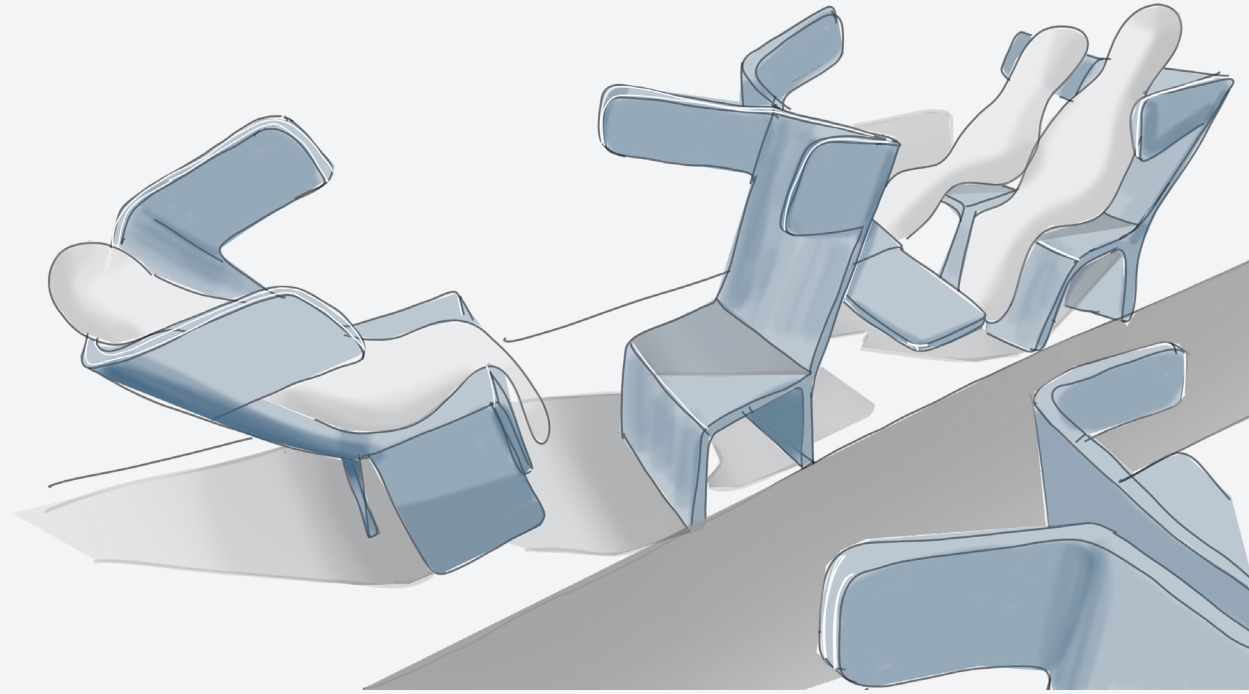


Standing work place

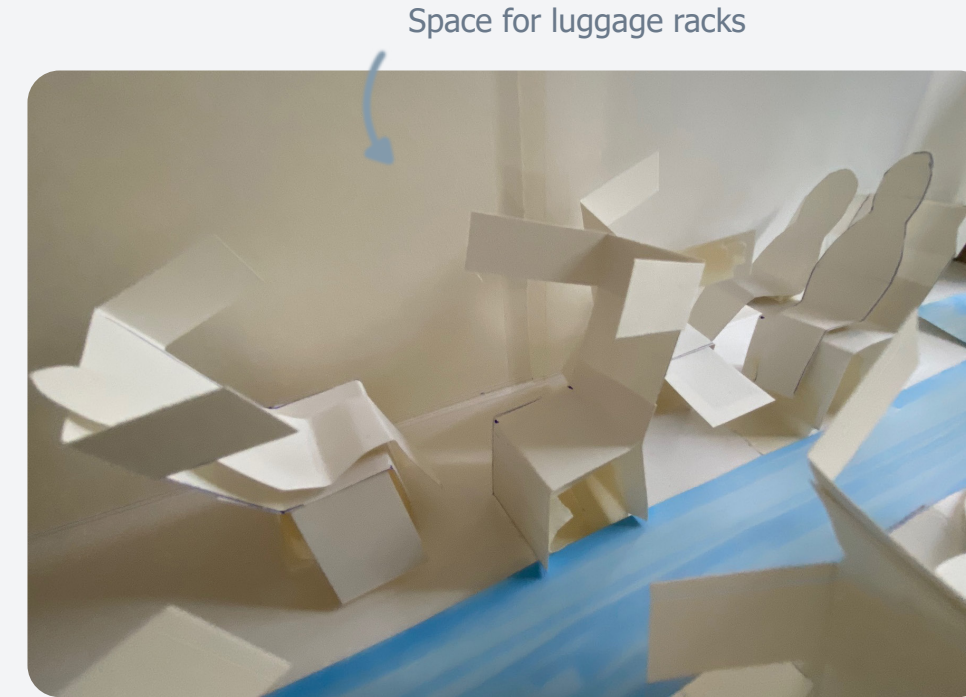
Figure 48. Flexible Foldouts

Opposite Occupation

This concept consists of a 2 seats - aisle - 2 seats configuration. The seats face each other diagonally. The seats have a headrest with privacy screens. On the side of the seats is a folding seat. These can be folded out to create a four-seater. This could be used during rush hour or when people are travelling in a group. The headrest of the 'normal' seat folds out which will provide the person on the folding seat head support.



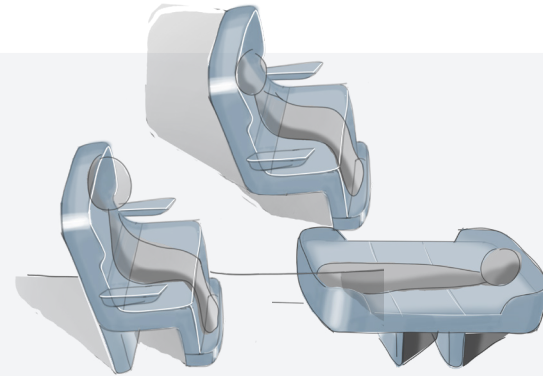
Seats
 Folding seats
 Toilet
 Washing room



Foldable seat and headrest

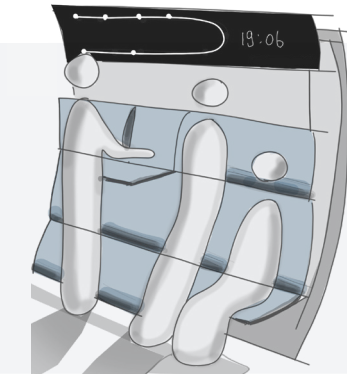
ZigZag

Capacity seating & lying = 45 passengers



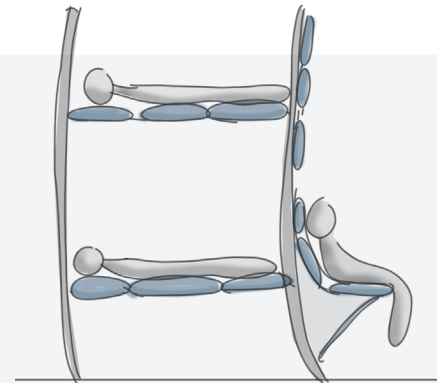
Flexible Foldouts

Capacity seating = 80 passengers
Capacity lying = 40 - 80 passengers (depending on use of double beds)



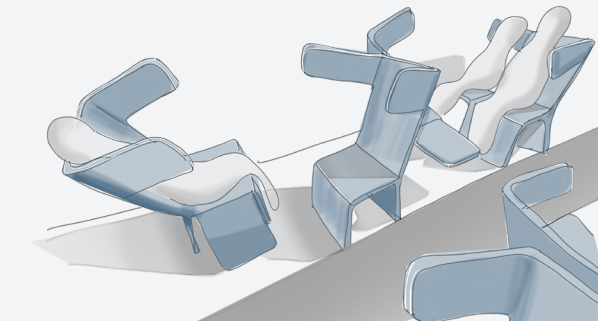
Sliding Seats

Capacity seating = 66 passengers
Capacity lying = 60 passengers



Opposite Occupation

Capacity seating = 80 passengers
Capacity lying = 40 passengers



03

04

Concept direction assessment and choice

// 01 Approach

// 02 Criteria

// 03 Conclusion & concept direction choice

01 / Approach

In order to choose the most suitable direction, an assessment method was used. This 'traffic light' method uses red, green and yellow markers to assess different aspects of the concept. Each colour indicating the following:

- Red – project killer: the problem is very difficult to solve.
- Yellow – needs adjustment: there is an attainable way to solve the problem.
- Green – solved: problem is solved in the proposed design.

For a concept direction to be valid, all points need to be marked green. This way, for each proposed design direction, a clear overview is created of which criteria need to be prioritised to make the concept work. Additionally, the overview can be used to indicate which directions are closer to being valid, and which need more development. In this case the assessment criteria contained 20

requirements, in addition to 2 wishes. The requirements were used to filter out which design direction would not work, or which direction would require substantial further development to become valid. The wishes were then used to determine which direction or combination thereof would be most interesting to develop further.

02 / Criteria

Based on previous research, several assessment points were defined. These criteria are divided into five categories: improving passenger comfort, crew comfort and concerns, capacity and margin, production and development, and safety and regulations. These assessment criteria can be found in Table 3 along with a description of each of these criteria. The criteria with a green background are considered wishes. The criteria with a star are not yet measurable in the concept direction so far.

Improving passenger comfort

Daytime travel	Seating	Passengers want to travel seated during the day. The seating position should have a backrest angle between 115-120 degrees. Legroom should be more than 60 cm. Passenger should be able to work on a traytable.* Passengers should be able to charge electronic devices.*
	Privacy	Passengers want to sit as far away from others. Passengers do not want to smell others.*
Nighttime travel	Lying flat	Passengers can lie flat during the night.
	Privacy Safely stored luggage	Passenger are able to shield themselves from others. Passengers want their luggage to be safe (locked) during the night.
Both daytime & nighttime travel	Space	The cabin has an open and spacious design.
	Noise	The noise level should be minimised.*
	Light	Light color and strength should be able to be personalised.*
	Temperature	Temperature should be able to be personalised.*
Crew seating	Seat	The seat should be (easily) adaptable.* The seat should be easy to clean.* The seat should stand in the direction of travel or counterclockwise.
	Groupsize	Passengers should be able to travel alone, in pairs and in a group of four.
Transition day - night		There should be enough space for crew seating without compromising the required minimum capacity. Passengers can make the transition from day position (sitting) to night position (lying) by themselves.

Development	The concept should contain as few mechanisms as possible (also for maintenance). The concept should contain as few elements as possible (also for maintenance). The concept should consist of existing elements.
Development timescope	The concept should be able to be developed within 18 months.
Target group	The target group for the design will be business travellers
Emergency routes	The location of the emergency exits are clear and can be sufficiently accessed.
Aisle width	The aisle width is between 60 and 80 cm wide. Preferably, the aisle width is as wide as possible.
Accessibility seat	It should be easy to get in and out of the seat.
Minimum capacity	For both nighttime travel is the minimum capacity around 36 passengers per coach. Preferably is the capacity is as high as possible as long as it does not compromise on passenger comfort.
Adaptability	The capacity is adaptable to the need (peak hours, week vs weekend travel).

Production & development

Safety & regulations

Capacity & margins

Table 3. Assesment criteria

03 / Conclusion & concept direction choice

As can be seen in table 4, all concept directions only have green or yellow markers in the requirements section. This indicates that when looking at these requirements, all directions could be used for further development.

The scores are fairly close to each other. Concept direction 2 has 9 yellow markers, concept direction 3 has 6 and concept direction 1 has 3. Concept direction 1 also has a red mark at the wish 'adaptability'. Concept direction 4 has the fewest yellow markings, namely 2. Therefore, concept direction 4 is chosen and will be developed further. In addition, this concept direction was chosen because its flexible capacity, adaptability and spacious arrangement. The spaciousness makes the seats considered more luxurious but also causes that the seat price to go up. As a result, this concept direction will be a good fit for the target group. Besides, it is possible to travel alone, in pairs and also with a group of four. Which makes the layout suitable for both daytime and nighttime travel. For daytime, the layout could be used in two ways. The first scenario is as luxury (first class) seats that can accommodate 40 passengers per coach. In the other scenario, the side folding seats are folded out allowing a maximum of 80 passengers to sit in the coach. These seats can be offered for reduced prices (e.g. as second class) or the arrangement can depend on capacity of the people travelling. For example, 80 passengers in peak hours and 40 to 80 passengers in off-peak hours.

A more detailed explanation on how the choice was made can be found in Appendix 5.

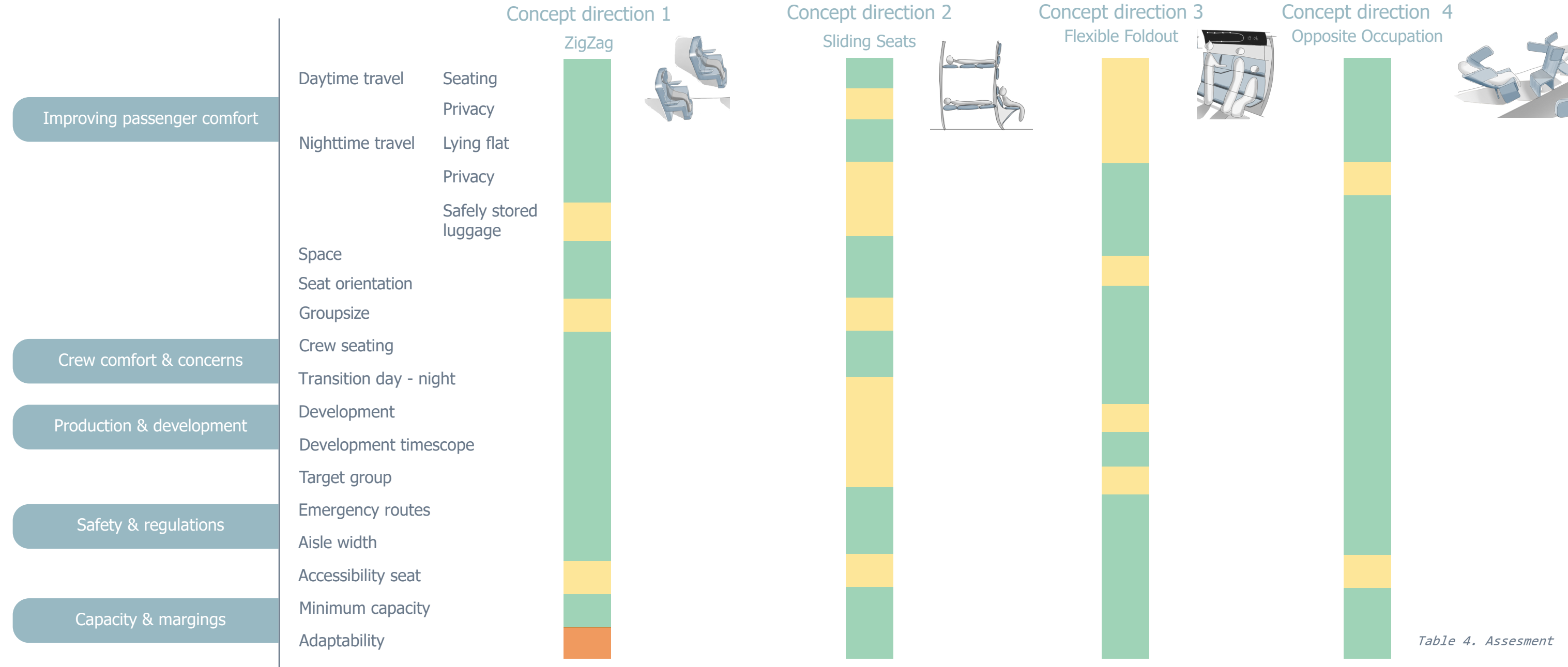


Table 4. Assessment

04
00

Concept development Day & night train interior

- / 01 Ergonomics sprint
- / 02 Design sprint
- / 03 Evaluation current vs new design
- / 04 Expert panel



04
01

Ergonomics sprint

// 01 Accessibility improvement

// 02 Research: creating a feeling of privacy, security and comfort

Take aways ergonomics sprint

01 / Accessibility seats & facilities

In the 'night layout' of the train, the bed on the window side (i.e. not on the aisle) is inaccessible. Namely, one has to climb over the aisle-side bed (passenger) to reach the window-side bed. To address this, a solution is depicted in figure 51, allowing aisle-side passengers to exit through the aisle and window-side passengers to pass diagonally to access the aisle.

The train layout includes two toilets and two washing rooms to cater to the needs of passengers, particularly those on business trips. This adjustment slightly reduces the capacity to a maximum of 72 passengers during the day and 36 passengers at night while still meeting minimum overnight capacity requirements.

To enhance convenience, toilets and washrooms are placed at both ends of the wagon, minimizing the distance passengers need to walk. The middle entrance facilitates quick boarding and alighting, offering accessibility for people with reduced mobility by avoiding raised floor areas at the ends of the coach (Ace4Rail, 2023).

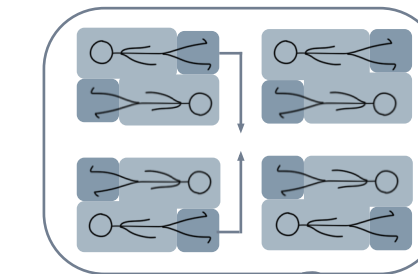
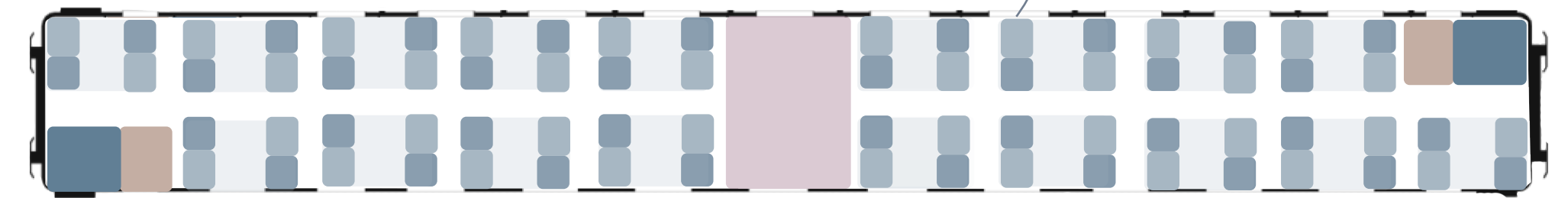


Figure 50. Accessibility night layout



Seats Folding seats Entrance Toilet washing room

Figure 51. Coach floorplan

02 / Research: privacy, security and comfort

Since the sense of privacy and security are closely linked to comfort, more research has been done on how these factors can be improved in the concept. The research phase showed that passengers naturally want to sit in a 'safe' place in the train. These are places where they feel secluded, next to walls for example, and where they sit as far away from others as possible. However, it was found that too much distance from others and too much open space again leads to a lowered sense of (social) safety. This research aims to find the right balance between the feeling of privacy and security for optimal comfort.

The main question is: *'How is the feeling of privacy and security influenced by the placement of different interior shielding options in a day and night train scenario?'*

Based on this question, a train interior was designed in which various elements could be added to potentially increase the sense of privacy and security. Participants could experience this interior with the different elements in Virtual Reality to gauge their opinion and perception of the interior.

The sub research questions are:

1. How does the amount of visual shielding from other passengers affect the sense of privacy, safety and comfort for day and night travel?
2. How does the size of spaces in the carriage affect the sense of privacy, security and comfort for day and night travel?
3. How does having an enclosed space in a train affect the feeling of privacy, security and comfort for day and night travel?
4. How does the location of luggage affect the feeling of privacy, security and comfort for day and night travel (under seat, over seat, in personal area, at back of carriage)?
5. How does the way of storing luggage affect the sense of privacy, security and comfort for day and night travel? (open, with lock?)

Participants

Because the study is about train transportation, the participants should have experience with train travel. However, previous research showed that there is no (significant) difference between expectation and the actual experience of what people find comfortable during night train travel (Out, 2023). Hence, a mix of experienced and inexperienced night train travellers was asked.

The target group of the project are business travellers or a somewhat higher socio-economic class, given that these people have more money to spend. However, since it would take a long time to find 24 participants who travel for work fellow students are also used in this test. A total of 24 participants were invited for the test. Table 5 shows their details.

Male	10
Female	14
Origin	Dutch
Age	21 - 62 years
Weight	56 - 100 kg
Length	1.64 - 1.94 m
Experience regional train travel	24 yes
Experience night train travel	10 yes 14 no

Table 5. Data participants

Tools & equipment

For this test, a three-dimensional (3D) train coach was modelled in Blender, incorporating various seats and shielding elements. Subsequently, this model was transferred to a virtual reality (VR) environment called 'unreal engine'. By using VR, a realistic representation of the design could be created, allowing the participant (the passenger) to make a reliable judgement.

Moreover, the application of VR is interesting because of its valuable contribution to empirical experiments in the dilemma between achieving everyday realism and experimental control (Birenboim et al., 2019). With VR, environmental features can be displayed much more accurately and dynamically, providing a means to realise an "embodied experience". In this test, the interior of the train can be easily modified, for instance by adding a partition wall. This experience includes participants in such a way that it appeals to multiple senses and thus enables interaction (Kilteni et al., 2012).

Procedure

The participants completed the test one by one. First, the context of the project and the aim of the study was briefly explained. Then the participant was asked to sign a consent form (see Appendix 7). During the VR experience, participants were interviewed about their perception of the space. The interviews were verbal in order to collect qualitative data. Figure 52 shows the whole procedure.

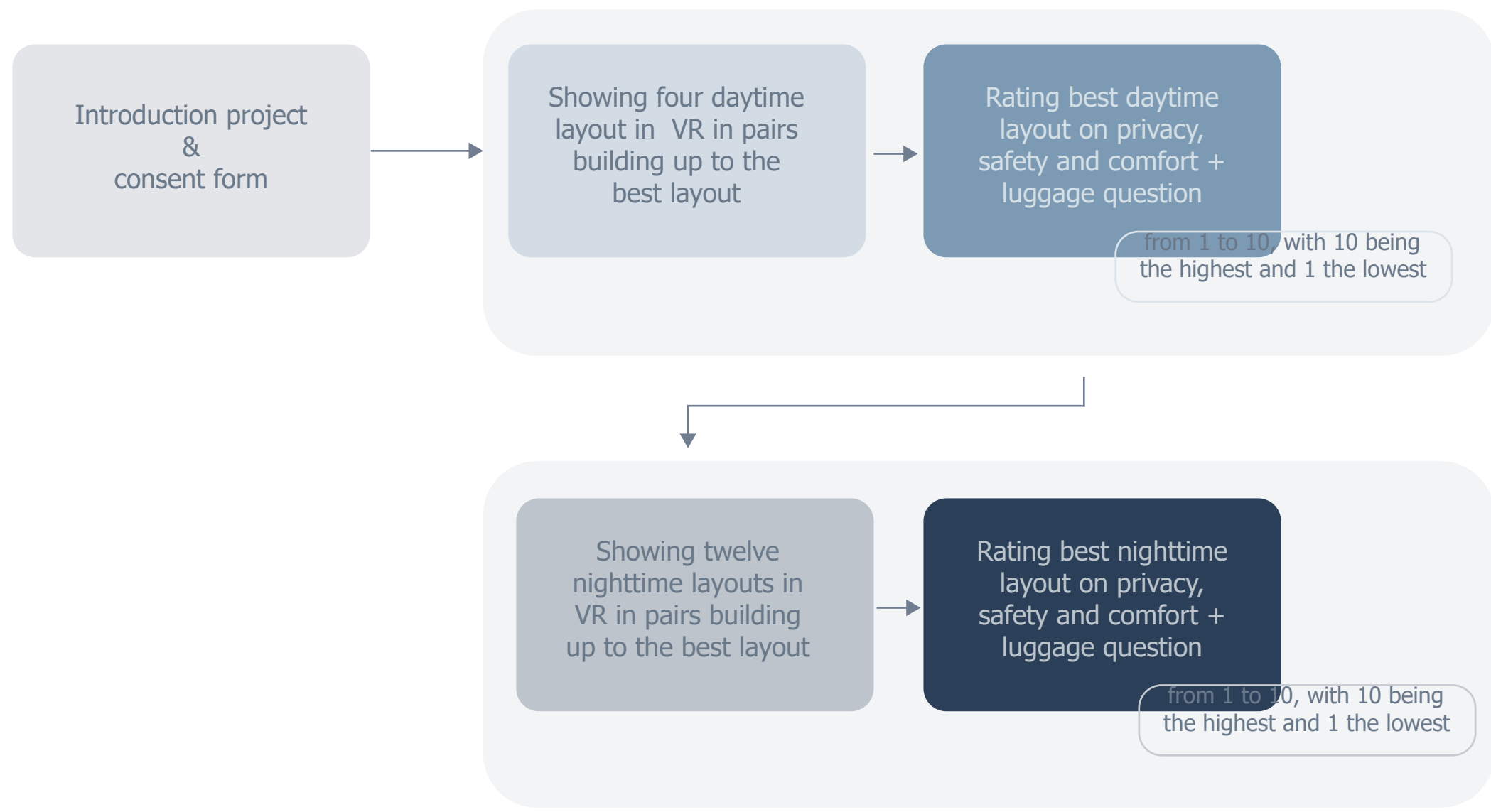


Figure 52. Flowchart procedure layout testing

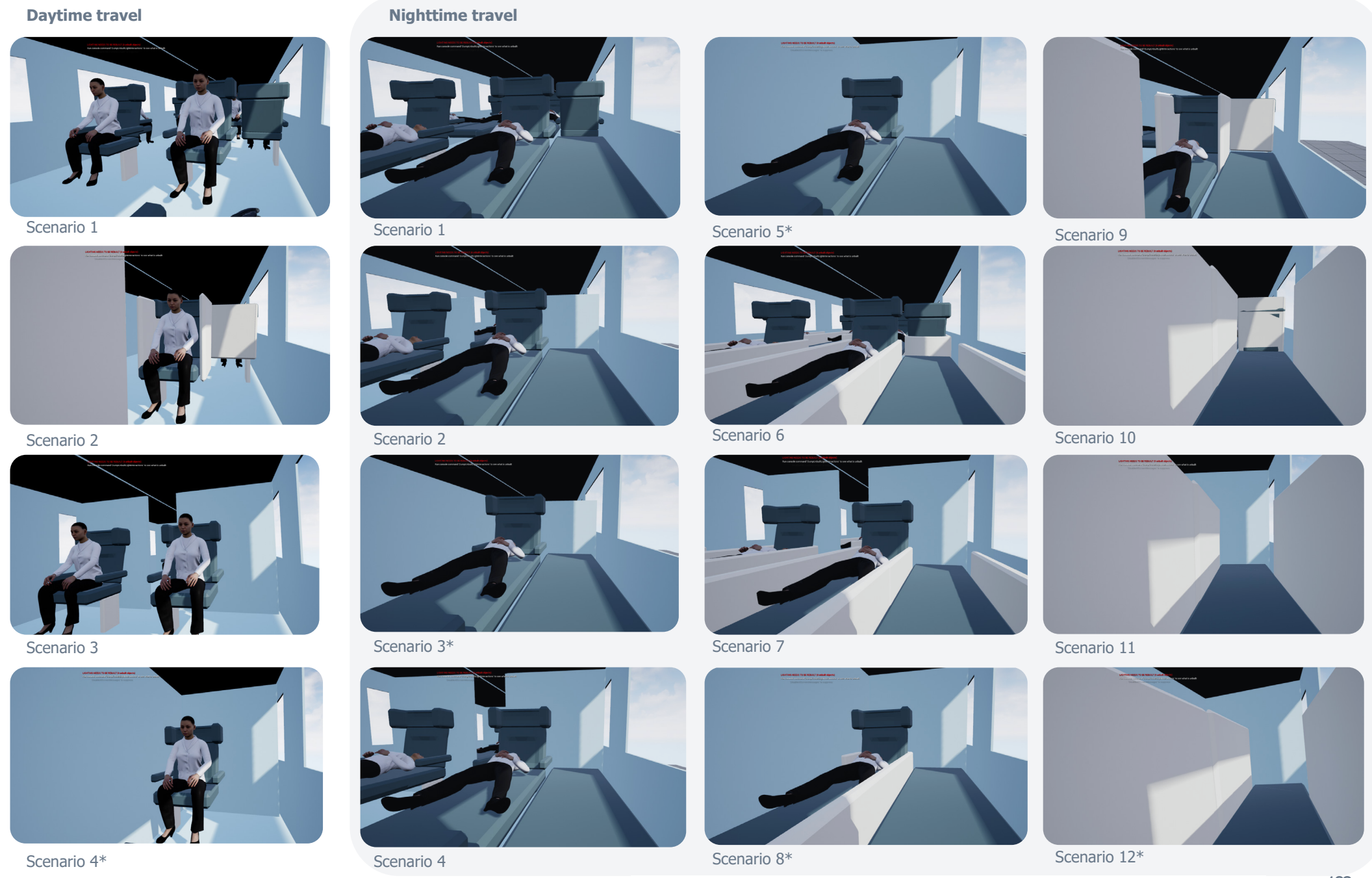


Figure 53. Layouts in VR

*For the scenarios (with the wall on the left side), it was mentioned that there should be a door in the left wall and that this wall can be either transparent or solid.

Research environment:
The test is held at the Faculty of Industrial Design. The test setup can be seen in figure 54.

Research pilot:
Before the research was conducted, the VR environment was first checked by myself. After that, a pilot test was carried out with a fellow student.



Figure 54. Research setup

Data processing & analysis

The first step in the data analysis is the conversion of qualitative data into a quantitative format. Qualitative data, often rich in subjective observations and opinions, is systematically translated into measurable and numerical values. This transformation facilitates a more structured and objective approach to understanding the underlying trends and patterns. Microsoft Excel is used for data analysis. Its versatility allows for efficient data organization and visualization.

To derive meaningful insights, descriptive statistics play a pivotal role. Key statistical measures such as mean, max, min, median and standard deviation are computed to summarize and describe the central tendencies and variations within the dataset. The insights gained from the data analysis serve as the basis for informed decision-making in the layout design of the coach interior.

Results

The tables below contain the results of the interviews. Table 6 shows the results for daytime travel and table 7 for nighttime travel.

Best scenario Daytime	Amount chosen	Gender	Experience Regional train travel	Average grade Privacy	Average grade Security	Average grade Comfort	Reasons	Reasons Privacy	Reasons Security	Reasons Comfort
1	2x	Female 2	Yes	4,50	9,00	7,50	+	Distance to others	Overview	Interaction, Freedom, Space
		Male 0								
2	3x	Female 1	Yes	8,33	8,00	8,67	+	Visual shielding	Secure feeling	Own space
		Male 2								
3	12x	Female 7	Yes	6,79	7,88	8,04	+	Own space, Visual, Noise and Smell shielding, Distance to others	Overview, Social Control, Easy entry and exit	Calm environment, Interaction, Travelling with others possible
		Male 5								
4	6x	Female 4	Yes	8,17	7,25	8,50	+	Sound and smell minimalisation, private place	Luggage in your own space	Calm environment
		Male 2								
Combination 2 & 3	1x	Female 0	Yes	8	10	10	+	Visual	Own space	Overview
	Male 1									

Table 6. Results daytime travel

Best scenario Nighttime	Amount chosen	Gender	Experience night train travel	Average grade Privacy	Average grade Security	Average grade Comfort	Reasons	Reasons Privacy	Reasons Security	Reasons Comfort
9	8x	Female 6	Yes 2	7,44	7,88	7,56	+	Own space, Visual (head) shielding	Overview, Social control, Multiple escape routes	Open space that yet feels cosy, easy access, feels like businessclass seats
		Male 2	No 6							
12	6x	Female 0	Yes 4	8,83	7,75	8,92	+	Not bothered by others (walking by), Visual shielding, Sound minimalisation, Own space relative to other travelling companion	Almost private compartment, Shielded, Luggage locked with you	Own space, Easy access, Feels private (therefore willing to pay more money).
		Male 6	No 2							
11	9x	Female 7	Yes 4	9,00	8,72	8,89	+	Own space, Visual shielding, Sound minimalisation, Not touching anyone	Not totally closed (therefore fast escape route), Overview, Sound for social control	Own space, Easy access, Feels private
		Male 2	No 5							
10	1x	Female 1	Yes 1	9	8	8	+	Visual shielding	Social control	Looks calm
		Male 0	/							

Table 7. Results nighttime travel

Discussion

Daytime travel

The results from the daytime travel scenarios show that scenario 3 emerged as the preferred option, receiving support from half of the participants (12 out of 24). Participants gave their views on privacy in this scenario, expressing feelings about personal space, enough physical separation, visual seclusion due to raised partitions, anticipation of noise attenuation and a reduced likelihood of odour spread in the train. Participants' mean rating of privacy was 6.5 on a scale of 1 to 10. This somewhat modest rating was attributed to the fact that the participants did not have very high privacy requirements during daytime travel.

In terms of safety considerations, participants preferred the scenario for providing a sense of individual surroundings while at the same time having an extensive overview. The configuration of train sections for 4 to 8 people was considered favourable to social control, reinforcing the safety perceived by participants. In addition, the open design was praised due to the provision of multiple means of escape, making entry and exit smoother. The overall safety rating was an average of 7,88.

In terms of comfort, participants noted that they got a positive impression of calmness and spaciousness within the designated setup, factors that contributed to an increased sense of comfort. The scenario was also praised for promoting opportunities for interaction and group travel, which aligned with preferences for daytime travel. The average comfort rating for this scenario was 8.04. A group of four participants underlined that the scenario offers a good balance between privacy and overview, increasing the level of comfort.

It is notable that the quantitative indicators related to scenario 3, which was considered the preferred option, did not always receive the highest marks, which gives cause to reflect on the possible discrepancy between perceived preference and the resulting numerical evaluations. This discrepancy may be due to a non-linear correlation between privacy considerations and comfort, or may indicate that participants rated certain facets of the scenario lower.

It is noteworthy that both male and female participants, both of whom had previous experience of regional train travel, unanimously favoured scenario 3.

Scenario 4 received six votes from both males and females and got comments highlighting its closed nature, although with a glass wall. Criticisms included reduced social control, the sense of intimacy when sitting with a stranger and the feeling of enclosure. The scenario received the highest praise in terms of privacy, with participants expressing appreciation for the safe storage of personal belongings within their own designated space.

Scenario 1, with two votes from female participants, was praised for its spacious seating arrangements that provided plenty of privacy during the day. The open layout provided an increased sense of situational awareness, which gave a sense of security and facilitated interpersonal interactions. However, the dissenters experienced too little privacy because of the open layout.

Finally, three participants expressed their preference for scenario 2, expressing admiration for the visual shielding and associated sense of isolation. In contrast, dissenters found the scenario too restrictive and felt it evoked feelings of oppression. These diverse perspectives highlight the multifaceted nature of participants' evaluations regarding spatial configurations, with privacy considerations and perceived openness being important determinants in the decision-making process.

Nighttime travel

The best scenario for overnight travel is a close call. Scenario 11 received 9 votes and scenario 9 received 8. For nighttime travel, several interesting findings were found. First of all, from the perspective of experienced and inexperienced night train travellers, it seems that experienced night train travellers prefer Scenario 11, while less experienced travellers tend towards Scenario 9. This could be attributed to the need for a more enclosed environment that experienced travellers desire, while inexperienced travellers may prefer a more open environment for a sense of security.

Another remarkable finding is the difference in preferences between men and women. Women seem to prefer a (semi) open environment for social control, while men are more inclined towards an enclosed environment, as they seem to be less concerned about travelling with strangers. These gender differences highlight the need to consider diverse needs when designing night train accommodations. Scenario 12, with 6 votes, is less popular due to perceived lower social control in its completely enclosed setup. While men find it comfortable, the lack of social control raises concerns for female participants, leading to its discontinuation.

Scenario 10 was voted once. This scenario is similar to scenario 11 but without a wall between the seats. The difference in number of votes between the two scenarios could be explained by the fact that the presence of a wall in Scenario 11, possibly enhances a sense of privacy and security. The figures show that Scenario 11 has generally higher ratings for privacy, security and comfort compared to Scenario 9. This suggests that the majority of respondents prefer the features of Scenario 11. Suggested improvement options include: offering multiple layouts or flexible layout options to meet various preferences, e.g. group travel, and considering a specific women-only section to meet the needs of different groups of travellers.

Finally, luggage preferences play a vital role in evaluating overnight train scenarios. Out of 24 respondents, 21 consider the possibility of storage of the luggage with a locking mechanism essential, emphasizing the significance of security during (nighttime) travel. Next to that, the majority of respondents prefers the top rack as a storage place for luggage. This preference may be related to easy access to luggage, as well as a sense of space and openness in the traveller's immediate vicinity. In conclusion, by integrating secure storage options and ensuring that they are easily accessible, the comfort level of travellers can be substantially increased.

Conclusion

It can be concluded from this study that the right balance between privacy and security (i.e. personal space and openness/overview) differs between day and night travel. In addition, preferences differ between experienced and inexperienced night train travellers and between men and women. The layouts that came out best from the test and the insights about luggage storage will be taken into account in the next phase: the design sprint.

04
02

Design sprint

// 01 Moodboard form & feeling

// 02 Design sketches

Before designing the seats, a mood board was created. The mood board serves as inspiration for designing and is explained in the section below.

01 / Moodboard form & feeling

The shape and color collage, shown in figure 55, serves as inspiration for the design of train seats. The collage features several elements. Firstly, continuous surfaces that create a spacious visual experience. In addition, there are many rounded, soft forms, and in the top-left, a kind of enveloped shape that evokes a sense of security. The color palette is soft, incorporating natural tones. These natural tones contribute to a calming and timeless atmosphere, expressing the train's sustainable image. Simultaneously, robust steel elements with a solid structure and honest forms create a harmony between organic softness and industrial strength.

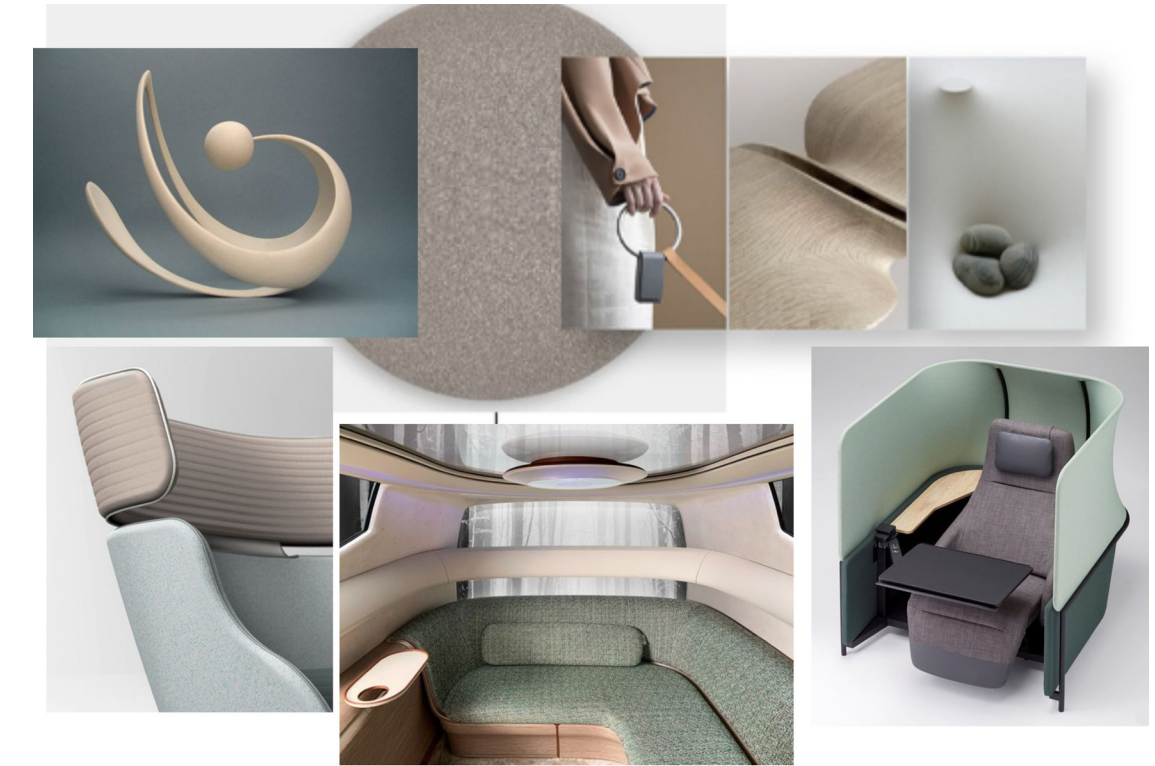


Figure 55. Moodboard

02 / Design sketch

Based on the results of the layout test and the mood board, several sketches were made for the design of the seats. They can be seen in Appendix 6. When sketching, the shape of the chair and the design of the privacy screens were considered. Furthermore, the folding chair with folding headrest was replaced by a full-fledged (fixed) seat with rotating backrest. Different mechanisms were investigated how the backrest could be rotated. Finally, an enclosure around the seat was added.

Figure 56 and 57 show the final sketch. The day configuration consists of rows of two seats facing each other. These seats feature wide cushions and a lumbar support backrest. The headrest is soft, providing comfortable support for the head. Surrounding the seats is an enclosure that creates a sense of security. One of the seats has a fixed position, while the other can rotate its backrest through a hinge. Additionally, the seats have armrests at both ends.

In the night configuration, both backrests are rotated along with the enclosure. Furthermore, the cushions are shifted using the same mechanism as used for business-class seats. The last cushion is connected to the opposite seat, allowing passengers to lie completely flat. The enclosure on both sides contains screens that can be extended. On the aisle side, there is a long screen to fully enclose the passenger from the aisle, while between passengers, two shorter screens can be closed or left open according to passengers' preferences.

Due to the curvature of the backrest, a hollow space is created around the passenger's head and shoulders, resulting in less space at the feet. However, research from Smulders & Vink (2021) indicates that this does not affect sleep comfort or sleep quality.

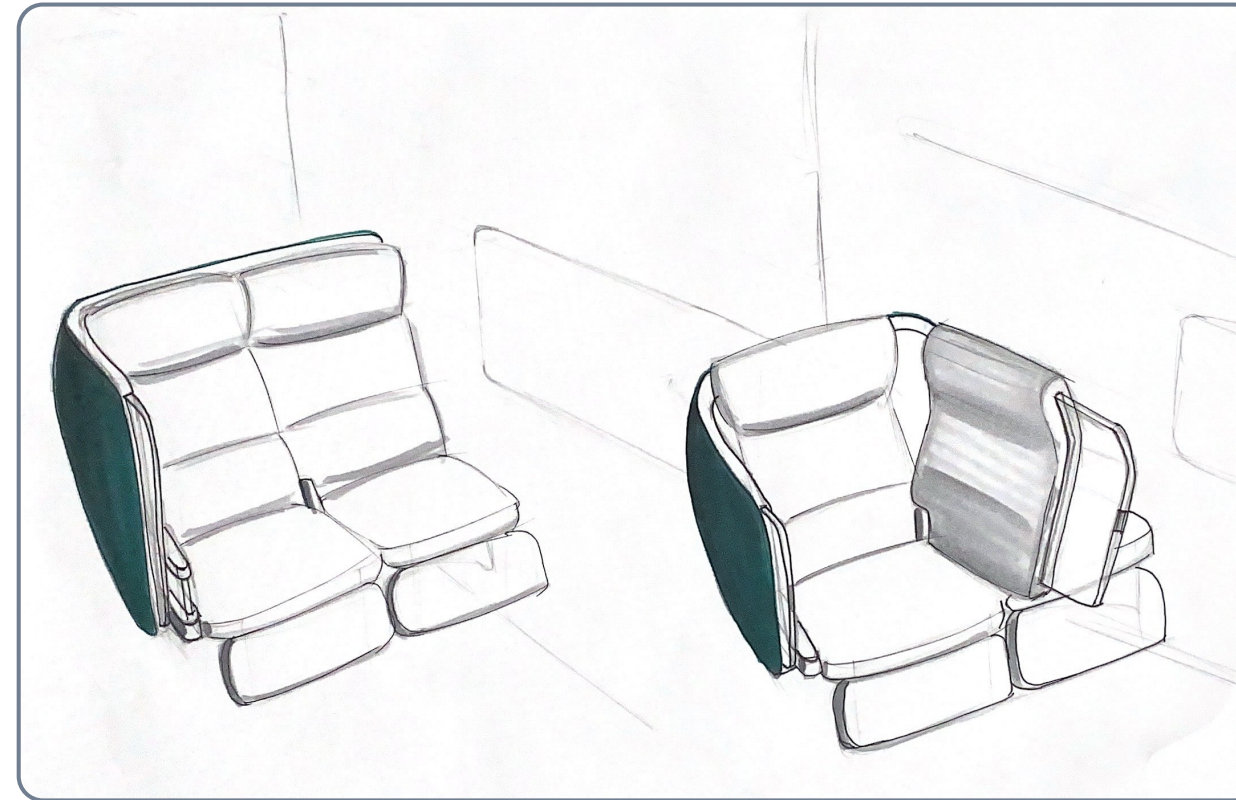


Figure 56. Sketch day layout & transition

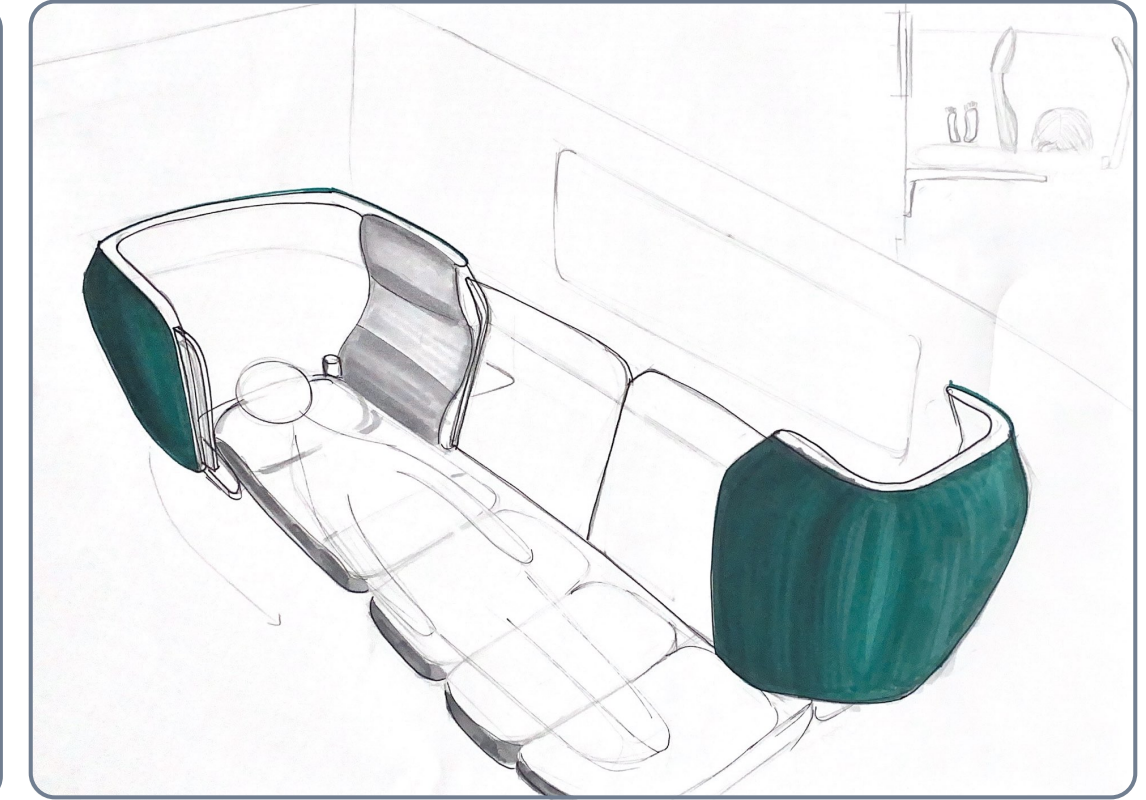


Figure 57. Sketch night layout

Evaluation current vs new design

// 01 Research

// 02 Conclusion and design suggestions

01 / Research evaluation current and new design

This test was conducted with the aim of testing whether the new design for a day and night train is an improvement over the current night train design. Both designs were modelled in 3D and then modelled in VR. As in the previous study, participants experienced both interiors in VR to gauge their opinion and perception of both interiors.

The main question is: *'How do both designs compare on aspects focused on privacy, security and comfort?'*.

The sub research questions are:

1. What is your perception of privacy (for daytime and nighttime)?
2. What is your security experience (for daytime and nighttime)?
3. What is your comfort experience (for daytime and nighttime)?
4. What do you think of the design?
5. What do you think of the walking routes in the carriage and the accessibility of your seat/bed?
6. What do you think of the facilities?
7. Would you travel on this train and how much would you pay for it?

Participants

For the study, participants were invited who have experience with train travel but not necessarily with night train travel. All of them also participated in the previous VR test. In total, 11 participants were tested. The decision to stop after 11 participants was made because after 7 participants they gave many of the same answers and I could not spend too much time on this test. However, different types of people, for example different ages, gender, work status and whether or not they had experience with night train travel. Table 8 shows their details.

Male	5
Female	6
Origin	Dutch
Age	23 - 62 years
Weight	63 - 97 kg
Length	1.80 - 1.94 m
Experience regional train travel	11 yes
Experience night train travel	7 yes 4 no

Table 8. Participants

Tools & equipment

Please see tools & equipment previous research in VR.

Procedure

Participants took part in the test one by one. Firstly, the context of the project and the purpose of the study were briefly explained. Then the participant was asked to sign a consent form. During the VR experience, participants were interviewed about their perceptions of the space and had to grade a number of aspects. After the VR experience, photographs of both designs, figures 58 - 63, were shown and a number of questions were also asked about these. The interviews were oral to collect both quantitative and qualitative data.

Research environment

The test is held at my home as it was performed during the Christmas break. The participant sat on a chair with the VR headset on.

Research pilot

Before the research was conducted, the VR environment was first checked by me. Then a pilot test was carried out with a fellow student.

Data processing & analysis

Data analysis incorporates both qualitative and quantitative data. All data was gathered in Excel. Statistical analysis was performed using IBM SPSS Statistics Version 28. A comparison between two paired groups was done. To test whether the data is normally distributed, the shapiro wilk test was done. It revealed that the data is not normally distributed and therefore Wilcoxon Sign Tests were performed to identify significant differences. The significance level was set at $p = 0.05$ for all statistical tests.

Current design



Figure 58. Current design day layout

Figure 59. Current design night layout

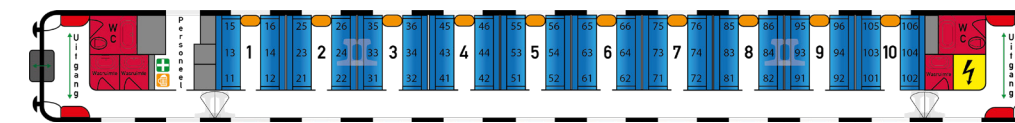


Figure 60. Current design floorplan

New design

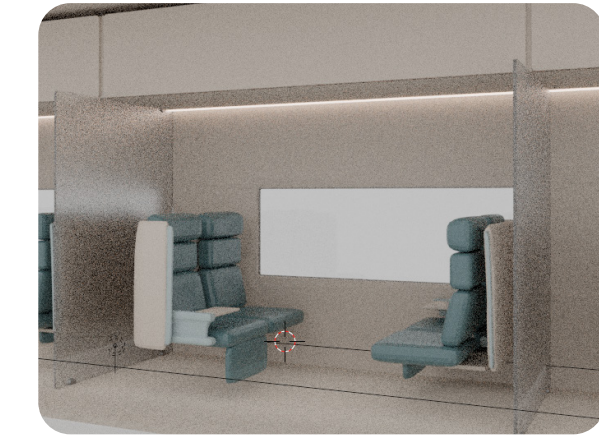


Figure 61. Current design day layout

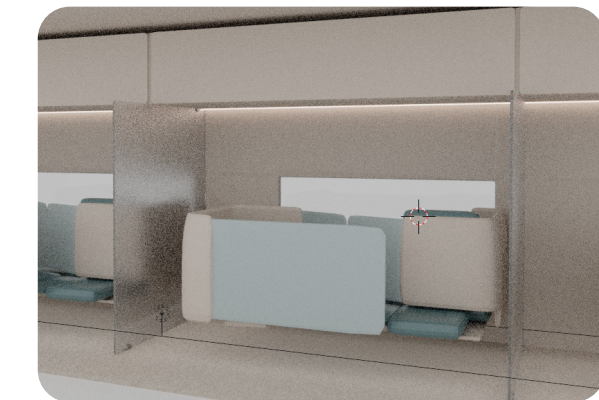


Figure 62. Current design night layout

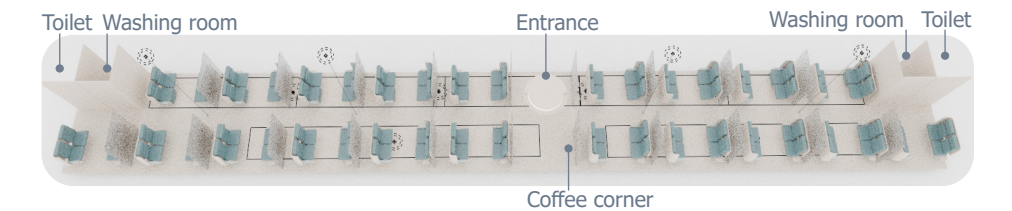


Figure 63. Current design floorplan

Results

Day Layout

Graph 1 shows the average scores of how the current design and the new design score on aspects related to comfort during the day. The current design scores best (compared to itself) on feelings of safety, followed by comfort, space perception and as lowest privacy. Privacy is again divided into a number of aspects with smell scoring lowest and noise highest.

The new design scores highest for space perception and sense of security, then comfort and then privacy. Within privacy, smell and distance from others scores higher than noise.

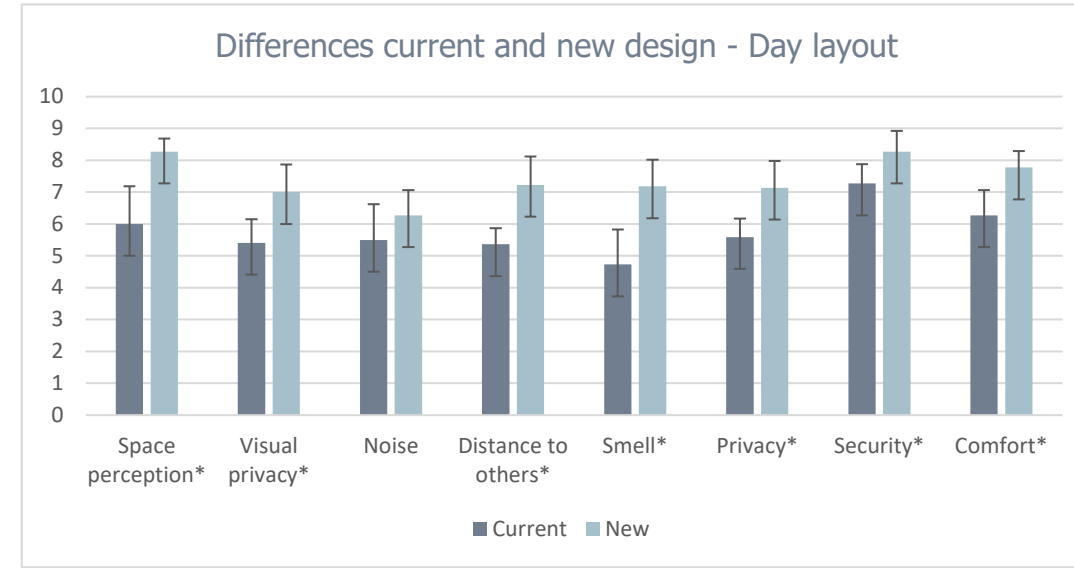
Finally, between all aspects are significant differences ($P < 0,05$) between the scores of the current design and the scores of the new design except for noise ($P = 0,075$). In all aspects, the new design scores higher, mainly on the aspects smell and perception of space.

Night layout

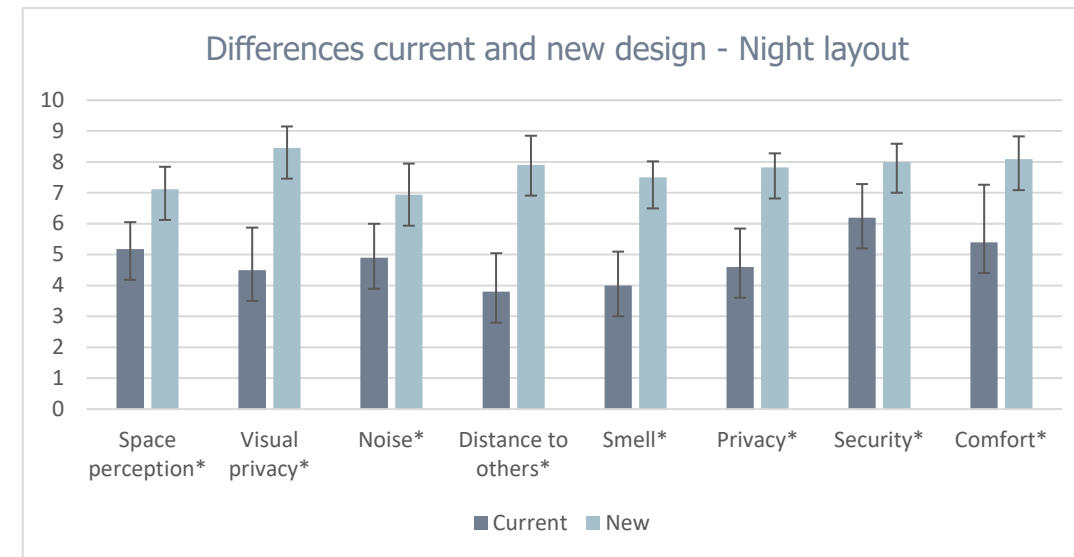
Graph 2 shows the different scores between the current design and the new design during the night. The current design scores best on sense of safety, then comfort, space perception and as lowest privacy. Within privacy, noise scores highest and distance from others lowest.

The new design scores highest on comfort, then sense of security, then privacy and lastly space perception. Within privacy, visual privacy clearly scores highest and noise scores lowest.

Finally, for all aspects there are significant differences ($P < 0,05$) between the scores of the current design and the scores of the new design. The difference between the scores from distance to others and visual privacy are the largest.



Graph 1. Average scores current and new design - Day layout



Graph 2. Average scores current and new design - Night layout

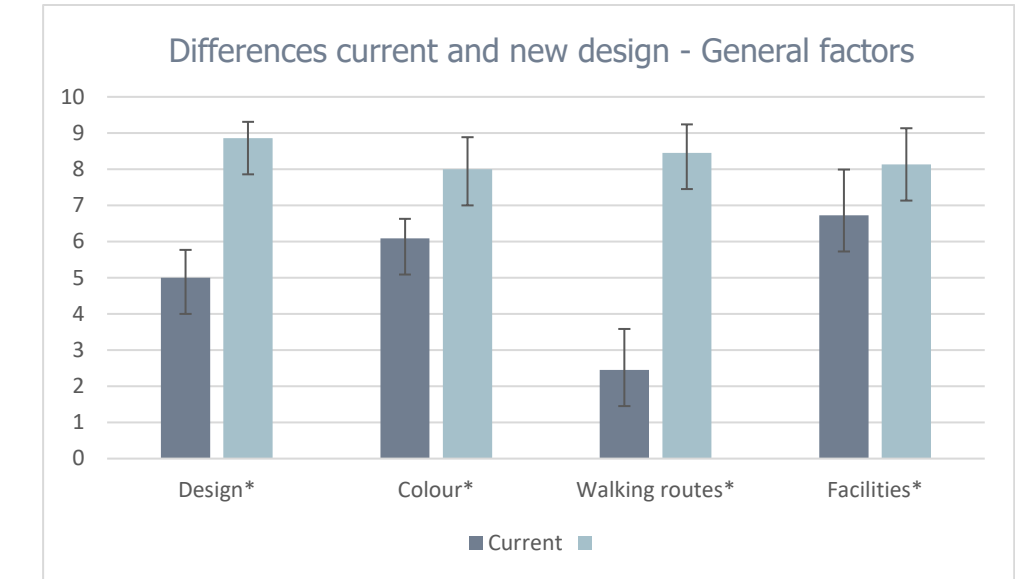
General aspects

Graph 3 shows the different scores between the current design and the new design for general factors of the designs. The current design scores highest on facilities, then colour, then design and lowest on walking routes. The new design scores highest on design, then walking routes, then facilities and finally colour.

All factors differ significantly between both designs ($P < 0.05$). The biggest difference is between the assessment of walking routes.

On average, participants would pay 55 euros for a ride from Amsterdam to Vienna in the current accomodation (if booked a month in advance) (median is 50 euros). Also, 5 of the 11 people indicated that they would not travel in this accomodation. The 6 people who would travel in this accomodation were all students. For the new design, all participants would travel in this accomodation and they would pay on average 105.83 euros for a ride from Amsterdam to Vienna (if booked one month in advance)(median is 112,50 euros).

All results from the SPSS analysis can be seen in Appendix 8.



Graph 3. Average scores current and new design - General factors

Discussion

Day layout

The findings indicate a significant overall improvement in the new design, with the exception of noise privacy. This discrepancy can be attributed to the fact that the old design features an enclosed compartment for 6 people, while the new design has an open layout accommodating 8 people, allowing sound to propagate more freely. In particular, the new design scored well on smell and perception of space. The open layout facilitates better smell circulation, reducing the likelihood of musty smells. Participants highlighted the new design's enhanced spaciousness and improved feeling of security. In addition, participants highly appreciated the increased amount of legroom in the new design. Finally, the preference for rows of 2 seats over rows of 3 was evident, as participants found sitting in the middle uncomfortable.

Night layout

The results indicate a significant improvement in the new design for the night layout across all aspects. The largest distinctions between the two designs were shown in the distance from others and visual privacy, with these aspects being interconnected. Participants expressed feeling a greater distance from others due to visual shielding and the open layout. Despite both designs providing a sense of safety through social control, the old design hindered quick exit due to its enclosed space and connecting beds. While the open layout in the new design fosters social safety, it also introduces more noise, necessitating

a careful balance between the two factors. Additionally, the open layout promotes better air circulation, reducing the persistence of unpleasant smells. Participants favored the new design for its comfort, appreciating the ability to lie flat and having more space per person for luggage. However, concerns were raised about cramped space near the feet. Research by Smulders & Vink (2021) indicates that this does not impact sleep quality. Nevertheless, passengers must be able to move comfortably through this area to access the aisle.

General aspects

About the current design, participants said they thought the design looked a bit underwhelming, they did not like that they could not lie flat and the seats did not look very comfortable because they are close together and facing each other. About the use of colour, the majority said 'fine but could be nicer'. The walking routes were rated the worst considering the seats are close together and one has to crawl over another to reach the aisle at night.

The new design scores a lot higher on design because of its modern and minimalist look. In addition, participants said they liked that they could lie flat, that there is a lot of privacy (especially at night) and that the seats are not accessible to people without tickets. The use of colour was rated better. The walking routes were also rated better, as passengers do not have to cross each other. The coffee corner located in a different environment from the beds was well-received.

Finally, for the current design, participants would on average pay 55 euros for a ride from Amsterdam to Vienna (median is 50 euros). This amount is lower than the current price of the accommodation which is between 60 - 80 euros if booked one month in advance. For the new design, participants would pay an average of 105.83 for a ride from Amsterdam to Vienna (median is 112,50 euros). Which means people would be willing to pay on average 52% more than in the current accommodation.

02 / Conclusion and design suggestions

In conclusion, the comparison between the old and new train designs reveals significant improvements in various aspects. The new design performs better than the old one in the day layout, excelling in smell, perception of space, and overall comfort. However, noise privacy is compromised due to the open layout. For the night layout, the new design surpasses the old one in all aspects, particularly in distance from others and visual privacy. Despite concerns about noise, the open layout provides better air circulation and comfort for passengers. While the old design receives criticism for its

substandard appearance, no flat beds, and cramped seating, the new design is praised for its modern, minimalist look, increased privacy, and improved accessibility. Participants are willing to pay a higher price for the enhanced features of the new design. Nevertheless, finding a balance between social safety and noise remains crucial for the success of the new layout.

Suggestions for improvement of the new design were also given. They are listed below:

1. Introduce an armrest between the two seats to enhance comfort and establish a clear boundary between passengers, fostering a heightened sense of privacy.
2. Enhance safety measures by incorporating a 'danger/help' button that enables passengers to summon train staff promptly.
3. Elevate the visual appeal of the train coach by incorporating lines or relief on its walls.

With these suggestions, a final design sprint was done and is shown in Chapter 5.

05
00

Concept showcase

24H COACH

/ 01 Layout overview

/ 02 Day layout

/ 03 Night layout

/ 04 Transition

/ 05 Luggage storage

/ 06 Facilities

/ 07 Walking routes

/ 08 Details to consider

/ 09 Floorplan dimensions

/ 10 Journey



24H COACH

01 / Layout overview

The train coach has a symmetrical layout as shown in figure 64. The entrance is located in the middle of the coach and is at the same height as the platform, allowing passengers with reduced mobility to get in and out easily. In the central hall is a small self service bar, where people can get a drink or a snack. From the central hall, passengers can pass through doors to the sitting/sleeping areas. A toilet and washroom

are located at both ends of the coach. During the day the coach has a capacity of 72 passengers and during the night a capacity of 36. The night capacity is the same as in a sleeping car in the current night trains.

During the day, 36 people share one toilet and one washroom and at night, 18 people share one toilet and one washroom. According to the ratio in aircraft (1 toilet for every 63 passengers), two toilets and two washrooms should be enough and even better.

The following sections illustrate the proposed design of the train coach with regard to its day and night layout, details and working principle.

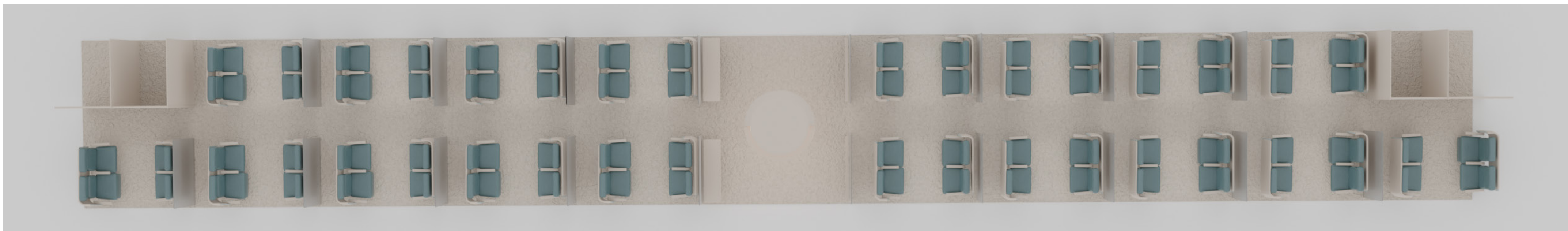


Figure 64. Layout coach

02 / Daytime layout

Figure 65 shows the daytime layout of the coach. Passengers can sit on comfortable train seats throughout the day. The seats consist of wide cushions with lumbar support and a supporting headrest.

Deliberate attention has been directed towards striking a balance between the feelings of safety and privacy within the design. The open space provides safety through social control and the smaller sections simultaneously provide privacy. The main change from current day trains is the amount of legroom, given that this is one of the most important factor for comfort. Too much legroom in turn makes people feel overexposed (unsafe). Hence, cloudy glass walls have been placed between a set of seats for shielding. These walls increase the sense of privacy and reduce the amount of noise moving through the coach. The walls also allow different zones to be created within the coach (e.g. a quiet zone or a socialise zone). Another element that increases the feeling of a private environment, next to the distance between the seats and the walls, are the armrests. The armrest are able to be lowered for safety. Finally, passengers sit facing each other, allowing them to interact easily.

Figure 65. Day layout coach



03 / Nighttime layout

Figure 66 and 67 show the nighttime layout of the coach. The main requirement was that passengers could lie flat. In addition, a minimum of 36 passengers had to fit in the coach. Both requirements were met with this design. However, to increase comfort, additional privacy and safety measures have been taken, as both factors are more important during night travel compared to day travel. First of all, in addition to the large privacy walls, extra screens along the length of the bed have been installed. These can be pulled out if desired by the passenger. In addition to visual privacy, these screens make passengers feel that they are less close to each other and have their own space. The layout is open because it allows smells to be better dispersed and it allows passengers to exercise social control through sound and sight. Therefore, the sense of safety is improved compared to the current design in night trains. The negative side of it is that noise can be better dispersed is that it can cause discomfort. Therefore, a good compromise between noise for safety and too much noise causing discomfort is needed. Section 8 (Concept elements) discusses this in more detail.

To conclude, this layout sought the ideal balance between getting 36 passengers lying in a coach with an optimal sense of comfort through the right balance between safety and privacy.



Figure 66. Section view night layout coach

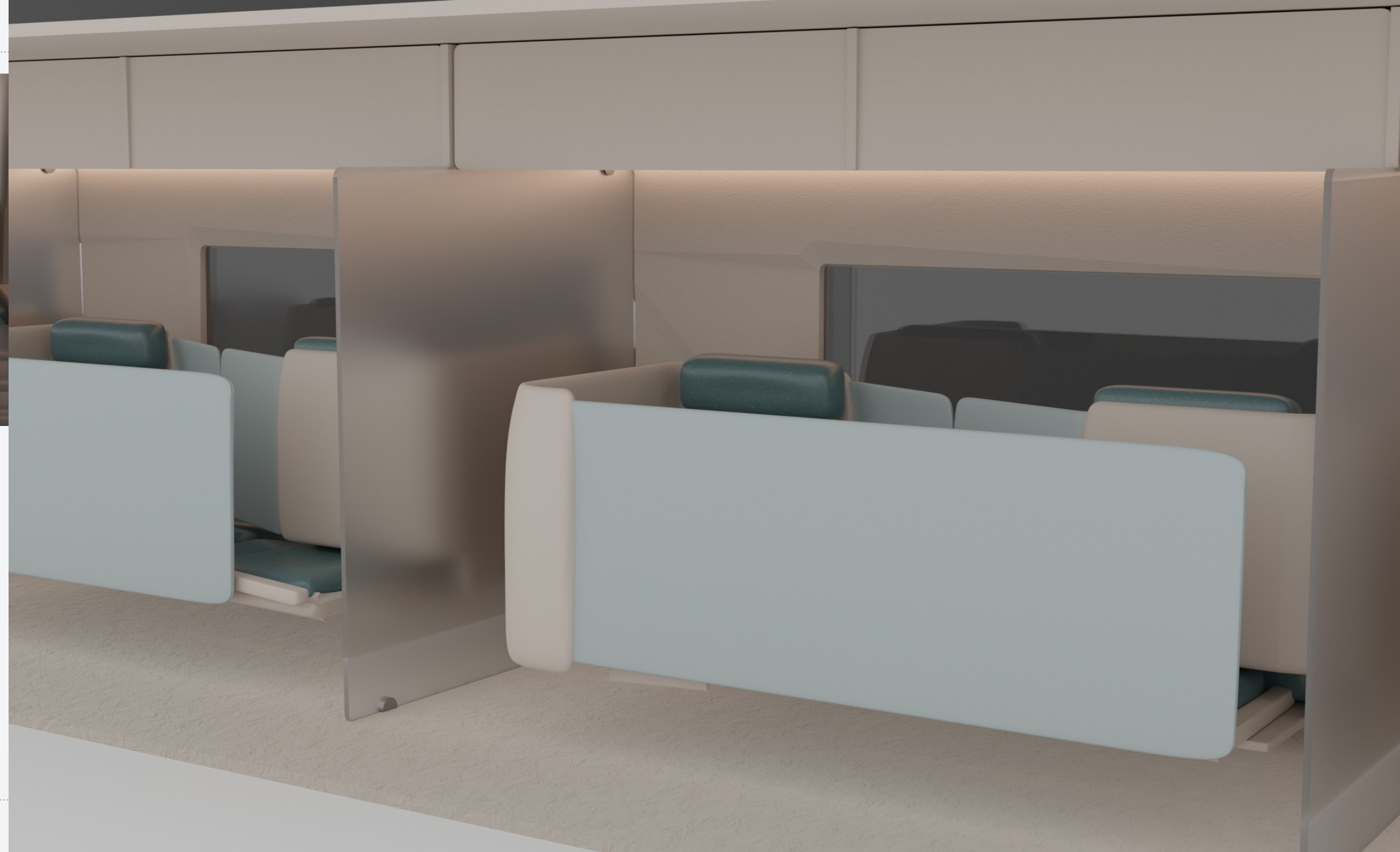


Figure 67. Night layout coach

04 / Transition

Figure 68 shows the transition from day layout to night layout in five steps. The exact mechanism of seat transition has not been worked out however it has the same functioning as in business class seats in aircraft. Two seats (diagonally opposite to each other) are extended to a flat position and connect with the

opposite seat. The backrests of the other, not flat, seats including the enclosure are rotated by 90 degrees. Privacy screens can be pulled out from the enclosure. They are located in between the seats and on the aisle side. In between the seats, the privacy screens can connect with each other.

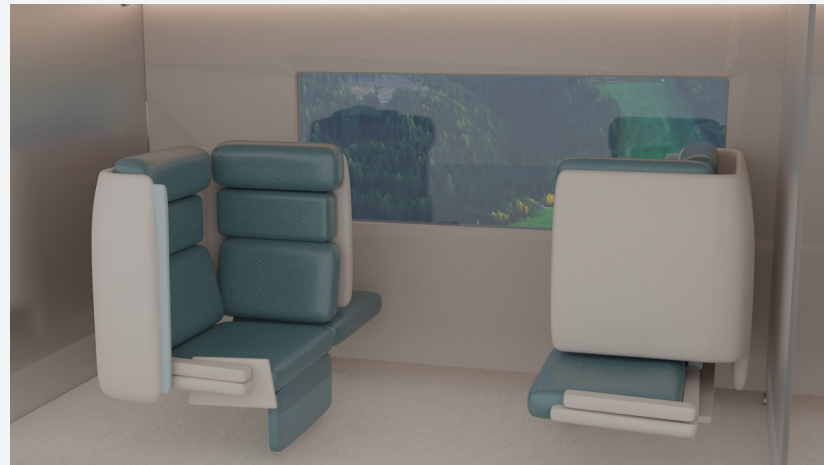
Passengers can individually choose when to make the transition from seat to bed. Bedding is stored in the luggage compartments above the seats. In this way, passengers can make the transition completely by themselves. It requires no train crew and the train does not have to stop. Both of these are very important

elements for the train's profitability. Train staff, especially for overnight service, is very expensive and if savings can be made on staff members it will make a big difference. Besides, the 24H-COACH is meant to run as much as possible. There is no time to stand still to convert the interior.

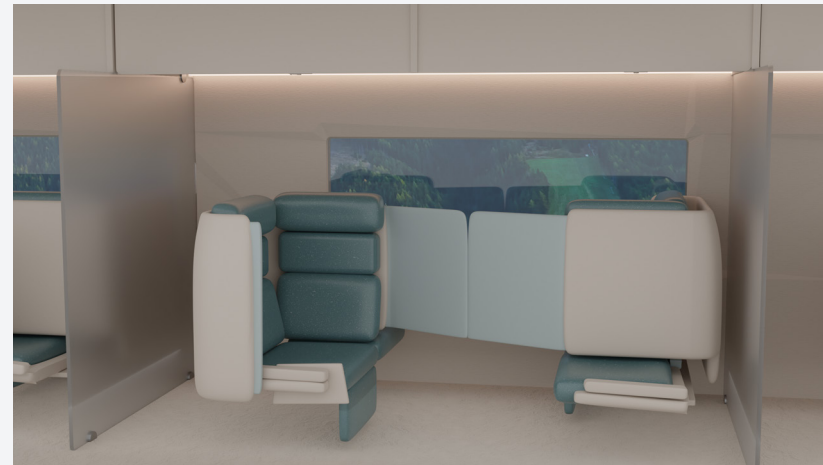
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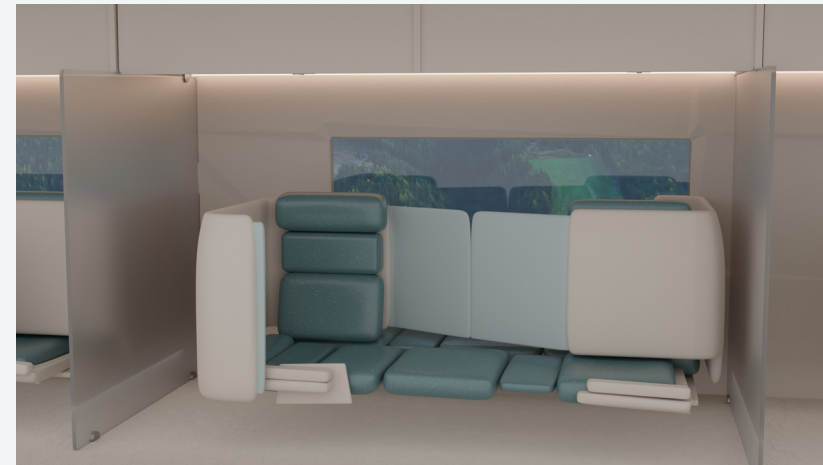
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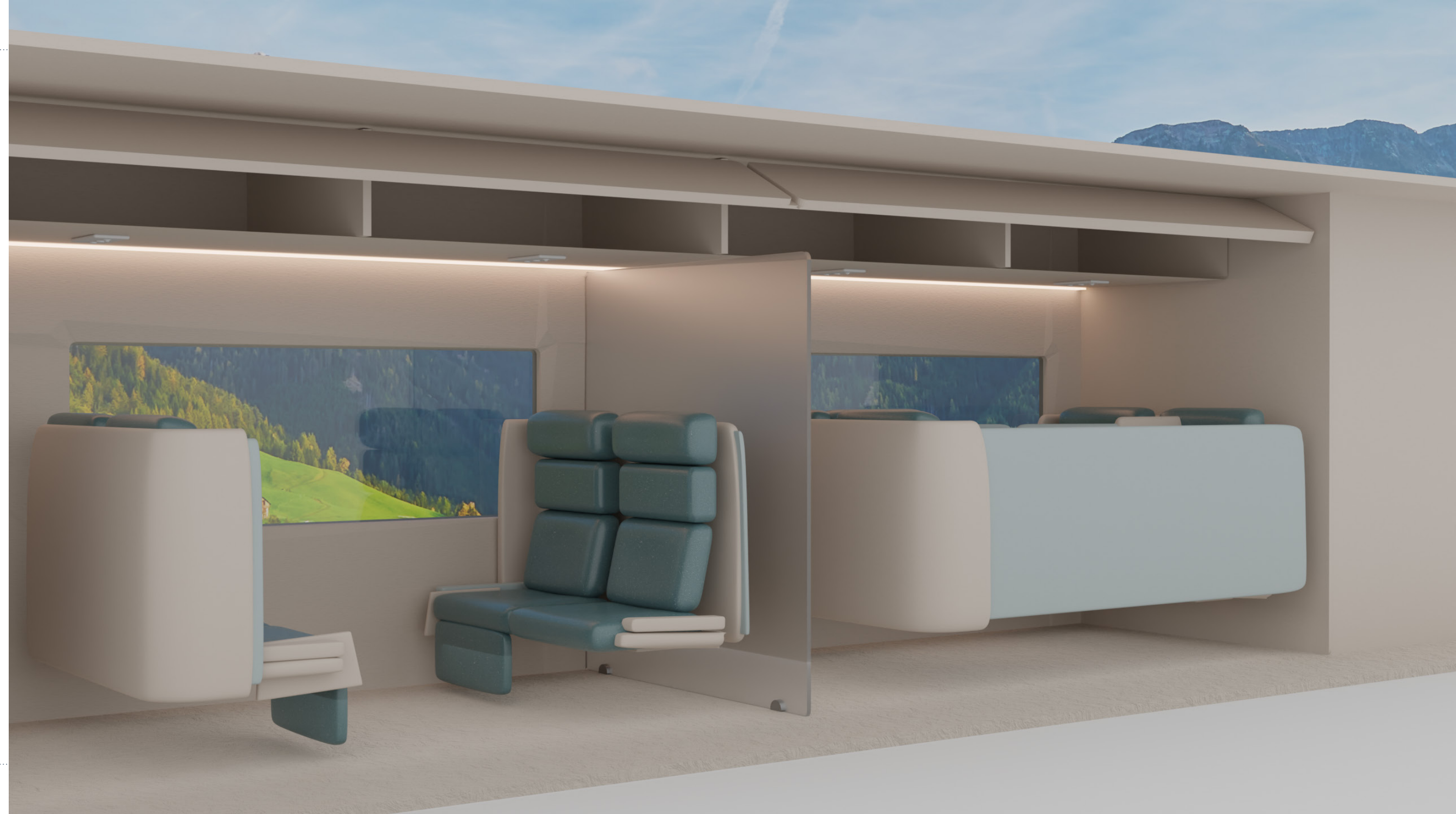
5



Figure 68. Transition

05 / Luggage storage

Figure 69 shows the luggage lockers in the coach. Research showed that the way luggage is stored plays a vital role in the comfort experience of train passengers. Especially during the night, it is important that luggage is stored safely. Securely stored in this context means locked at night, possibly locked during the day, in a place close to you, in sight and easily accessible. Research showed that the best location to store luggage is in luggage racks above the seats with a lock on them. The lock could be a physical or digital one, for example using your 'OV chip card'.



06 / Facilities

As the layout overview showed, the coach contains two toilets and two washrooms at both ends of the coach. The toilets are gender neutral and indicated with the typical signs for a toilet so that international travellers will have no trouble finding it. The washrooms are indicated with icons of a toothbrush and toothpaste. See figure 71 for the toilet and washroom area.

In the middle of the train, in the central hall, is a self-service bar with coffee and tea machine. Its central location makes it easy to reach for passengers from both areas. Breakfast boxes are also kept at this location for overnight passengers. The entrance hall can be seen in figure 70.

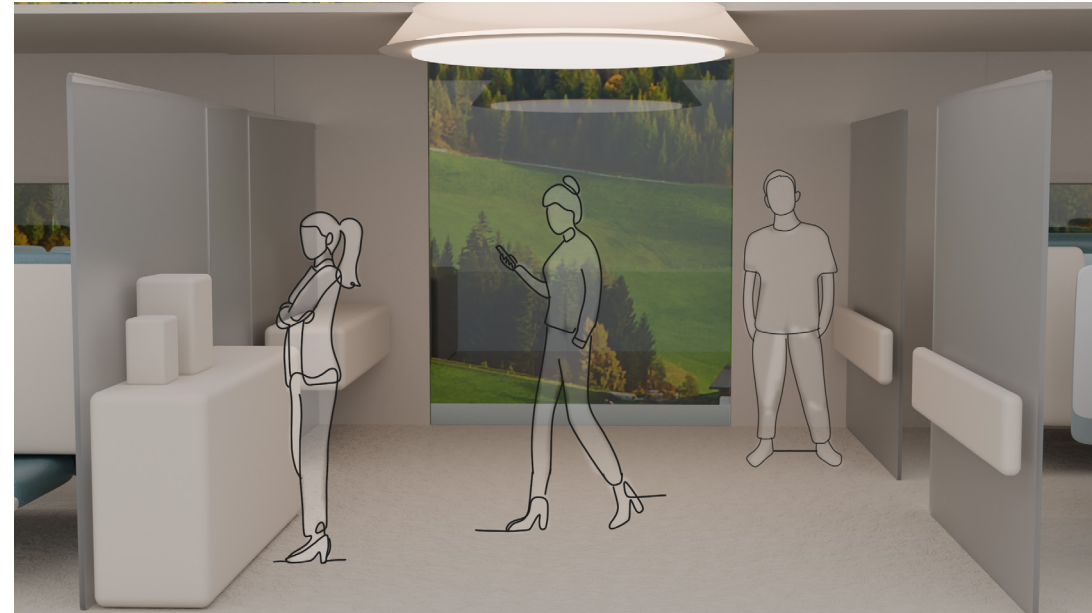


Figure 70. Central hall



Figure 71. Toilet & Washroom



Figure 72. Washroom Design Yao Xinhe

Design from Yao Xinhe. Design washroom for better hygiene experience in Flying-V aircraft.

07 / Walking routes

The walking routes are indicated by arrows in figure 73. The layout of the coach is symmetrical making that the walking routes are the same on both halves of the coach.

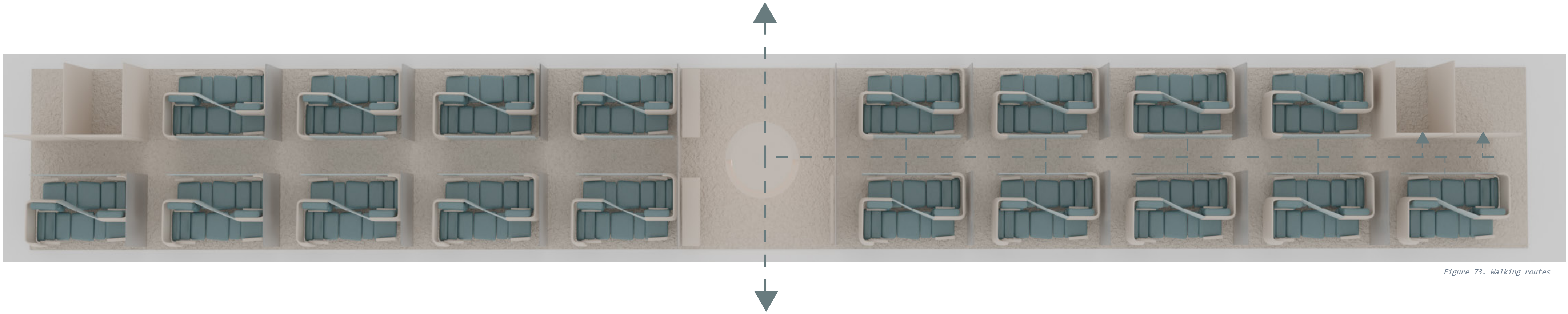


Figure 73. Walking routes

08 / Concept elements

Wifi

Free wireless internet is offered in the train.

Travel info boards

The walls consist of digital boards displaying up-to-date travel information, see figure 74. These show arrival and departure times but also delays or other real-time updates. During the night, it will give updates on where the train is running and it will indicate punctuality.

Help button

To ensure safety on the train, 'help buttons' are placed above each pair of seats, see figure 75. If a passenger becomes unwell or an unsafe situation arises, the button can be pressed and the train crew will be called to come and help.

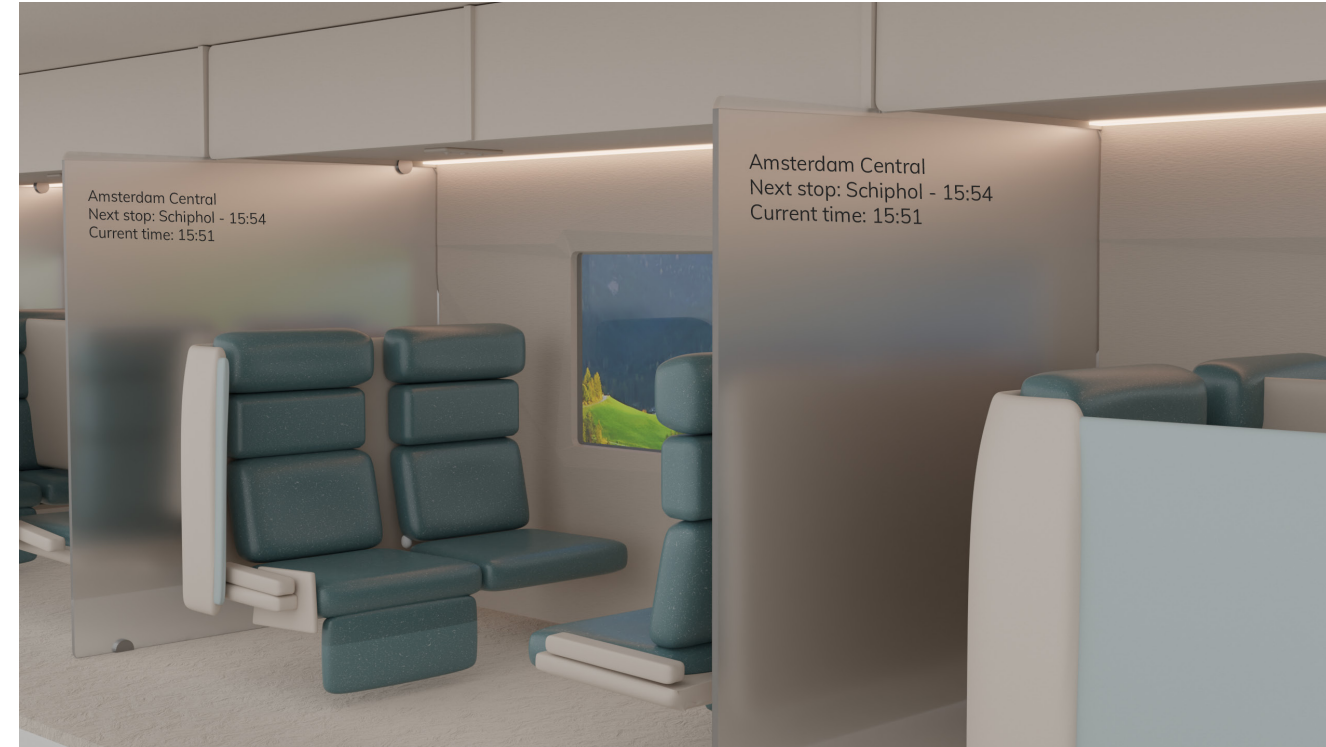


Figure 74. Travel info boards



Figure 75. Personalisation

Sockets

One socket and usb port is available per passenger.

Temperature control

Above each seat is an air inlet allowing passengers to control the temperature individually, see figure 75.

Scents

An air freshener is placed at each set of seats, which can be used to mask unpleasant odours or to simply infuse the coach with a fresh scent.

Noise cancelling material

Noise cancelling material is added to the privacy screens around the seat to minimise noise for the passengers, especially during the night.

Lighting

Interior lighting is an important factor in creating a comfortable atmosphere. Therefore is the coach equipped with both functional and so-called 'mood lighting'. Examples of functional lighting are lights in the toilet and washroom, light strips along the ceiling of the coach and the small night lights above the bed (see figure 78). Examples of 'mood lighting' include the round dome lamp in the central hall (see figure 76). This lamp should add a calm, comfortable feel to the central hall so that passengers can relax as soon as they board on the train. In addition, the lamps can emit different colours of light. For example, they emit white or blue light during the day and warmer yellow light in the evening.

These light colours have another function besides providing comfort, which is to indicate different seating zones. The next paragraph explains more about these seating zones.



Figure 76. Central hall daytime



Figure 77. Central hall nighttime



Figure 78. Warm lights during evening

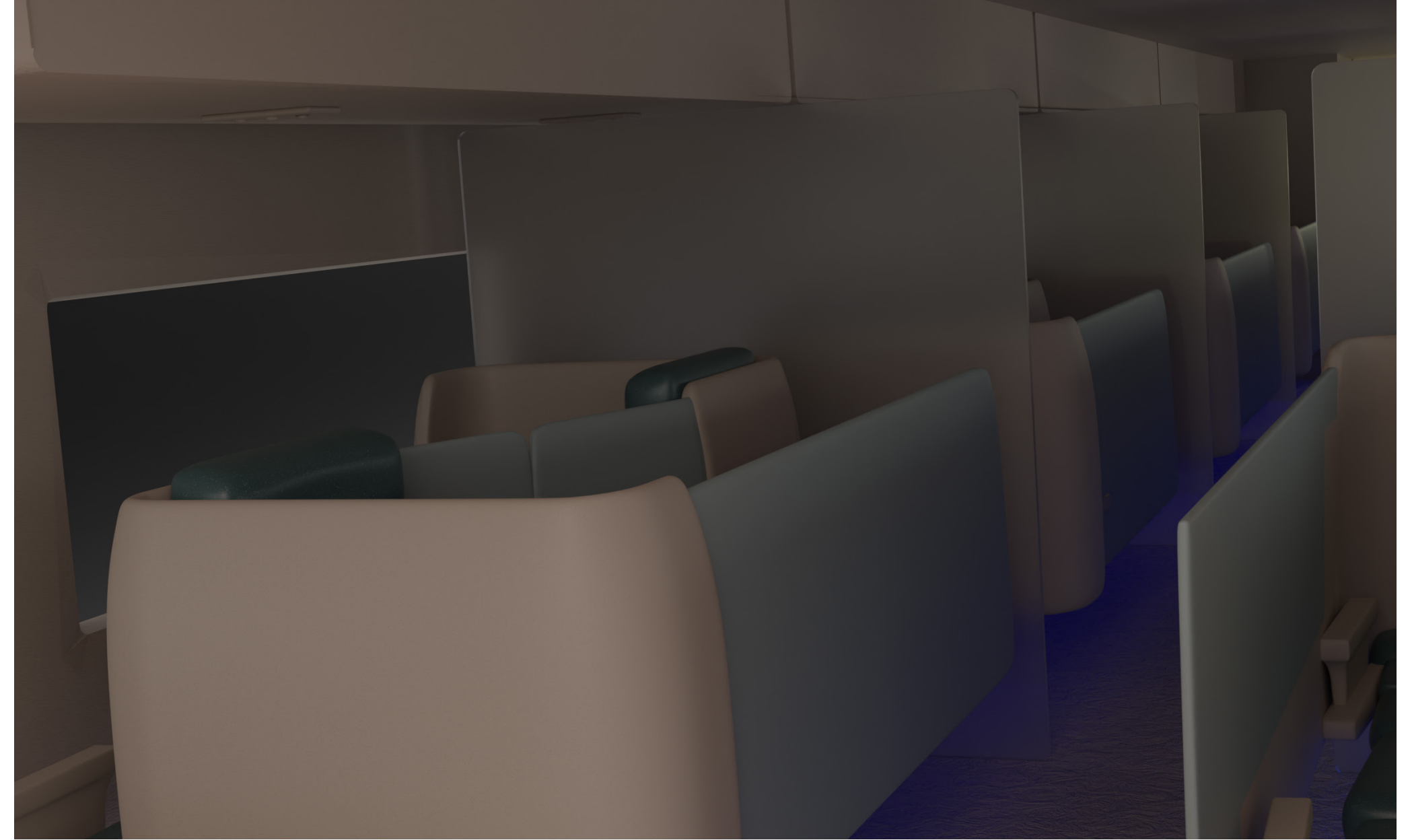


Figure 79. Travel zone light during evening

Seating zones

In the coach, certain zones have been provided to enable like-minded people to sit together. For example, during the day, the train has a silence zone and a meet & greet zone. In the silence zone, as the name suggests, passengers are meant to be truly quiet. This way, they can enjoy the travel in peace. The silent zone is indicated with an silence icon on the digital screens and with blue lighting as can be seen in figure 80.

The meet & greet zone, on the other hand, is meant for meeting people or travelling in groups. As the seats are arranged opposite each other, it is convenient to have a chat. This zone is indicated with an chatting icon on the smart screen and with purple light as can be seen in figure 80.

At night, these zones also exist, however the number of seats per zone is flexible. When booking a night ticket, passengers are able to specify in which zone they want to travel. Based on the bookings, passengers are seated together. In addition to these zones, there is also a women-only zone at night, as research showed that women travelling alone like to sit next to other women. The women zone is indicated with a women icon and no specific light color as can be seen in figure 80.

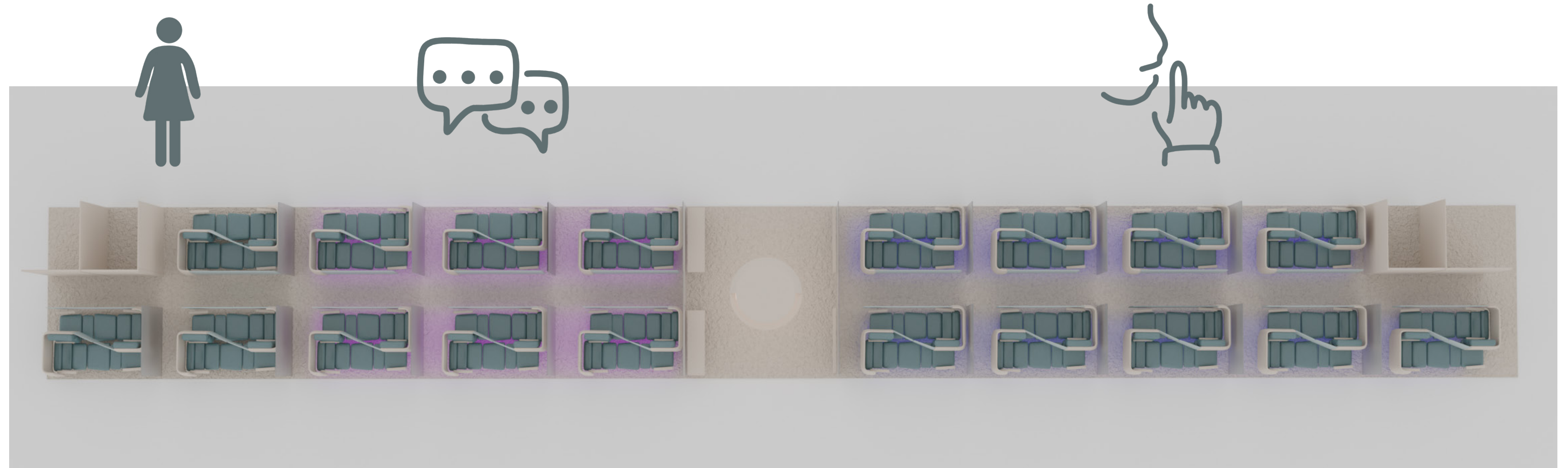


Figure 80. Topview travel zone light

Hygiene

Since COVID, the focus within interiors of public or shared travel modalities has been on hygiene and personal space. Hygiene has to do with material choice, air ventilation and cleaning protocols. Personal space involves actual physical space but also shielding from others. The train crew should have an established cleaning protocol that pays attention to physical touch points, especially seats, ceiling air vents, door handles, tables and window shades. There should also be good airflow throughout the coach with enough fresh air being supplied.

Breakfast service

Breakfast should be included in every night trip. It should be served at the passenger's seat and the time should depend on the route and arrival time. The advantage of this layout is that not everyone (in a compartment) has to wake up at the same time to have breakfast. Instead, passengers can decide for themselves when they want to have breakfast.

Night ticket reservation

It is necessary to work with ticket reservations at night to enable people to travel in their desired zone. Next to that, is it also necessary because of the difference in capacity between the daytime and nighttime layout. This means that not everyone who has a seat during the day also has a bed at night. Section 10 'Journey' further explains how this will work.

09 / Dimensions

Figure 82 shows the dimensions of the entire coach from a top view and figure 81 shows the dimensions of a seating section from a top view. As mentioned in chapter 2.04, the train type G2 is assumed. It is 3.15 metres wide, 4.68 metres high and 26 metres long. The design combined with the height of this train makes that this layout can also be implemented in double-decker trains.

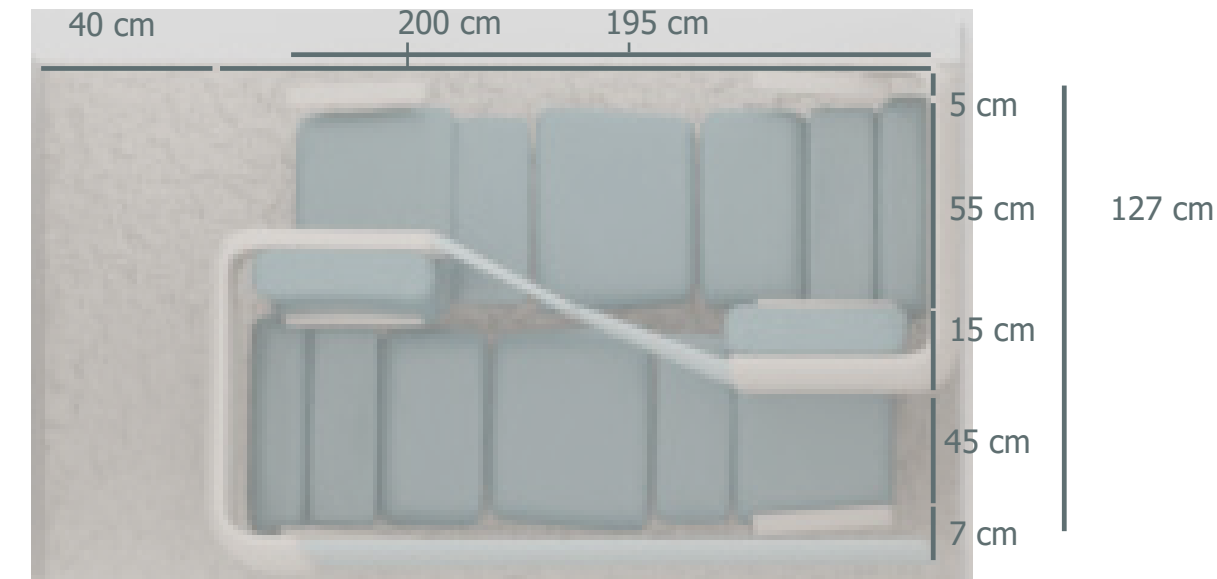


Figure 81. Dimensions seat section

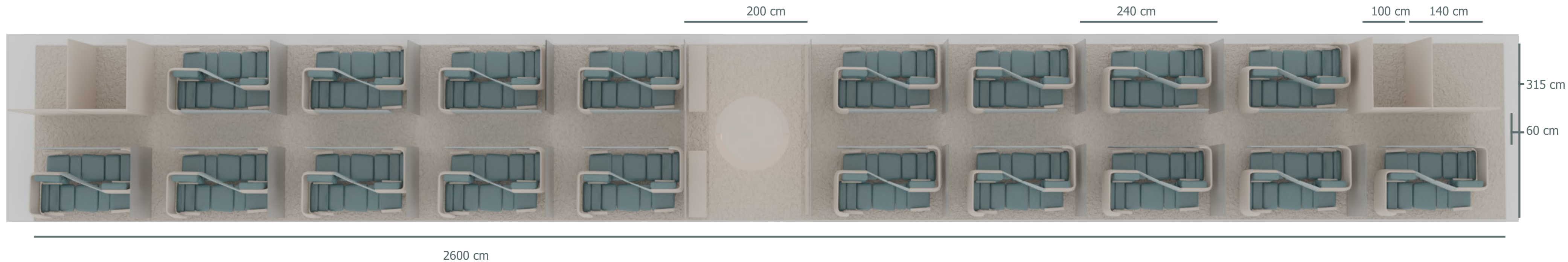
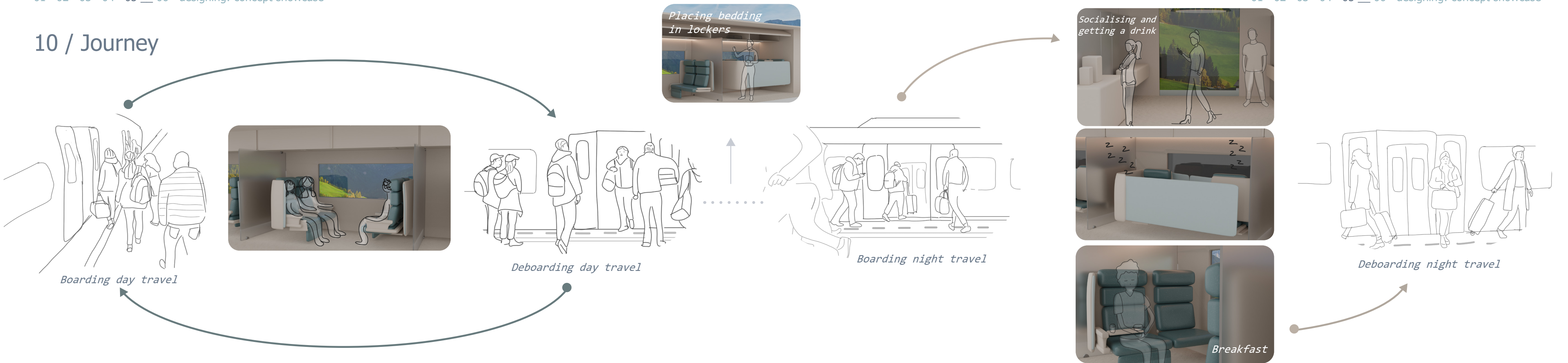


Figure 82. Dimensions coach

10 / Journey



10:03
Departure Amsterdam Central station

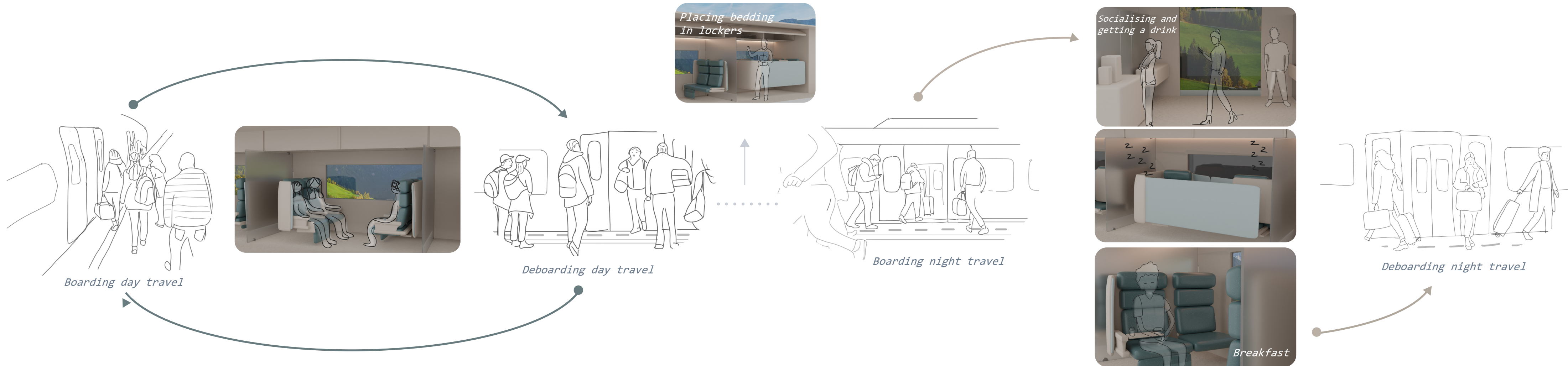
Daytime travel:
No reservation necessary
Traject Amsterdam Central - Eindhoven central

19:00
Arrival Amsterdam Central Station

19:30
Departure Amsterdam Central Station

Nighttime travel:
Reservation necessary
Traject: AMS - Vienna

9:19
Arrival Vienna Hauptbahnhof



7:00
Departure Vienna Hauptbahnhof

Daytime travel:
No reservation necessary
Traject unkown

19:45
Arrival Vienna Hauptbahnhof

20:13
Departure Vienna Hauptbahnhof

Nighttime travel:
Reservation necessary
Traject: Vienna - AMS

9:59
Arrival Central Station

Business case

To get a better idea of what the revenue is from the different types of coaches, a global revenue calculation was done, see Appendix 9 for the full calculation.

The calculation is based on the capacity of the coach, the revenue per seat or bed, the occupancy rate and the number of hours the coach is in operation. For aspects on which no source could be found, assumptions were made. For the price per seat or bed during the night, a journey from Amsterdam to Vienna has been assumed. Table 9 shows the revenue in euros per type of coach. These results show that the financial revenue of the 24H-COACH is higher than that of a normal coach. The smaller number of seats during the day is more than compensated by the revenue from the beds at night. The revenue is also well above that of a conventional night train (for all three classes). In short, making the interior usable for day and night allowing the train to be used more has a financial gain.

Type of coach	Revenue (euros)
Day coach	13926,40
Night coach - Seating accomodation	6600
Night coach - Couchette	6615
Night coach - Sleeper	7200
24H-COACH	16853,76

Table 9. Revenue different types of coaches

Conclusion

The 24H-COACH is a train wagon with a flexible interior that allows the coach to be used both during the day and at night. The exterior dimensions of a standard international coach have been assumed. Thus, if the interior in these trains is replaced to the 24H-COACH interior, the current night trains become more deployable. The interior is made up of interchangeable modules that can be easily moved around the train, allowing the capacity to go up or down depending on the wagon type (operator type). The capacity of the 24H-COACH layout, as proposed in this report, is 72 passengers during the day and 36 passengers at night. With this capacity, the 24H-COACH is more profitable than a train that can only travel during the day or only at night. Because the 24H-COACH is more employable, operators can reduce the ticket price, which may make people more likely to opt for the (night) train.

The interior design was a challenge. Because it had to be usable during the day and at night, it had to meet several requirements. These are requirements from the operator, which are mainly about capacity, but also requirements from the passenger, which are mainly about comfort. The focus for the interior design was on creating the right balance between privacy and safety to provide optimal comfort. The choices made were based on the research that was done.

The interior consists of existing elements combined in an innovative way. This would allow the design to be further developed into a fully-fledged product in a relatively short period of time.

Now that the 'revival of the night train' is in full swing, it is an excellent opportunity to inspire operators how night train travel can be more profitable and more comfortable, and to convince travellers to choose the (night) train rather than a plane or car.

06
00

Concept discussion

Requirements, Expert meetings, Recommendations and Reflections

/ 01 Requirements evaluation

/02 Expert meetings

/ 03 Recommendations

/ 03 Reflection

06
01

Requirements evaluation

In chapter 3.04, requirements for the design were established. In table 9, these requirements are shown again with the addition of whether the requirement has been met (green), not met but still feasible (yellow) or not met (red).

The figure shows that two requirements have not yet been met and are marked yellow. The first one is about noise levels. The noise cancelling material and privacy walls may not provide enough attenuation of noise. This needs further testing, more elaboration on this is given in chapter 6.02. The other requirement marked in yellow is about sleeping places for the train crew vs the minimum capacity. In this design, there is no room for the crew if there have to be at least 36 passengers in a coach. However, an idea has been devised for this which can be seen in chapter 6.02.

Improving passenger comfort	Daytime travel	Seating	<ul style="list-style-type: none"> ● Passengers want to travel seated during the day. ● The seating position should have a backrest angle between 115-120 degrees. ● Legroom should be more than 60 cm. ● Passengers should be able to work on a traytable. ● Passengers should be able to charge electronic devices.
		Privacy	<ul style="list-style-type: none"> ● Passengers want to sit as far away from others. ● Passengers do not have to smell others.
	Nighttime travel	Lying flat Privacy Safely stored luggage	<ul style="list-style-type: none"> ● Passengers can lie flat during the night. ● Passenger are able to shield themselves from others. ● Passengers want their luggage to be safe (locked) during the night.
	Both daytime & nighttime travel	Space Noise Light Temperature Seat	<ul style="list-style-type: none"> ● The coach has an open and spacious design. ● The noise level should be minimised. ● Light color and strenght should be able to be personalised. ● Temperature should be able to be personalised. ● The seat should be (easily) adaptable. ● The seat should stand in the direction of travel or counterclockwise. ● The material of the seat/bed can be easily cleaned.
Crew comfort and concerns		Groupsize	<ul style="list-style-type: none"> ● Passengers should be able to travel alone, in pairs or in a group of four.
	Crew seating		<ul style="list-style-type: none"> ● There should be enough space for crew seating without compromising the required minimum capacity.
	Transition day - night		<ul style="list-style-type: none"> ● Passengers can make their own switches from day position (sitting) to night position (lying).

Production & development	Development	<ul style="list-style-type: none"> ● The concept should contain as few mechanisms as possible (also for maintenance). ● The concept should contain as few elements as possible (also for maintenance). ● It is advantageous if the concept consists of existing elements.
	Development timescope	<ul style="list-style-type: none"> ● The concept should be able to be developed within 18 months.
	Target group	<ul style="list-style-type: none"> ● The target group for the design should be business travellers
Safety & regulations	Emergency routes	<ul style="list-style-type: none"> ● The location of the emergency exits are clear and can be sufficiently accessed.
	Aisle width	<ul style="list-style-type: none"> ● The aisle width is between 60 and 80 cm wide. <p>Preferably, the aisle width is as wide as possible.</p>
	Accessibility seat	<ul style="list-style-type: none"> ● It must be easy to get in and out of the seat.
Capacity & margins	Minimum capacity	<ul style="list-style-type: none"> ● For nighttime travel is the minimum capacity around 36 passengers per coach. <p>Preferably is the (daytime) capacity is as high as possible as long as it does not compromise on passenger comfort.</p>

Table 9. Assesment criteria

Expert evaluation

// 01 Expert meeting setup

// 02 Expert feedback

01 / Expert meeting setup

To find out more about the feasibility, viability and desirability of the 24H - COACH, I pitched the concept to a number of experts and asked for their opinions and feedback. Both experts around (night) trains and experts around airplanes and airports were invited. Some meetings were physical and others online as can be seen in figure 83 - 85. All people listed below were interviewed. The next section explains their feedback.

Train experts

These experts were asked mainly to test the feasibility and viability of the concept.

- Thomas Sauter-Servaes - Professor Engineering Mobility University of Zürich
- Axel Kiese - Founder & CEO Ace4Rail
- Albert Koch - Customer Direction Ace4Rail
- Designer Ace4Rail
- Evelien Fleskens - Customer Experience and Community Manager European Sleeper
- Barth Donners - Consultant sustainable mobility Royal HaskoningDHV (and my supervisor)
- Anton Dubreau - Founder Luna Rail
- Martijn Heufke Kantelaar - NS international
- Brigitte Matheussen - lead architect/ formule manager NS
- Roeland Reitsema - Design manager NS

Airplane experts

These experts were asked to test the desirability of the concept.

- Piet Ringersma - Airport Architect Royal HaskoningDHV
- Maarten - Airport Architect Royal HaskoningDHV
- Youri - Airport Architect Royal HaskoningDHV



Figure 83. Pitch European Sleeper

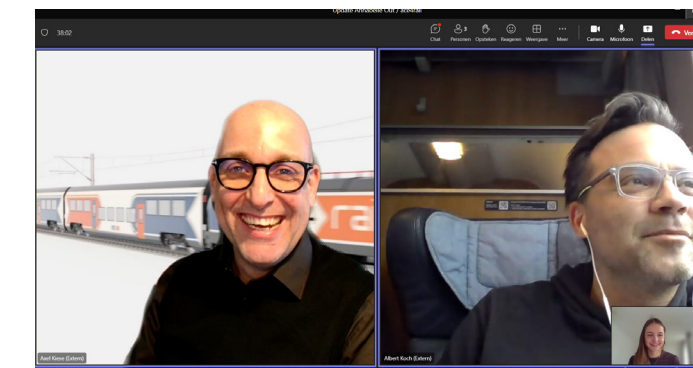


Figure 84. Pitch Ace4Rail

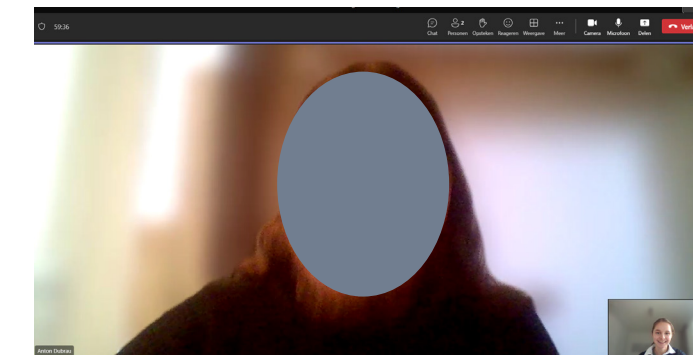


Figure 85. Pitch Luna Rail

02 / Expert feedback

A number of positive points about the concept and process emerged from the meetings with various experts, as well as some suggestions.

I received positive feedback on how I approached the project. My vision and focus on sense of privacy and security was recognisable and they thought it was a good direction. They also liked the fact that I used Virtual Reality for testing different layouts and for evaluation. This 'new' technique is being used more and more and is very valuable for quick testing.

From an operator view, it was said that they already find the capacity benchmark of the concept very good (for the daily schedule only 10% reduction). After hearing the dimensions, they said they still found it quite spaciously designed and would look into adding another row, increasing capacity to 80 passengers during the day and 40 at night. The flexible interior makes capacity easily adaptable which is valuable because capacity is money and capacity and quality are opposites in this context.

About the design, they really felt that passengers have their own space and that this fits well with the needs of passengers in this era. In addition, the extra aisle to the window-side

seats was seen as a quality advantage because this space can be used for luggage space during the day. One expert indicated that he would still find it quite intimate to lie next to a stranger in this way.

A suggestion was that I could present the design to current aircraft users to find out whether they would be willing to switch from aircraft to (night) train with this design.

I therefore asked a number of Airport architects from RoyalHaskoning DHV for their opinion. These people fly around once a month for business trips and therefore have a lot of experience with flying. They were enthusiastic about the design. They thought it resembled business class seats in planes. They would like to travel in this interior but indicated that there are more factors influencing why they choose flying. With flying, you usually do not have to transfer and if there are delays or cancellations, the airline takes responsibility. With (night) trains, this is not the case. If there were more direct routes (which means you cannot miss transfers with delays), all interviewees would take the 24H- COACH but as this is not the case now, they would not take it for business trips were you want to arrive on time.

Barth Donners (Supervisor from Royal HaskoningDHV): "You have invented the egg of columbus among trains".

Thomas (Professor): "Great evolution of seating couchette, modern version of it".

Axel (Founder Ace4Rail): "The simplicity of the design makes it very good. No 'student magic' but all elements of the concept can be implemented in the real world".

Recommendations

// 01 Materials

// 02 Noise levels

// 03 Facilities

// 04 Testing desirability

// 05 Women only coach

// 05 Development feasibility

// 06 Capacity

// 07 Floorplan suggestion

Based on this assessment, several recommendations for improvement can be formulated. These will be further elaborated on below.

01 / Materials

Extensive research should be done on which materials would be suitable for the different interior elements. Requirements for the materials should be ease of cleaning and durability. Preferably, only circular materials should be used. These could be recycled plastics, renewable materials or other reused components. Preference should be given to using materials with low environmental impact throughout their life cycle.

02 / Noise levels

Given the open layout of the train, tests should be carried out to see what the daytime and nighttime noise levels are. In the current concept, noise cancelling material has been added on the seat privacy screens. However, if the noise levels are still higher than 35 db source (Caddick et al., 2018), consideration should be given to adding more noise cancelling material in the coach. These noise cancelling materials could be placed on the privacy walls in the coach, on the ceiling and on the sides of the coach.

03 / Facilities

In terms of facilities, it should be tested whether passengers prefer a shower with sink or just a sink. If the shower is not used, more attention could be paid to what the sink should look like and what facilities should be available (see report from Yao Xinhe). In addition, ways of providing entertainment in the coach could be considered. Research by Heufke Kantelaar (2022) showed that entertainment is essential for comfort during long-distance travel.

04 / Testing desirability

To test more comprehensively whether the 24-hour coach will meet its initial design goal of bringing more people onto trains. It would be worthwhile to ask more current flyers, people who currently only fly for long-haul trips, about their willingness to travel with the 24-hour coach. This is a new target group for the train and therefore important to inquire. In addition, the VR test comparing the current seating compartments with the new design could also be done with the couchette. This test will even more clearly indicate how the interior of the 24H coach is perceived compared to the interior of current night trains.

In addition, in terms of design, it would be worth further brainstorming whether it would be possible to use 2 seats instead of 4 seats for daytime travel as these are more popular for daytime travel.

05 / Women only coach

If this train were to be realised, it would be better to make a women-only coach instead of having a women-only section in each coach. That way single women travellers have their own coach, in which no other travellers can enter, which will increase their sense of security.

06 / Art details

Art is an important means of enhancing the experiential value and identity of the railway, thus improving the quality of the journey. For example, art makes passengers more aware of their surroundings and each other. In addition, art also acts as a connecting factor between different spaces (Art and the Train, n.d.). For these reasons, more research should be done on types of artworks for trains.

07 / Development feasibility

More attention should also be paid to the feasibility of the concept. Currently, the mechanism for making the seat-bed transition has not been worked out. In theory, the same mechanism could be used as for business class aircraft seats, but it needs to be investigated whether this is at all feasible and what the effect is on space usage in the train coach.

A step that could be taken right away is to be able to make a 1:1 scale model (of cardboard, for example) to test and evaluate the space. By giving a tangible image of the concept, it can be used as an effective communication tool towards, for example, companies or other designers/developers.

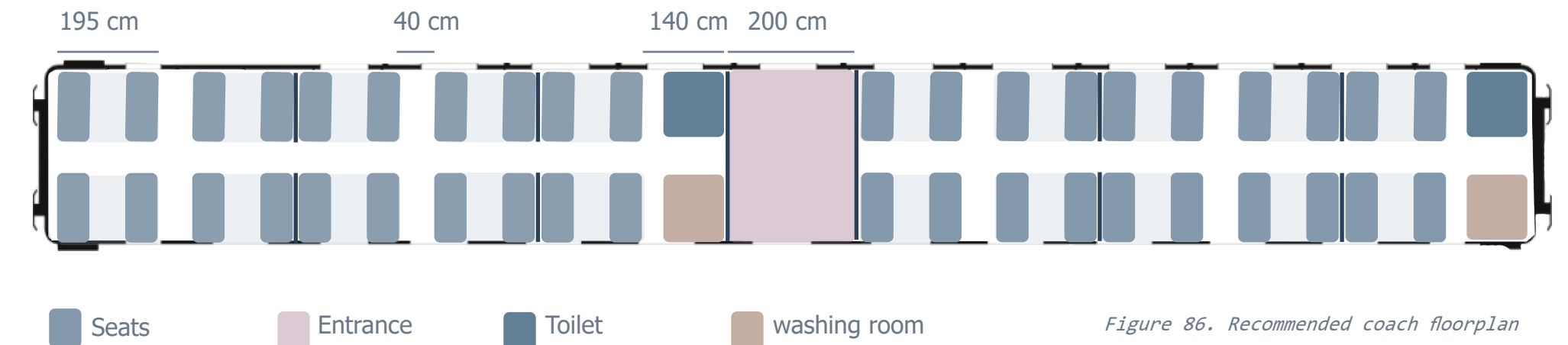
In addition, for further development, it is important that the mechanism and all connections between seating elements take into account circular principles, such as disassembly, reuse and recycling. For this in combination with materialisation, an expert meeting with a train seat manufacturer or train seat design agency would be a very good first step to get a better idea. Finally, consider production methods that use less raw materials and generate less waste, such as 3D printing.

08 / Capacity

Axel and Albert from Ace4rail mentioned that they thought the design was still reasonably spacious and recommended looking at whether one more row could be placed in the coach. In that case, the capacity during the day would be 80 passengers, the same as in current 'day' trains, and 40 passengers during the night. Train crew will then have a place in the coach without compromising the minimum capacity (36) of passengers. This adjustment will improve the business case of the 24-hour coach.

09 / Floorplan suggestion

Figure 86 shows a new schematic proposal for the coach's layout. What has changed from the layout in Chapter 5 is that the capacity has been increased to 80 passengers during the day and 40 at night. As a result, each seat no longer has its own side aisle but these will be shared. In addition, a toilet and washroom module has been moved more to the centre of the coach so that passengers with reduced mobility can reach it. The elevation of the floor at the end of the coach, due to the wheel arches, would otherwise not allow them to use the toilet and washroom.



Reflection

// 01 Project reflection

// 02 Personal reflection

This chapter looks back at how the project progressed and what I learned from it. To this end, it reflects on the learning objectives I had set at the beginning of the project.

01 / Project reflection

The brief I was given by Royal HaskoningDHV was quite broad. I had not a lot restrictions and much freedom to discover for myself where I wanted to go with my graduation project. All that was predetermined was that the design had to make the train usable for day and night travel. I had set a goal for myself: I want to inspire Royal HaskoningDHV and train operators how things can be done differently. I wanted to do this by making a conceptual design, not fully detailed. I had already gathered many insights from my preliminary research but it was a bit of a search where to start. Once I started, the project gained momentum. As choices were made, the scope of the project became smaller and smaller. At the same time, the possibilities kept growing. Looking back, I approached the project with an open mind and explored all possibilities. After I had chosen my concept

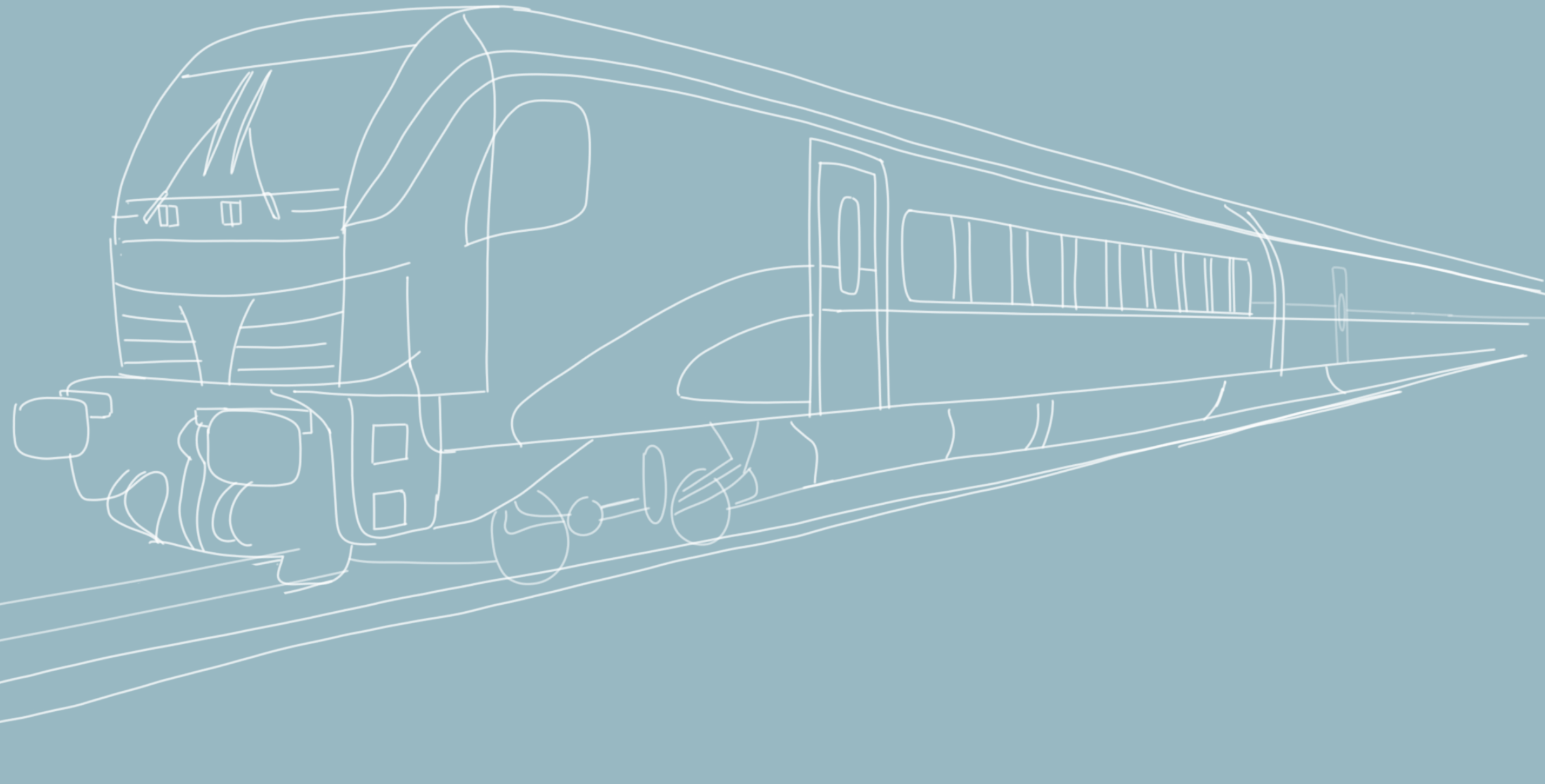
direction, making steps (what research am I going to do, what choices should I make and why and what/who do I need to take the concept to the next level) became easier because the steps felt logical.

Looking back on the process, I would not have done much different. I would have liked to do even more (such as defining the materials and making a 1:1 cardboard model) but unfortunately there was no more time for that. Furthermore, I am very happy with the fact that Royal HaskoningDHV gave me so much freedom to choose my own path. I was able to use my passion for mobility, knowledge and skills to come up with my own design. I learned working with new programmes like Blender, Unreal Engine (for Virtual Reality) and SPSS, also how to set up user tests and use them to scientifically substantiate my design choices. I am thankful that Royal HaskoningDHV and TU Delft gave me the opportunity to work on this relevant project now that we are in the midst of the era the 'Renaissance of the night train'. I would also like to thank Barth Donners, Peter Vink, Gerbera Vledder and Suzanne Hiemstra-van Mastrigt for their excellent guidance during my project.

02 / Personal reflection

First of all, I really enjoyed working on this project. My aspiration is to work in the sustainable mobility sector. To work on integrated systems but also physical modalities both aimed at improving the user experience. This project therefore perfectly matched my interests. What fascinated me even more about this project is its timeliness in relation to developments in today's world. There could not be better timing for this project. Besides being happy with the outcome of my project, I am thankful for the development I have gone through as a designer and as a person.

Now that I have almost completed my studies and talked to many experts, who are not designers, I know what I have learned and what I am good at (and not good at of course). I have found out that I can independently carry out a project from A to Z, can communicate with different people, can empathise with a user, can arrive at information that does not yet exist through research, and I think one of the most valuable skills I have learnt over the past five years is to discover the root causes of large complex problems and from there solve it in a simple way. As a designer, I have developed a different view on the world and a different way of thinking. I am neither an engineer nor an artist but I am someone who can think logically, out of the box and is solution-driven. I am grateful for all the experience I have gained over the past 5 years and I am ready for the future!



References

Acubed, Airbus. (2016, December 13). The future of flight is customizable: Introducing Transpose. Retrieved January 2021, from Acubed: <https://acubed.airbus.com/blog/transpose/the-future-of-flight-is-customizable-introducing-transpose/>

Airbus. (n.d.). Inspiring Space, Cabin Ambience. Retrieved January 2021, from Airbus: <https://www.airbus.com/aircraft/passenger-aircraft/cabin-comfort/air-space/inspiring-space>. Html

Amtrak. (n.d.). <https://www.amtrak.com/onboard/onboard-accommodations-for-all-your-needs/sleeper-car-accommodations.html>

Augusteijn, N., & Augusteijn, N. (2022, 15 november). Dutch government earmarks billions for investment in rail | RailTech.com. RailTech.com. <https://www.railtech.com/infrastructure/2022/11/15/dutch-government-earmarks-billions-for-investment-in-rail/>

Beïnvloedbare factoren veiligheidsbeleving. (2023, 15 september). Het CCV. <https://hetccv.nl/themas/veilige-woon-leefomgeving/veiligheidsbeleving/beïnvloedbare-factoren/>

Bouwens, J. (2018). Design Considerations for Airplane Passenger Comfort. <https://doi.org/10.4233/uuid:306dd9f8-fab9-4f1f-8c1a-1a208e815c21>

Burroughs, D. (2020, 8 december). ÖBB, DB, SBB, and SNCF announce NightJet Collaboration. International Railway Journal. <https://www.railjournal.com/passenger/main-line/obb-db-sbb-and-sncf-announce-nightjet-collaboration/>
Caballero-Bruno, I., Lingelbach, K., Wohllebe, T., Weng, M., Piechnik, D., Tagalidou, N., Vukelić, M., & Castellano, P. M. H. (2024).

Sleep quality and comfort in fully automated vehicles: A comparison of two seat configurations. Applied Ergonomics, 114, 104137. <https://doi.org/10.1016/j.apergo.2023.104137>

Caddick, Z. A., Gregory, K. B., Arsintescu, L., & Flynn-Evans, E. E. (2018). A review of the environmental parameters necessary for an optimal sleep environment. Building and Environment, 132, 11–20. <https://doi.org/10.1016/j.buildenv.2018.01.020>

Clarkson, J. (2008). Human capability and product design. In H. N. Schifferstein & P. Hekkert (Eds.), Product experience (pp. 165–198). Amsterdam: Elsevier.

e2ip technologies. (n.d.). e2ip. Retrieved February 2021, from Intuitive Interactions, Moulded to the Moment: <https://e2ip.com/printed-electronics/>

EenVandaag. (2021, 3 maart). We willen straks weer massaal gaan reizen, maar het liefst wel duurzaam: “Houding is door de coronacrisis veranderd”. <https://eenvandaag.avrotros.nl/item/we-willen-straks-weer-massaal-gaan-reizen-maar-het-liefst-wel-duurzaam-de-houding-is-door-de-coronacrisis-wel-veranderd/environment>. Work, 54(4), 963-979.

Eisenbahn-Bundesamt (EBA), Bijlage 1 van de Eisenbahn-Bau- und Betriebsordnung (EBO). Geraadpleegd op 2 april 2013. (Doctoral dissertation). Retrieved from Repository Universität Oldenburg.

European Rail Traffic Management System (ERTMS). (2023, 11 oktober). European Union Agency for Railways. https://www.era.europa.eu/domains/infrastructure/european-rail-traffic-management-system-ertms_en

Fabio. (2023). How to Choose Train Types & Seat Class in China, China Train. China Highlights - Since 1998! <https://www.chinahighlights.com/china-trains/choose-china-train-types-and-seat.htm>faith

Facilities on the train | Travel information | NS. (z.d.). Dutch Railways. <https://www.ns.nl/en/travel-information/facilities/facilities-in-the-train.html>

Faith, A. (2022, 21 december). All aboard! The Lost Romance of the Sleeper Train. Messy Nussy Chic. <https://www.messynussychic.com/2020/08/07/all-aboard-the-lost-romance-of-the-sleeper-train/>

Geerts, E., & Geerts, E. (2023, mei 25). A real night train renaissance? Join the discussion on RailTech Belgium | RailTech.com. RailTech.com. <https://www.railtech.com/infrastructure/2023/05/17/a-real-night-train-renaissance-join-the-discussion-on-railtech-belgium/>

Goedkoop treinkaartje. (2019, 21 maart). Faciliteiten, zitplaatsen en meer aan boord van de ICE International. Goedkoop-treinkaartje.nl. <https://goedkoop-treinkaartje.nl/blog/faciliteiten-zitplaatsen-en-meer-aan-boord-van-de-ice-international/>

Groenesteijn, L., Hiemstra-van Mastrigt, S., Gallais, C., Blok, M., Kuijt-Evers, L., & Vink, P. (2014). Activities, postures and comfort perception of train passengers as input for train seat design. Ergonomics, 57(8), 1154-1165.

Hendrikx, R. (2021). A service design vision for air-rail journeys Stimulating travellers to make a. Tu Delft repository. Heufke Kantelaar, M. H., Molin, E., Cats, O., Donners, B., & Van Wee, B. (2022). Willingness to use night trains for long-distance travel. Travel Behaviour and Society, 29, 339–349. <https://doi.org/10.1016/j.tbs.2022.08.002>

Hiemstra-van Mastrigt, S. (2015). Comfortable passenger seats: Recommendations for design and research (Doctoral dissertation). Retrieved from Repository Delft University of Technology

Hildebrand (2021, maart 29). Dit is waarom de exploitatie van nachttreinen nog steeds uitdagend is. *Treinreiziger.nl*. <https://www.treinreiziger.nl/dit-is-waarom-de-exploitatie-van-nachttreinen-nog-steeds-uitdagend-is/>

NightJet: tickets, prijzen en meer praktische informatie. *Treinreiziger.nl*. <https://www.treinreiziger.nl/nightjet-tickets-prijzen-en-meer-praktische-informatie/>

Hoelang zijn alle treinen van de NS als je ze op een spoor zet achter elkaar? (2021, 23 februari). Willem Wever. https://willemwever.kro-ncrv.nl/vraag_antwoord/wetenschap-techniek/hoelang-zijn-alle-treinen-van-de-ns-als-je-ze-op-een-spoor-zet#:~:text=Rijtuigen%20en%20bakken%20van%20treinstellen,NS%20er%20ongeveer%202775%20van.

IAA Mobility 2021: Automotive Interior Trends of the Future | Accuride. (2021, 9 maart). Accuride. <https://www accuride-europe.com/en/blog/iaa-mobility-2021-automotive-interior-trends-of-the-future>

Inspiratiegids DUURZAME MOBILITEIT. (z.d.). VNG. Kunst en de trein. (z.d.). Spoorbeeld. <https://www.spoorbeeld.nl/beleid/trein/kunst-en-de-trein>

LaVerda, T. (2023, 2 oktober). 12 of the world's most luxurious sleeper trains. *The Handbook*. <https://www.thehandbook.com/12-of-the-worlds-most-luxurious-sleeper-trains/>

Limb, L. (2023, 23 mei). It's official: France bans short-haul domestic flights in favour of train travel. *euronews*. <https://www.euronews.com/green/2022/12/02/is-france-banning-private-jets-everything-we-know-from-a-week-of-green-transport-proposals#:~:text=France's%20ban%20on%20short%2Dhaul,be%20taken%20as%20a%20flight.>

M.Ryu. (2022, 5 juli). Home Interior Trends Reveal: Mobility Interiors. Hyundai Motor Group. <https://www.hyundaimotorgroup.com/story/CONT0000000000041127>

Mark, V. H. (z.d.). Developing a train interior which fits the needs of customers. <https://trid.trb.org/view/1729270>

Maung, Y. S. Y., Douglas, I., & Tan, D. (2022). Identifying the drivers of profitable airline growth. *Transport Policy*, 115, 275–285. <https://doi.org/10.1016/j.tranpol.2021.11.007>

Mellert, V., Baumann, I., Freese, N., & Weber, R. (2008). Impact of sound and vibration on health, travel comfort and performance of flight attendants and pilots. *Aerospace Science and Technology*, 12(1), 18-25.

Mellert, V., Baumann, I., Freese, N., & Weber, R. (2008). Impact of sound and vibration on health, travel comfort and performance of flight attendants and pilots. *Aerospace Science and Technology*, 12(1), 18–25. <https://doi.org/10.1016/j.ast.2007.10.009>
Ministerie van Infrastructuur en Waterstaat. (2019, 15 juli).

Möller, T., Schneiderbauer, T., Garms, F., Gläfke, A., Köster, N., Stegmüller, S., ... & Bobka, K. (2021). The future of interior in automotive. *future*.

Nightjet of the new generation. (z.d.). Nightjet. <https://www.nightjet.com/en/komfortkategorien/nightjet-neue-generation>

Night trains | Travel Information | NS. (z.d.). Dutch Railways. <https://www.ns.nl/en/travel-information/special-routes/night-trains.html>

Night trains in Europe. (z.d.). Eurail. <https://www.eurail.com/en/plan-your-trip/trip-ideas/trains-europe/night-trains#:~:text=Night%20trains%20offer%20a%20comfortable,the%20next%20while%20you%20sleep.>

ÖBB and Siemens Mobility present the interior design of the next . . . (z.d.). <https://press.siemens.com/global/en/pressrelease/obb-and-siemens-mobility-present-interior-design-next-generation-nightjet>

Omgevingspsycholoog, D. (2021, 19 februari). Hoe wordt privacy beïnvloed door de fysieke omgeving? *De Omgevingspsycholoog*. <https://www.omgevingspsycholoog.nl/voorbeelden-privacy-in-fysieke-omgeving/#:%7E:text=Hoe%20be%C3%AFnvloedt%20de%20fysieke%20omgeving,zijn%2C%20zonderen%20we%20ons%20af.>

Optimares. (2018, March 18). Glad to introduce you PASSME, innovative aircraft seat concept. Retrieved 13 2021, from Optimares: <http://www.optimares.com/news.php?id=14>

Out, A. A. (2023). Design considerations for night train passenger comfort. *Tu Delft*.

Pasut, W., Zhang, H., Arens, E., Kaam, S., & Zhai, Y. (2013). Effect of a heated and cooled office chair on thermal comfort. *HVAC&R Research*, 19(5), 574-583.

Pierini, J. (2023, 3 juli). New night trains in Europe - everything you need to know. *Greens/EFA*. <https://www.greens-efa.eu/opinions/new-night-trains-in-europe-for-the-climate/#:~:text=And%20they%20also%20protect%20the,use%20the%20UIC%20EcoPassenger%20tool.>

Public awareness inspires shift towards sustainability. (z.d.). <https://www.easy-skill.com/blog/public-awareness-inspires-shift-towards-sustainability>

Quehl, J. (2001). Comfort studies on aircraft interior sound and vibration.

Recaro. (2017, March 30). More spaciousness and comfort with Recaro's Flex Seat concept. Retrieved January 2021, from Recaro: <https://www.recaro-as.com/en/press/press-releases/details/more-spaciousness-and-comfort-with-recaros-flex-seat-concept.html>

Roel. (2023, 31 oktober). Waarom de nachttrein niet eenvoudig kan concurreren. *Wintersport weblog*. <https://www.wintersport.nl/weblog/31/10/2023/waarom-de-nachttrein-niet-eenvoudig-kan-concurreren>

Slapend onderweg: potentieel van de internationale nachttrein van en naar Nederland. Document (onderzoekpublicatie) | Kennisinstituut voor Mobiliteitsbeleid. <https://www.kimnet.nl/publicaties/rapporten/2019/06/20/slapend-onderweg-potentieel-van-de-internationale-nachttrein-van-en-naar-nederland>

Smulders, M., & Vink, P. (2021). Sleep quality and (dis)comfort in minimal space envelope. In International Comfort Congress 2021 (3rd ed., pp. 169-174). <https://publications.ergonomics.org.uk/publications/sleepquality-and-discomfort-in-a-minimal-space-envelope.html>

Stahl, E. P. (2023, 29 augustus). Exploring the latest trends in In-Vehicle personalization. Medium. <https://medium.com/@experiencespermile28/exploring-the-latest-trends-in-in-vehicle-personalization-9bd67e7623d3>

The Good Night Train | European Sleeper. (z.d.). European Sleeper. <https://www.europeansleeper.eu/de-trein>

The Pullman History Site : The Pullman Company. (z.d.). <https://www.pullman-museum.org/theCompany/>

Trein naar Wenen - v.a. € 35 enkele reis | NS International. (z.d.). NS International. <https://www.nsinternational.com/nl/oostenrijk/trein-wenen>

Turner, Daniel. (2010). Qualitative Interview Design: A Practical Guide for Novice Investigators. Qualitative Report. 15. 10.46743/2160-3715/2010.1178.

Van Boeijen, A.G.C., Daalhuizen, J.J., Zijlstra, J.J.M., van der Schoor, R.S.A. (eds.)(2013) Delft Design Guide. Amsterdam: BIS Publicers.

Van Hagen, M., & Exel, M. (2012). De reiziger centraal. Spoorbeeld. https://issuu.com/bureauspoorbouwmeester/docs/14_08_12_sb-es-say4-dereizigercentraal

‘Veel mensen vinden het ov maar gedoe’. (z.d.). OV-Magazine. <https://www.ovmagazine.nl/vakartikel/veel-mensen-vinden-het-ov-maar-gedoe>

Vink, P., & Brauer, K. (2016). Aircraft interior comfort and design. In CRC Press eBooks. <https://doi.org/10.1201/b10815>

Xiaoyuan, S. (n.d.). “Double-layer” sleeper EMU debuts in Spring Festival! Netizens exclaimed: This is a mobile hotel! Weixin Official Accounts Platform. https://mp.weixin.qq.com/s/Y_2M7dJxWcBEjyWM-n9m8Ig

Young, M. (2015, 17 april). Staggered airplane seating. TrendHunter.com. <https://www.trendhunter.com/trends/cozy-suite>

Zhang, L., Helander, M. G., & Drury, C. G. (1996). Identifying factors of comfort

Zijlstra, T., & Rienstra, S. (2021). Zakelijk vliege. Kennisinstituut voor Mobiliteitsbeleid - KiM, 978-90-8902-259-2(KiM-21-A019).

Appendix

01 / Cultural impact night train

Night trains have historically had and continue to have a significant cultural impact. Here are some ways night trains have been and continue to be culturally influential:

Literature and film: Night trains have a romantic and mysterious appeal that has inspired writers and filmmakers. Famous novels like Agatha Christie's "Murder on the Orient Express" and films like "Before Sunrise" have used night trains as a backdrop (Faith, 2022).

Cultural exchange: Night trains serve as platforms for cultural exchange. Travellers from different countries and cultures meet on board and share experiences and stories (Faith, 2022).

Civil Rights Movement: The union the Brotherhood of Sleeping Car Porters (founded in 1925), became a major source of strength for the burgeoning Civil Rights Movement.

Travelling as adventure: Travelling by night train is often seen as an adventurous way to reach a destination. The sense of excitement when boarding and the anticipation of a new destination add to the cultural appeal (Faith, 2022).

Iconic routes: Certain night train routes, such as the Orient Express, have become iconic symbols of luxury travel and adventure. These routes have earned a place in popular culture and continue to capture the imagination (LaVerda, 2023).

Environmental considerations: With growing concerns about climate change and sustainability, cultural appreciation for overnight trains has grown. They are seen as a more environmentally friendly option than air travel, which has led to a resurgence of interest in night trains (Pierini, 2023).

Some more personal impressions:

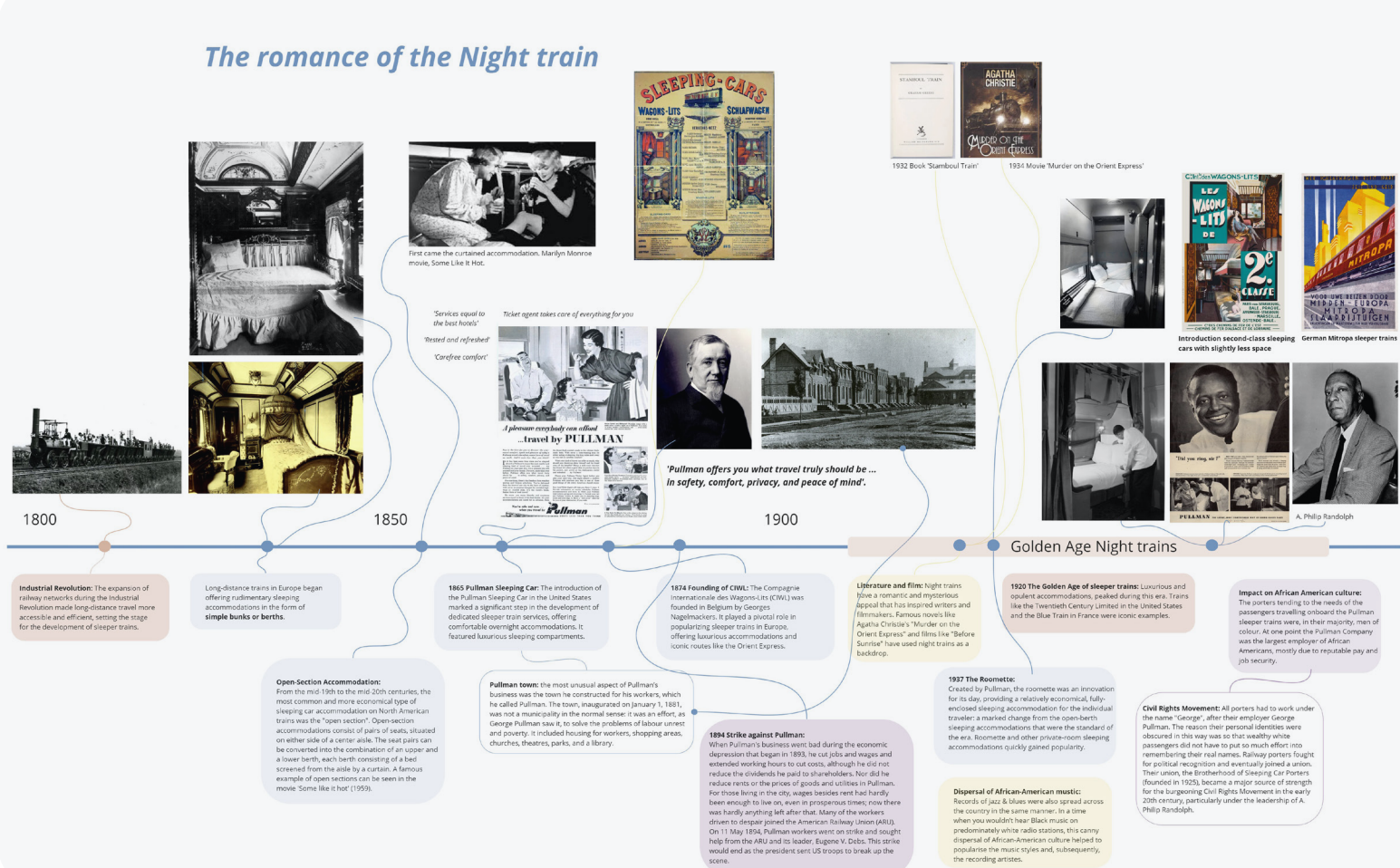
Memories and nostalgia: For many people, night trains evoke memories of days gone by or special journeys. This can create a sense of nostalgia and contribute to the cultural value of night trains.

Connectedness: Night trains offer a unique social experience, with travellers often sharing compartments with strangers. This can lead to engaging conversations and the opportunity to meet new people and cultures.

Promotion of tourism: Night trains often play a role in promoting tourism to remote or less accessible areas. They can contribute to the economic development of regions and facilitate cultural exchange between visitors and local communities.

These impressions show that night trains have a rich cultural history. They offer not only practical benefits, but also contribute to the cultural diversity and human connections that travel can provide.

The romance of the Night train



The lost romance of the Night train



The Renaissance of the Night train

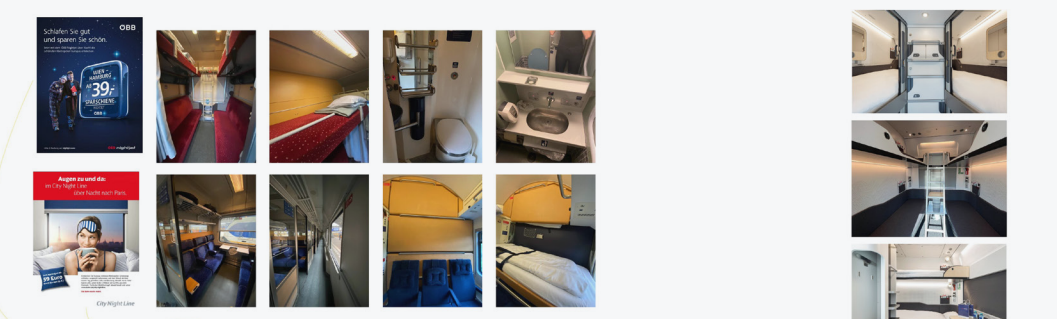


Figure 87. Historical timeline

02 / Future projection: current trends and developments

This section describes an analysis of current trends and developments in the field of mobile interior design. This analysis has focused on concepts for aircraft interiors, as a lot of innovation is taking place in this field, and trends in the field of mobility interiors in general. Search terms used were 'aircraft interior concept', 'aircraft seating concept', 'aircraft floor plan design' and 'aircraft interior elements'. It also looked at which trends emerged from hyperloop space concepts. A mood board of all mobility concepts was created and within all these pictures a number of main trends were chosen see figure 88. These were clustered into 5 themes and are further explained in this section.

Social lounge space

Alongside improvements in personal space, a shift in the design of social spaces can be seen. This relates to group travel areas but also dedicated social areas (Stahl, n.d.) & (Mark, n.d.).



Figure 88. Social space

Hybrid interiors

A clear focus can be seen on the design of hybrid interiors. This relates to modules that define a larger space of the interior, as well as smaller interior parts, like seats (IAA Mobility 2021: Automotive Interior Trends of the Future | Accuride, 2021) & (Mark, n.d.). This shift can be explained by the desire to optimise the interior for the type of travel, by wanting to offer different quantities of seats number and by creating a possibility for passengers to choose different areas.

For example the Airbus Transpose concept, uses large modules to make the complete interior of the aircraft. The idea behind the concept is to load experience modules into the aircraft, with the intention of reducing the time it takes to reconfigure the aircraft by threefold (Acubed, Airbus, 2016). This includes areas such as a café, gyms, and children's play areas.

Other concepts show more flexible and adaptable solutions. An example of this is the seating width concept, which decreases in width during boarding and deboarding, and automatically becomes wider again when passengers are seated. The intend of which is to decrease boarding times and increase passenger comfort (Optimares, 2018).

Seats that move along the aircrafts longitudinal axis are also introduced, like the Recaro's Flex Seat. When the aircraft is not a full capacity, these seats can be moved back to increase passengers' legroom. Reconfiguring the seat takes less than a minute (Recaro, 2017). This optimises capacity usage while increases passenger comfort. Another Concept is the Sky Nest Bunk Beds. These seats can easily be transformed to beds and makes this concept usable for day and night travel.



Figure 89. Modularity & Flexibility

Comfort & Personal space

Concepts are being developed that focus on improving personal space and passenger comfort. This relates to seat design, as well as the design of cabin interior elements such as lighting, smell, temperature etc (Mile, 2023) & (Möller et al., 2023).

One of the most visible trends is the staggering seats and opposite seats in the business class. This will increase the passengers' sense of personal space. This is perfect for passengers who travel alone but not ideal for group travellers (Young, 2015).

More recently, due to the COVID-19 pandemic there is an increase in the development of interior concepts that focus on hygiene and social distancing between passengers (M.Ryu, 2022).



Figure 90. Comfort & Personal space

Integration of technology

Furthermore, it can be seen that more technology and electronics is integrated in interior concepts (Stahl, n.d.).

In-mould electronics are being developed to seamlessly integrate electronics within the surfaces of the cabin and its seats. The IME panel by e2ip electronics for example, is an interactive smart surface based on printed electronics, with customisable finishes (e2ip technologies, n.d.). Furthermore, trends towards huge displays could be reversed, eg, through holographic systems Voice may become the predominant input; rise of postpurchase features (Möller et al., 2021).



Figure 91. Integration of technology

Open cabin

With regard to the spacial perception of the cabin as a whole, a clear shift can be seen towards design that appears light, more spacious, and less cluttered.

Several concepts are being developed and introduced that increase perception of space in the cabin.

For example by replacing windows with large video screens that project the view of outside into the cabin wall (Airbus, 2019). Also adaptable light panels and light patterns can be used to create a sense of space and openness in the cabin, and change the ambience throughout the journey. This adaptable lighting can also be used to mimic the natural day and night rhythm.

To make the cabin appear more calming and less cluttered, continuous surfaces and (partially) open partition walls can often be seen in new interior concepts like the Hyperloop interior concept. This also has advantage for cleaning purposes.



Figure 92. Open cabin



Figure 93. Clustering trends & developments

03 / Clustering insights passenger studies

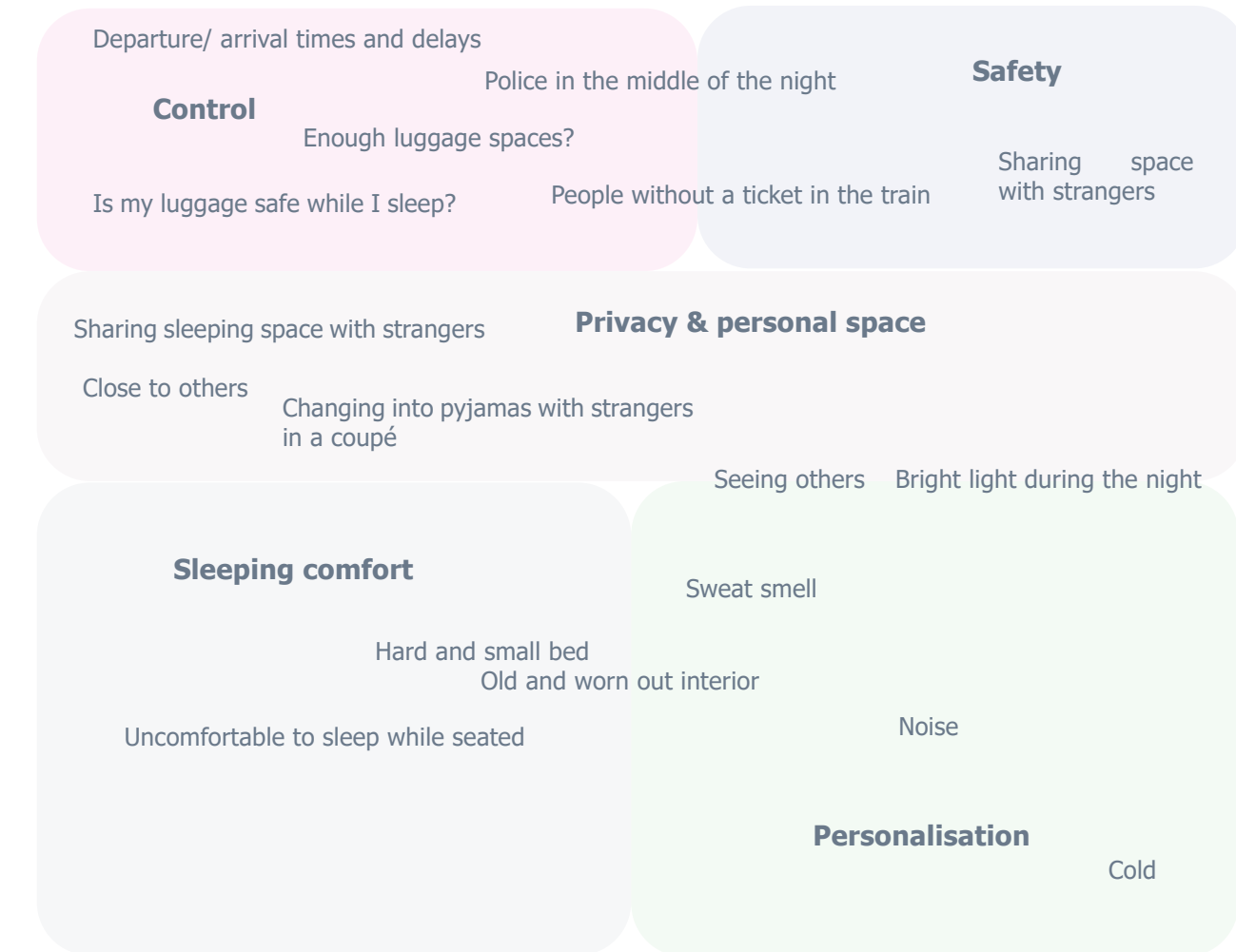


Figure 94. Clustering passenger studies

04 / Ideation I: Idea generation

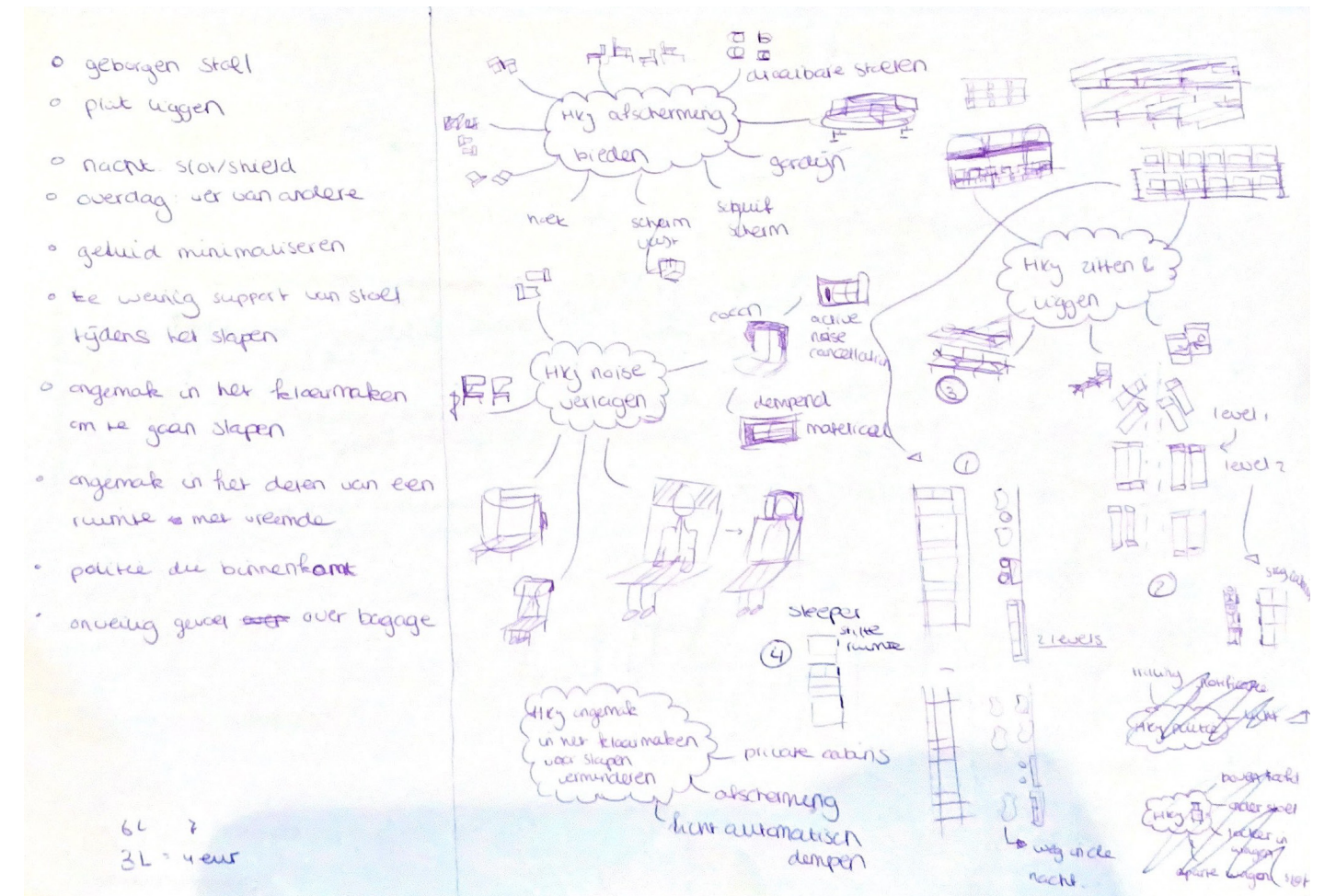
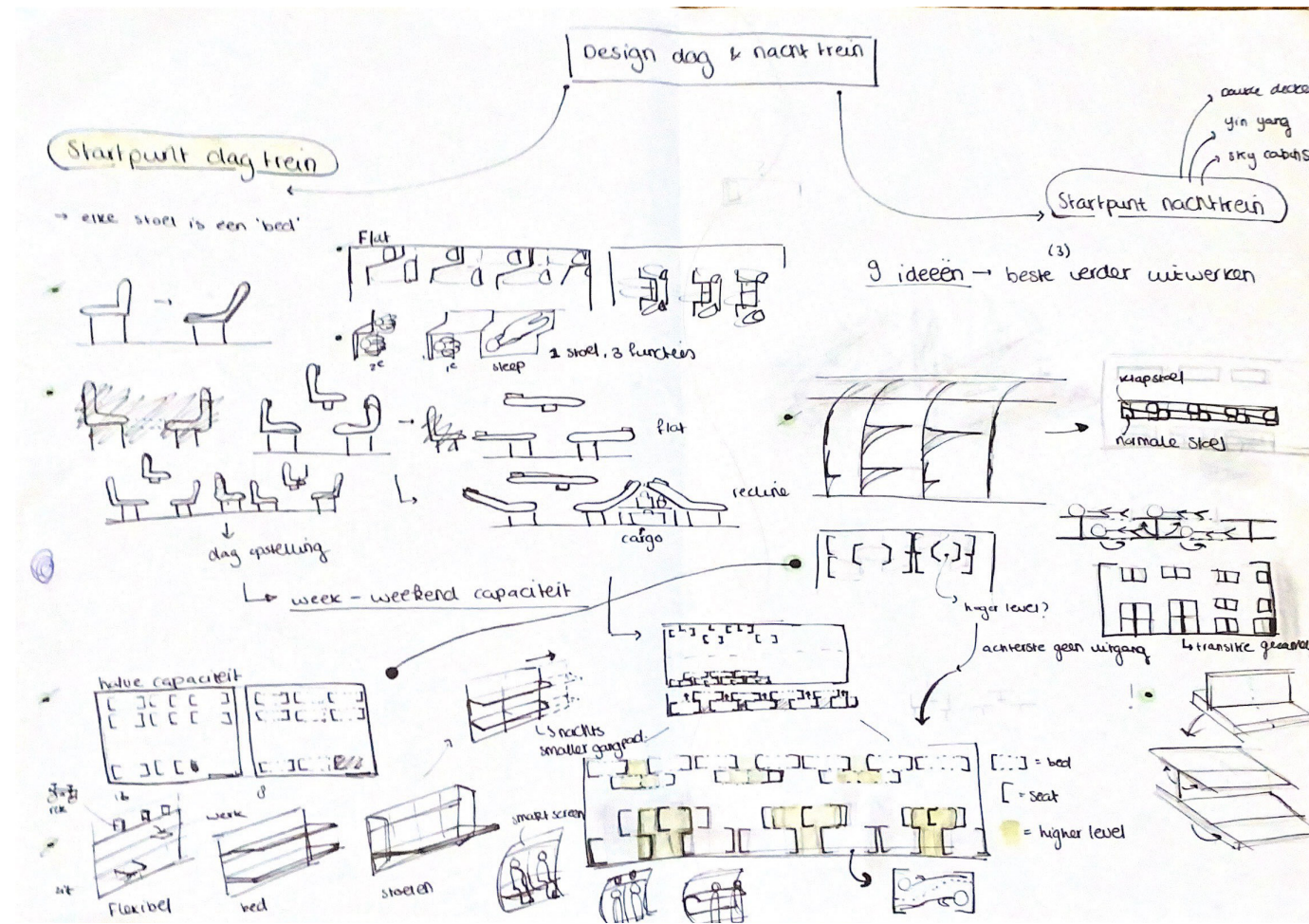
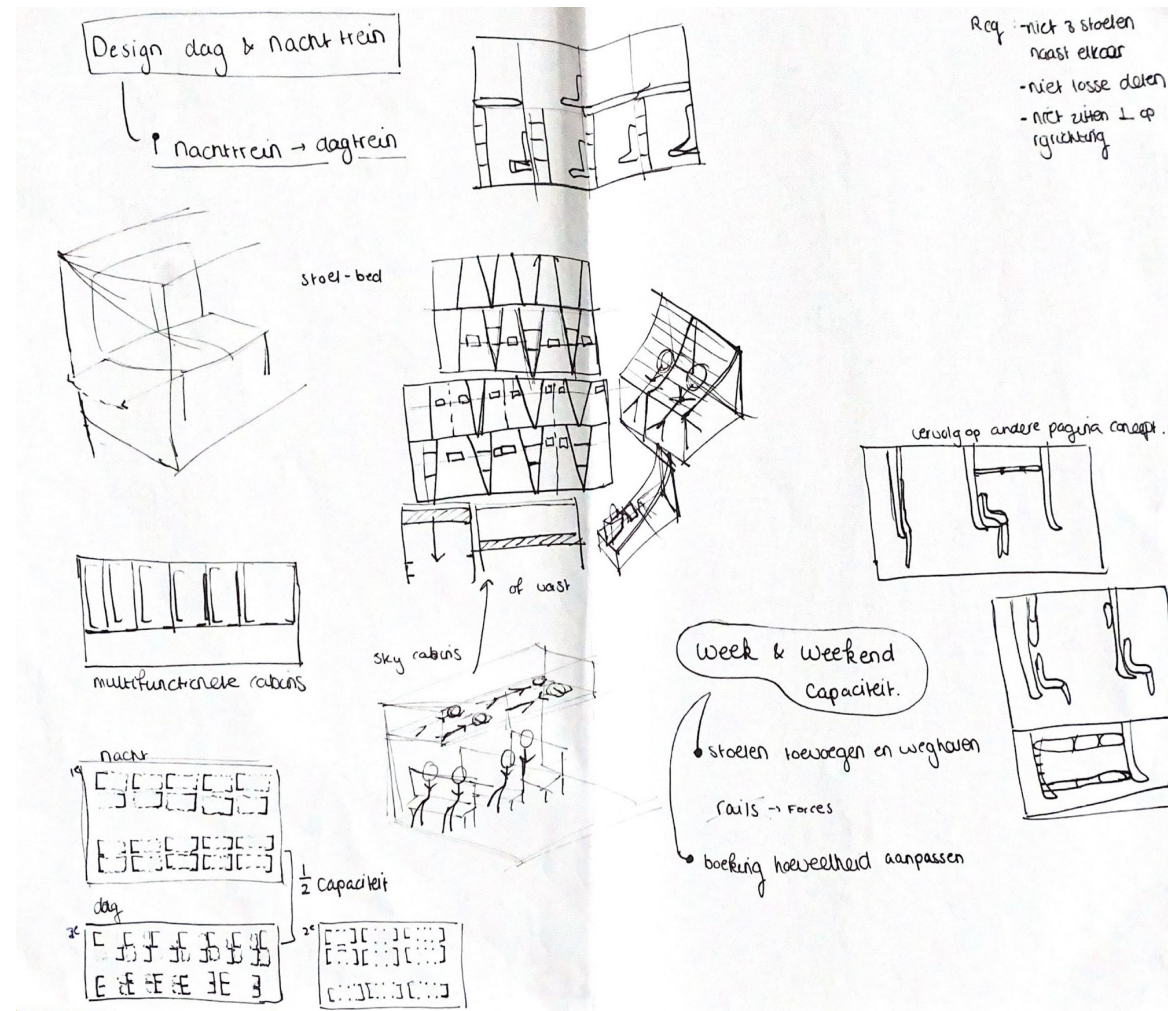
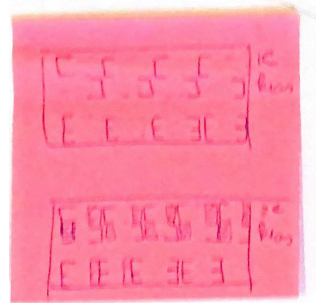
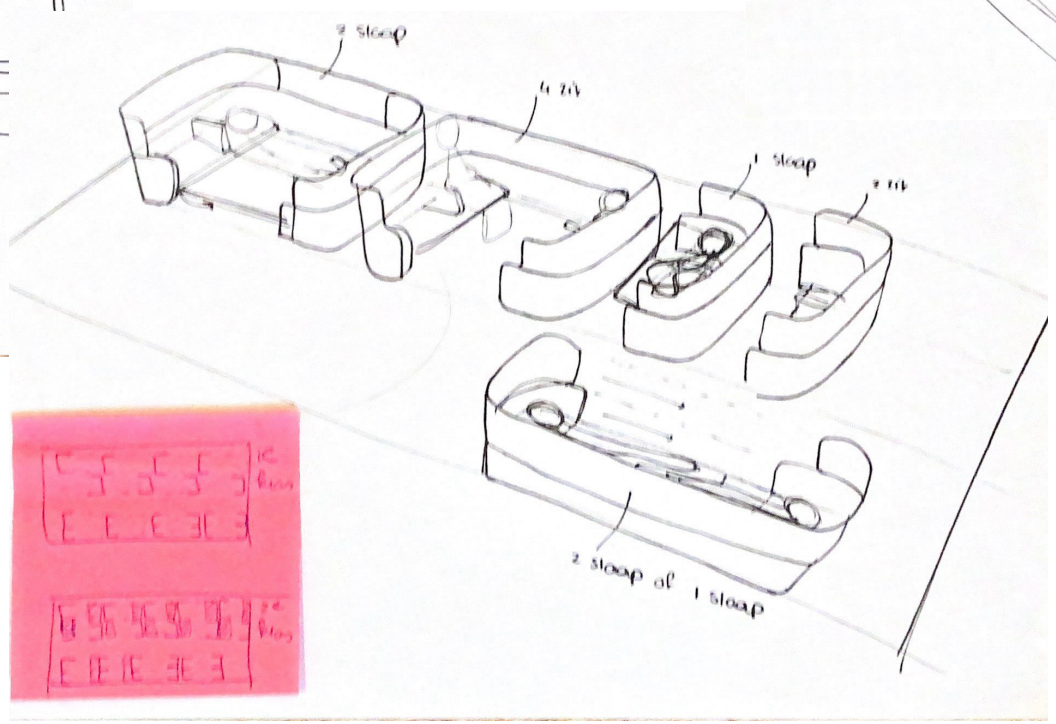
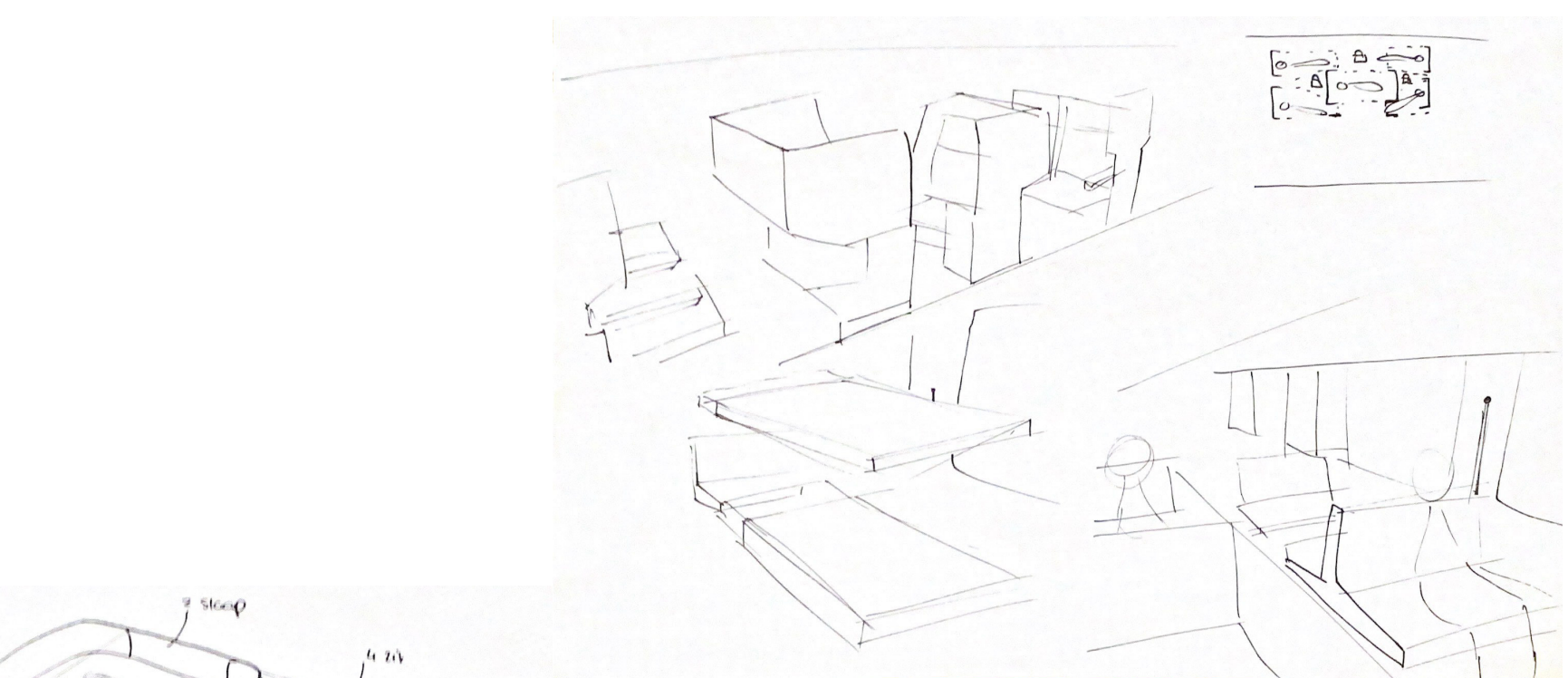
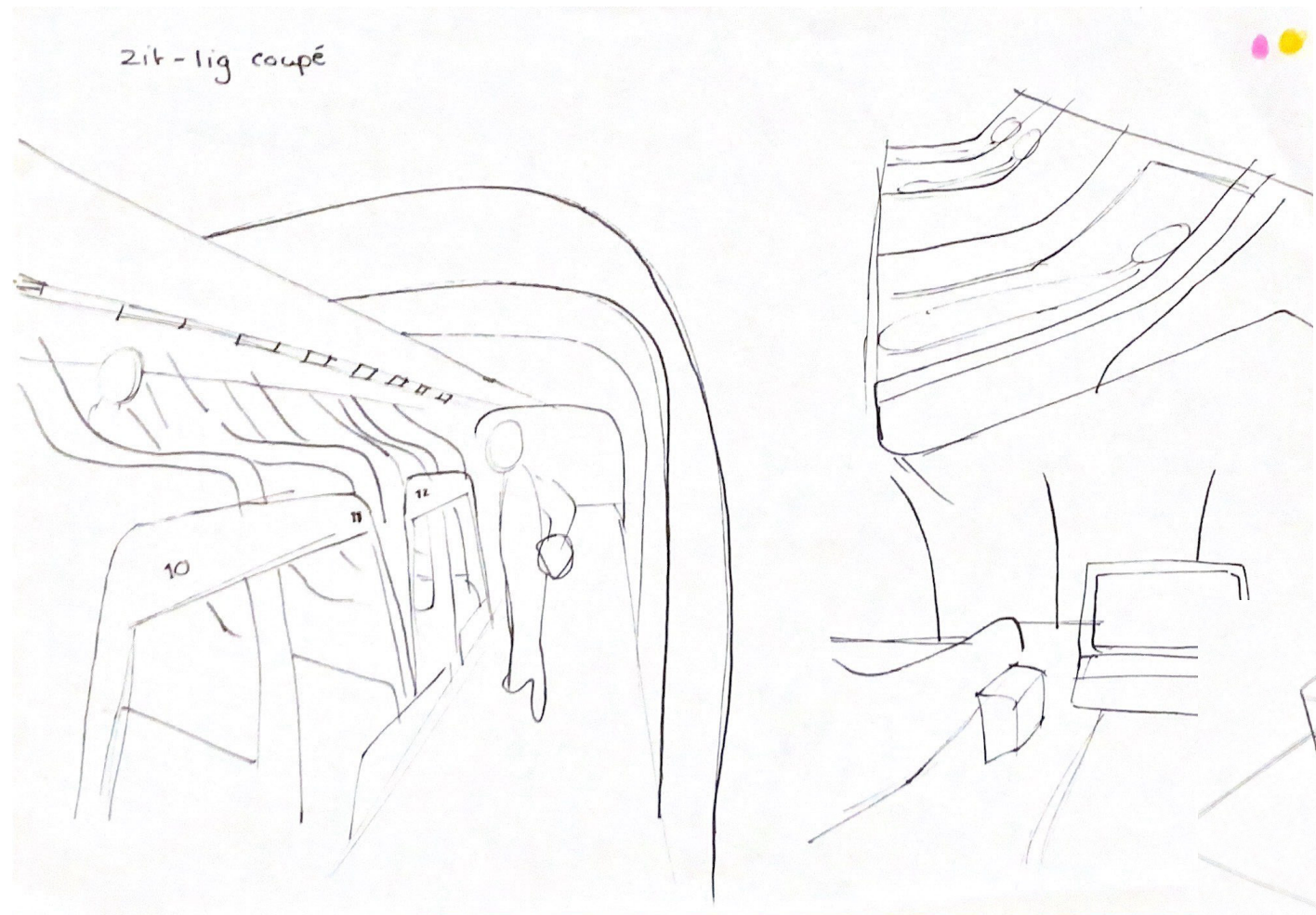


Figure 95. Idea generation I



Seats perpendicular to direction of travel

Staggered seats

wagen 26 m lang
3.15 m breed

2x toilet 1 m
2x wasruimte 1.5 m
ingang 1.5 m
= 6.5 m
26 - 6.5 = 19.5 m

Scenario 1
bedden ⊥ rijrichting
19.5 m aan 'bed ruimte'
bed = 65 cm breed → krap
 $\frac{19.5}{65} = 30$ bedden
 $\frac{19.5}{210} = 9$ bedden
gangpad breedte ~~210~~
315 - 200 - 65 = 50 cm
↳ krap x

Scenario 2
bedden schuin rijrichting

$A = \sin(50) \cdot 200 = 153$ cm
 $B = \sin(40) \cdot 65 = 42$ cm
gangpad = 315 - 153 - 42 - 65 = 55 cm krap

$C = \cos(50) \cdot 200 = 128.5$
 $D = \cos(40) \cdot 65 = 50$ cm
 $C + D = 178.5$ cm
 $\frac{19.5}{178.5} = 10 + \frac{19.5}{210} = 9 \Rightarrow 19$ bedden totaal
schuin rech

Figure 96. Idea generation II

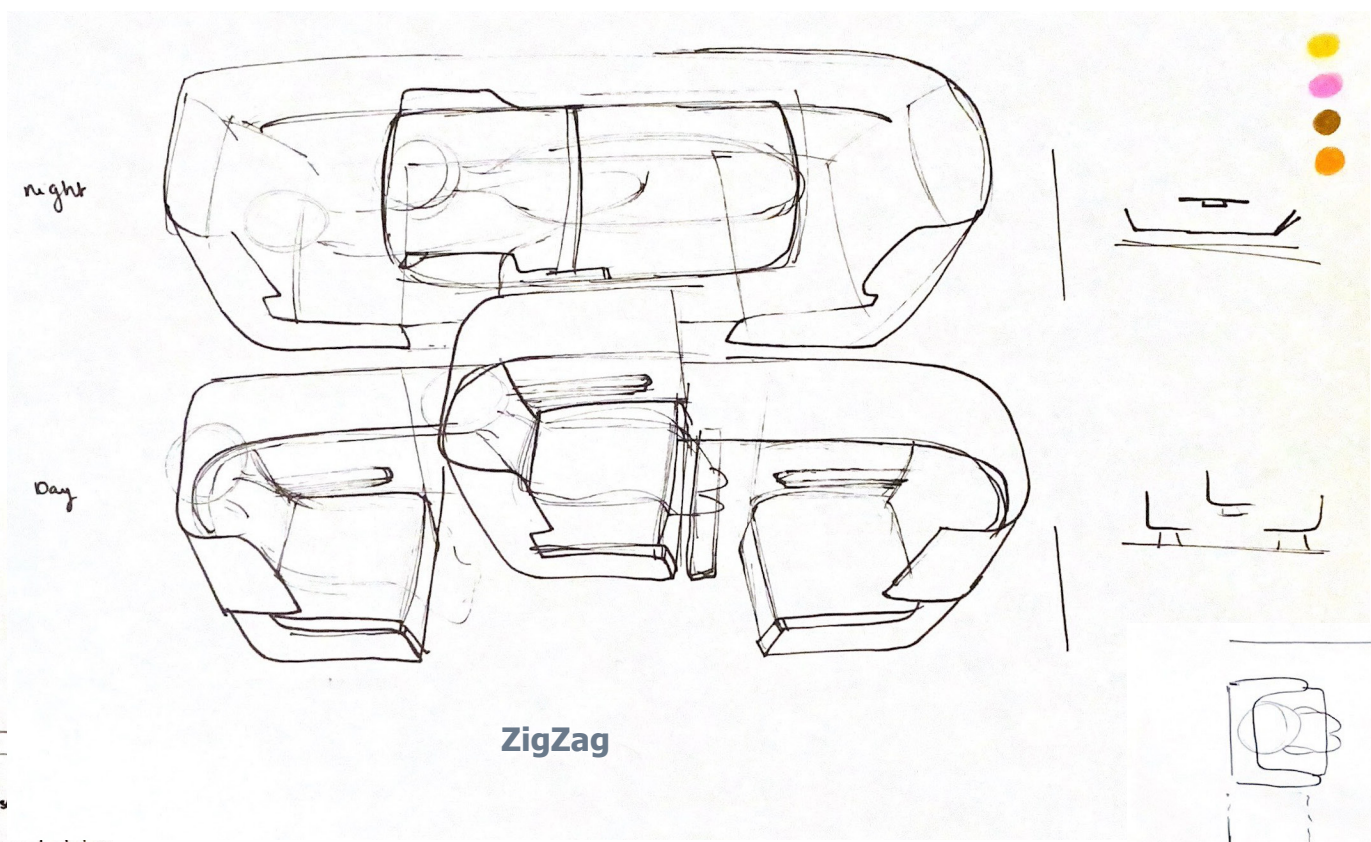
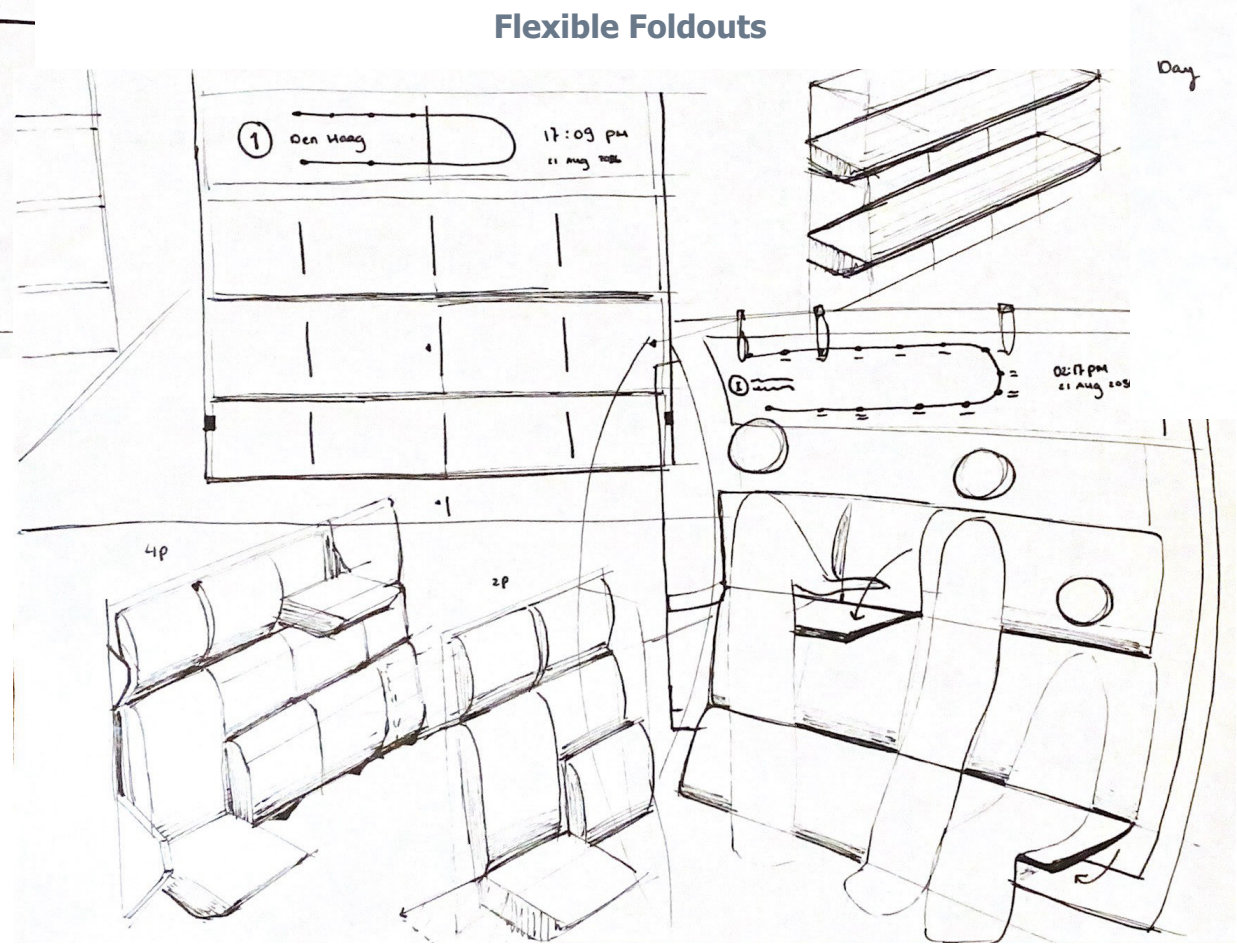
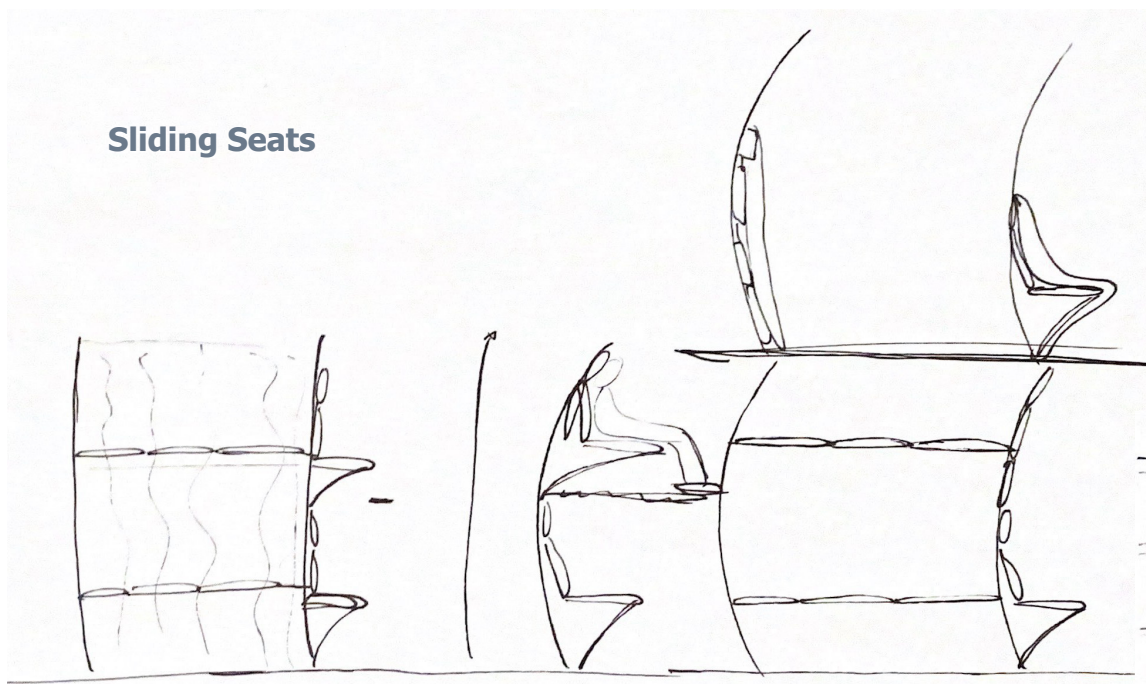
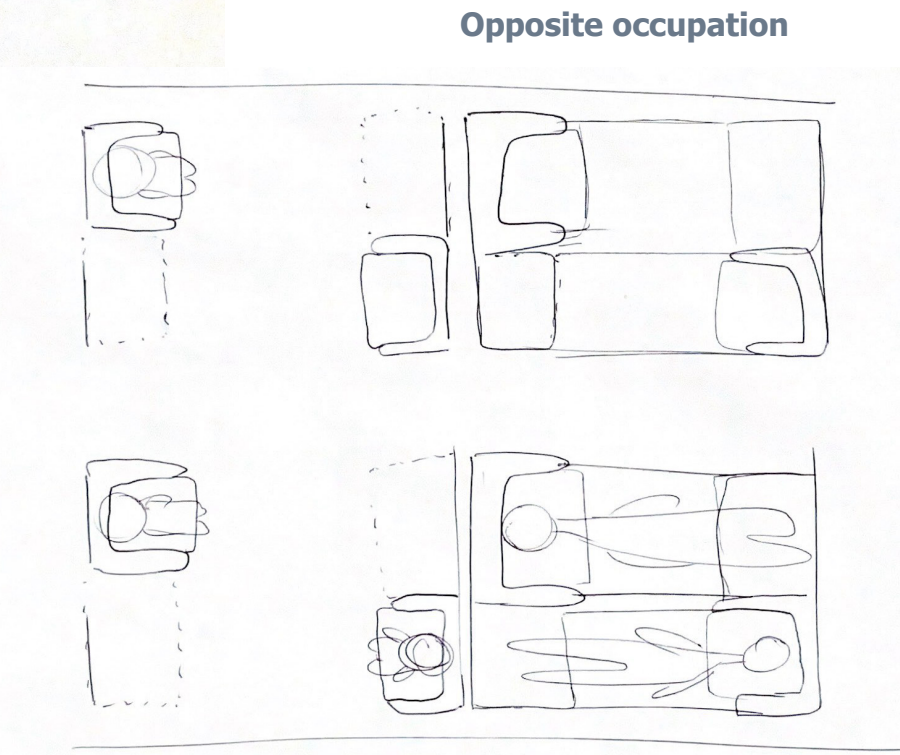


Figure 97. Concept directions



05 / Justification concept choice

All concepts score well on privacy at night, minimum capacity, emergency routes, aisle width, crew seating, transition between day and night and a business case can be imagined. Many of these requirements were already considered during the ideation phase. For example, that the minimum capacity can be met, that the transition between day and night set-up can be done by the passengers themselves and that passengers can sit during the day and lie flat at night. Also, the business case is automatically improved if the train can travel both during the day and at night. However, for some concepts, the business case will be better than for others.

Furthermore, the concepts differ on what they score less good for (indicated with a yellow or red color). The reason why they score less good on those requirements is explained below.

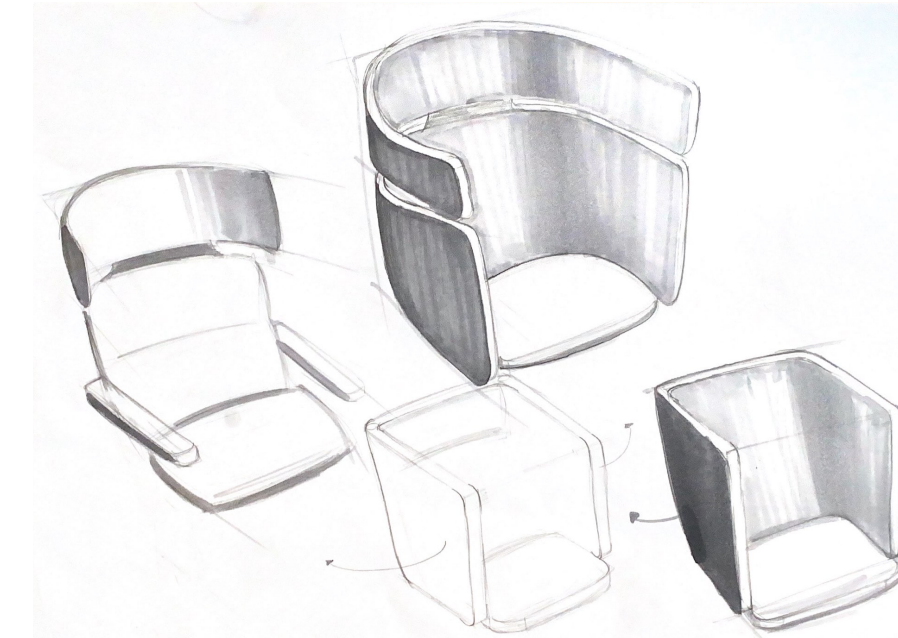
In Concept 1, passengers sitting in the low seats can store their luggage under their seats, but this is not (yet) possible for passengers sitting in the high seats. Furthermore, the high seats are a bit more difficult to reach. Especially the seats on the side, not on the aisle, on the high level. Finally, the capacity in this concept is the lowest and not flexible. A maximum of 45 passengers can be fitted in the coach and the seats cannot be folded to make room for people who can stand or for luggage.

In Concept 2, the same problem applies as in Concept 1. Passengers on the lower seats can put their luggage under the seat but passengers on the upper seats cannot (yet). In addition, the development of this concept is slightly more difficult. Many strong mechanisms need to be developed and the seat consists of many different parts. As a result, the development time will be longer and probably more expensive. Finally, this concept also scores less well on the accessibility of the seats. This in turn applies to the upper seats. Not everyone will be able to reach these seats via a small staircase.

Concept 3 scores less well on the requirement 'travelling during the day'. This requirement consists of the seat and privacy. The seat of this concept will be less comfortable because it is a folding chair set at a 90-degree angle. In addition, they are rows of four seats next to each other. As a result, people will experience less privacy during the day. The concept also scores less well on lying flat. It is possible to lie flat, but because these are four separate folding chairs, this will be less comfortable. Because the rows are high, the feeling of spaciousness in this concept will also be less than in the other concepts.

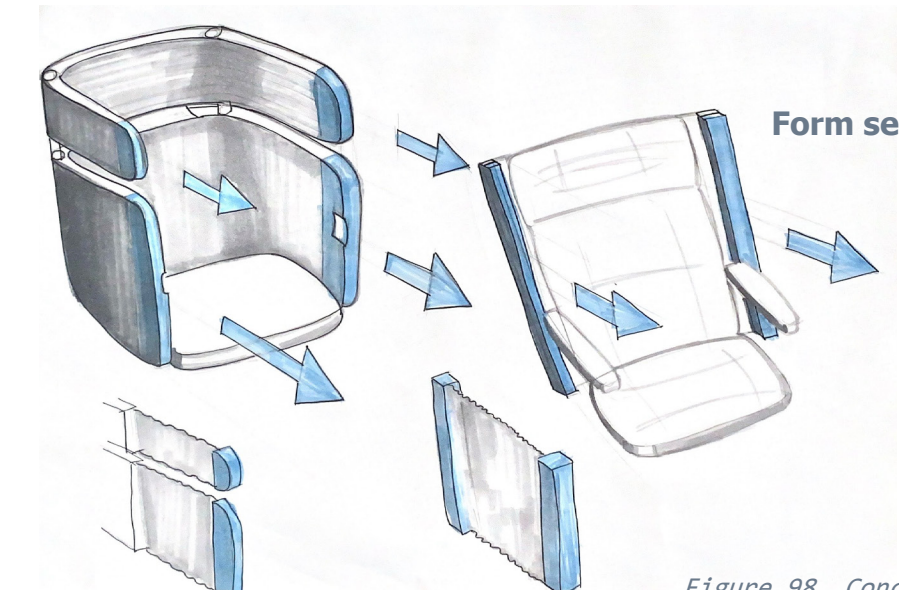
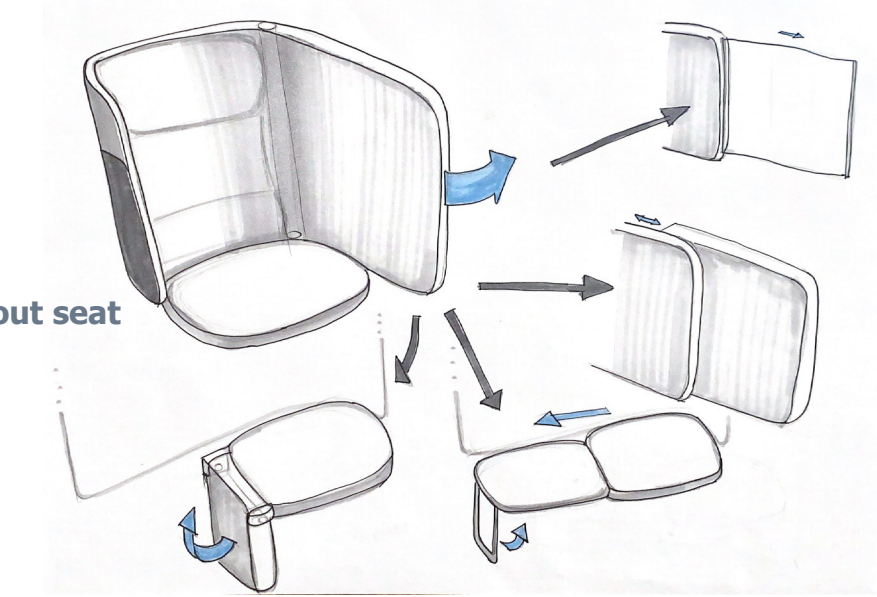
Concept 4 scores less good on the accessibility of the seats. During the night, the seats not next to the aisle are more difficult to reach. In addition, this concept scores less well on privacy during the night. More attention will be paid to both the accessibility and privacy during the concept development phase.

06 / Ideation II: Concept development



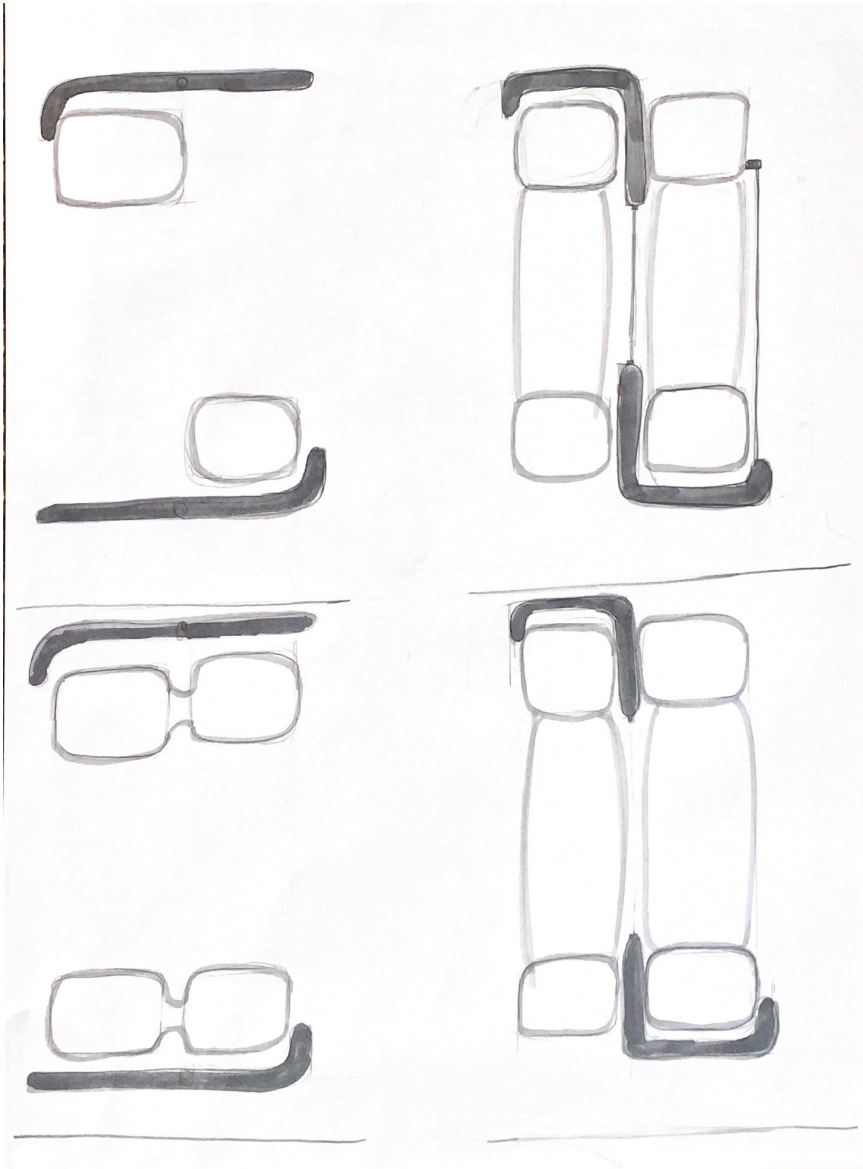
Form seat

Screens & Foldout seat

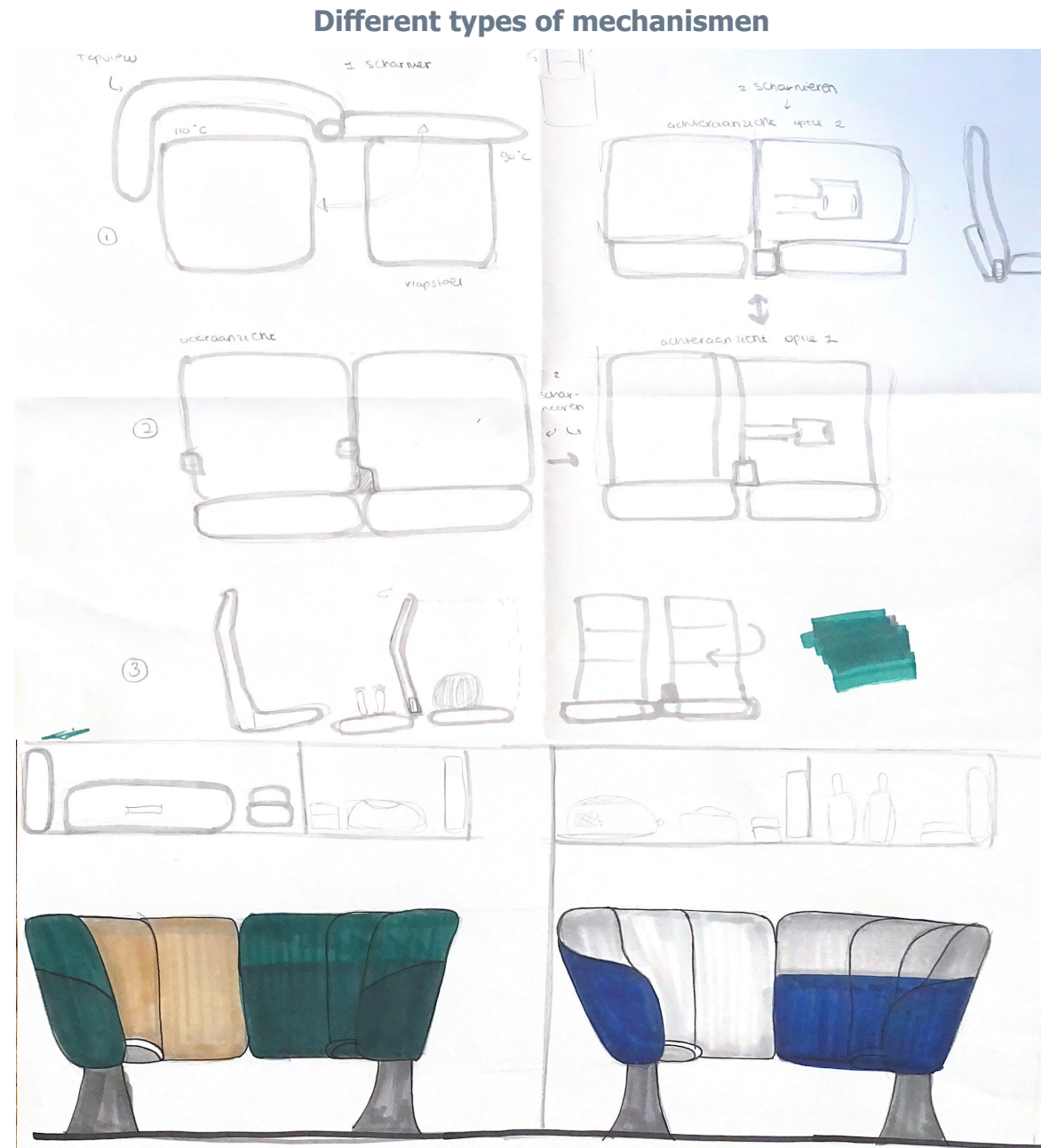


Form seat & Screens

Figure 98. Concept development I



Topview



Sideviews

Figure 99. Concept development II

07 / Consent form VR test

Nachttrein interieur ontwerp

Dit onderzoek wordt uitgevoerd als onderdeel van de MSc opleiding Industriel Ontwerpen aan de TU Delft.

Student: Annabelle Out

Contactpersoon: Annabelle Out – 4884388 – a.a.out@student.tudelft.nl

Toestemmingsverklaring participant

U wordt uitgenodigd om deel te nemen aan een onderzoek genaamd comfort level in dag & nachttrein interieurs. Dit onderzoek wordt uitgevoerd door Annabelle Out van de TU Delft.

Het doel van dit onderzoek is erachter komen welke elementen in een dag en nachttrein interieur voor optimaal comfort zorgen. Hierbij gaat het voornamelijk om het gevoel van privacy en veiligheid verhogen. Het onderzoek zal ongeveer 35 minuten in beslag nemen. De data zal gebruikt worden voor mijn afstudeer project van de master Integrated Product Design aan de TU Delft en een wetenschappelijke publicatie. Aan het begin van het onderzoek verzamelen wij de volgende persoonlijke informatie van u: leeftijd, gewicht, lengte, geslacht en etniciteit. Vervolgens word u gevraagd om uw beleving van meerdere trein interieurs te beschrijven in de vorm van een interview. Uw zult deze interieurs waarnemen in Virtual Reality terwijl u stil zit op een stoel.

Zoals bij elk onderzoek is het risico van een databreuk aanwezig. Wij doen ons best om uw antwoorden vertrouwelijk te houden door de data anoniem te verzamelen en de data op te slaan op een betrouwbare locatie waar alleen de onderzoekers toegang toe hebben.

Uw deelname aan dit onderzoek is volledig vrijwillig, en u kunt zich elk moment terugtrekken zonder reden op te geven. U bent vrij om vragen niet te beantwoorden.

Contactgegevens uitvoerende onderzoeker:

Annabelle Out
A.A.Out@student.tudelft.nl

Contactgegevens verantwoordelijke onderzoeker:

Gerbera Vledder
g.vledder@tudelft.nl

Vink de hokjes die voor u van toepassing zijn aan	Ja	Nee
A: ALGEMENE OVEREENSTEMMING – ONDERZOEKSDOELEN, TAKEN VAN DEELNEMERS EN VRIJWILLIGE DEELNAME		
1. Ik heb de informatie over het onderzoek gelezen en begrepen, of deze is aan mij voorgelezen. Ik heb de mogelijkheid gehad om vragen te stellen over het onderzoek en mijn vragen zijn naar tevredenheid beantwoord.	<input type="checkbox"/>	<input type="checkbox"/>
2. Ik doe vrijwillig mee aan dit onderzoek, en ik begrijp dat ik kan weigeren vragen te beantwoorden en mij op elk moment kan terugtrekken uit de studie, zonder een reden op te hoeven geven.	<input type="checkbox"/>	<input type="checkbox"/>
3. Ik begrijp dat mijn deelname aan het onderzoek de volgende punten betekent - dat ik op een stoel zit met VR glasses op waardoor het lijkt alsof ik in een trein zit - een audio recorded interview die indien nodig getranscribeerd wordt tot tekst - geschreven notities gedurende de interview	<input type="checkbox"/>	<input type="checkbox"/>
4. Ik begrijp dat de studie rond februari eindigt.		
B: MOGELIJKE RISICO'S VAN DEELNAME (INCLUSIEF GEGEVENS BESCHERMING)		
5. Ik begrijp dat mijn deelname het risico's met zich meebrengt dat ik me oncomfortabel ga voelen in de Virtuele omgeving. Ik begrijp dat deze risico's worden geminimaliseerd doordat ik op elk moment kan stoppen met de test.	<input type="checkbox"/>	<input type="checkbox"/>
6. Ik begrijp dat mijn deelname betekent dat er persoonlijke identificeerbare informatie en onderzoeksdata worden verzameld, met het risico dat ik hieruit geïdentificeerd kan worden wordt geminimaliseerd doordat de vragen anoniem beantwoord kunnen worden. Uw leeftijd, afkomst, ervaring met regionaal reizen, ervaring met nachttreinen en comfort level in meerdere interieur scenario's worden gevraagd.	<input type="checkbox"/>	<input type="checkbox"/>
7. Ik begrijp dat de volgende stappen worden ondernomen om het risico van een databreuk te minimaliseren, en dat mijn identiteit op de volgende manieren wordt beschermd in het geval van een databreuk: de data is anoniem, de data wordt veilig opgeslagen, de data is alleen beschikbaar voor de betrokkenonderzoekers.	<input type="checkbox"/>	<input type="checkbox"/>
C: PUBLICATIE, VERSPREIDING EN TOEPASSING VAN ONDERZOEK		
8. Ik begrijp dat na het onderzoek de geanonimiseerde informatie gebruikt zal worden voor product ontwikkeling en een onderzoek publicatie. In deze publicatie zullen alleen statistische uitkomsten van de data vermeld staan op een manier dat ze niet meer naar u te herleiden zijn.	<input type="checkbox"/>	<input type="checkbox"/>
D: (LANGDURIGE) OPSLAG, TOEGANG EN HERGEBRUIK VAN GEGEVENS		
9. Ik geef toestemming om de geanonimiseerde data over de comfort levels van de verschillende trein interieurs gearhiveerd worden in de TU Delft repository zodat deze gebruikt kunnen worden voor toekomstig onderzoek en onderwijs.	<input type="checkbox"/>	<input type="checkbox"/>

Vink de hokjes die voor u van toepassing zijn aan	Ja	Nee
10. Ik begrijp dat de toegang tot deze repository beperkt is tot studenten en werknemers van de TU Delft.	<input type="checkbox"/>	<input type="checkbox"/>

Night train interior design

This research is conducted as part of the MSc programme in Industrial Design at TU Delft.
 Student: Annabelle Out
 Contact person: Annabelle Out - 4884388 - a.a.out@student.tudelft.nl

Participant consent form

You are invited to participate in a research project called comfort level in day & night train interiors. This research is conducted by Annabelle Out from TU Delft. The aim of this research is to find out which elements in a day and night train interior provide optimal comfort. This mainly involves increasing the sense of privacy and safety. The research will take about 35 minutes. The data will be used for my graduation project of the master Integrated Product Design at TU Delft and a scientific publication. At the beginning of the survey, we will collect the following personal information from you: age, weight, height, gender and ethnicity. You will then be asked to describe your experience of several train interiors in the form of an interview. You will observe these interiors in Virtual Reality while sitting still on a chair.

As with any survey, there is a risk of data breach. We do our best to keep your answers confidential by collecting the data anonymously and storing the data in a reliable location that only the researchers have access to.

Your participation in this study is completely voluntary, and you may withdraw at any time without giving a reason. You are free not to answer any questions.

Executive researcher contact details:
 Annabelle Out
A.A.Out@student.tudelft.nl

Contact details responsible researcher:
 Gerbera Vledder
g.vledder@tudelft.nl

Handtekeningen		
_____	_____	_____
Naam deelnemer	Handtekening	Datum
Ik, de onderzoeker , verklaar dat ik de <u>informatie en het instemmingsformulier</u> correct aan de potentiële deelnemer heb voorgelezen en, naar het beste van mijn vermogen, heb verzekerd dat de deelnemer begrijpt waar hij/zij vrijwillig mee instemt.		
_____	_____	_____
Naam onderzoeker	Handtekening	Datum
Contactgegevens van de onderzoeker voor verdere informatie: Annabelle Out +316 27494523 A.A.Out@student.tudelft.nl		

Tick the boxes that apply to you	Ja	Nee
A: GENERAL AGREEMENT - RESEARCH OBJECTIVES, TASKS OF PARTICIPANTS AND VOLUNTARY PARTICIPATION		
1. I have read and understood the information about the survey, or it has been read to me. I had the opportunity to ask questions about the survey and my questions were answered to my satisfaction.	<input type="checkbox"/>	<input type="checkbox"/>
2. I am voluntarily participating in this study, and I understand that I can refuse to answer questions and withdraw from the study at any time, without having to give a reason.	<input type="checkbox"/>	<input type="checkbox"/>
3. I understand that my participation in the study means the following points - an audio recorded interview which will be transcribed into text if necessary - written notes during the interview	<input type="checkbox"/>	<input type="checkbox"/>
4. I understand the study ends around February.		
B: POTENTIAL RISKS OF PARTICIPATION (INCLUDING DATA PROTECTION)		
5. I understand that my participation carries risks of becoming uncomfortable in the Virtual environment. I understand that these risks are minimised by the fact that I can quit the test at any time.	<input type="checkbox"/>	<input type="checkbox"/>
6. I understand that my participation means that personally identifiable information and research data will be collected, with the risk that I can be identified from this minimised by the fact that the questions can be answered anonymously.(please state what data will be collected).	<input type="checkbox"/>	<input type="checkbox"/>
7. I understand that the following steps are taken to minimise the risk of a data breach, and that my identity is protected in the event of a data breach in the following ways: the data is anonymous, the data is stored securely, the data is only available to both researchers.	<input type="checkbox"/>	<input type="checkbox"/>
C: PUBLICATION, DISSEMINATION AND APPLICATION OF RESEARCH		
8. I understand that after the study, the anonymised information will be used for product development and a research publication. In this publication, only statistical outcomes of the data will be stated in a way that they cannot be traced back to you.	<input type="checkbox"/>	<input type="checkbox"/>
D: (LONG-TERM) STORAGE, ACCESS AND RE-USE OF DATA		
9. I give permission for the anonymised data on the comfort levels of the different train interiors to be archived in the TU Delft repository so that it can be used for future research and teaching.	<input type="checkbox"/>	<input type="checkbox"/>
10. I understand that access to this repository is restricted to TU Delft students and employees.	<input type="checkbox"/>	<input type="checkbox"/>

Signatures		
_____	_____	_____
Name of participant	Signature	Date
I, as researcher, have accurately read out the information sheet to the potential participant and, to the best of my ability, ensured that the participant understands to what they are freely consenting.		
_____	_____	_____
Researcher name	Signature	Date
Study contact details for further information: Annabelle Out +316 27494523 A.A.Out@student.tudelft.nl		

08 / SPSS Evaluation current vs new design

Normality test

Tests of Normality

	Scenario	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Ruimtebeleving	1,00	,189	11	,200*	,921	11	,326
	2,00	,202	11	,200*	,880	11	,104
VisuelePrivacy	1,00	,266	11	,028	,878	11	,099
	2,00	,382	11	<,001	,701	11	<,001
Geluid	1,00	,277	11	,018	,849	11	,042
	2,00	,217	11	,155	,893	11	,150
Afstandandere	1,00	,194	11	,200*	,938	11	,498
	2,00	,266	11	,029	,877	11	,095
Geur	1,00	,227	11	,117	,938	11	,498
	2,00	,353	11	<,001	,649	11	<,001
Privacy	1,00	,280	11	,016	,851	11	,045
	2,00	,380	11	<,001	,772	11	,004
Veiligheid	1,00	,235	11	,091	,936	11	,478
	2,00	,318	11	,003	,855	11	,050
Comfort	1,00	,270	11	,024	,807	11	,012
	2,00	,186	11	,200*	,890	11	,138

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Daytime travel

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Ruimtebeleving1 and Ruimtebeleving2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between VisuelePrivacy1 and VisuelePrivacy2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Geluid1 and Geluid2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,080	Retain the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Afstandandere1 and Afstandandere2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,004	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Geur1 and Geur2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,005	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Privacy1 and Privacy2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,004	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Veiligheid1 and Veiligheid2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,004	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Comfort1 and Comfort2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,002	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Nighttime travel

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Ruimtebeleving1 and Ruimtebeleving2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Visueleprivacy1 and Visueleprivacy2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Geluid1 and Geluid2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Afstandandere1 and Afstandandere2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Geur1 and Geur2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Privacy1 and Privacy2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Veiligheid1 and Veiligheid2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,005	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Comfort1 and Comfort2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,005	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

General factors

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Design1 and Design2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Kleur1 and Kleur2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,004	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Looproute1 and Looproute2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,003	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

Hypothesis Test Summary

	Null Hypothesis	Test	Sig. ^{a,b}	Decision
1	The median of differences between Faciliteiten1 and Faciliteiten2 equals 0.	Related-Samples Wilcoxon Signed Rank Test	,006	Reject the null hypothesis.

a. The significance level is ,050.

b. Asymptotic significance is displayed.

09 / Business case

The tables below show the approximate yield calculations of different types of coaches.

normale wagon	
aantal zitplaatsen	80
opbrengst per zitplaats per uur in Euro (aannname)(Wat Kost Reizen met de Trein?, z.d.)	13,6
bezettingsgraad % (aannname)	80
aantal uur in bedrijf	16
opbrengst	13926,4

slaapwagon - sleeper	
aantal slaappleatsen	66
opbrengst per slaappleats in Euro (aannname)(Trein Naar Wenen - v.a. € 35 Enkele Reis NS International, z.d.)	100
bezettingsgraad (aannname)	100
aantal uur in bedrijf	
opbrengst	6600

slaapwagon - couchette	
aantal slaappleatsen	54
opbrengst per slaappleats in Euro (aannname)(Trein Naar Wenen - v.a. € 35 Enkele Reis NS International, z.d.)	122,5
bezettingsgraad (aannname)	100
aantal uur in bedrijf	
opbrengst	6615

slaapwagon - sleeper	
aantal slaappleatsen	36
opbrengst per slaappleats in Euro (aannname)(Trein Naar Wenen - v.a. € 35 Enkele Reis NS International, z.d.)	200
bezettingsgraad (aannname)	100
aantal uur in bedrijf	
opbrengst	7200

24hour coach slaapwagon	
aantal zitplaatsen	72
opbrengst per zitplaats per uur in Euro (aannname)(Wat Kost Reizen met de Trein?, z.d.)	13,6
bezettingsgraad % (aannname)	80
aantal uur in bedrijf	16
	12533,76
aantal slaappleatsen	36
opbrengst per slaappleats per uur (aannname)	15 (120 per nacht)
bezettingsgraad (aannname)	100
aantal uur in bedrijf als slaapwagon	8
	4320
opbrengst totaal	16853,76

10 / Project brief

Personal Project Brief - IDE Master Graduation



Design a night train interior suitable for both day- and nighttime travel

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 04 - 09 - 2023 end date 16 - 02 - 2024

INTRODUCTION **

Please describe, in a concise yet complete manner, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...)?

Mobility is undergoing a profound shift worldwide. Air travel has put Europe at our fingertips and has become one of our favorite ways to travel around Europe. From a sustainability perspective, there is a huge demand for more sustainable mobility. The night train could be a suitable replacement for air travel for trips between 750-1500km. Royal HaskoningDHV is an expert in, among other things, this Air-Rail transition. Their purpose is to enhance society to solve complex challenges in the built environment and industry through their engineering, design and consulting services, combined with software and technology products.

A recent study by Heufke Kantelaar et al. (2022) highlights the crucial role of comfort in the choice between plane and night train travel. New night train interiors are showing improvements in terms of comfort level, e.g. more private travel options, modern design, etc. However, it is still a dedicated train with separate compartments. This means that these trains are often used only once/day and that the train occupancy is low. To be able to use night trains more efficiently, and thus improve the business case, it is essential to design interiors that cater both daytime and nighttime usage.

The project offers several opportunities, including the potential for an interior that promotes efficient utilization and provides an enhanced comfort experience, encouraging travellers to opt for the night train over less sustainable modes of travel, like air and car. Additionally, the project allows for a fresh perspective on floor plan design, providing an opportunity to reflect the low-impact image of night trains through the use of sustainable materials and production methods. With climate concerns higher on the public agenda, decarbonisation imperative beginning to take shape in European policy, changing behaviour and (travel) habits in the wake of the global pandemic, the renaissance of the night train is in full swing. By responding to this, a major impact can be made in the field of sustainable mobility. However, there are certain limitations to consider. Developing entirely new trains would incur substantial costs and resource consumption, making redesigning existing train interiors a more sustainable approach, although with design constraints imposed by the exterior dimensions of the train. Passenger capacity represents a crucial concern, impacting profitability, yet maximizing capacity may compromise passenger comfort, necessitating a careful balance between these aspects. Safety regulations will also influence design possibilities. Furthermore, human adaptability poses a limitation, as we are accustomed to fast travel times and luxury associated with air travel, necessitating a shift in preferences to align with sustainability goals.

Key stakeholders in this endeavor include night train operators, who act as sellers of the night train service and representatives of the new travel perspective for distances between 750 and 1500 kilometers. Passengers, who seek a comfortable travel experience, and night train and interior manufacturers, responsible for constructing the train and its interior, are vital collaborators in acquiring and developing the night train and relevant interior elements. The concerns and comfort of the train crew should also be considered and not compromised during the design process.

space available for images / figures on next page

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Initials & Name A.A. Out 6810 Student number 4884388
Title of Project Design a night train interior suitable for both day- and nighttime travel

Personal Project Brief - IDE Master Graduation

introduction (continued): space for images



image / figure 1: Current design Sleeper cabin night train



image / figure 2: Minisuits, ÖBB (testing with this concept)

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Personal Project Brief - IDE Master Graduation

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The night train industry has seen limited innovation, particularly in terms of interior design, which hinders their optimal utilization. Conventional interiors featuring fixed beds and cabins restrict their usage to nighttime, resulting in low occupancy rates. The perceived comfort is the most important in influencing passengers' preference for night trains over other transport modes (Heufke Kantelaar et al., 2022). However, due to the limited innovation in this aspect, there is considerable room for improvement to enhance the comfort experience. Night trains currently offer three travel classes, each varying in comfort level. Notably, the privacy of the accommodation is a significant determinant of perceived comfort. While the sleeper class provides a luxurious and private experience, it comes at a higher cost compared to air travel, which often offers lower prices and shorter travel times. Beyond the study conducted by Heufke Kantelaar (2022), there is a lack of literature on comfort in night trains. Consequently, during my research elective, I explored the essential factors contributing to comfort and found that these factors differ between daytime and nighttime travel. My biggest challenge lies in merging these comfort factors into a coherent interior design for night trains. This research project focuses on the European market, as it allows for convenient testing with individuals traveling within Europe. The primary objective is to develop a future vision for Royal HaskoningDHV and night train operators, illustrating potential novel approaches for night train interiors. Royal HaskoningDHV has provided me with considerable flexibility, offering no specific restrictions on the desired outcome. Thus, I have the liberty to be creative in the design process. However, the ultimate interior design should be suitable for both daytime and nighttime travel scenarios.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

Through extensive research on existing night trains, future developments and the passenger experience. My goal is to identify opportunities for improving the interior. Based on this research, I will create a vision that will serve as the foundation for designing an improved floorplan and interior for the night train cabin(s), embodying the envisioned enhanced passenger experience.

Through comprehensive research encompassing current night trains and upcoming developments in the night train domain, I aim to examine the passenger experience and identify potential opportunities for interior and layout enhancements. Subsequently, I intend to create a vision on the necessary changes that must be implemented to create a distinctive and comfortable passenger experience for the night train. This vision will serve as the foundation for designing an improved floorplan and interior for the night train cabin(s), embodying the envisioned enhanced passenger experience.

The envisioned design can encompass a holistic transformation of the general cabin space, or it can be targeted towards specific areas within the interior, such as the entrance, private seats, or group seating arrangements. At present, the optimal approach to showcase the newly designed interior(s) remains undetermined and will be contingent upon research outcomes during the initial phases of the project. However, I anticipate that a design for a particular section of the cabin can potentially offer valuable features that can be applied more broadly across the entire cabin.

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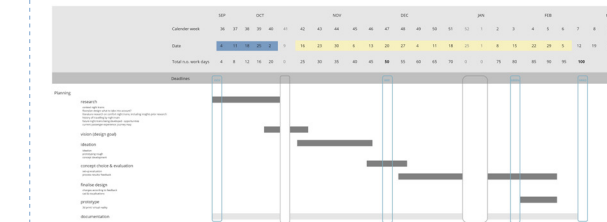


Personal Project Brief - IDE Master Graduation

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 4 - 9 - 2023 end date 16 - 2 - 2024



Hereby my planning for my graduation. Due to my TA job until mid-October, I plan to work 4 days a week on this project till that time. After that, I will be on holiday for a week. From then on, I plan to focus fully on my graduation and work 5 days a week.

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Personal Project Brief - IDE Master Graduation



MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

In my future career, my aspiration is to work within the sustainable mobility sector, focusing on significant integrated systems like Mobility as a Service (MAAS), as well as the physical modalities, aimed at enhancing user experience. Therefore this project aligns perfectly with my interests. Throughout my past design projects, I consistently recognized the importance of the interplay between users and products, and it has always been my primary consideration. Particularly in the context of designing interior spaces, this interaction holds great significance, as it consciously or unconsciously influences people's emotions and behavior (Van Hagen & Van Oort, 2019). Thus, I aim to delve deeper into the factors that impact perceived passenger experience and comfort during this project, leveraging insights from my prior research to inform the design process. Moreover, what particularly fascinates me about this project is its timeliness in relation to the current world developments, as "the renaissance of the night train in full swing" (European Sleeper Trains Are waking up, 2022). I firmly believe that this project has the potential to make a meaningful impact on contemporary mobility.

This project presents an opportunity for me to demonstrate, for my future career, that I can adopt a holistic approach to the concept of a night train. Throughout the course of this project, I have outlined the following Learning Objectives:

1. Project Organization: Independently leading a comprehensive design project, encompassing presentations, analytical tasks through setting up and conducting user tests, prototyping, user testing, validating design decisions, and seeking specific knowledge or assistance when necessary. This poses a real challenge, as such tasks are typically undertaken by a team, whereas I aim to tackle them on my own.
2. Professional Visuals: Elevating the quality of visuals in my work, encompassing both hand-drawn and computer-aided design (CAD) visualizations, understanding how they complement each other. Digital visualizations are vital for generating interior design concepts, allowing for a more comprehensive understanding of spatial dimensions. Furthermore, these visualizations could be utilized later in the process for user research and concept validation.
3. Justification of Design Choices: Demonstrating the ability to independently employ appropriate methods and justifying and validating design choices in terms of the methods and approaches used throughout the project. Adaptation of methods, when required, will also be a crucial skill.
4. Conducting User Tests: Planning and executing user tests, followed by thorough analysis and interpretation of the results.
5. Communication and Presentation Skills: Effectively communicating with all stakeholders involved in the project, providing timely updates and relevant information to the supervisory team. Additionally, being capable of explaining decisions in a manner understandable to individuals from diverse backgrounds.
6. Self-Evaluation: Reflecting on the quality of my work and planning, utilizing feedback to evaluate my performance, and striving to improve based on this feedback and self-assessment.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

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