AN INTERIOR PROPOSAL FOR A FUTURE SHARED AUTONOMOUS CAR WITHIN URBAN CITIES

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MARTUR INTERNATIONAL Automotive Seating Systems

TU Delft Delft University of Technology

D I S C L A I M E R

Disclaimer
This master thesis is part of the master
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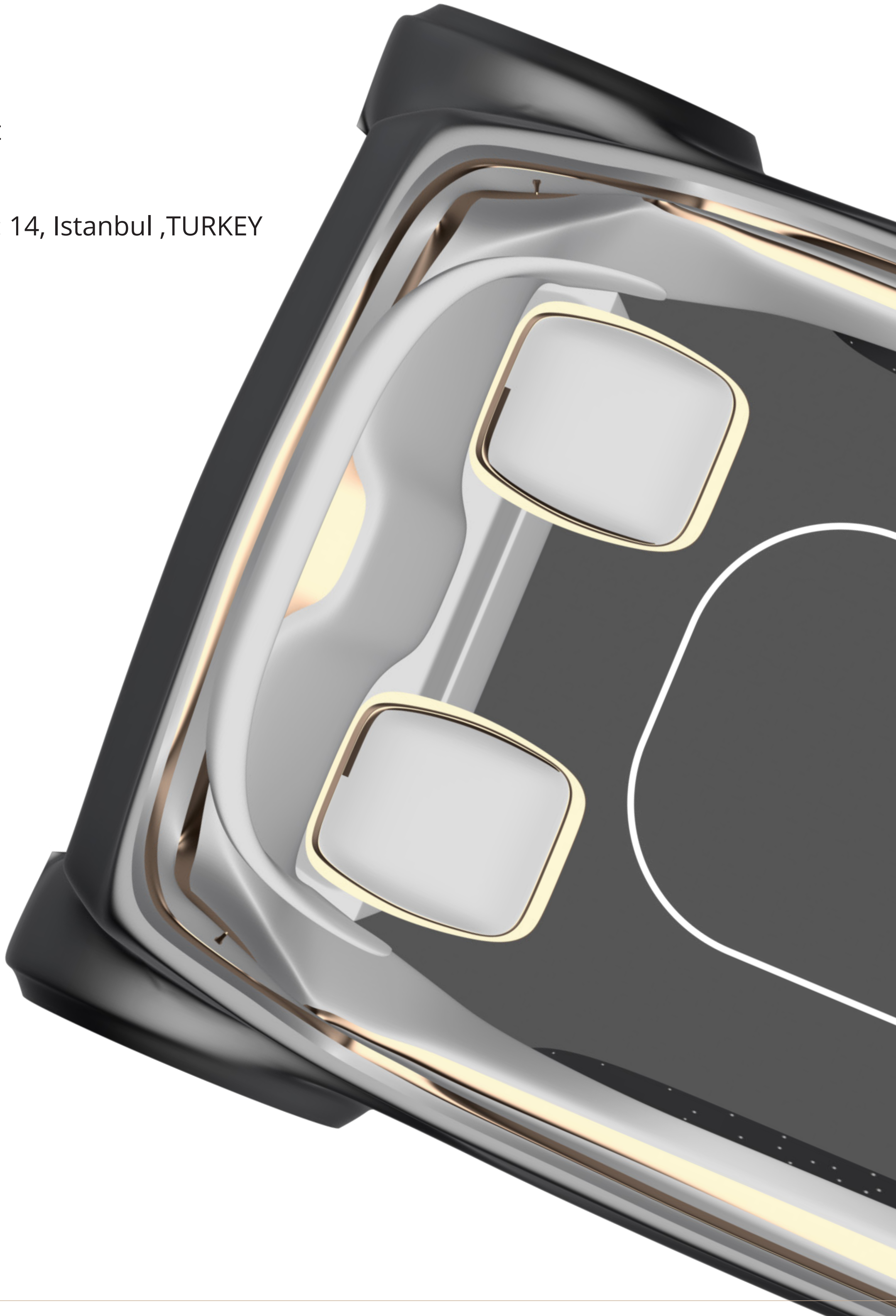


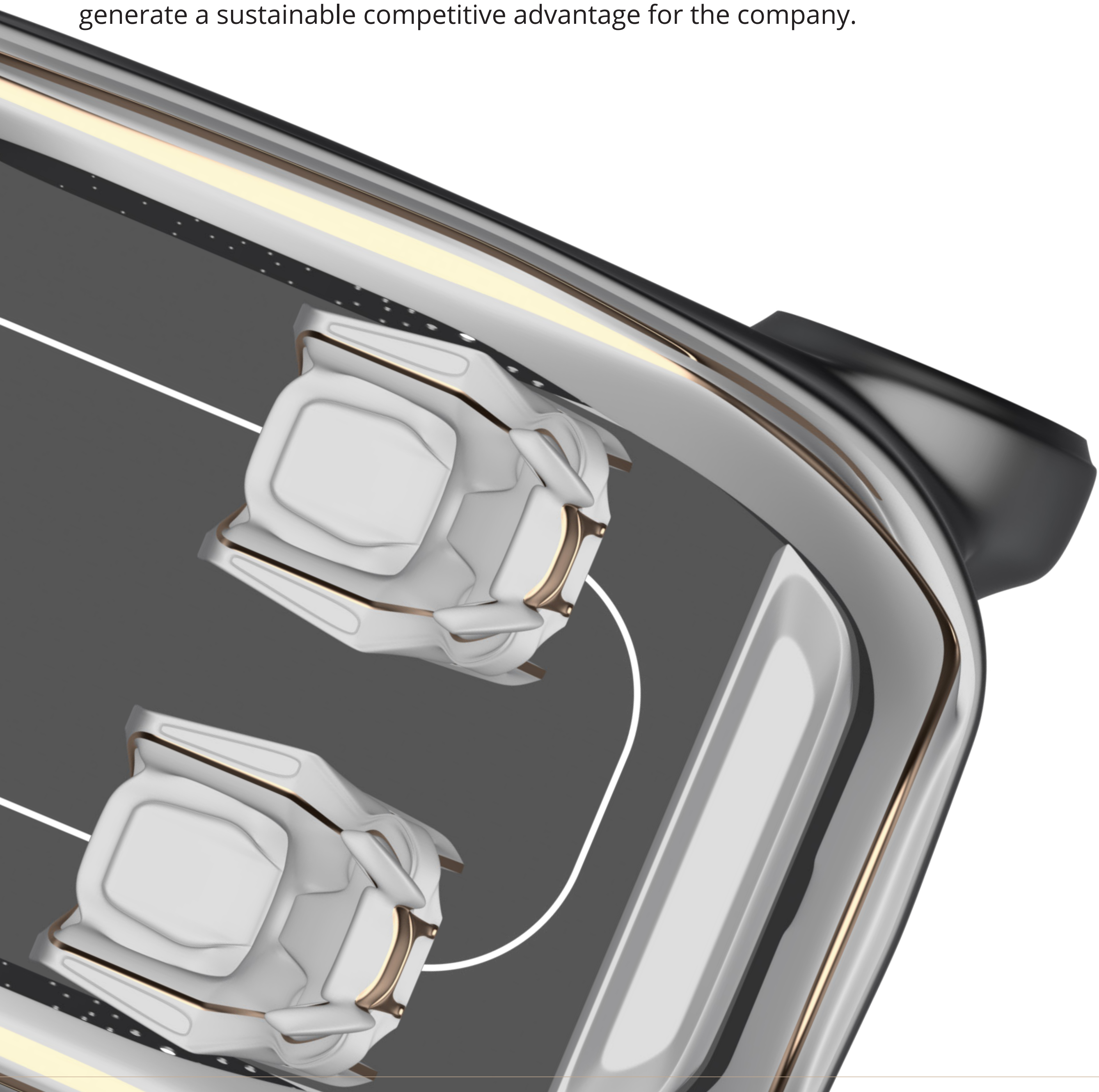
PREFACE

This graduation project concludes my time as being a student and officially marks the end of my master Integrated Product Design. Finishing this project sets the beginning of my professional career as a designer.

The graduation project was a great experience in which I got introduced to doing freelance work with many stakeholders involved. The main benefit was that I could design from my own perspective about the future of shared autonomous cars without getting influenced too much by the company. The project started with a general analysis of this market and together with some staff members of our faculty, we came up with a new academic study about the future activities that people will do and how the interior will support these activities. This study could then be used as input for an interior proposal in which the mechanism and design were explored.

This project has enabled me to improve my preparation skills, academic research skills, CAD skills and communication skills with all stakeholders.

While the final proposed interior can be improved in many ways, I believe that this interior is a solid proposal which shows a new perspective in this future market, thus using it could generate a sustainable competitive advantage for the company.



TEAM INTRODUCTION

BSc. Önder Turgut
He did his bachelors in Industrial Design Engineering and has a great passion for (transportation) interior. Besides that, he likes to spend his free time with family and friends.

Prof. Dr. P. Vink (Chair)
Peter is a Professor of Environmental Ergonomics and Head of the Design Engineering Department at the faculty of Industrial Design Engineering. Peter is working in the fields of seating, aircraft interior, office interiors, and office environments and makes sure that while we sit, we enjoy it comfortably.

Ir. Martijn Haans (Mentor)
Martijn represents the department of Human Information Communication Design of the faculty of Industrial Design Engineering. Martijn is also a graduate from IDE and has his own design agency. Furthermore, Martijn is a full-time lecturer in Design Drawing at the faculty of Industrial Design Engineering.

Dr. Recep Kurt (Advising Mentor)
Recep started his career by doing a Ph.D. in composite materials. After this, he worked at Figes Ltd. on finite element analysis, at Coşkunöz Metal Fabrikas as a specialist in analysis and design and finally at Martur as a specialist of seating and trim. In 2010 he became the director of the R&D department at Martur.

A WORD OF GRATITUDE

To make this interior proposal for a future autonomous car a success, a lot of guidance was required. An example is during the initial phase of the project, were Peter shared a lot of literature that guided me in the right way and proposed a meeting for me with the ergonomics staff of our university.

Thanks to Peter and all these people, I was able to come up with an observational study that provided real value and was the first step of doing research within the field of autonomous vehicles. Shabila and Joyce helped me to simplify the research while Silvana and Iolanda helped with the initial ideas and pilot.

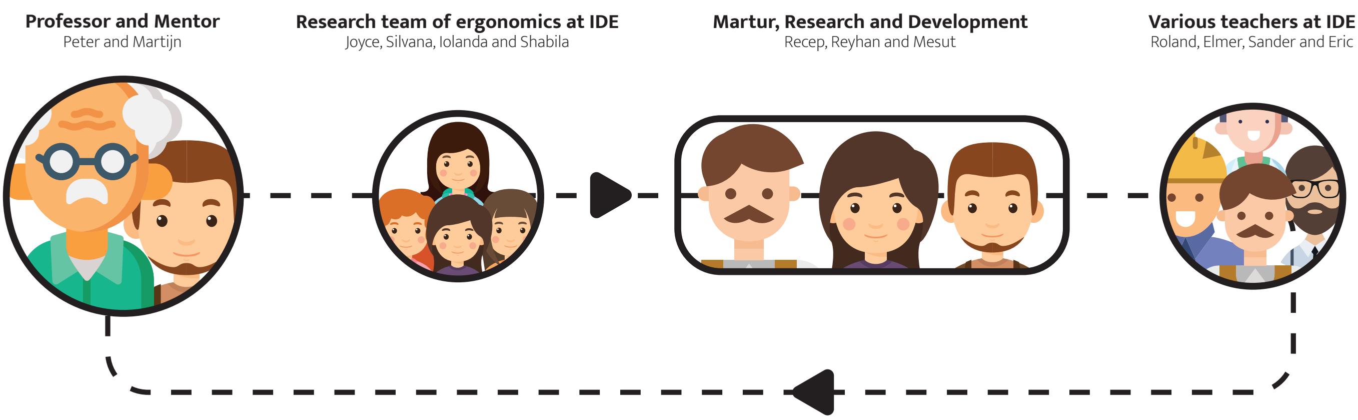
When it came to building the required mock-up, Roland from the PMB was able to come up with ingenious simple solutions that really helped a novice like me, with building these stuff.

Most of my participants in the observations study were close family or friends who made time free and supported me during the project. While working alone on this project it really helped me that I talked with people who were genuinely interested and thought that I was doing a great job, like Peter himself. After one of my presentations he told me: “Reyber, you are doing good work but are shy about it. You do not realize how good the work is that you are delivering right now.” It is just good to hear this as it boosts my motivation. Besides Peter, I had Martijn as a mentor.

Martijn always had time to give advice about any part of the project and we brainstormed a lot together to bring the best solutions possible. This makes him a great mentor.

While the mechanical system was thought of, Martur proposed an engineer (Mesut Yaylak) who was willing to brainstorm and optimize the mechanical system. Besides Mesut, advice was taken from Eric Thomassen and Sander Minnoye. This was necessary because mechanical thinking is not my biggest strength.

During the design process, a visit was made to Elmer van Grondelle. He proposed his view regarding BMW as a brand within this project and gave new methods to come up with styling solutions.



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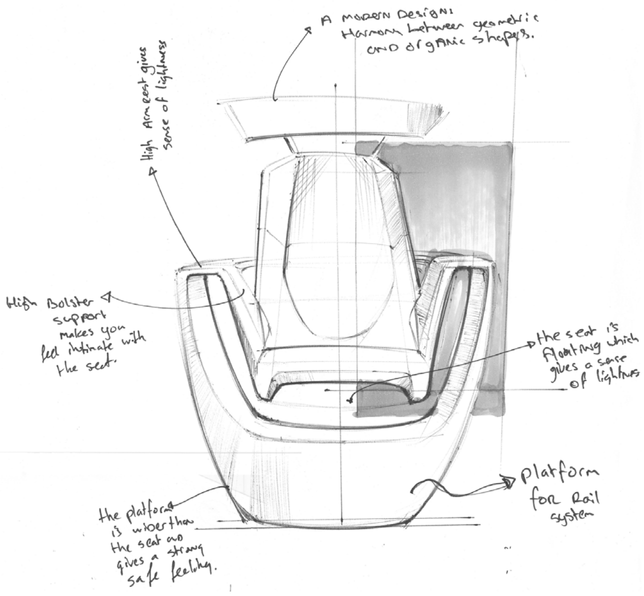


EXECUTIVE SUMMARY

Dear reader,

As you well know we are entering a new era. An era in which more and more things are becoming smart including the cars that we see around us. This technology will soon bring us new services like car- and ridesharing with autonomous capabilities. Big brands like Renault and Audi expect self-driving cars on the road around 2022. Nevertheless, a lot of questions remain unanswered. One of these questions is the adaptation of the interior to self-driving technology. What will we do, when we do not have to drive anymore? Every OEM has a different answer to it and the study was done in this project shows that we will spend our time doing activities like sleeping, eating, working, socializing, using in-car entertainment or being private while daily commuting in this private ride-sharing car with friends or family members.

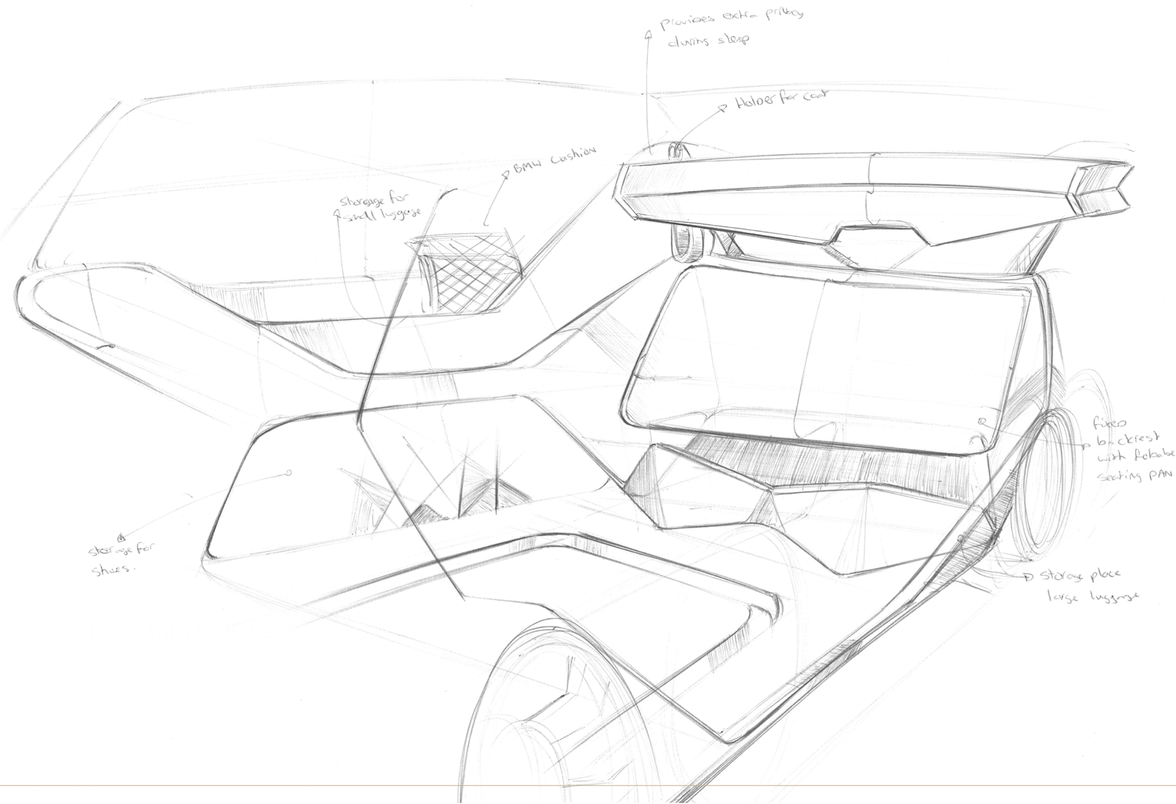
The next question that probably pop-up in your mind right now is how this interior will look like. The solution that I provide exists out of a mechanical rail system that enables different seating layouts which ensures that all occupants (in most cases this will be two) can enjoy the activity that they do during commuting to the utmost. Imagine that you want to have some private time while your friend is sleeping. He wants his personal space in the rear and does not want to be seen by you while sleeping. Besides that, he desires to feel safe and wrapped around by the interior. All this is possible thanks to the simplistic mechanism that resulted after a lot of iteration with the client.

Before sleeping people tend to have rituals like reading a book or watching something on the tablet and slowly fade away. These rituals show that the interior should provide solutions like a foldable table and space in which they can store their small or big luggage. A creative session resulted in a cabin package which was used as a reference during the interior design. This session looked at the required stuff that people take with them during commuting which creates an atmosphere that feels like a second living room.

The design of the interior has function over form. Every part is designed with a specific scenario in mind while the aesthetic laws of automotive design were used, like indexing and coherent spaces. The design inspiration came from the interior philosophy of BMW, a visual comparison of current living rooms and a collage, in which the aim was to bring a design which has a nice harmony between simplicity and complexity with a balance of geometric and organic shapes. I present to you a proposal interior of a ride-sharing autonomous car for urban cities around 2022.

G L O S S O R Y

SHARED AUTONOMOUS CAR	A self-driving car that uses technology found in level 4 or level 5 autonomy and does not have a steering wheel or pedals. This car is used for ride-sharing within the city
DAILY COMMUTING	Transporting oneselves daily by the use of mobility
INTRAGROUP RELATIONSHIPS	A relationship in which people know each other
INTERGROUP RELATIONSHIPS	A relationship in which people do not know each other
SWIVEL	A seat that rotates in the z-axis of it’s own origin
OCCUPANT	A person commuting within a car
H-POINT	Theoretical, relative location of an occupants hip
CHAIR HEIGHT	The height of the h-point relative to the floor
SGRP COUPLE DISTANCE	The distance between two h-points in the top view
CAD MODEL	A computer aided design which is often used to test or manufacture products
FOS	Factor of safety, used in the world of mechanics to find out how much stronger the product is than it needs to be for an intended load
FATIGUE	The weaking of a material caused by repeated loads
INDEXING	The art of making coherent designs by using lines that end at the same point (when extended)



01/ A INTRODUCTION TO AUTONOMOUS CARS

We begin our journey by exploring the development of autonomous cars. What happened in history and why is it now, the right moment to design a new kind of interior? Different levels of autonomy will be explained and facts about driving and car seats will be given. The chapter ends with a scope and a goal.

Figure 1: The future illustrated in the 50's by Chrysler

01/ A INTRODUCTION TO AUTONOMOUS CARS

After a couple months of searching for a graduation project, I knocked on Peter Vink's door. Peter is our Professor of Environmental Ergonomics and the Head of the Design Engineering Department, which means that he basically knows everything about how you, my reader, should sit. So, when he suggested Martur, one of the global car seat manufacturers, things started to roll. Martur is a Turkish company which produces car seats globally for companies like Fiat, Ford, and Renault and is mostly interested in how car seats will change when cars become autonomous. To answer this question, we have to first look at the history of autonomous cars:

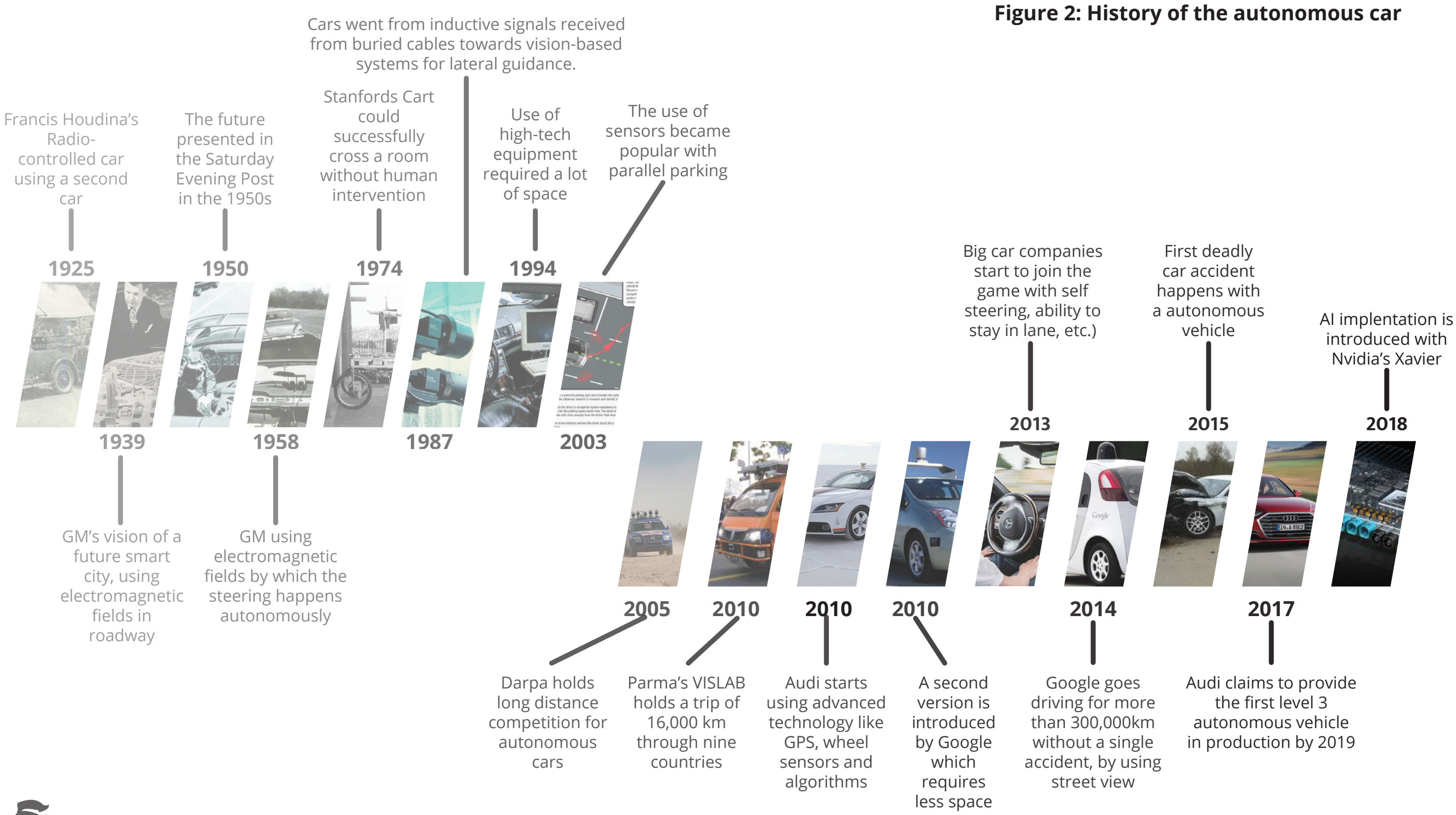
1.1 A BRIEF HISTORY OF AUTOMOUS CARS

Autonomous cars have been in our imaginations basically immediately after the introduction of the first automobile in 1886 by Mercedes-Benz (Daimler,2014).

Francis Houdina started this revolution in 1925 by controlling a car with radio technology, making use of a second car (see figure 2). But the real revolution started in 1974 when Stanford created the Stanford Cart. This was the first vehicle that was able to move on its own, without human intervention or remote control (WIRED, 2016). Cars went from inductive signals that they received from buried cables towards vision-based systems. Vision-based equipment took a lot of space until the introduction of small sensors. These sensors were used in 2003 to introduce parallel parking.

When Darpa challenged car companies for a long-distance competition with autonomous cars in 2005, most vehicles did not make the finish line. So, most car companies went back to their drawing board to come up with smart solutions that would make them win this competition and be remembered as 'the first company that introduced autonomous cars'.

Figure 2: History of the autonomous car



01/A INTRODUCTION TO AUTONOMOUS CARS

The year was 2010 when 3 companies introduced their vision of autonomous and got this title simultaneously. Parma's VISLAB is an Italian company that was founded in the early 90s as a research laboratory of the University of Parma, broke records with their first vehicle, driving 16.000km through nine countries autonomous. Audi, as one of the major OEM's, became successful by introducing advanced technologies like GPS, wheel sensors and algorithms, while Google drove 300.000km without a single accident, by combining radar technology and Google Street View (Vanderbilt, 2012), 2018).

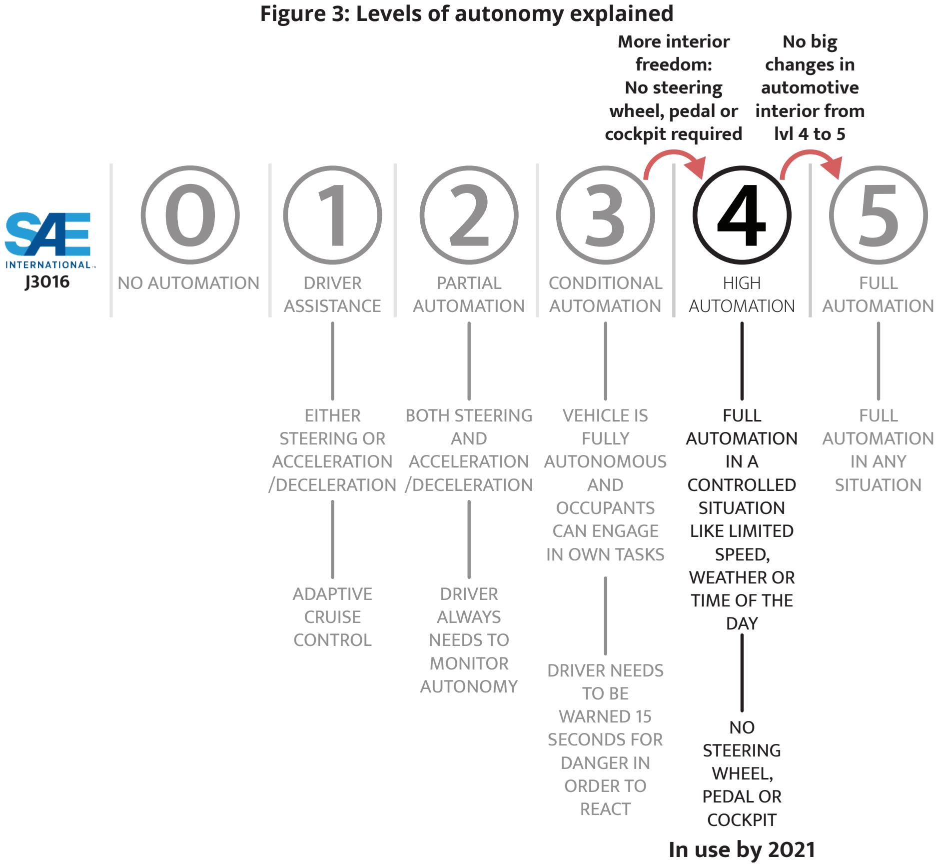
Other OEM's started to join the game with technologies like self-steering and ability to stay in the lane. Tesla brought autonomous cars to the early adopters, and then to the majority of the consumers with the introduction of the Autopilot in their Model S vehicles. While the Model S may seem quite advance, it has currently only Level 2 autonomy. Audi claims to provide the first Level 3 autonomous car in 2019 by using AI technology like Nvidia's Xavier (Digital Trends, 2018).

So, you are probably now wondering something like: "What the hell is he talking about. What is level 2 or level 3?" Have patience my reader and I will explain.

1.2 SELECTING THE RIGHT LEVEL OF AUTONOMY

According to the SAE J3016 (see figure 3) there are different levels of autonomy (SAE, 2016). Most new cars that we see on the road have level 1 autonomy. This basically means that the driver is being assisted with either adaptive steering or adaptive cruise control while riding on a highway. In level 2, both options are simultaneously working, and the driver needs to monitor the vehicle. In Level 3, the vehicle gets fully autonomous and the driver is allowed to engage in other tasks but should be able to take over the steer in case of an emergency.

Figure 3: Levels of autonomy explained



01/A INTRODUCTION TO AUTONOMOUS CARS

According to Ford, level 3 is as difficult as level 4, because the driver gets the option to do other things which will reduce the responsiveness. Ford calculated that 15 seconds are necessary for a driver to react properly, but that this is problematic for current day sensors. So, the proposed idea is to skip level 3 and go to level 4 in which the vehicles decides for themselves what to do, in case of a nearing accident (Techemergence, 2o18). Other characteristics of level 4 are that the steering wheel and pedals get removed and that the car will drive itself within controlled conditions like specific routes, time of the day or weather.

Level 5 brings real autonomous experience like it was already envisioned by GM in the late 50s (Jalopnik, 2015). In level 5, the car is fully automated and is able to adapt to any situation in any condition.

So, you are probably now thinking that this sounds too much like science fiction. I would not blame you if I didn't do the desk research on the future market of autonomous concepts myself (see appendix 3).

Major OEM's promise that level 4 autonomy will be possible in the following 10 years, with Renault promising the first adaptation of this, with the Renault EZ-GO, in 2022 (Renault, Mediagroup, 2018).

Because the major difference in the automotive interior will happen between the transition from level 3 to 4, level 4 has been selected as the right autonomy to design for. Therefore, the proposed interior concept will aim for a release in 2022.

Figure 4: A use-scenario of the Renault EZ-GO

1.3 THE RAISON D'ETRE

Like the introduction of the first wheel, most technologies have been invented to keep up with our needs and to make our lives easier. The need for driving is slowly disappearing (Autoexpress, 2018) while connecting with others around the world is increasing. This brings us to an age in which people would desire to occupy their driving time, which is currently 52 minutes a day, with something else (Visual Capitalist, 2018). Autonomous vehicles will make this possible and the technology is already there. Figure 5 shows a couple of benefits that autonomous cars bring (see appendix 1).

Driving Time could be spend other

Every day we spend 50 minutes driving and with the introduction of self-driving cars, we could spend this time, doing whatever we like to do.

Reduce of car crashes

93% of the 1.2 million number of death world wide due to road accidents are caused by human error. This total cost worldwide is 1.2 trillion due to medical, property damage and productivity

Desire for an Innovation Push

Technology companies like Nvidia provide new AI-technologies which will give self-driving an enourmous boost. 99% of car brands see these consumer technology companies as a catalyst for innovation.

Figure 5: Main benefits of autonomous cars

Besides this, autonomous cars will reduce traffic congestion (Volkswagen Group, 2018), reduce time looking for parking place, double the current automotive market value (Adient, 2018), reduce CO2 emissions by 300 million tons per year, introduce higher speed limits and make cars more versatile (Business Insider, 2016).

These benefits make the introduction of autonomous cars inevitable and because of this, automotive UX designers have a new task in which they need to find out how new users want their interior to be (as most of the actual interaction with the car happens inside the car).

1.4 THE SCOPE OF THIS PROJECT

Like Hendriks, a senior interior designer at Yan Feng, suggested: "Interior now plays a big role in customer satisfaction. This is where we will be spending our time doing new things, as you no longer have to control or drive the vehicle." (Automotive IQ, 2017), the interior is the right place to set focus on. Nevertheless, designing a fully detailed and well-thought interior is too much to ask of one student, so the scope of this project lies mostly on the seats, with secondary attention to the interior.

When daily commuting was analyzed, it appeared that in a lot of cases, most of the seats were not used at all and that there is an inverse relation between customer satisfaction and an increase of seating problems which create business opportunities for companies who reduce seating problems (Jabil, 2018). Besides this, the following facts were visualized in (see figure 6).

Minimal use of seats

Only 1.4 car seats are averagely used in a car ride

No rear seat use

Eighty percent of the time, the rear seats are not in use

Influence on Customer Satisfaction

Customer satisfaction reduces with a increase of seating problems

A lot of misadjusting

Occupants misadjust their seat, which creates significant long-term discomfort and injuries

High contribution to car mass

Seats typically contribute 6% of the car's mass

Figure 6: Main problems with seats

1.5 THE GOAL OF THIS PROJECT

So, seating has currently a lot of problems that could be worked on and because of this, the goal of this project becomes:

To design an efficient seating concept for a future autonomous car in 2022 that provides occupants the ability to spend their time however they like.

02/ INTERNAL AND EXTERNAL ANALYSIS

To gain more knowledge about what's out there, an internal and external analysis has been done. This analysis exists of an internal analysis of Martur, an external analysis of facts & trends and a market analysis. The chapter ends with 3 perceptual maps that clearly visualize the possibilities that Martur has to shock the world.

Figure 7: BMW Intel 2017 Autonomous Concept

02/ INTERNAL AND EXTERNAL ANALYSIS

The goal has finally been set and now it is time to do an initial research into the context of this project. The context is a combination of a company analysis, DEPEST analysis, market analysis, and facts.

2.1 COMPANY ANALYSIS

Martur is a car seat manufacturer (first-tier supplier) that is based in twelve locations, which together provide all elements that are necessary for building an automotive seat. Most of these locations are either in Turkey or Europe. Martur produces car seats for leading OEM's like Fiat, Ford, Peugeot, and Renault.

Figure 8: Adient AI18

Martur's vision is to bring innovative solutions in the product design, process and material selection of car seats. By doing so, Martur hopes to become a global leader like their main competitors: Adient, Lear Corporation and Faurecia (Martur, 2018).

Unlike Martur, these companies have big R&D departments resulting in a lot of concepts, which shows OEM's what these first-tier suppliers are capable of.

An example is the Adient AI18 (see figure 8), which is the first (first-tier) concept that really shows how the future of automotive seating could become like. Adient AI18 is a concept for a level 3 or 4 vehicle that uses the latest (safety) technologies and combines this with expected trends and scenario's (Adient, 2018).

Martur is currently missing a strong concept like this because they have been focusing more on producing for their clients instead of developing something themselves which could shock the world.

When analyzing Martur's strengths and weaknesses, it becomes clear that they do not really have a sustainable advantage. The things that they are good at, for example, being customer orientated, produce efficiently or having a social responsibility, are strengths that all other competitors also have.

When compared to Adient, Adient has around 200+ locations and promises an order to delivery time of 90 minutes. So, in this way, having strengths that are not unique becomes a weakness.

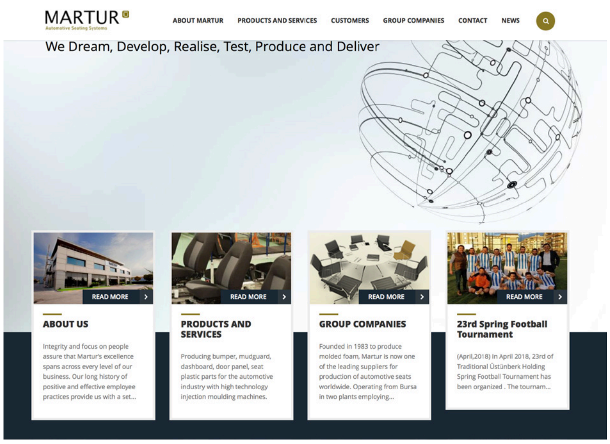


Figure 9: Main page of Martur's website

Another weakness is that they are not able to present themselves well globally. A quick look at their site (see figure 9), which is basically the only place to find any information about the company, shows that there is no transparency in the seats that they produce, which makes it more difficult for new clients to get attracted to them.

Nevertheless, this project will bring an interior proposal for future shared autonomous cars that go together with Martur's philosophy: "Providing an innovative high-quality solution that is comfortable, lightweight and multifunctional", and show OEM's what Martur is capable of, bringing them a sustainable advantage. Figure 10 shows a visualization of Martur as a company.

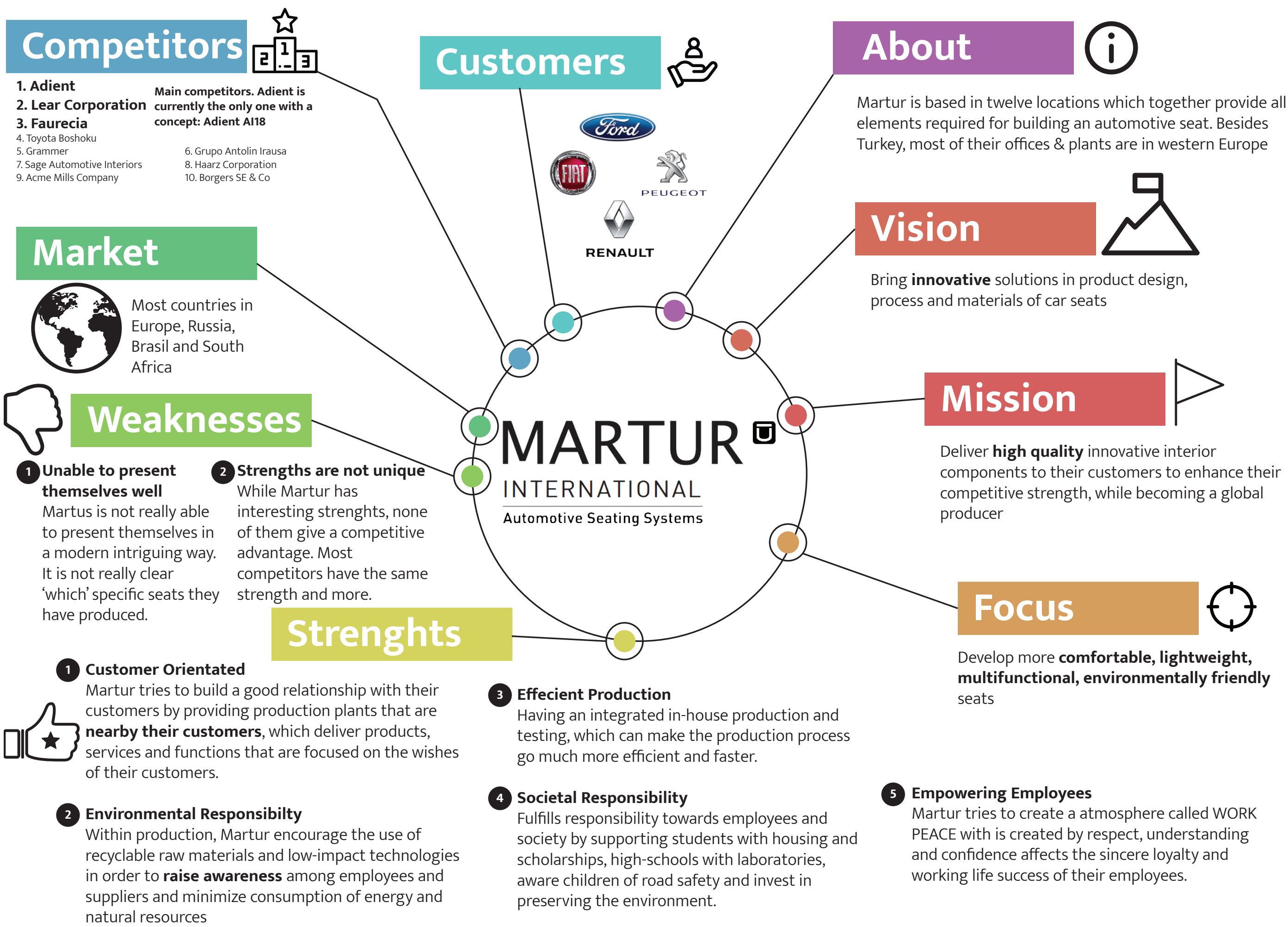


Figure 10: Company Analysis

2.2 EXTERNAL ANALYSIS: FACTS

Like every big step in technology, autonomous cars seem futuristic and most people assume that it will bring us one more step into robotizing everything, which makes the general public believe that it may be a bad thing. But like all other technologies before (for example, the automation of gas stations, in which personal service was replaced by self-service (NACS,2011), autonomous cars will provide a service that needs some time before it is culturally accepted. The benefits mentioned in chapter 1, will speed up this process, which will make an autonomous car- and ridesharing possible.

Car sharing is a service in which owners rent their cars when they are not in use. Currently, most of our cars are just standing still (90% of the time) on a parking lot while these cars could be used more efficiently and create an economic profit for the owner while also reducing the number of cars on the road (IPI, 2012). Even so, 72% agreed that they would never rent their car to a stranger (PWC, 2016). This shows that cars, that people own, still feel personal and most people would possibly see it as their second home. This behavior and the fact that fewer people tend to get their driving license will probably steer our future into ride-sharing. So, what is ride-sharing?

Private Ride sharing, A first scenario

Imagine that you want to go on a one-day trip with a couple of your best buds, but no one owns a car. So, you all decide to go to a ride-sharing stop where this autonomous car is waiting for you. This car drives on fixed routes during specific moments of the day (which are characteristics of a level 4 autonomous car) while you and your friends relax. There are two possibilities: This car could either be seen as a private taxi or provide ride-sharing for everyone, thus making it publically accessible for everyone. Research outcomes in chapter 3, shows that most participants would not want to share this autonomous car with a stranger but rather with friends or family members. So, the interior that will be designed is for a private ride-sharing vehicle that drives on fixed routes, providing seating for up to 4 occupants (one of the requirements made by Martur). So, what do the occupants desire of such a vehicle?

02/ INTERNAL AND EXTERNAL ANALYSIS

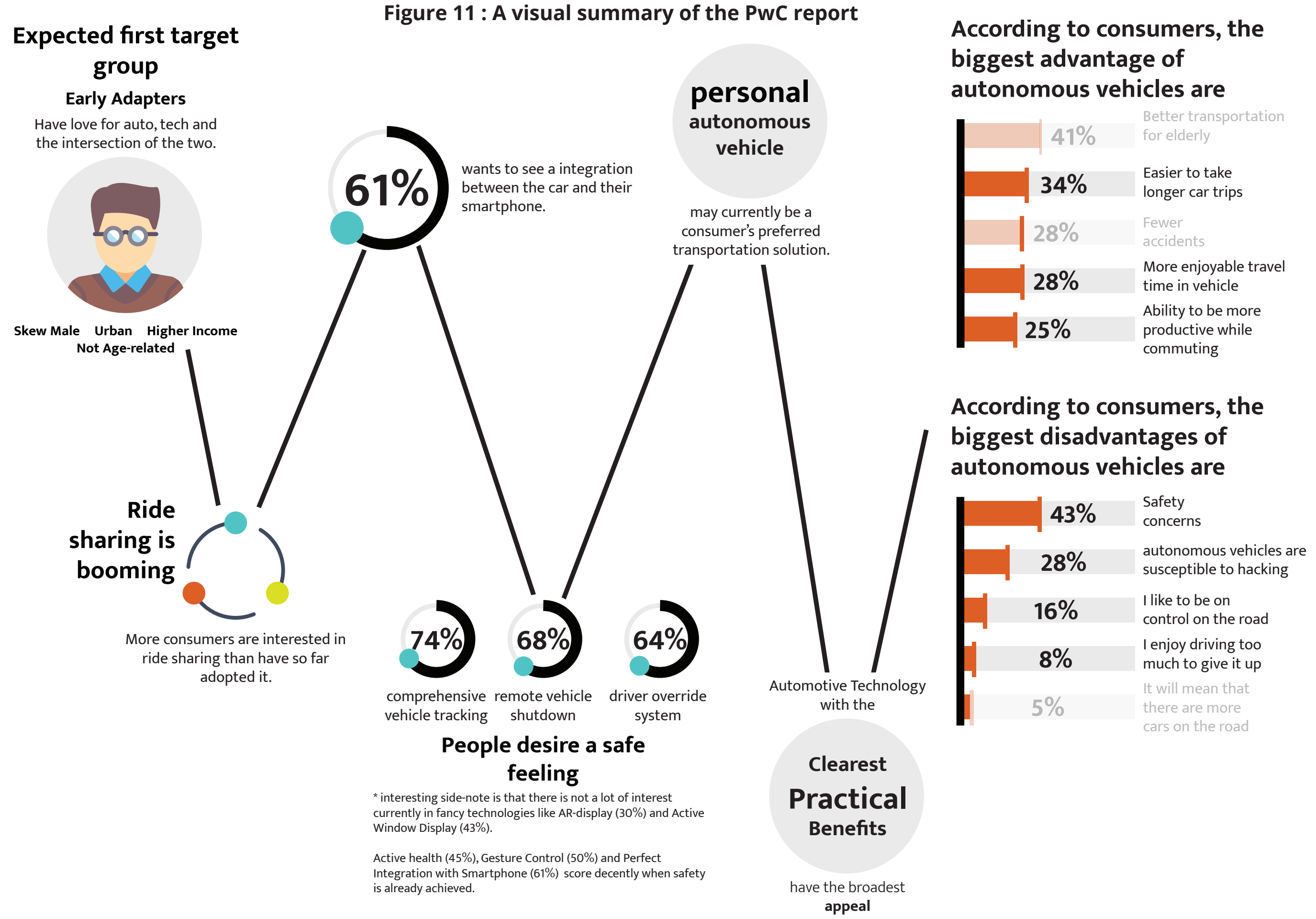
According to the PWC report, the expected first users of this service will be early adopters that love cars and all the tech around it. Most of them live in urban areas and have a higher income. They are interested in ridesharing and want to see an integration between these cars and their smartphones. Safety seems to be the most important character, with technologies like comprehensive vehicle tracking, remote vehicle shutdown, and driver override system being the most popular.

Interesting side-note is that there is not a lot of interest into fancy technologies like AR-displays or an Active Window Display and that only 8% enjoys driving too much to give it up.

According to consumers, these cars will make it easier to take long car trips, make it more enjoyable to commute with a car and provide an opportunity to be more productive.

So, from this analysis, it becomes clear that the interior should provide an atmosphere that feels safe, personal and practical to the occupants (see figure 11).

Figure 11 : A visual summary of the PwC report



2.3 EXTERNAL ANALYSIS: DEPEST TRENDS

The last paragraph defined how people think about autonomous cars and now it is time to explore the future world in which these vehicles will be driving, by using a DEPEST-analysis (see appendix 2).

As health care improves, we as a western society start to live in an urbanized hyper-society where 21% of the citizens will be older than 65 (Hyundai, Motors, 2018). Within this hyper-society, it is expected that 70% of the world's population will live in, which results in even more megacities. These megacities with a large, established vehicle base seem to be the right fit for new mobility services, i.e. cities and suburbs of Europe and North America.

D1

In 2030, most of the developed countries will have a hyper-society where 21% of the citizens is 65+

D2

in 2030, 70% of the world population will live in urban areas

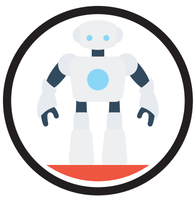
D3

Increasing dense areas with a large, established vehicle base will be the best fit for new mobility services i.e. cities and suburbs of Europe and North America

Figure 12: Trends 1

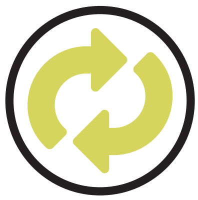
The annual growth of car sales is expected to drop from 3.6% to 2%. This drop will largely be because of car/ride-sharing services (Jabil, 2018). It is expected that one out of the ten new cars sold will probably be a shared vehicle and that the importance of private-car ownership will decline.

T1



Artificial Intelligence will be used more to anticipate occupants needs, inspire their imaginations and improve their lives.

T2



Shared mobility solutions with shorter life cycles will become more common, which will further increase demand for upgradability of their cars

T3

It is expected that by 2020, 90 percent of new cars will be connected to the internet, which will create a demand for new consumer services and applications

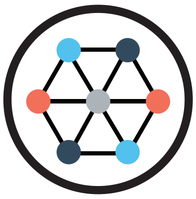
Figure 13: Trends 2

These vehicles will make use of AI technology, while being connected to the internet, in order to anticipate occupants needs, inspire their imaginations and improve their lives. Examples of this implementation are that payment of electricity (for the trip) could be done through the cloud and that occupants get suggestions about local restaurants or attractions that they might want to visit (Techcrush, 2018). Furthermore, the AI could be used to form a more human-type relation with its user(s) like greeting occupants and scan their emotions to provide suitable solutions (Leggert, 2018).

02/ INTERNAL AND EXTERNAL ANALYSIS

More cities will become 'smart' and all electronics between someone's home, office, infrastructure, and the car will become interconnected (Nokia Networks, 2018). Audi imagines a world in which it is inevitable to escape ads. Imagine commuting to work in a ride-sharing vehicle. It is early in the morning and all the displays inside the vehicle are portraying ads. Does not seem right, right? Some citizens may get social anxiety because of this and demand spaces and experiences that act as a healing medium (The Verge, 2017).

E1

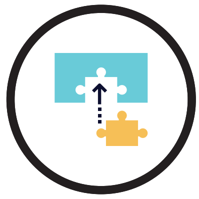


In 2030, one out of ten new cars sold in 2030 may likely be a shared vehicle.

S1

consumers with social anxiety will demand spaces and experiences that act as healing medium

S2



Consumer's new habit of using tailored solutions for each purpose will lead to new segments of specialize vehicles designed for very specific needs

Figure 14: Trends 3

Additionally, users may have specific needs and desire tailored solutions (McKinsey & Company, 2018). Because of this, it is expected that ride-sharing vehicles will be provided by OEM's that have tailored solutions for specific purposes, creating new vehicle segments. So, car brands like Porsche, Volvo or BMW may offer a 'car subscription program' which let users flexible swap between tailored solutions with a click of a button. Furthermore, it is expected that users get so used to the short product cycle of smartphones, with big updates in a short time, that they demand the same from car/ride-sharing vehicles (KSAT,2018).

Based on these trends, the choice is made to design this interior for a ride-sharing vehicle within a Western 'smart' megacity.

2.4 EXTERNAL ANALYSIS: FUTURE MARKET

Before starting with this initial research, the idea was to combine the strengths and weaknesses of the company with trends and facts, and create a SWOT-analysis which then would produce search areas, but after the company analysis it appeared that Martur does not have real strengths that were different from the competition so a SWOT analysis would not make much sense.

Plan B was to make multiple Perceptual maps that provide possible market gaps which could propose a clearer direction. The first step was to analyze the current autonomous concepts that were presented either at CES2018, Geneva Motor show or that popped up after some desk-research (see appendix 3). The table in appendix 3 shows all concepts found. The idea behind this table was to analyze the level of autonomy, characteristics of the vehicle, the expected release date, the trends that it relies on and the seating positions these concepts have, in order to understand the perspective of OEM's regarding the future of autonomous vehicles.
An example is the Rinspeed Snap (Youtube, 2018), which is a fusion of a skateboard and a pod and functions as a third living space. The pod can be leased, owned or shared while the skateboard drives around 24/7 and serves everyone. This vehicle is expected to be released in 2021 and is based on a trend in which everything is connected and adaptable. The seating position provides a face-to-face layout with lounge seats and a possibility to separate the occupants by displays.

2.5 PERCEPTUAL MAPS

To score these concepts on a perceptual map, useful characteristics were needed. The PWC report showed that the interior should provide an atmosphere that feels safe, personal and practical to the occupants and some of these characteristics were used as a starting point for the vertical axis. The variables on the horizontal axis came from the comparison between the concepts. Some concepts really focus on connectivity or provide an interior that is versatile while others still focus on the driving experience, i.e. BMW Next 100 (BMW, 2018).

Figure 15: A visual comparison of autonomous car concepts

There were also other characteristics (see appendix 4) found when comparing the concepts, but after making some perceptual maps, it became clear that the before mentioned characteristics gave the best results.

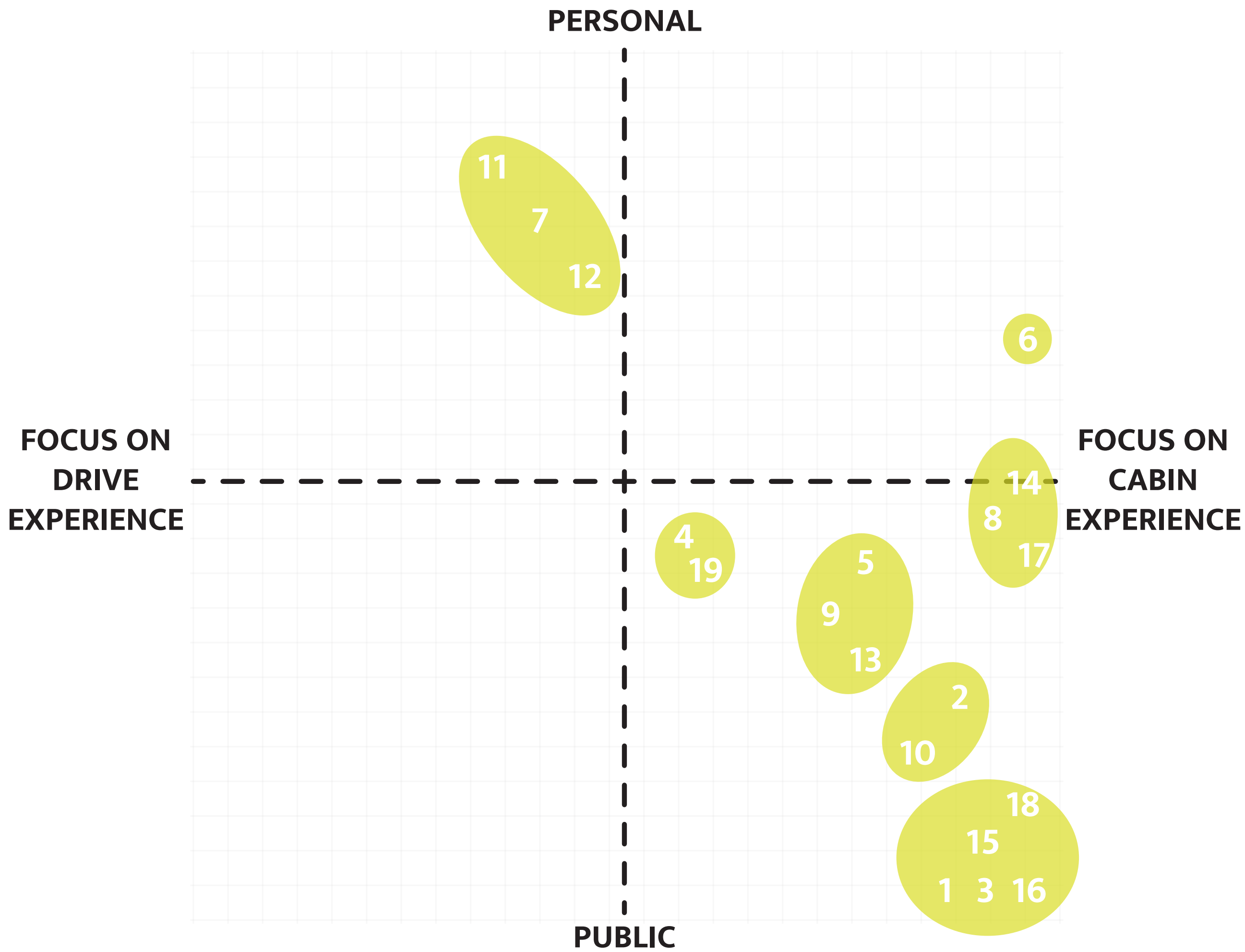


Figure 16: Perceptual map 1

Perceptual map 1:

- Personal vs. Public: An automotive interior is seen as personal when it provides solutions which resemble the desires of the individual occupant. Think about an AI which knows what you want and adapts the interior accordingly to it or a combination of the right seat set-up, materials, and setting.

- Focus on drive experience vs. cabin experience: The automotive interior of tomorrow may focus on driving or on the cabin experience itself.

Like mentioned before, ride-sharing will boom in the future and OEM's could aim to provide a service that is either personal or publically available to everyone. The perceptual map shows that most OEM's aims to provide public service (5,9,13,2,10,18,15,1,3,16). Good examples are the Volkswagen Sedric or the Renault EZ-GO which function as taxis/busses and have certain stops on which everyone can just hop in and participate in the ride. Besides that, most of these concepts have a face-to-face seating layout which does not really focus on an individual's wishes. The ones that do focus more on the individual occupant, are traditional seating positions that focus more on the driving experience (7,11,12). So, it becomes immediately clear that there is a gap in the right upper quadrant which focuses on the cabin experience for the individual. This is quite interesting because desk research showed that only 1.4 seats are currently used and that the rear seats were almost never used and still, most concepts provide seating for at least two or more occupants. From this, it can be concluded that the proposed design should satisfy an individual's wishes, by providing a good cabin experience even during ride-sharing with others.

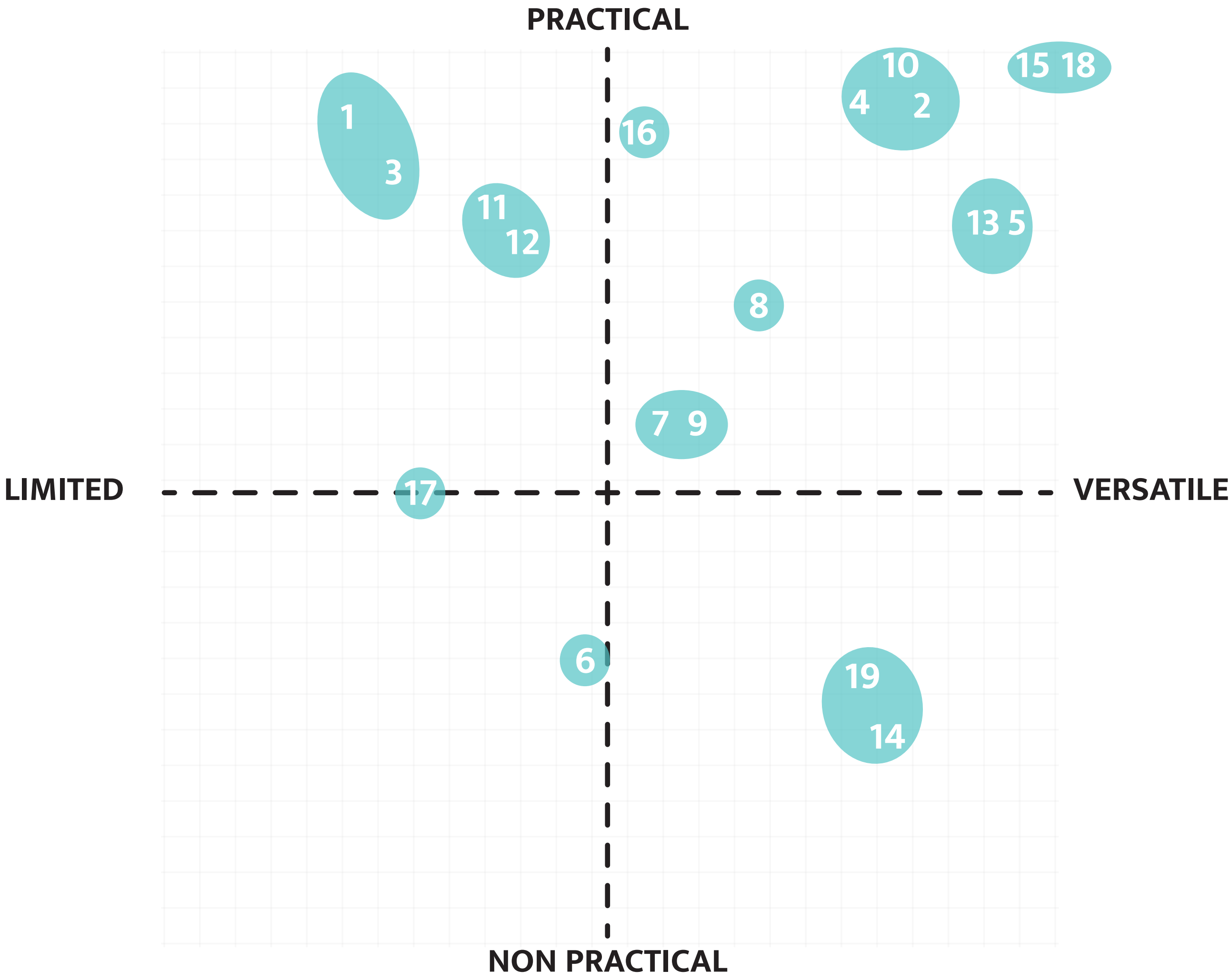


Figure 17: Perceptual map 2

Perceptual map 2:
- Practical vs. Non-Practical: An automotive interior is seen as practical when it fulfills its functions up to a satisfied level.

- Versatile vs. Limited: An automotive interior is described as versatile when it does more than 'only supporting' the occupant during seating. Examples are like additional room for luggage, massage capabilities, providing information to the occupant but also the ability to propose multiple modes like work mode or relaxation mode.

The second map shows that the market is quite spread. A lot of concepts provide versatile options that are quite practical (13,5,2,4,10,15,18), like for example the Adient AI18, which has multiple seating layout and makes use of the space quite efficiently when seats are not in use or the Mercedes F015 (Mercedes-Benz, 2016) which could either be used as a luxury lounge or a meeting place where things are discussed. The door trim and instrument panels of the Mercedes F015 are efficiently used when someone wants to present something but absent when it is not required. This should be the aim of the proposed design: To bring versatile options that are useful and practical.

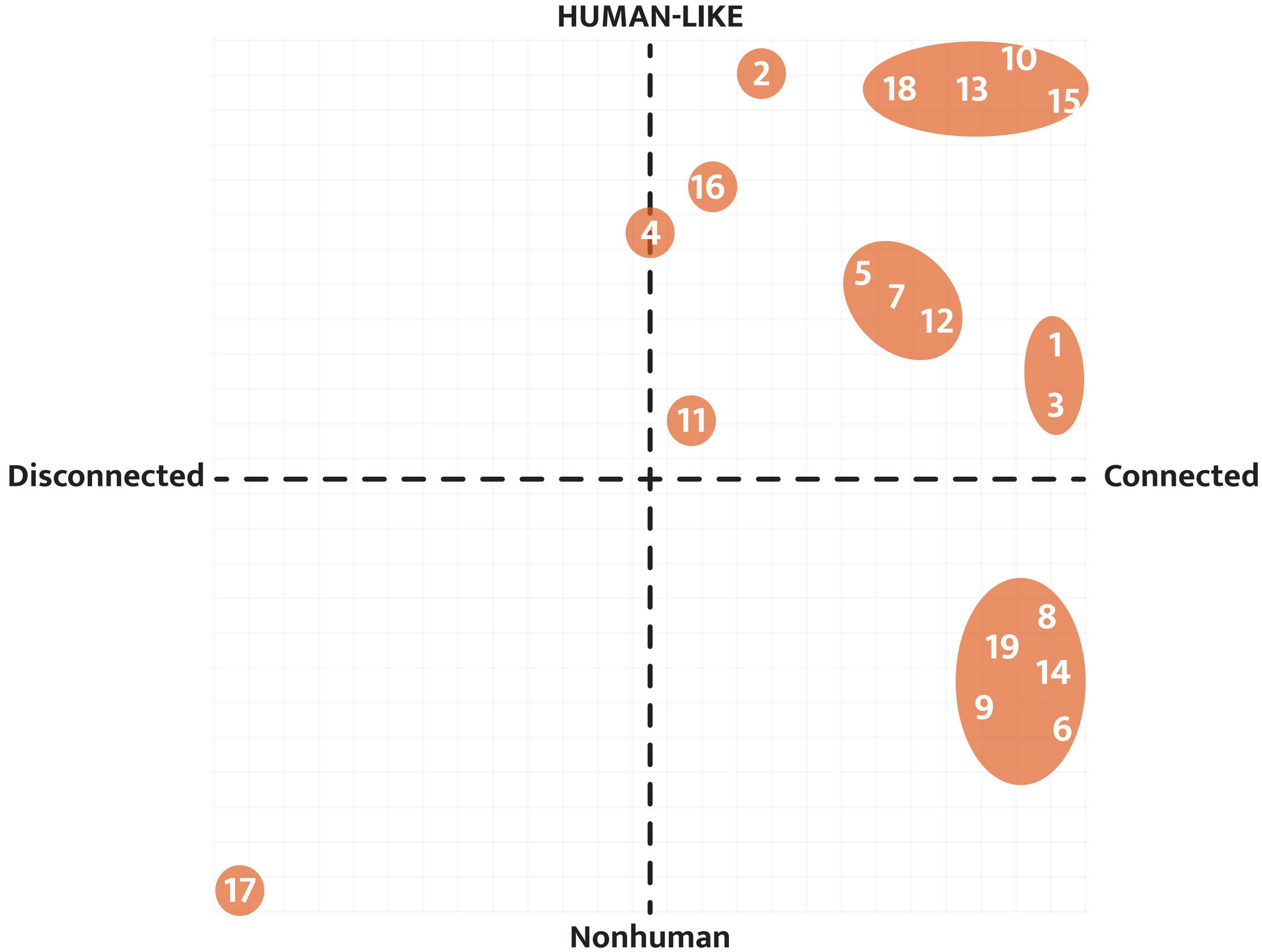


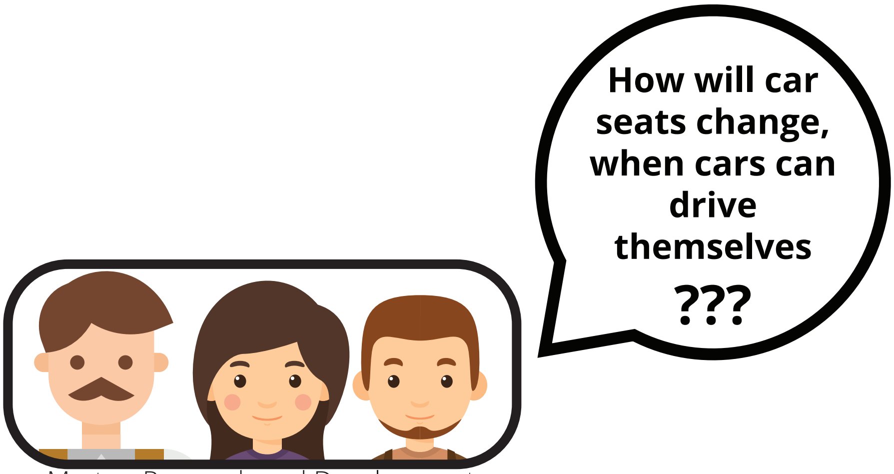
Figure 18: Perceptual map 3

Perceptual map 3:
- Humanlike vs. Nonhuman: An automotive interior of the future may become too robot-like and cause anxiety. This will result in a desire to have a more humanlike interior.

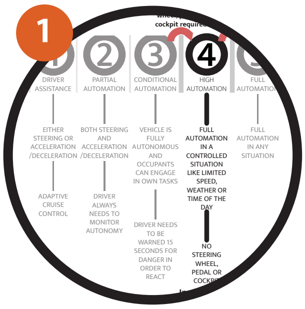
- Connected vs. Disconnected: An automotive interior that is connected is capable of getting information through the cars V2V/V2X possibilities and the cloud.

The last map derives from the expected trend that people will feel social anxiety with all these new technologies, so the assumption was made that providing a human-like experience could add value to the proposed design, while still being connected. The map shows that there are quite some concepts that already successfully do this (12,7,5,2,18,13,10,15). An example is the Renault Symbioz (Renault, 2017) which is designed in such a way that it feels like your second home while still being connected to the infrastructure and your home itself to bring a smart synergic AI system. This could be an aim of the proposed design but would go outside the scope of the project, which mostly aims at the experience inside the cabin.

To conclude this chapter a visualization has been made which shows the choices that have been made after the first two chapters (see figure 19). Like said before, the idea first was to do a SWOT analysis and continue from there on but instead Perceptual maps were made. Perceptual map 1 showed that there is a clear gap which could be designed for, but there is still information missing about the activities that occupants would like to do when being in such a ride-sharing vehicle. Chapter 3 gives an answer to this question.

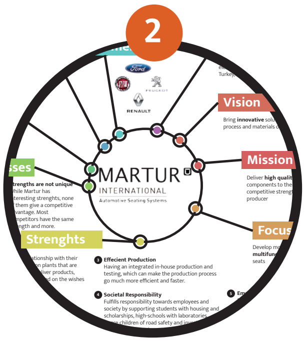


Martur, Research and Development
Recep, Reyhan and Mesut



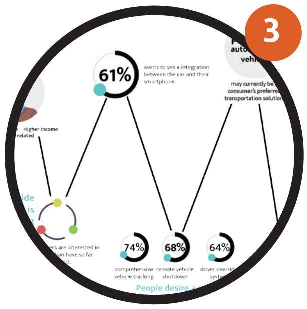
Research into levels of autonomy

Level 4 autonomy seems the right choice. release of this seating concept is aimed for 2022



Company analysis

The proposed interior should provide an innovative high-quality solution that is comfortable, lightweight and multifunctional

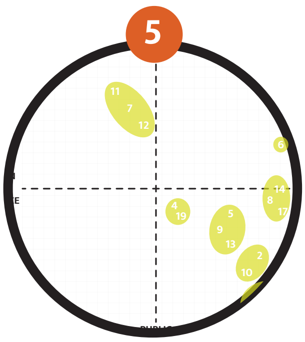


External analysis: facts

The proposed interior should feel safe, personal, practical and provide a seating up to 4 occupants

External analysis: DEPEST trends

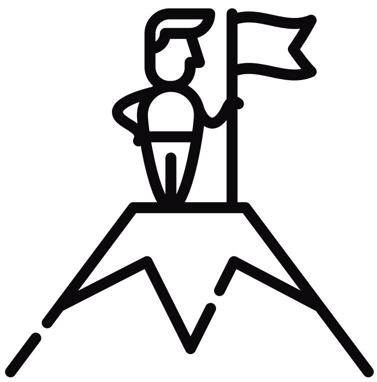
The interior should be designed for a private ride-sharing vehicle that drives on specific routes in a 'smart' Western megacity



Gaps in perceptual maps

The proposed interior should satisfy an individual's wishes, by providing a good cabin experience even during ride-sharing with others. Additionally, it should have versatile options that are useful and practical.

GOAL



To propose an interior for a level 4 shared autonomous car that provides occupants the option to spend their time how they like

Figure 19: Summary of first two chapters

03/ EXPERIMENTAL EXPLORATORY STUDY

The interior of autonomous cars are about to change and this study looks at this change. First, an online survey was done to find out which activities people will perform in a self-driving car and the attributes that they find most important. These findings were used in the experimental exploratory study in which participants were asked to place the moveable seats as they desire within specific scenarios. The resulting seating positions are used as a reference point for the mechanical system.

Figure 20: Seating position, Group 4, scenario 2

03/ EXPERIMENTAL EXPLORATORY STUDY

This project started with the idea to either do an extensive ergonomic research, a context mapping session or to use the VIP-method throughout the whole project. Because Peter is our Professor of Environmental Ergonomics, he suggested to first look into the ergonomic papers/ books that he provided, to see if that information could help with making a decision and steer the project. After reading all the literature, it became clear that a lot of this information filled the gaps in knowledge and helped to move on to the next step: A online survey. When compared to VIP, it felt like the results that this experimental exploratory study would give, would hold more value in this new field of autonomous cars where everything is still abstract.

So back to the literature (see figure 21-24). From all the papers that Peter suggested, 2 out of 10 were immediately used for the online survey and observation study, while 3 more were used while analyzing and designing the interior. Nonetheless, all papers gave inspiration and a visual summary of all these papers can be found in (see appendix 5).

To form the online survey, information found in chapter 1 & 2 were used together with the findings of these papers illustrated below.

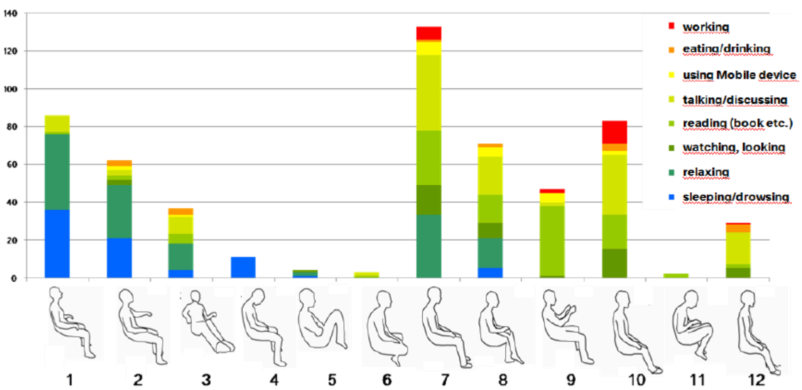


Figure 21: Research of typical activities of train passengers and the resulting postures (Kilincsoy et al, 2014)

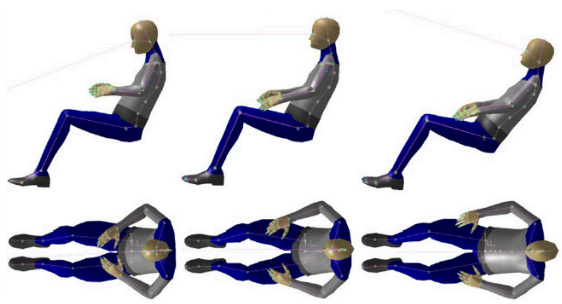


Figure 22: Resulting comfortable rear seat postures preferred by car passengers (Kilincsoy et al, 2014)

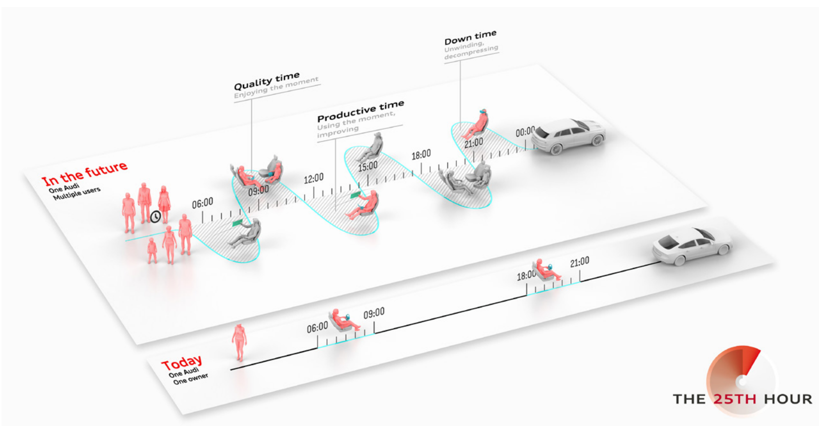


Figure 23: Use of future autonomous cars (Audi and Fraunhofer, 2017)

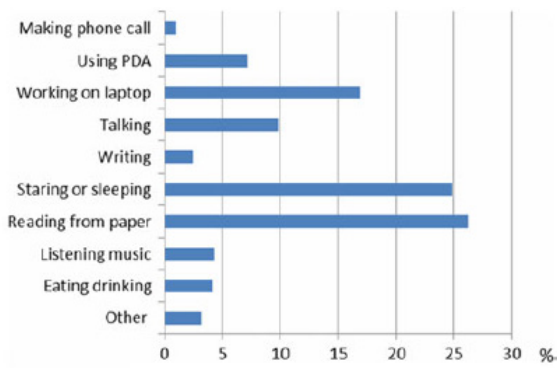


Figure 24: Distribution of activities based on frequencies of 786 short observations in trains (Groenenstijen et al, 2014)

3.1 ONLINE SURVEY: FORMULATING THE QUESTIONS

The online survey (see appendix 7) starts with general questions about age, gender, current occupation, and current household situation. These questions were asked to show the spread of the participants Q1-Q5.

Next, a couple of statement cards Q6 were made in which the goal was to find out:
- If people value personal space as the PwC report suggests
- If there is social anxiety towards commuting in an autonomous car and if it makes people desire to be disconnected from these technologies
- If people would value being social with strangers or family during ride-sharing, as the trends suggest.

BMW observed that during current daily commuting, most people used compact cars (Kilincsoy et al, 2014), but it was unclear if people would want to use compact cars for daily commuting with future ride-sharing vehicles, Q7 asks this question. Besides that, earlier research showed that only 1.4 seats are used and that 80% of the time and that the rear seats are not used in current cars (see chapter 2), So Q9 and Q13 were asked to see if people desired to travel with more occupants in the future.

Q10 and Q11 derived from observation studies done by BMW (Kilincsoy et al, 2014) in which they looked at what people do during commuting in a train (see figure 21 and 24) and the postures they have during these activities (Groenesteijn et al, 2014). combined with the findings of Audi's 25th project (see figure x) in which show what they expect what future occupants will do different activities during different moments of the day within an autonomous ride-sharing car (Audi, 2018).

To score seating concepts in the online survey, attributes were needed. To get these attributes, a small preliminary survey (see appendix 6) was held in which 19 participants were asked the following:

Imagine that you are sitting in a seat of a future car that drives itself. This vehicle does not have a steering wheel or pedal and does not focus on the driving experience anymore but instead, lets the occupant(s) enjoy the time they spend within the cabin as they wish.

Which attributes of the interior of this cabin is important to you as a possible future user, during this scenario?

When participants filled in the attributes that they considered important, the researcher asked to circle the attributes on the other side of the paper. This was done to make sure that no important attribute was forgotten. The following statements were mentioned at least 4 times:

Table 1: Statements

Statement	Amount of times mentioned
The seating layout seems comfortable	18 out of 19 participants
The seating layout looks safe	16 out of 19 participants
The seating layout seems pleasant in use	12 out of 19 participants
The seating layout is multifunctional	10 out of 19 participants
The seating layout seems practical in the functions it proposes	9 out of 19 participants
The seating layout is nicely adaptable to my needs	8 out of 19 participants
The seating layout has smart options that I would use	6 out of 19 participants
The seating layout respects my individual space	4 out of 19 participants

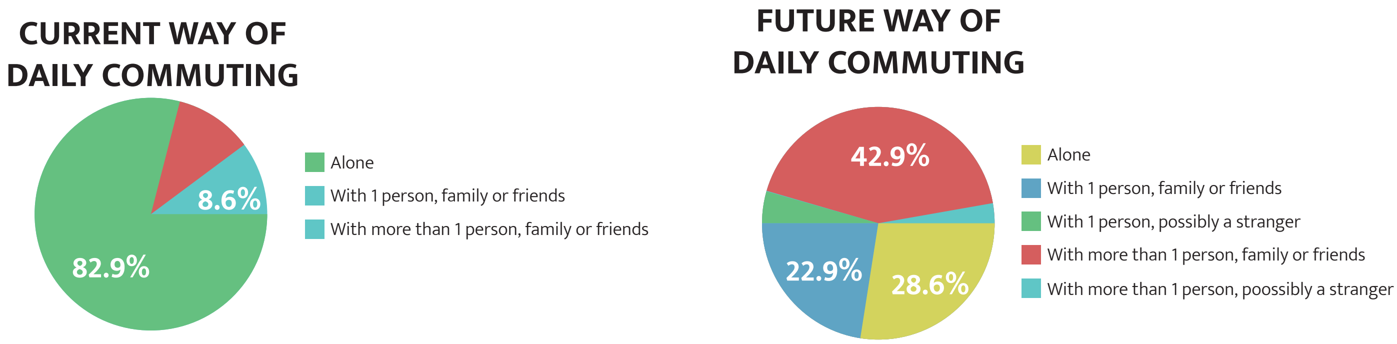
3.2 ONLINE SURVEY: RESULTS

The survey was now ready to be uploaded online and a goal was set to find 20 participants. This amount came from a discussion with the ergonomics staff but after one day and a lot of promoting, 35 participants filled in the survey.

Most of these participants were either students or graduates in the field of technology & design and between 18-34 years old. Twenty-three of the participants were single, living with family or friends and 29 of them was currently commuting alone.

The first result that is quite interesting, is that currently, most people commute alone while in the future, most of these people, would like to travel at least with one family member or friend (see figure 25).

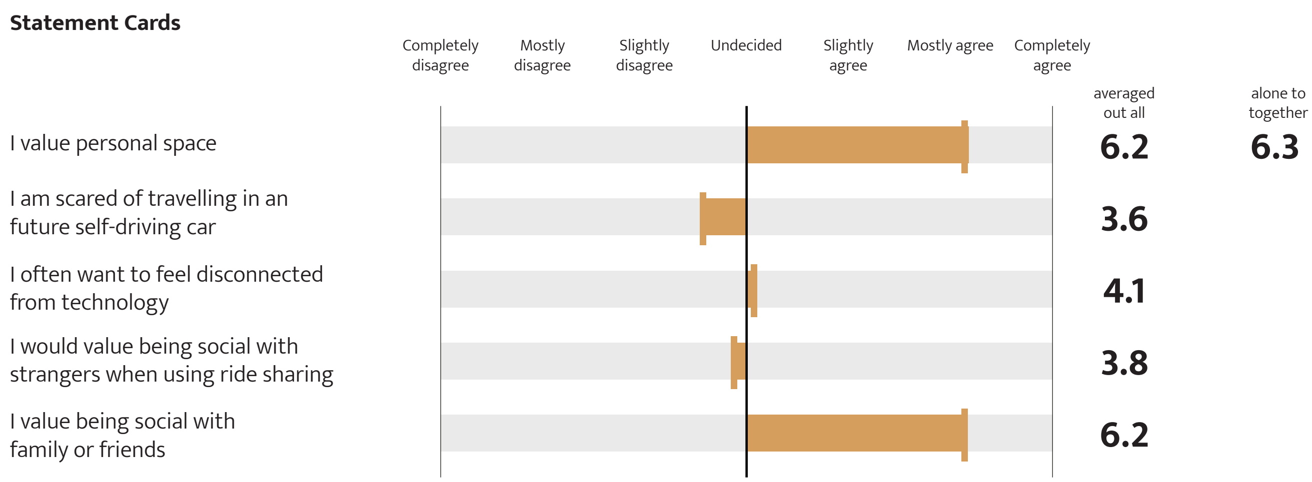
Figure 25: Current and future ways of daily commuting



Furthermore, the same survey shows that people value their personal space and are not really interested in socializing with strangers. Besides that, the survey shows that people are undecided about being disconnected from technology and that there seems no real fear of commuting in a future autonomous car, thus, there might not be social anxiety towards autonomous cars (see figure 26); Compact cars are chosen as the most attractive vehicle to daily commute with, which goes hand-in-hand with an increase in urbanization.

Safety has been stated as the most important attribute during daily commuting within a autonomous car, followed up by comfort and pleasantness in use.

Figure 26: Statement cards



As Audi suggested, occupants would indeed do different activities during different moments of the day while being in a autonomous car. An example is that in the morning occupants would like to either sleep, eat, work or use their smartphone(s)/tablet(s) to entertain themselves, while in the evening, occupants would rather eat, socialize with others or use the in-car entertainment (see figure 27).

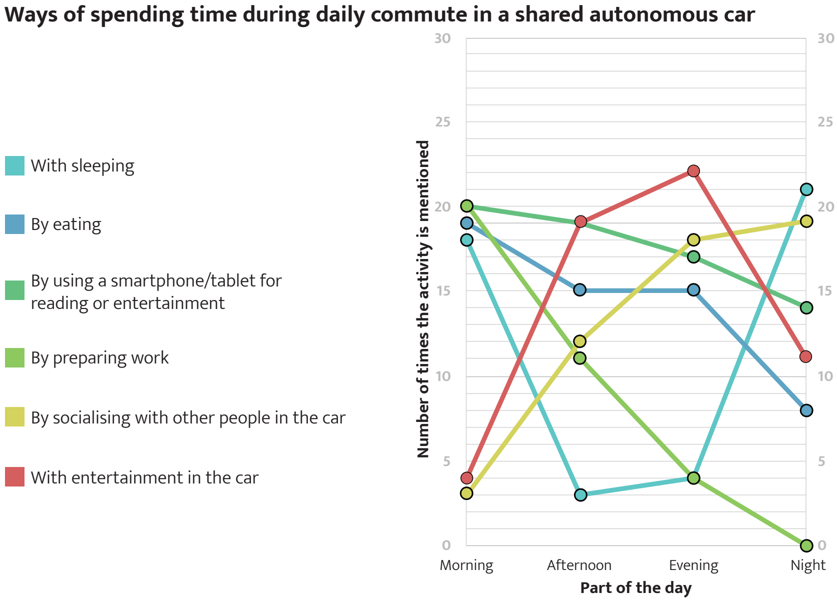


Figure 27: Ways of spending time during daily commute in a shared autonomous car

Furthermore, it seems that the use of a smartphone or tablet decreases slowly during the day but stays popular, the desire to sleep reduces during the afternoon and evening, the desire to eat decreases, the desire for socializing with family or friends increases and that the actual chance of doing any work vanishes.

Beside these activities, some participants also mentioned that they would just stare at the environment during commuting. The seating layouts that were presented at the end of the survey were scored by all participants but none of the proposed layouts was really satisfying. This might be because it is too difficult for participants to score a seating layout just based on pictures instead of actually experiencing it.

The main results of this online survey shows that personal space is important for everyone while at the same time, occupants desire to be with at least one friend or family member while daily commuting and performing the activities found earlier. These results are used as a starting point for the observational study in which the following research question is answered:

- What is the seating position that people take in most frequent seen activities?

3.3 STUDY: INTRODUCTION

While more and more people are interested in ride-sharing, information about comfortable seating positions and distances, during different activities, are still lacking. This study was done with 9 groups (of two participants each) and the only real requirement was that they knew each other as the previous survey showed that people are not interested in sharing the car with strangers and literature shows that distances may vary between intragroup and intergroup relationships (Novelli, D., Drury, J., Reicher, S. 2010).

This study focuses on delivering seating positions within a specific volume, where participants can do the desired activities while respecting the other occupant's personal space.

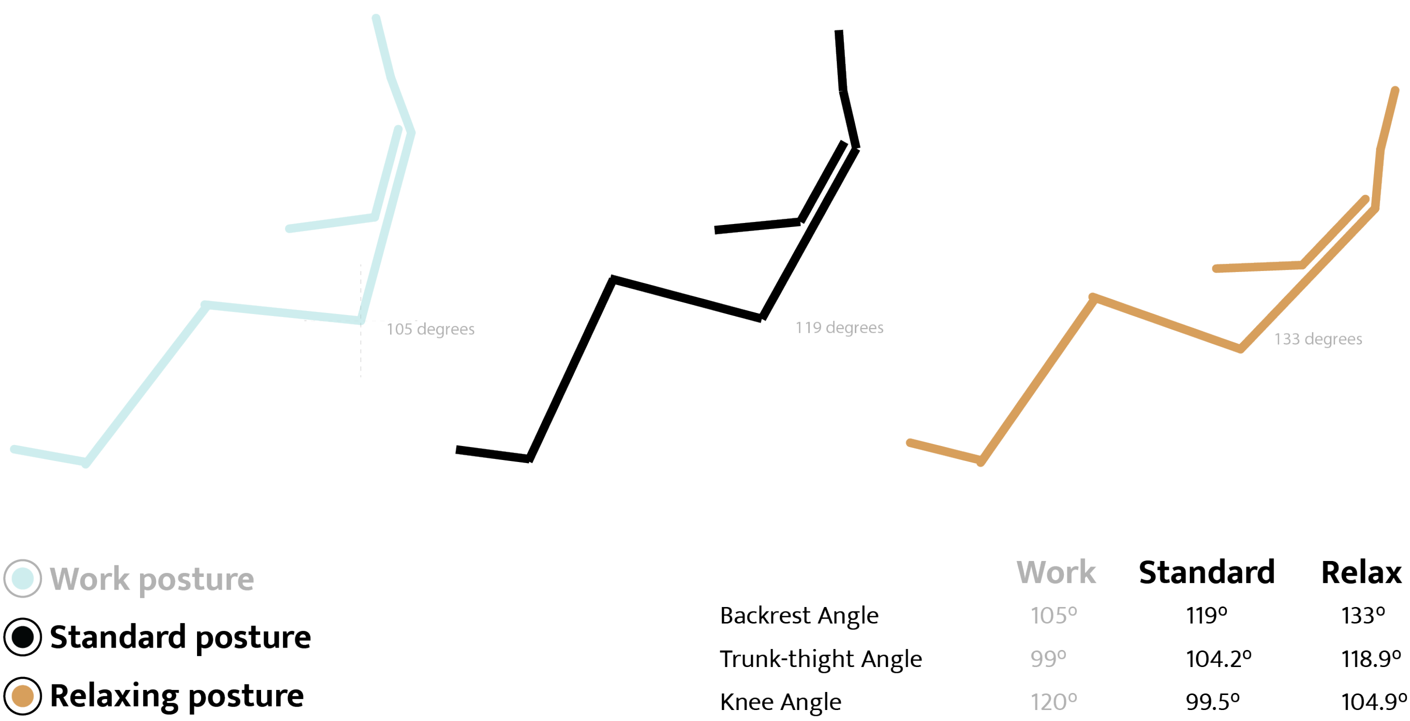
The following choices were made before the start of the study:

- The standard and relaxed postures used by BMW were taken and used during all seating scenarios (see figure 28).

- From the previous survey it became clear that compact cars will mostly be used during daily commuting in the future. The frame used during this study is based on the dimensions of the Smart Forfour, as this is seen as a compact car for up to four people.

- The observation study was done with two participants instead of 4 because each participant needs freedom of movement for the mock-up seats and this would be too chaotic with 4 people.

- the whole study was going to be recorded and was used as quantitative data (visual comparison of seating positions and the SgRP Couple distances) and qualitative data (the instinctive values and desires participants had during the study).



	Work	Standard	Relax
Backrest Angle	105°	119°	133°
Trunk-thight Angle	99°	104.2°	118.9°
Knee Angle	120°	99.5°	104.9°
Seat pan Angle	6°	15°	19°

Figure 28: Standard- and relaxed postures (Kilincsoy et al, 2014)

3.4 STUDY: ASSUMPTIONS

This observational study leans on a couple of trends that likely will happen. First off, to bring innovative seating position to production cars (that drive above a certain speed), new ways of safety belts and airbags should be thought of. Adient already proposed a safety belt that is embedded into the seat itself, which could be used. Finding a proper airbag solution is more difficult because the new seating position requires crash testing.

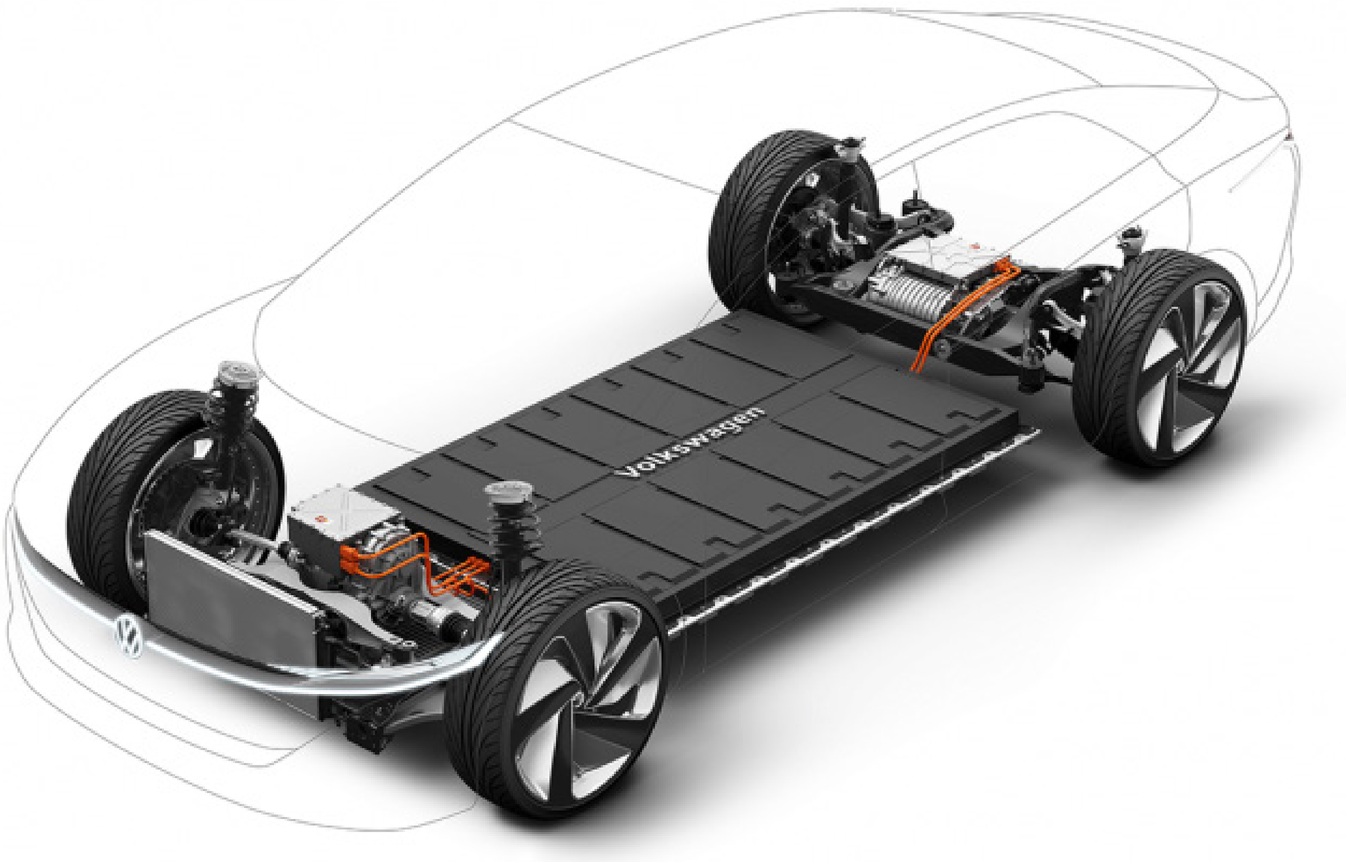
Furthermore, with the introduction of electric vehicles (EVs), cars have become less complex. To make maximal use of the space, it is expected that most cars of the future will have the batteries laid down (see figure 29) on the sill (to lower the point of gravity), that most cars use individual in-wheel electric motors, that the slope of the windshield is more vertical, like in trucks, that there is not a lot of storage requested for cargo during daily commuting besides small stuff like a smartphone, umbrella or handbags and that the front- and rear suspension systems do not take too much space.

Besides that, being used to driving on the left or right side of the way may also have influence and during this study, it is assumed that the vehicle is driving on the right side of the vehicle. As for last, the assumption is made that the postures that have been found by BMW could be used in this scenario, that the angles related to these postures are comfortable to everyone despite different stature heights.

What's neglected?

Comfort, or rather discomfort can be influenced by a lot of factors within the human-product-transportation comfort model presented by De Looze. Before starting with this observation study, a literature review was done (see the previous chapter) to understand what these factors were and how they relate to each other.

Figure 29: VW I.D. Vizzion MEB architecture



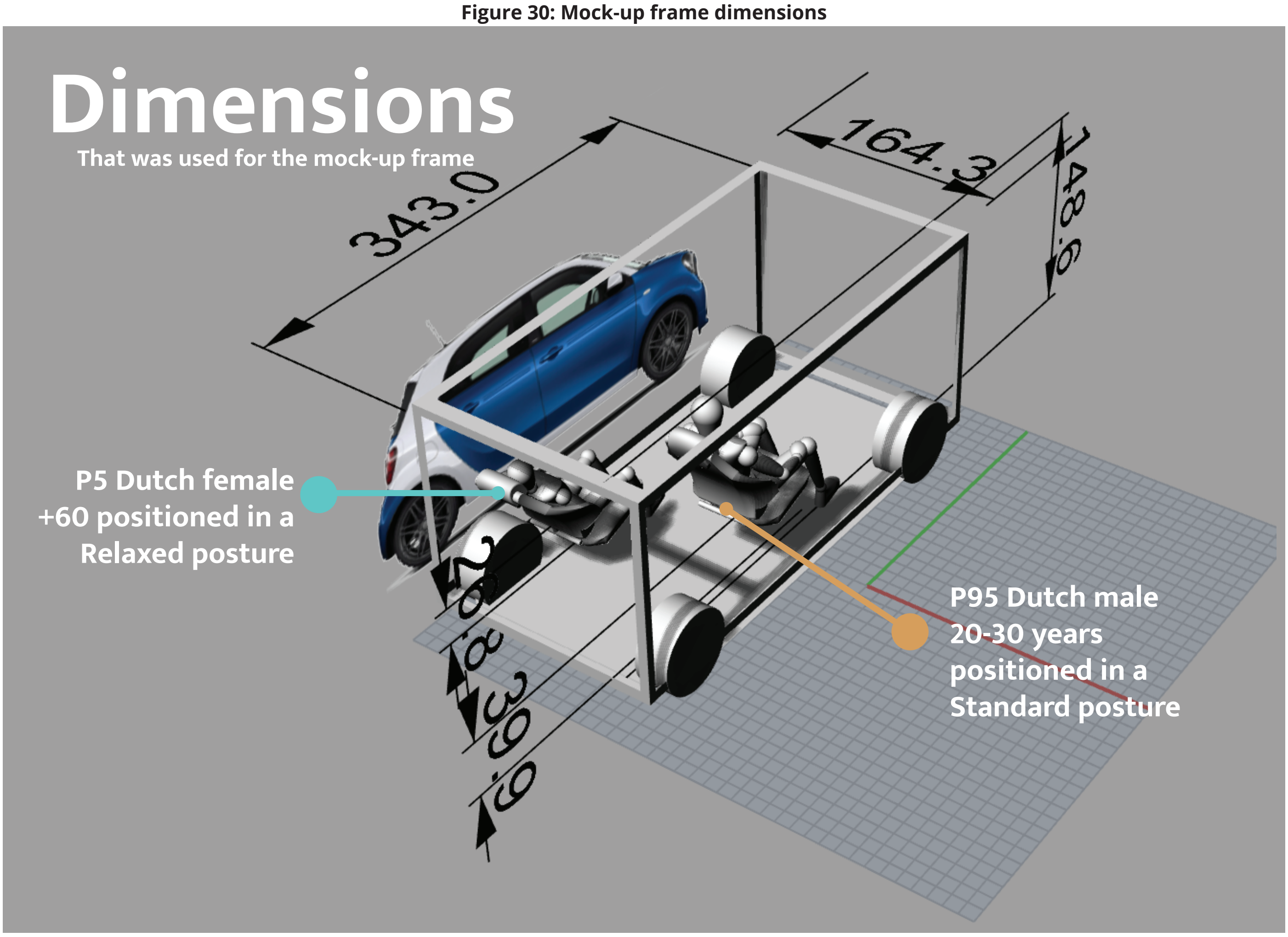
To simplify this observational study, only a couple of things are taken into consideration. Naddeo (2016), for example, found out that the level of comfort reduces when there is a clear temperature difference between the initial state and final state of the environment, the ideal pressure distribution is found when participants could decide for themselves what the ideal height of the h-point should be (Naddeo, 2018) and that there is a range of motion in which people would like to make certain movements (Naddeo, 2015).

To take all of this into consideration would not be possible and make the observation study too difficult, thus the reason to neglect them during the study. Furthermore, while the range of personal space is defined by earlier research, different cultures may have a different view on what they perceive as intimate or personal relationships, thus it is believed that the results would vary between different cultures.

3.5 STUDY: APPARATUS

For this study, a mock-up frame (see figure 30) was made based on the dimensions of a Smart Forfour as it was assumed that this size would be useful for daily commuting within a city. The car was simulated by a frame and tape on the floor. A boundary grid was taped out on the floor, which represents the overall dimensions of the Smart Forfour (3430mm x 1640mm x 1308mm) with an additional height of 178mm added, to accommodate for the height that is required when a P95 Dutch Male 20-30 year (www.dined.nl) takes place in a standard posture (Kilincsoy et al., 2018) within this frame. This space was chosen as up to four people should be able to sit in it and at the same time it should support the ideal interior seating positions for two people during different activities.

Figure 30: Mock-up frame dimensions



To represent the seats in the shared autonomous car two moveable seats (see figure 31) were built, which are based on the standard and relaxed posture angles defined by Kilincsoy et al. (2018). The width and length of the backrest are based on the P95 Dutch Male 20-30 years old (www.dined.nl). The length of the seat pan and the chair height are based on Dirken (1997, page 159 and 92). The moveable seats were able to move and rotate freely within the described frame.

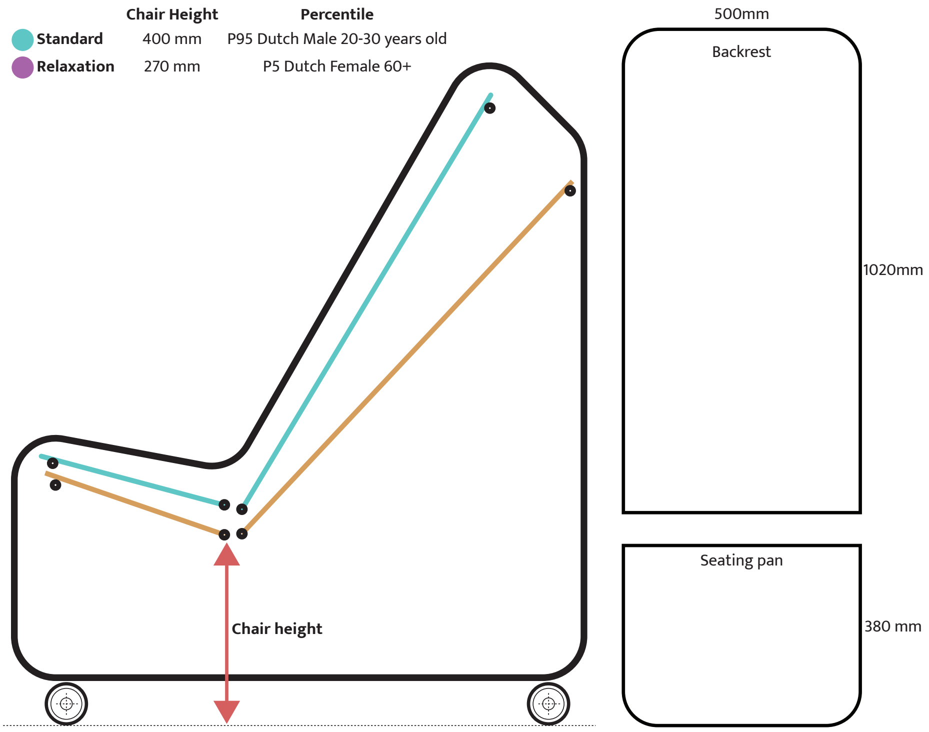


Figure 31: Mock-up of moveable seats

Next, to the frame and the moveable seats, products that supported the different tasks (such as eating, sleeping and socializing) like food, books, headsets, cushions, tablets or laptops were used to simulate the activities.

3.6 STUDY: PROCEDURE

Participants were all asked in groups of two. Upon arrival, the researcher gave them a brief introduction (appendix 9) about the project itself and afterward explained the steps of the study. First, the participants were asked to fill in a consent form (see appendix 10) and after that, they were asked to fill in Section A of Survey A (see appendix 8). This section asks general demographic questions and statements about things like feeling comfortable while being alone with the other participant or if they experience nausea during daily commuting.

After this, the participants were reminded that they were being recorded (a remote-controlled GoPro took top view videos, it was set to 1080p, with 30fps and linear view of reducing fish-eye distortion) and that they were asked to think loudly and really interact with each other to find solutions in which both are satisfied during different scenarios. These conversations were used to analyze the desires behind the chosen seating position during different scenarios by quantifying and comparing it in a table. All needs mentioned by 2 groups or more were compared.

The online survey showed 6 activities that could be used during this observational study. To reduce the complexity (and duration) of this observational study, 4 activities are selected: Sleeping, eating, spending time private (this could be either by reading a book, using your smartphone or staring at the environment, for example) or socializing (see table 1). Working and using in car-entertainment are neglected, because these were less popular overall, according to the results of the online survey (see figure 27).

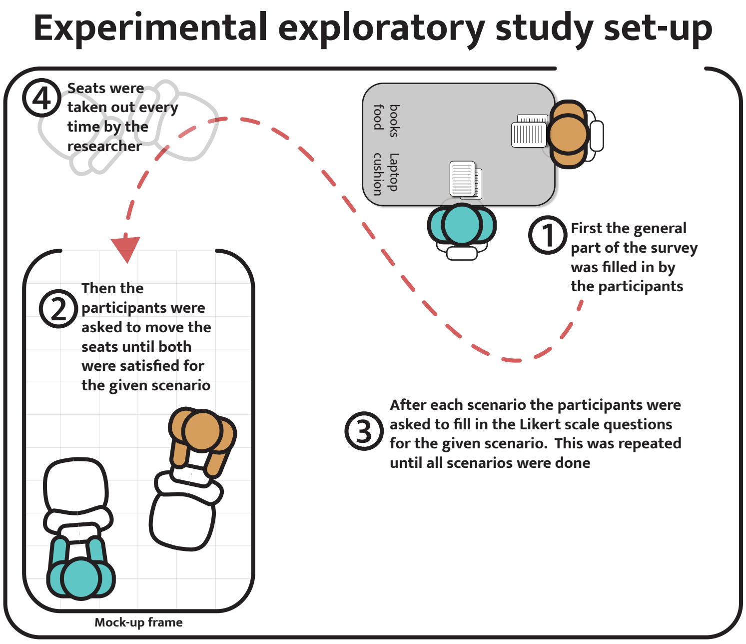
In the first scenario, one participant was asked to sleep while the other was asked to eat something. While placing the seats, the participants were reminded to think about their own personal space, safety and comfort. First, the participant that was supposed to sleep placed the seat inside the boundaries and while placing this seat, the other participant was asked to position the other seat. When both were satisfied (after interaction with each other, in order to come up with a compromising solution for both participants) the participants were asked to sit on the seat and perform the task described within that scenario. After approximately 20 seconds the participants were asked if they felt that the seating layout was satisfying and comfortable for them. If not, the participants were asked to adjust the seats until they were both pleased.

Table 2: Resulting scenarios

Activity & activity	**Participant 1:**	**Participant 2:**
Scenario 1: sleep & eat	Sleep (relaxed posture)	Eat (standard posture)
Scenario 2: private & Sleep	Private (standard posture)	Sleep (relaxed posture)
Scenario 3: sleep & sleep	Sleep (relaxed posture)	Sleep (relaxed posture)
Scenario 4: eat & private	Eat (standard posture)	Private (standard posture)
Scenario 5: socialize & socialize	Socialize (standard posture)	Socialize (standard posture)
Scenario 6: private & private	Private (standard posture)	Private (standard posture)
Scenario 7: eat & eat	Eat (standard posture)	Eat (standard posture)

After each scenario, the participants were asked to fill in the statements regarding that specific scenario in Survey A (how does the seating positions that were created facilitate the attributes personal space, comfort, and safety on a 7-point Likert scale from completely disagree to completely agree) while the researcher had time to place the seats outside the boundary in a randomized way that encouraged the participants to move them. The idea behind this was that the participants had some time to refresh themselves and that they were not influenced by the previous seating positions but instead created a new one every time (see figure 32). Before starting with the study, a pilot was conducted. The main focus of this pilot was to recognize elements of the study that could be done more effectively, in order to reduce time. Besides that, the durability of the mock-up seats was tested and optimized.

Figure 32: Experimental exploratory study set-up



3.7 STUDY: RESULTS

Figure 33 shows that most participants felt comfortable being alone with the other participant (average of 6.5 out of seven) and do not really experience nausea while commuting (average of 2.3 out of seven). The raw data of these statement cards can be found in appendix 11.

The following seating positions were found when groups were visually compared:

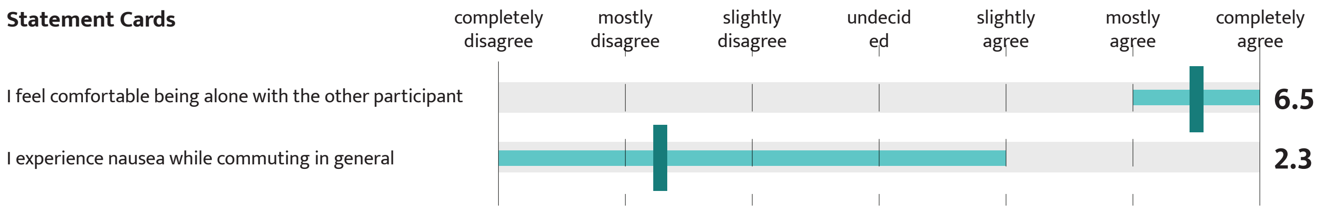


Figure 33 average scores (n=35) on statements regarding feeling comfortable being alone with the other participant and nausea

Figure 34 shows a visual comparison of all seating positions and figure 35 shows the popularity of all seating positions that were chosen by the participating groups.

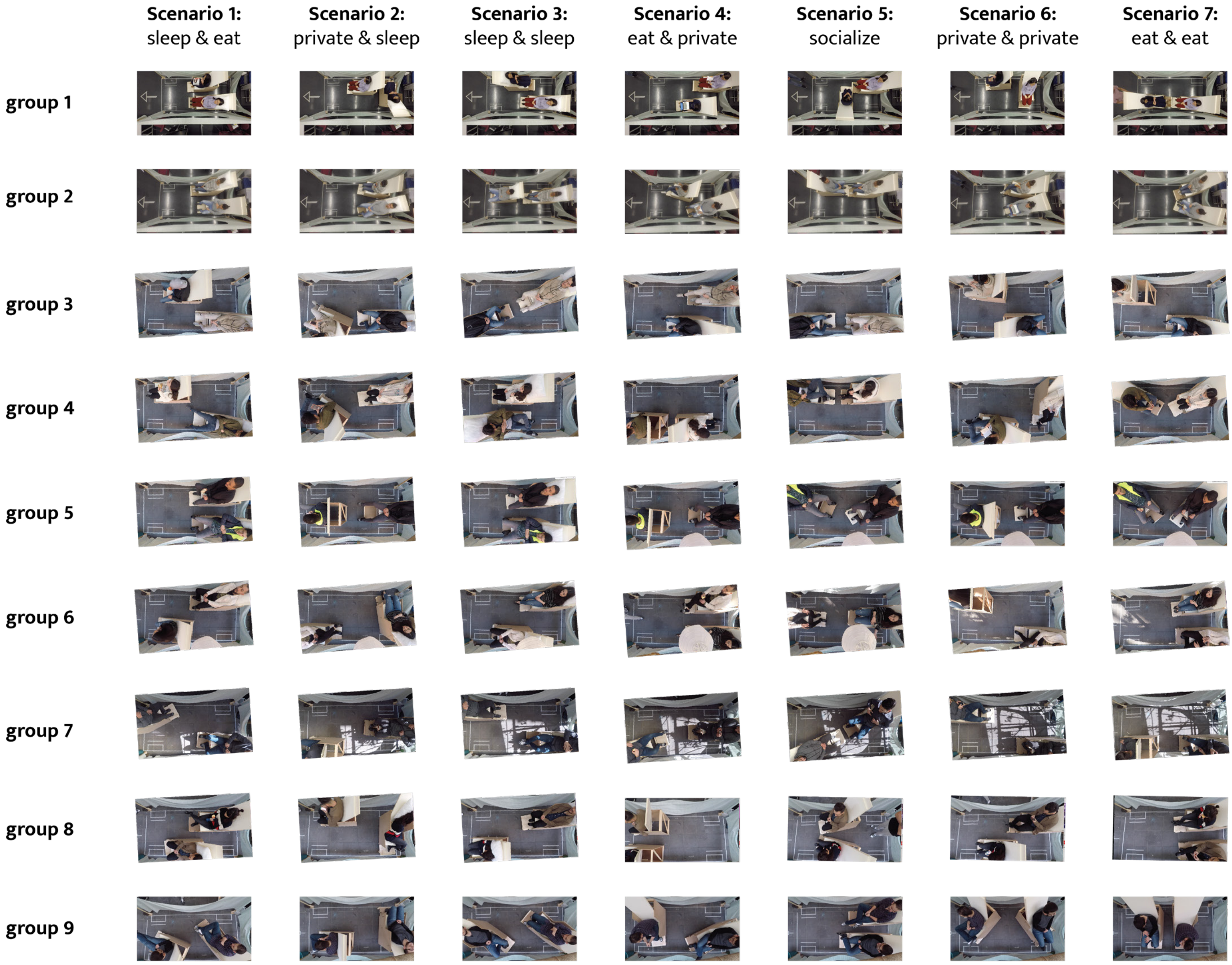


Figure 34: Visual comparison of seating positions

In some scenarios, it was quite clear which seating positions were preferred while other scenarios had large diversity. An example is scenario 1, in which one participant was asked to sleep while the other one was eating. Seven out of nine groups chose the same way of placing the seats while scenario 4,5,6 show a large diversity.

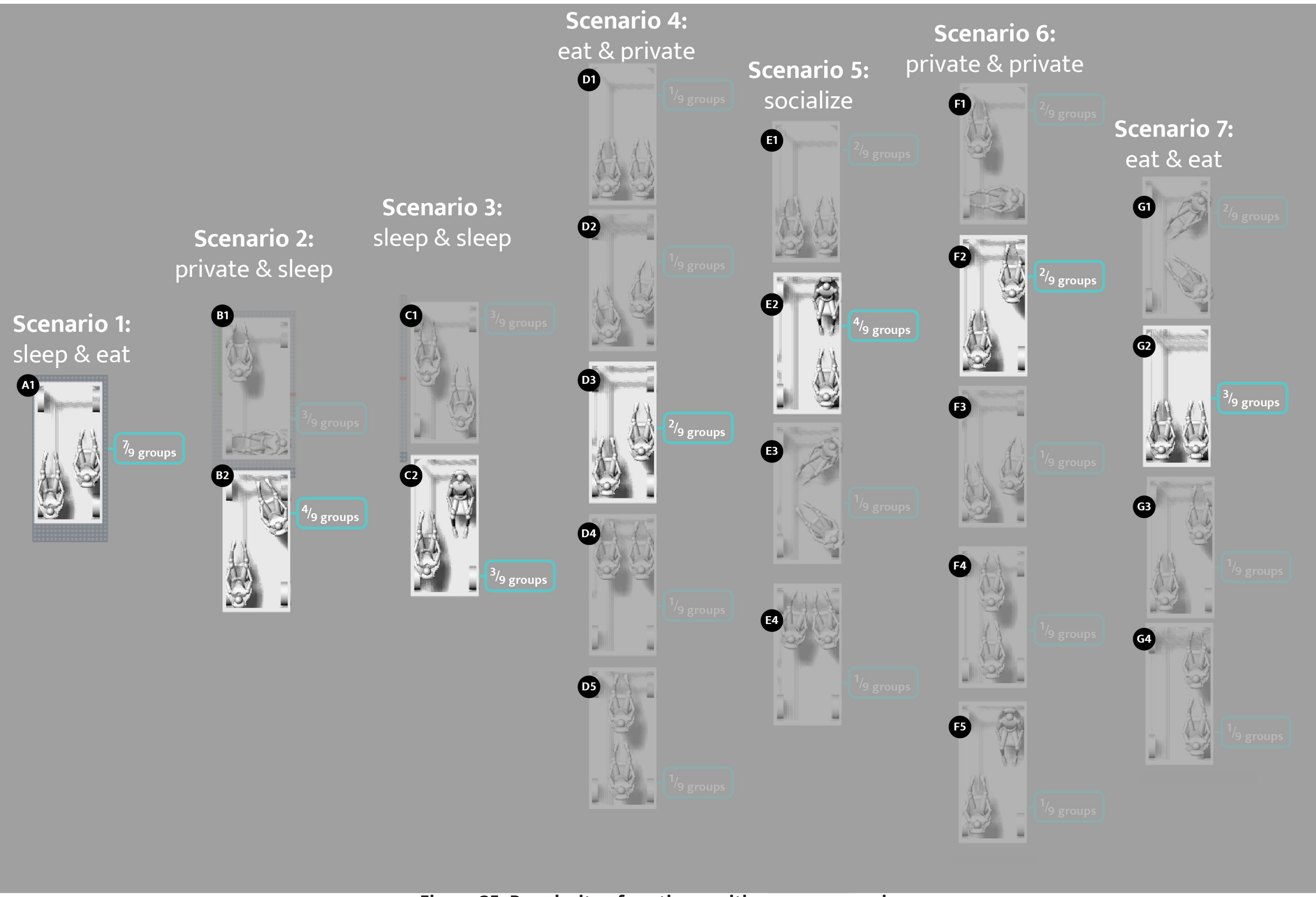


Figure 35: Popularity of seating positions, per scenario

The results of the questionnaire on how the seating layout would facilitate the personal space, comfort, and safety, scored all around six out of seven for the different scenarios (see table x). The raw data of this table can be found in appendix 12.

Table 3: average scores (n=35) on statements regarding personal space, comfort and safety

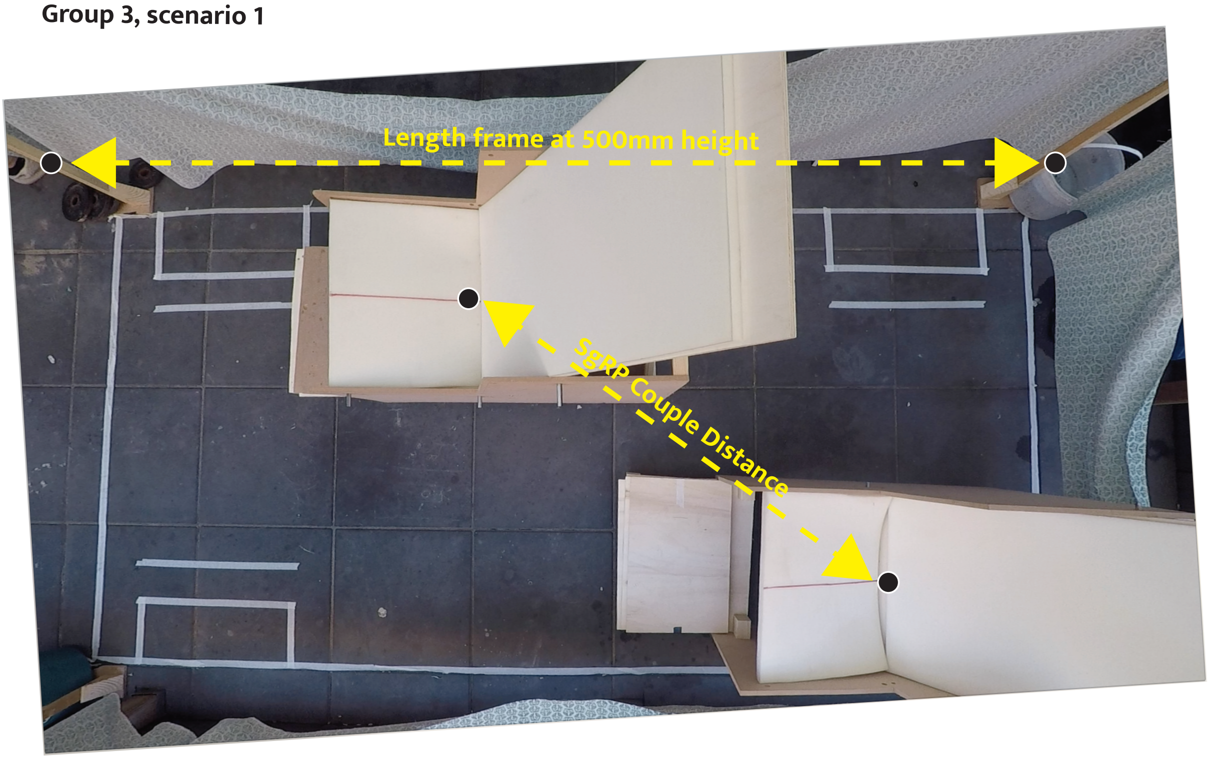
Scenario	respects personal space	feeling comfortable	feeling safe
Average of scenario 1	6.4	6.2	5.9
Average of scenario 2	6.4	6.2	6.0
Average of scenario 3	6.4	6.3	6.2
Average of scenario 4	6.6	6.4	6.1
Average of scenario 5	6.6	6.6	6.1
Average of scenario 6	6.5	6.4	6.1
Average of scenario 7	6.7	6.5	6.2

To strengthen the choice for the resulting seating positions in scenarios that had much diversity, i.e. scenario 3,4,6,7, a table (see table x, appendix 14) was made in which the number of steps between all seating positions was counted (linear movement or rotational movement all count as one step each) and divided by the number of groups that chose this seating position. This was done because in daily usage of this interior, it is assumed that people might switch between scenarios. Thus, minimal number of steps between seating positions are favourable.

The number of steps between the seating positions varied. Table X in appendix 14 shows the resulting score (ZZ) of the number of steps needed between all seating positions (XX) divided by the number of groups that chose this seating position (YY). The following seating positions have the best scores: **A, B2, C2, D3, E2, F2, and G2.** So it was decided to select these seating layouts as favourable within the specific scenario's.

Apart from this, the approximate distance between h-point to h-point, which is called the SgRP couple distance (SAE, 1984), was digitally measured with the use of Adobe Illustrator and multiplied with the ratio of the real dimension (3430mm) of the frame at a height of 500mm (approximate chair height, see figure 31) and the digitally measured dimension (see figure 36).

Group 3, scenario 1



SgRP Couple Distance in Adobe Illustrator = 159mm
Length frame in Adobe Illustrator (at 500mm height) = 341mm
Length frame in real life = 3430mm

SgRP Couple Distance in real life = SgRP Couple Distance in Adobe Illustrator * (Length frame in real life / Length frame in Adobe Illustrator (at 500mm height))
= 159 * (3430 / 341) = 1599mm

Figure 36: Measuring SgRP Couple Distance

The recorded SgRP couple distances were quite diverse among the participating groups in the different scenarios as shown in table 3. The lowest distance was recorded during sleep & eat and highest distance was recorded during sleep & sleep. The raw data of these distances can be found in appendix 13.

Table 4: average SgRP Couple distances (n=35)

Scenario	SgRP couple distance min in mm	SgRP couple distance average in mm	SgRP couple distance max in mm
Sleep & Eat	845	1305	1837
Sleep & Private	1759	2026	2320
Sleep & Sleep	878	1614	2718
Eat & Private	1107	1198	1310
Socialize & socialize	1540	2099	2576
Private & private	1503	2057	2610
Eat & eat	1026	1079	1156

Table 4 shows the desires that resulted out of the conversations that groups had during the study. An example is that in eight out of the nine groups there was a desire to sit apart as far as possible when only one person is eating because people do not want to hear or see the other person eat (see appendix 15 for the list of all important quotes mentioned by the groups).

Table 5: Desires mentioned by participants (n=35)

Desires of the participants	The number of groups that mentioned these desire	The scenario's in which the desire was mentioned
The desire to sit as far as possible from each other because people do not want to hear or see the other person eating (when only 1 person is eating)	Eight out of nine	Scenario 1 Scenario 4
The desire to have as much space as possible, while sleeping or when at least one person is being private	Eight out of nine	Scenario 1 Scenario 2 Scenario 3 Scenario 4 Scenario 6
The desire to enjoy the view outside during all scenarios	Seven out of nine	All scenarios
The desire to be alone and not to be looked at while sleeping	Six out of nine	Scenario 1 Scenario 2 Scenario 3
The desire to have a dinner like situation while both people are eating	Six out of nine	Scenario 7
The desire to face forward while the car drives, to reduce possibilities of nausea	Four out of nine	All scenarios
The desire for swiveling seats while having conversations in order to reduce stresses in the neck and have the possibility to look elsewhere	Three out of nine	Scenario 5 Scenario 7
The desire to feel safe in different seating positions	Three out of nine	All scenario
The desire to sleep in a corner and have the feeling that you are shielded from outside	Two out of nine	Scenario 1 Scenario 2 Scenario 3
The desire to sleep on your side	Two out of nine	Scenario 1 Scenario 2 Scenario 3

The desires of table 4 are visualized in figure 37-42.

Figure 37: The desire to sit as far as possible from each other when only one person is eating

Figure 38: The desire to have as much space as needed while sleeping or when one person is being private

Figure 39: The desire to watch the view outside

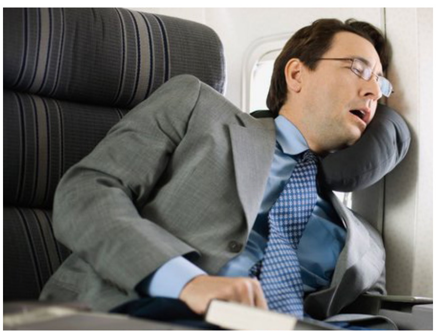


Figure 40: The desire to be alone and not looked at while sleeping

Figure 41: The desire to have a dinner-like situation when both people are eating

Figure 42: The desire for swiveling seats while talking

3.8 STUDY: DISCUSSION

The interior should provide seating positions for the seven scenarios that were selected and researched. Capturing the desires mentioned during the positioning of the seats delivered a lot of background information into the reasoning behind the seating positions.

In eating alone, sleeping or when at least one person is being private, the SgRP Couple Distances should be maximum (within the possibilities of the automotive interior), which makes sense as there is no social interaction needed. The desire to not hear or see the other person eat (when only 1 person is eating) together with the desire to have as much space as possible for yourself while sleeping or being private shows (scenario 1,2,3,4 and 6) that the largest SgRP Couple distance is desired.

When people are eating together (scenario 7) they tend to sit closer to each other to have a dinner like feeling (This scenario has the smallest standard deviation, see table x). However, there is no clear indication to the right SgRP Couple distance during this scenario.

While socializing (scenario 5), people desire to sit face to face with the ability to swivel in case that they want to look somewhere else. This seating position may differ from the ideal seating position found by Fiorillo (Fiorillo et at., 2018), who described that sitting opposite to each other is less preferable than having an angle of 22.5 or 45 degrees between two people, because people do not like to look each other in the eyes. However, this is solved by the swivel option mentioned earlier, making sitting opposite comfortably.

The right SgRP couple distance for socializing should be as close as possible (to improve the quality of the conversation) while taking into account that two P95 Dutch Male 20-30 years old can sit face to face and have enough leg room while sitting in the standard posture (Kilincsoy et al. (2014). According to the CAD model gained by www.dined.nl, this results in a SgRP distance that is around 1700mm, which is between the minimum and average distance that was found during this study.

Figure 43 shows an overview of the seating positions that two occupants take in all scenarios. Five different positions cover all scenarios of this study.

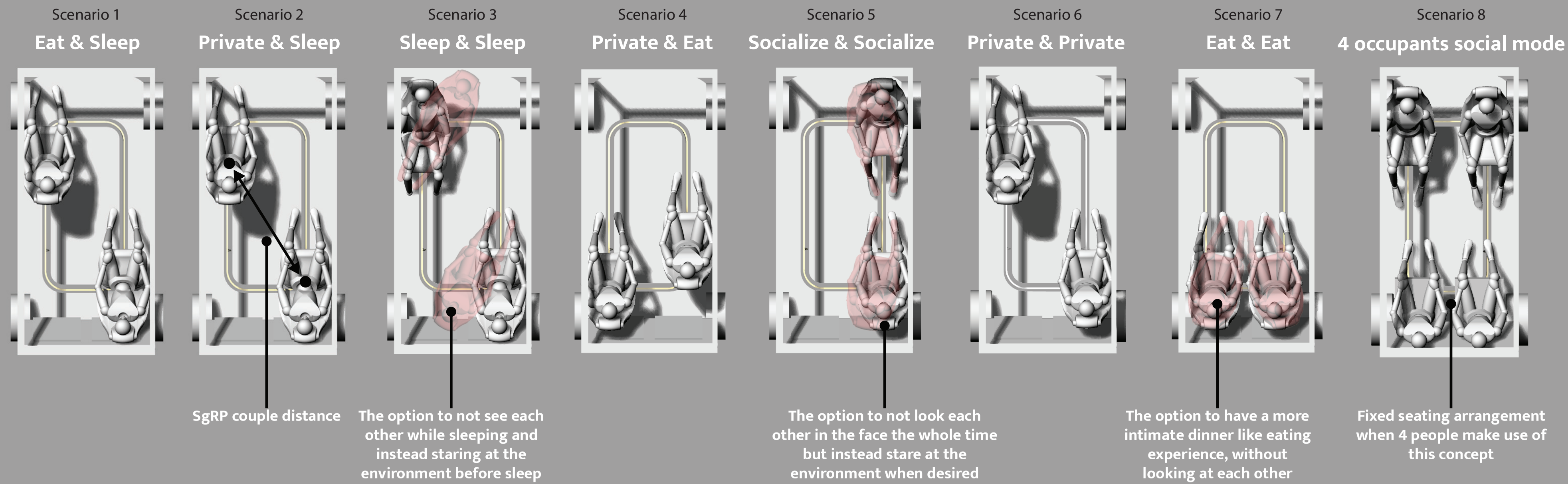
This study indicates that future shared autonomous cars perhaps should facilitate these positions. Concepts provided by companies like Adient or Audi also show the value of dynamic seating positions. Audi and Fraunhofer (2017) already proposed an interior that adapts to different needs during different moments of the day and Adient (2018) has the Adient AI18 which uses a rail- and swivel system to make five different seating positions possible. This all indicates that in future shared autonomous cars, more seating positions are preferable, but it is also possible to limit the possibilities to these five positions perhaps simplifying the engineering process.

3.9 STUDY: CONCLUSION

After asking 9 groups of 2 persons to position the car seats in a position they prefer for various activities, it became clear that seats that move in a certain path are needed to allow these activities: eating, sleeping, socializing and wanting private space. Five different seating positions were found that cover all scenarios. In scenarios where only one person is eating, or when at least one person is sleeping or being private, the maximum distance between the seats is preferred. During socializing or while eating together, a closer distance is desired (see figure 43).

Figure 43: Resulting seating positions & SgRP Couple Dimensions

Seating Positions & SgRP Couple Dimensions



	SgRP Couple Distance	Within Mock-up frame
Scenario 1	Maximum	1837mm
Scenario 2	Maximum	2320mm
Scenario 3	Maximum	2718mm
Scenario 4	Maximum	1310mm
Scenario 5	At least 1700mm[1]	At least 1700mm[1]
Scenario 6	Maximum	2610mm
Scenario 7	n/a	n/a

1) Two P95 Dutch Male 20-30 years old with leg room

04 / CONCEPTUALIZING THE MECHANISM

The study in the previous chapter shows that 5 seating layouts are required to fulfill the occupant's future activities. This chapter explores the conceptualization of the mechanism which makes all seating layouts possible from ideas to a professional solution.

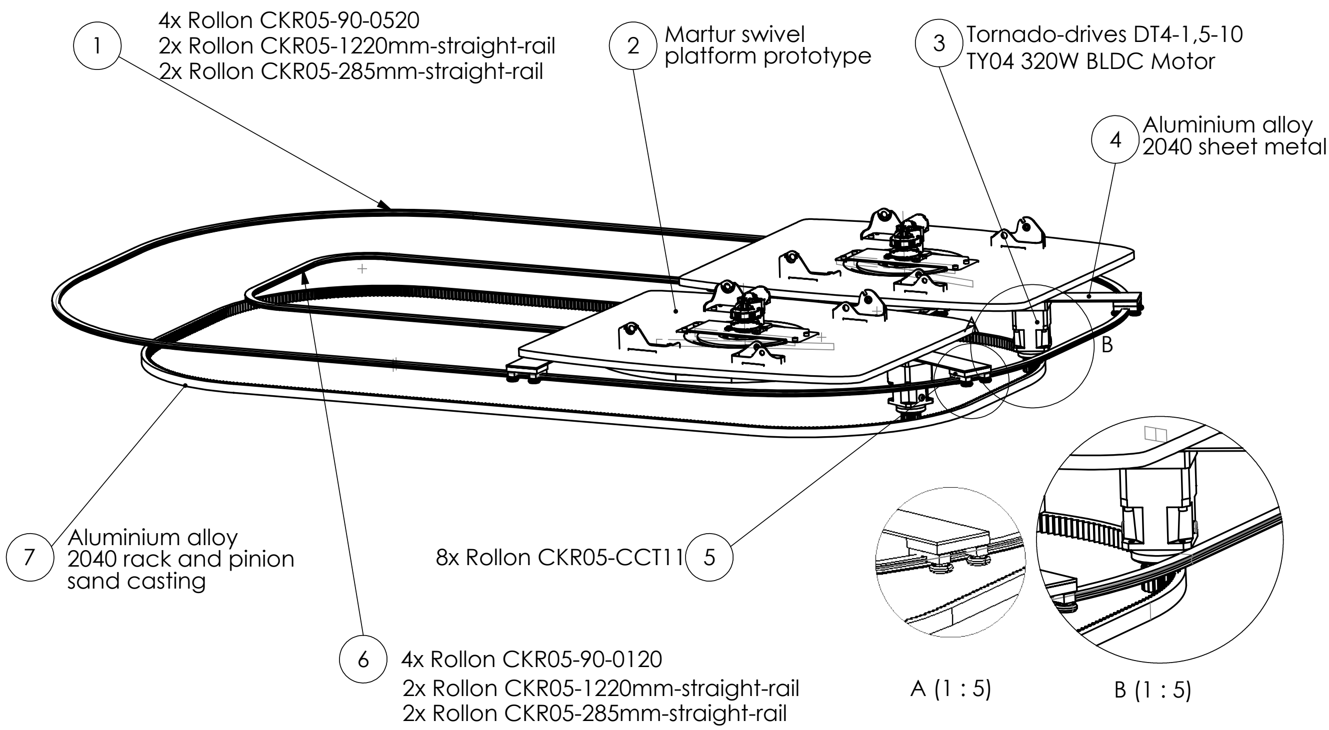


Figure 44: Technical drawing of the professional Rollon rail system

04 / CONCEPTUALIZING THE MECHANISM

4.1 INTRODUCTION

The results of the previous chapter shows that multiple seating positions should be realized to satisfy the various activities that will be performed in such a shared autonomous car. To come up with solutions a brainstorm session was held in which the following question was answered: “How can you move the seats to the desired positions?”

To validate all idea’s a Harris profile was made (see figure 45). This profile is based on the first version of the programs of requirements and wishes found in appendix 17. This list has been updated while the mechanism was being developed (see appendix 18). The most important requirements and wishes for the Harris profile were:

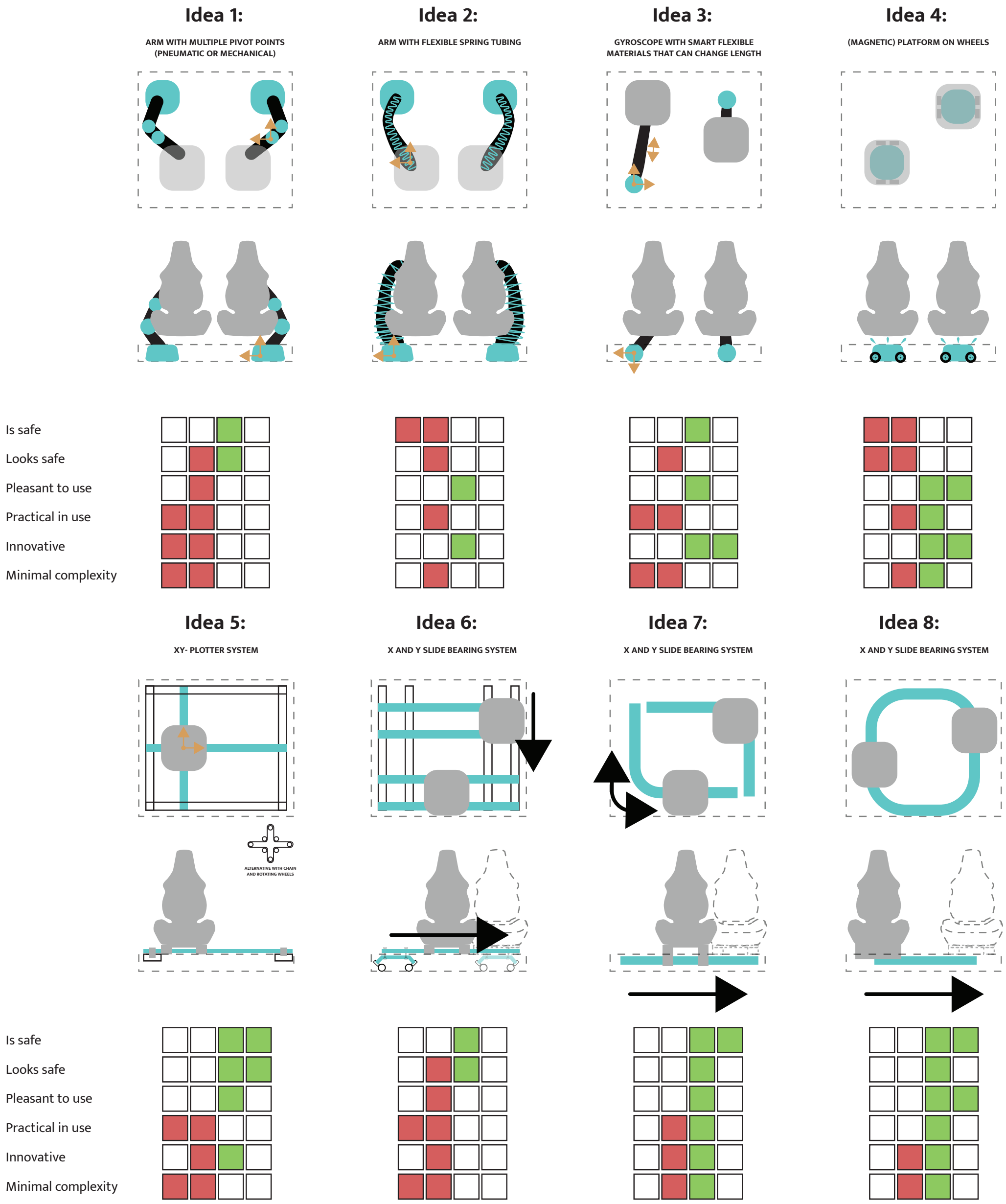


Figure 45: Harris Profile

04 / CONCEPTUALIZING THE MECHANISM

Requirements
- The seating mechanism should provide lateral- and rotational movements, which make all seating modes possible for the dynamic seats.
- The seating mechanism should have a lock feature that disables the seats from moving lateral or rotational when it is not required (for example when an occupant moves on the seat).
- The seating mechanism should not reduce the freedom of movement of occupants (the legs should be able to move freely within the space without colliding into some mechanical element)
- The seating mechanism should move the seats in a smart way without colliding occupants into each other.

Wishes:
- The seating mechanism should be as simple as possible (resulted from the experimental exploratory study)
- The seating mechanism should look safe (resulted from the experimental exploratory study))
- The seating mechanism should feel pleasant to use (resulted from the external analysis: facts & trends)
- The seating mechanism should feel practical in use (resulted from the external analysis: facts & trends)
- The seating mechanism should be innovative (resulted from company analysis)

4.2 IDEAS

Idea 1: An arm with multiple pivot points can be seen in many products that need to move around like tv displays and ergonomic monitors but would take too much space and be unnecessarily complex within the cabin.

Figure 46: Monitor Arm

Idea 2: Building on this, there was the idea to use flexible spring turning which could be seen on some desk lamps, but this tubing material is probably not stiff enough to move a seat with a person on it around.

Figure 47: Monitor Arm

Idea 3: The next idea derived from the self-balancing mono-wheels that have become popular these days. The idea was that the mechanism could tilt in the desired xyz-angle and that by using shape memory materials, which can change shape when heat or electricity is applied, the desired positions could be achieved. This idea is quite futuristic but currently not practical at all because most of these materials only have only one ‘memory’ shape to which they can turn to (Huang, 2010).

Idea 4: The next idea was equally innovative. Using magnetic fields with a trolley which can then move around. The problem with this idea (besides messing up all the other electronics within this electric car) is that there is not any safety mechanism built into it in case of a crash (which is unlikely but should still be considered).

Figure 48: Self-balancing tech

Idea 5 & 6: So, when safety and space become a priority, only a couple of solutions are realistic. The first one is the XYZ- plotter system which can be found on many CNC or 3D-printing machines. These plotters make use of multiple plain bearings with a servo motor to make the displacement either in X, Y, or Z possible. The problem with this idea is that it functions properly when only one seat is considered but that with two seats, the plain bearings holding the seats would probably crash into each other when changing the seating position between seats.


Figure 48: Magnetic fields

Idea 7 & 8: So, this brings us to the only actual possibility: a rail system. The benefit of a rail system is that it can save space and be safe when compared with all other ideas (even if the rail system itself is still quite complex). So multiple layouts of rail systems were thought of but the only shape that made all seating positions (see image 45) possible was a curved rectangular one.

4.3 CREATING THE CONCEPT

To develop this rectangular curve rail system further, a lot of analysis was done into different rail systems. Examples are a camera track that is used to move the camera linear or a camera dolly track that uses a wheel system similar to roller coaster cars. This resulted in a first rail concept that uses a rail with an inside chain and an electromotor which is connected to the platform. This platform is connected to a couple of wheels that run over the rail while the chain is tight around it (See figure 49).

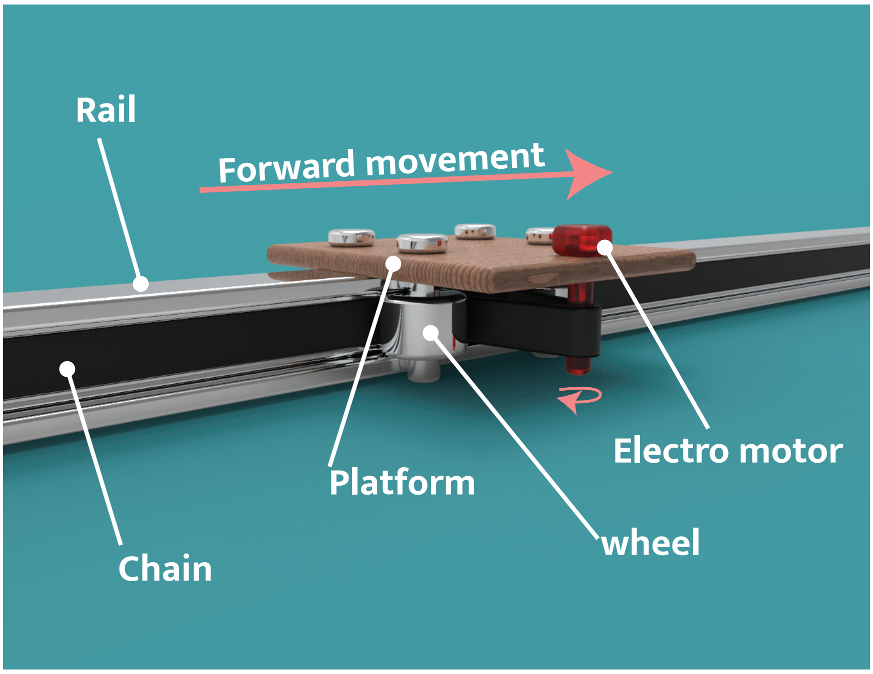


Figure 49: First version rail mechanism


Figure 50: Camera slider


Figure 51: Camera dolly track

04 / CONCEPTUALIZING THE MECHANISM

This first concept version (see figure 52) was presented to Martur and it became clear that a lot of work needed to be done to make this worth prototyping. While my own focus was to invest more time into the actual design of the interior, Martur was more interested in this prototype. So, in order to make this more professional, an engineer from Martur gave some feedback through Skype during this phase (see figure 53). It became clear that the concept (as it was presented) would not be able to endure the forces of a car crash or even the forces applied on the seat when the user is moving in his seat, creating inertia. The solution suggested was to use a second rail which fixes the platform on 4 points instead of two and to make the platform as long and wide as possible. This platform is connected to a ball bearing swivel system to make the seat rotate on its own origin.

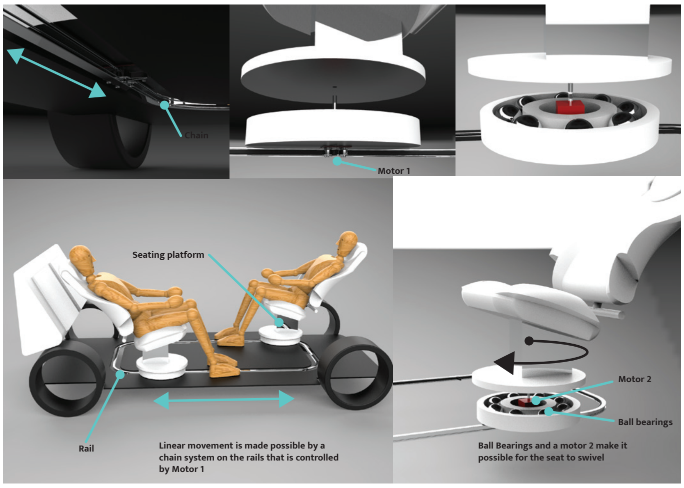


Figure 52: First proposal

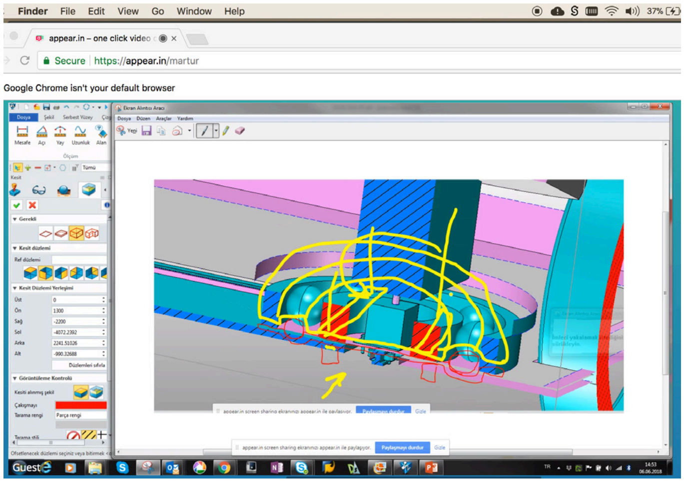


Figure 53: skype communication with Martur

Turning the corners

Using two rails brought the difficulty that the seats may not go around the corner as expected. Like with rollercoasters, this motion depends on the following variables:

Pitch: a rotation around the X-axis
Yaw: a rotation around the Y-axis
Roll: a rotation around the Z-axis

To turn the corner multiple solutions were thought of (see figure 54) like a caliper hinge, a spring connection, a axial hinge with vertical slot and multiple roller coaster hinges. All these different hinges were simulated in Solidworks path assemblies to see which motion was the simplest and took the minimal amount of space while being stable. After some testing, it became clear that solution 4 was the best option.

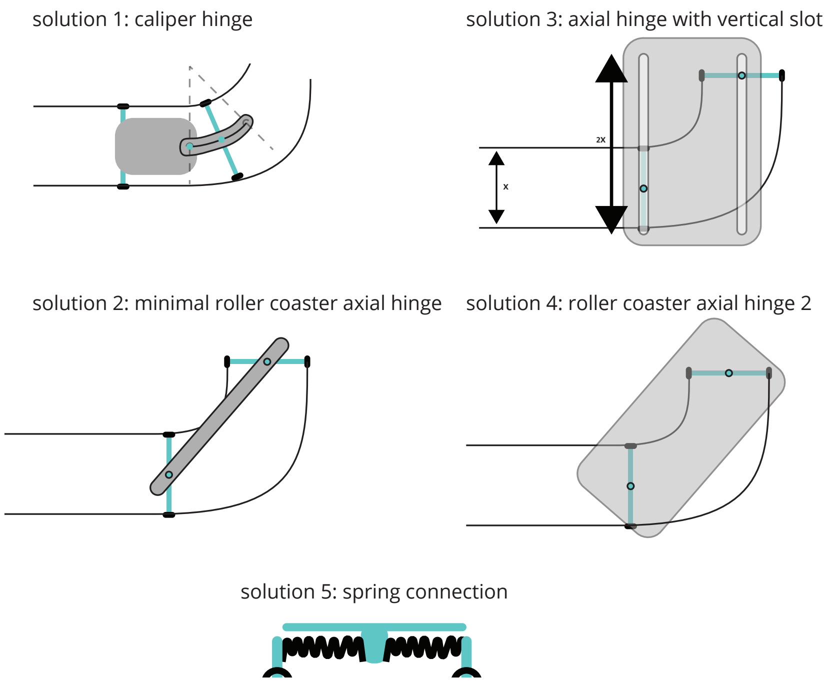


Figure 54: Solutions for turning the corner

Wheels & rail profiles

Figure 55 shows several options found in similar products. The main criteria were to find a wheel and rail configuration that was as safe as possible. The only solutions that actually 'lock' the wheels in case of an accident are the roller coaster wheels system and the rollon curviline system. The benefit of a tube rail profile is that it is better able to cope with loads from different directions like torsion and twisting moments while an I-beam is better at resisting bending and shear stresses. In this case, bending and shear stresses are more important because the probability of torsion and twisting moments on the rail is quite small.

In the end two versions were presented to Martur:

Version 1: Based on solution 3, we could build it ourselves instead of relying on professional parts of different companies

Version 2: Based on solution 4, with a waiting time of 14 weeks for the professional parts to arrive. Assembled at Martur.

Both versions were proposed to Martur and Martur decided at first to go for version 2 and asked me to find out how long it would take to order the different parts. After a couple emails with Rollon, ATBautomation and Sander Gears it became clear that the order time was 14 weeks. When this was communicated to Martur again they asked me to continue with version 1 instead.

So, for some moments the focus was on further developing Version 1. So the next step was to select the right material for the wheels.

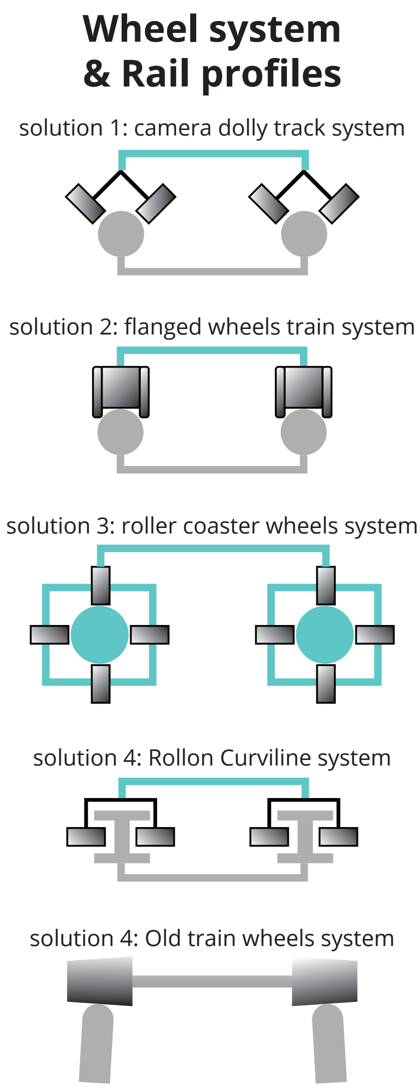


Figure 55: Solutions for wheels and rail profile

Types of wheels (nylon vs. polyurethane):

When plastic is compared with steel tires, plastic absorbs more energy resulting in a slower movement, but it has the benefit of reducing noise. Between plastics, there is either nylon or polyurethane. Nylon wheels are from hard plastic while the polyurethane is a softer material. Nylon wheels vibrate a little more and put more wear on the rails, making the movement a little bit rougher but at the same time slightly faster. Polyurethane is a softer material with a high rolling resistance (when compared to nylon) resulting in less vibration but more friction, providing a smoother but slower movement (Weisenberger, 2013). In our concept it is more important to provide a smooth experience instead of a fast movement, thus polyurethane wheels were selected for the concept version which we could build ourselves.

figure 56: Polyurethane flanged wheels of a roller coaster

Brake systems

There are different brake systems possible. An example is friction breaks that consist of two opposite shoe clamps that brake the wheels on a rail on demand. The clamping force is given by two springs located inside two pneumatic jacks. Another possibility is the use of magnetic braking systems. This technique is based on mounted permanent magnets on the track that oppose the motion of the dynamic seats that travel past the permanent magnets creating a magnetic repulsion. The main benefit of using magnets is that there is no physical contact between the platform and brakes, which is easier to maintain and quieter (Weisenberger, 2013), but these magnets would not be sufficient as brakes in case of a car crash in which there are forces from all directions (in rollercoasters and Maglev trains this is not the case, which makes magnets a suitable solution).

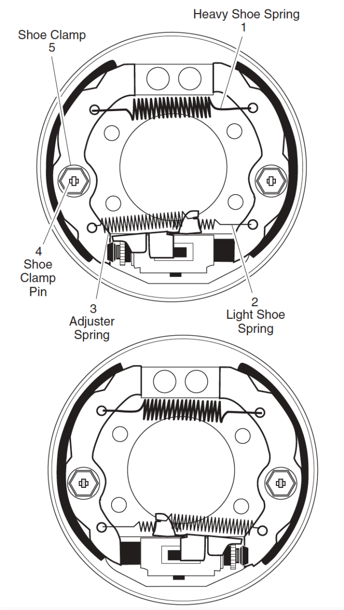


figure 57: Shoe clamp brake

figure 58: Maglev train

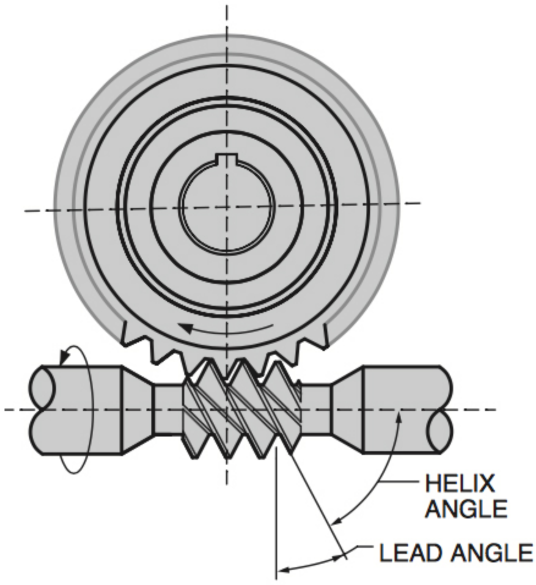


figure 59: Worm wheel

Another possibility is to use the self-locking worm wheel which is often implemented into the motor as a braking system. When the coefficient of friction between the gear and the worm is larger than the tangent of the worm's lead angle, the worm gear is considered self-locking and will not back drive. This static coefficient depends on the material, lubrication, condition of the surfaces and the presence of external vibrations (Motioncontroltips, 2017). For both versions, it was assumed that this self-locking worm wheel within the motor was sufficient and otherwise a shoe clamp brake could be added within the wheels. Nevertheless, the brake system is neglected from the final proposal as it would take too much time to figure it out in detail. Figure 60 shows the mechanism concept up until this phase of the proces.

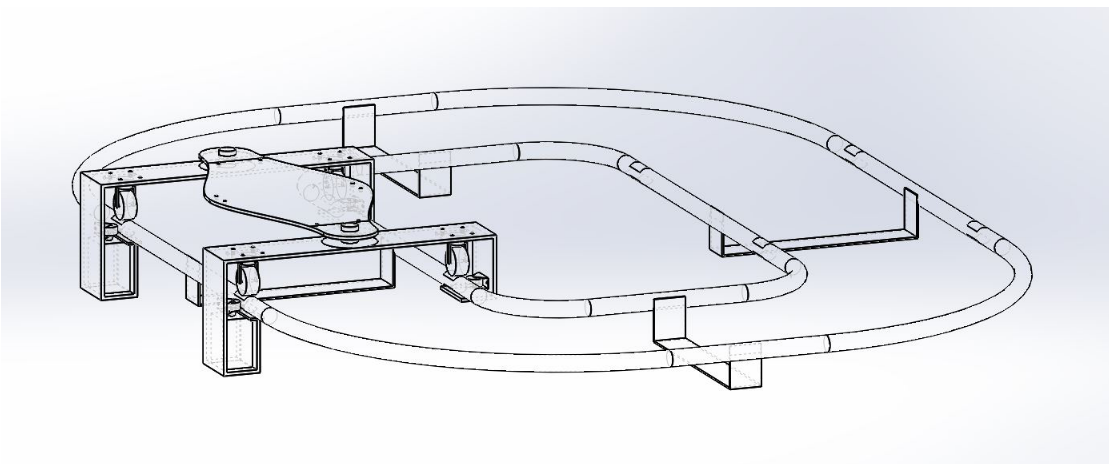


Figure 60: second iteration of Version 1

Propulsion

Like with all other elements of this mechanism, the aim is to be as simple, minimalistic and save space where possible, Because of this requirement, the idea was first to connect the propulsion of the motor directly onto the outer wheels (as seen in figure 60). When this idea was proposed to Sander Minnoye, he argued that this would cause the wheel to slip, thus make the mechanism unstable.

So,

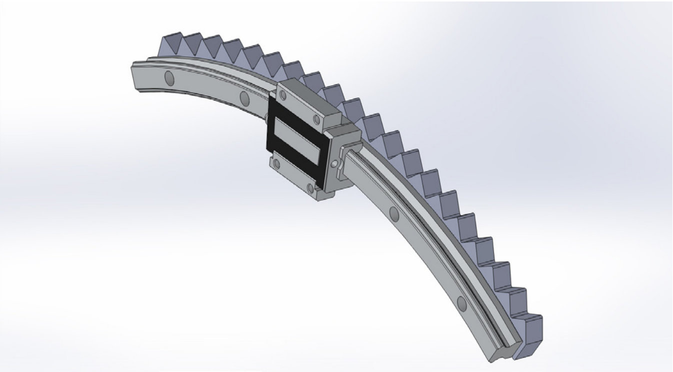


Figure 61: Rack & Pinion systems for automatic opening of windows

Figure 62: Rack & Pinion on Rolon Curviline (found online)

after some research, I stumbled upon curved rack and pinion systems (see figure 61). An idea came to mind where the rack and pinion were combined with the rails like seen in figure 62 but I could not find any company that could make this. Beside this, Sander suggested to keep the propulsion part separate from the rail and make the mechanism more fail-proof. So instead, a third rail was designed which functioned as a rack and pinion system were the motor was connected to (see figure 63).

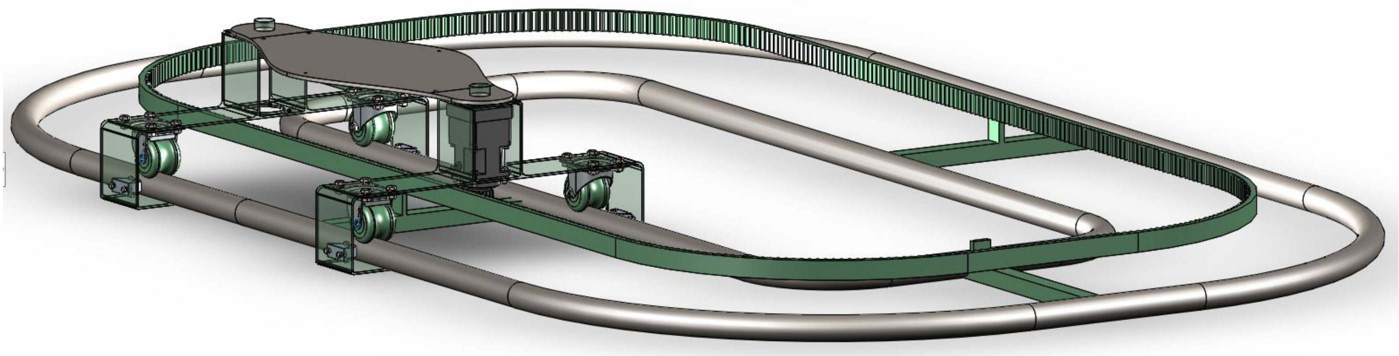


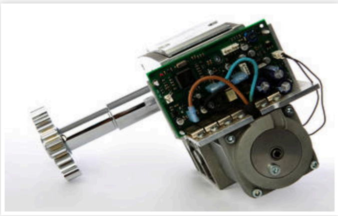
Figure 63: third iteration of Version 1

As you can see this version (version 1) takes a lot of space in the height. The reason for this is because there was not a lot of time for optimizing the parts separately. The DC motor used is from Stoeber (I could not find other CAD models) and is slightly too big. The same goes for the diameter of the flanged wheels (which are based on what companies had to offer), while these could also be smaller.

Power

So the last step was to find out how much power was needed to move a person on a rack and pinion. At first, I tried to calculate the moments of Inertia and rolling resistance forces and translate this into electric power but after some time, I realized that stair lifts have the exact same scenario so instead I used the information found about stairlift motors as an example (see figure 64-65). Most stair lift nowadays uses a DC motor of around 250Watt+ with an inventor that changes it from DC to AC. The inventor and additional electronics are neglected.

Worm helical gear



DT4-1,5-10 TY04

Type	Worm helical gear with BLDC motor
Motor power	0,3 kW
Nominal voltage	24 V DC
Nominal current	16 A
Nominal input speed	2270 min^{-1}
Gear ratio	138
Output speed	27 min^{-1}
Rated torque	65 Nm
Operation type/ Duty cycle	S3 - 40% according to DIN VDE 0530
Speciality	Brushless direct current machine with controller
Branch	Curved stairlift

Figure 64: worm gear DC motor (tornado-drives, 2018)

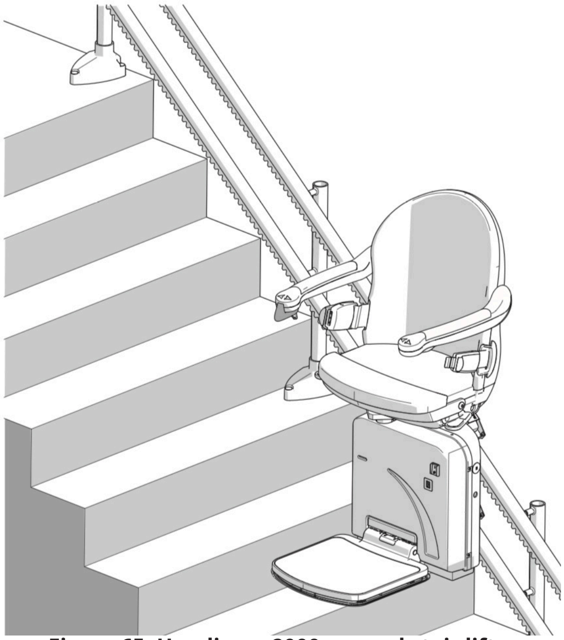


Figure 65: Handicare 2000, curved stair lift

Martur is currently building a simplified type of the proposed version 1. Ideally, we would want to produce version 2 which can be seen below in figure 66. This version is connected to the swivel prototype of Martur and is enhanced for the design of the dynamic seats (see chapter 6). It's professional, simpler and takes less space (especially in height).

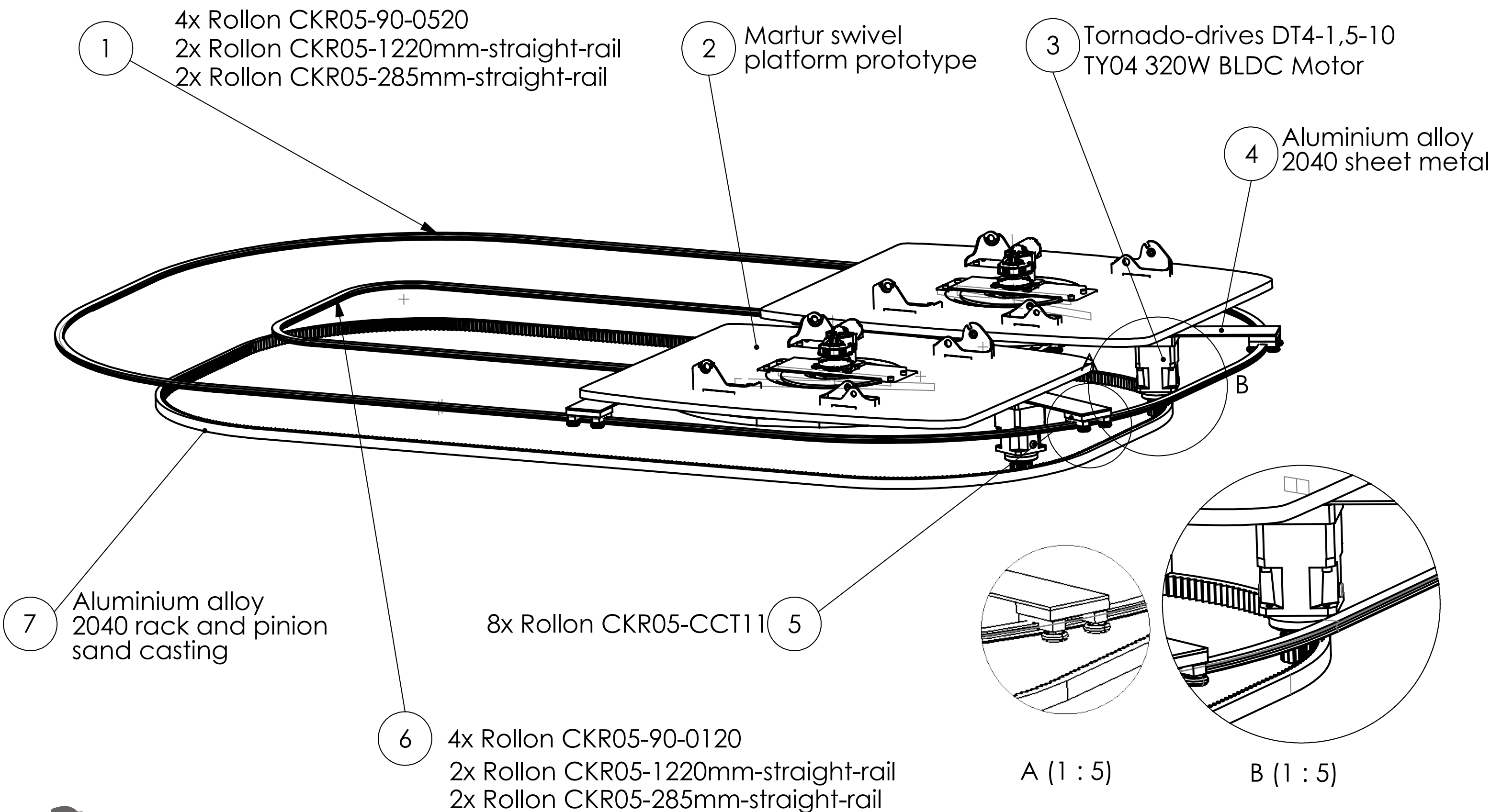


Figure 66: Final interation of Version 2

This version exists out of several parts from the Rollon Curviline family which form two rails and can withstand a force of 1500N each (Rollon, 2018). The offset between the outer and inner radius is 400mm (which is approximately the width of a car seat) and the inner radius is 120mm (minimal radius possible with these parts). A Factor of Safety and Frequency analysis has been done on part 2 and 4 (see figure 66). These two analyses make sure that the stresses are far beneath the yield strength during it's expected the use of 13 years (see appendix 14) to ensure that permanent bending and cracks will not happen (see figure 67). A FOS of 3 is standard within the automotive industry (SAE, 1966) and aluminum alloy 2040 is used mostly in heavy-duty applications like this with a sheet thickness of 6mm (Tailor-steels, 2018). The sn-curve of this alloy was selected for these analysis.

A simplified Solidworks simulation was done with the following scenario:

-1500 N normal force is acting on the two connecting plates (part 2 & 4)
- The surface of part 4 acts as fixed hinge for part 2
- The cilinder of part endures pull and push forces because of the normal force applied to part 2
- The outer area of part 4 is supported by the rollon rails, thus is seen as fixed hinge

The goal was to fullfil the abovementioned requirements with minimal thickness. So after some trial and error, it became clear that the thickness of part 2 should minimally be 6mm and results in a minimal FOS of 8.5 and a minimal use cycle of 10.000.000 (2.200.000 is the expected use cycle, appendix 16). For part 4 a thickness of 3mm is more than enough (see figure 69-70).

part 2

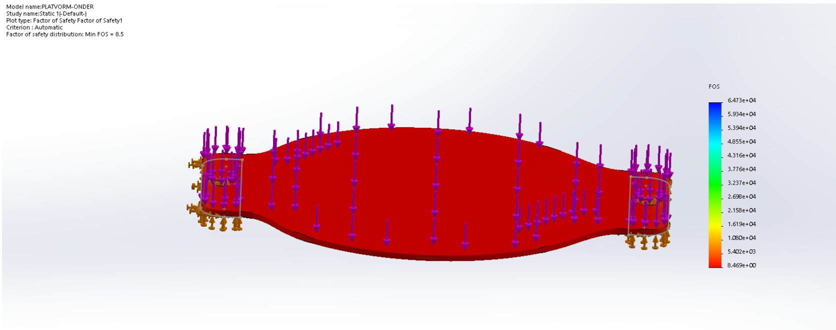


Figure 68: minimum FOS of part 2 (8.5)

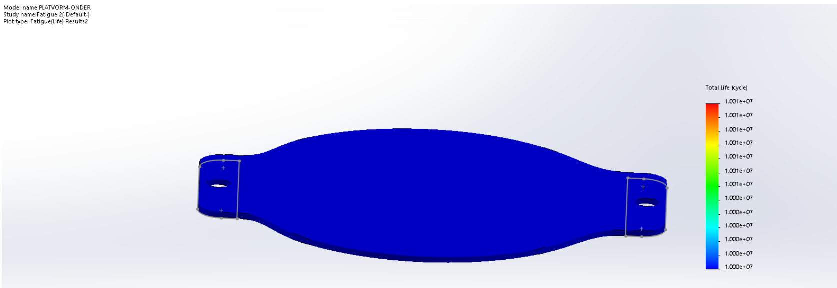


Figure 69: Minimum life cycle of part 2 (10.000.000)

part 4

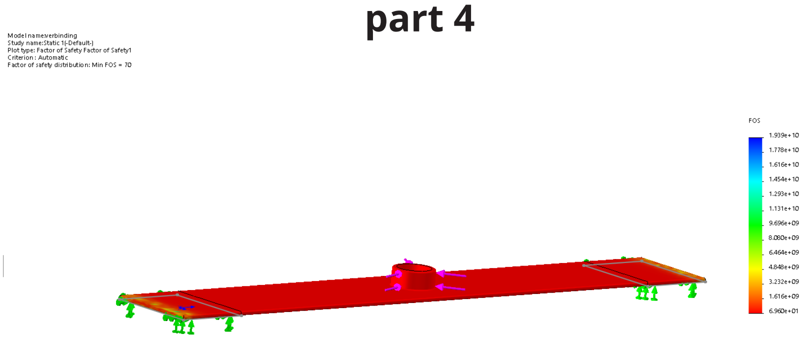


Figure 70: Minimum FOS of part 4 (70)

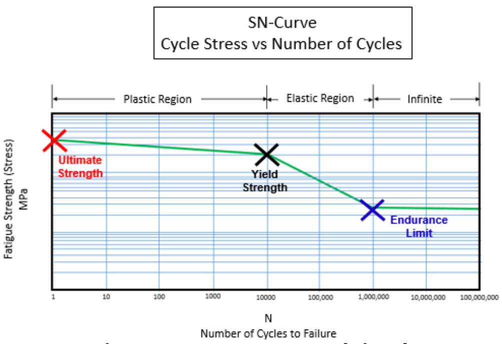


Figure 67: SN-Curve explained

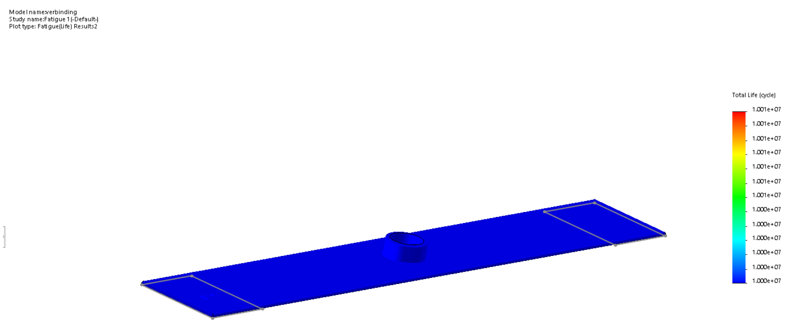


Figure 71:Minimum life cycle of part 4 (10.000.000)

A exploded view is made of the total mechanism to visualize how everything is connected. See figure 72 below.

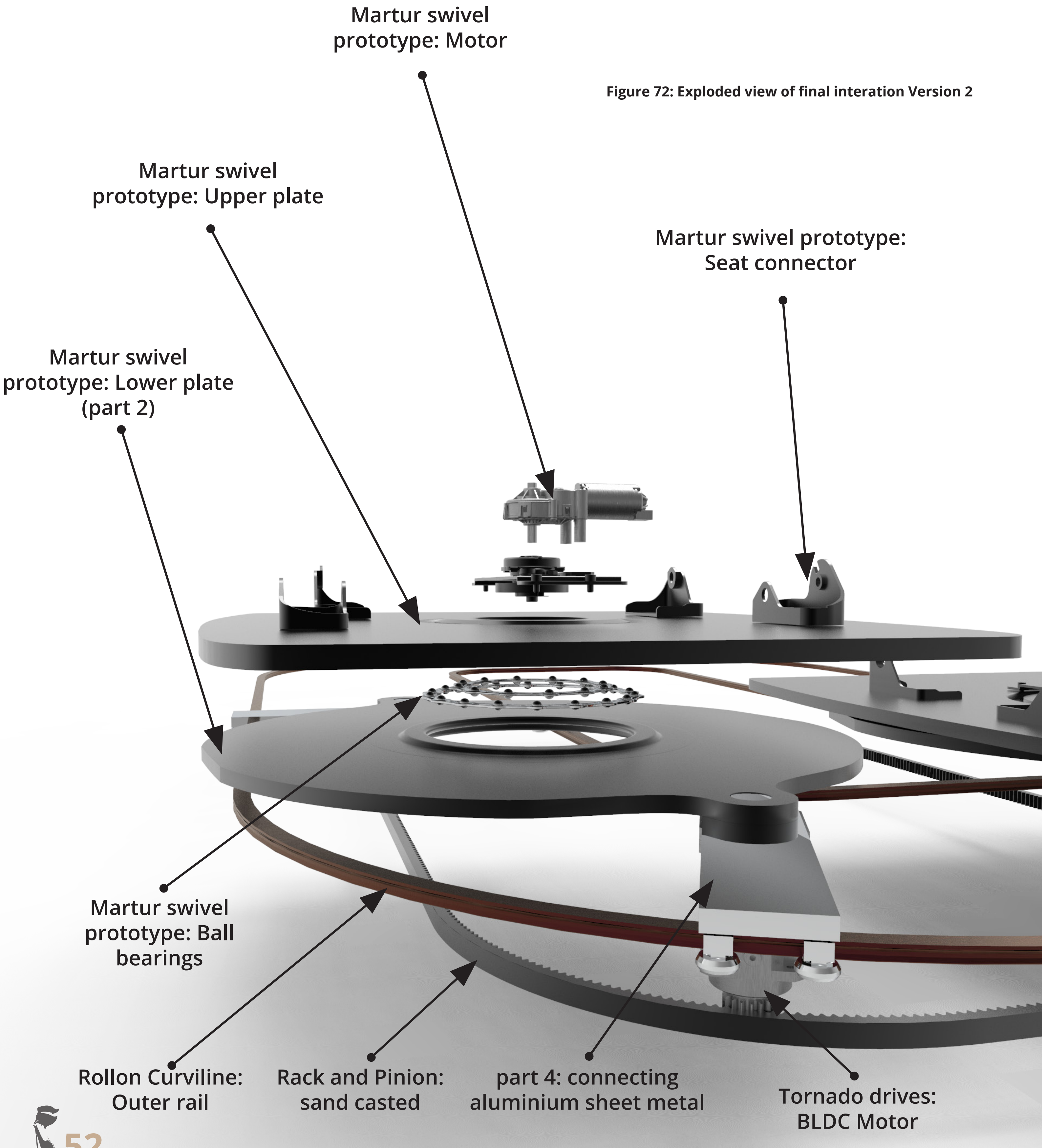


Figure 72: Exploded view of final interation Version 2

05 / CREATIVE SESSION

We now have explored what people will do in the future while daily commuting. The next question to ask is, what do they need while doing these activities?

A creative session was held and exists of interview questions, drawing exercises and an exercise in which scenarios were simulated and stuff was placed within a top view.

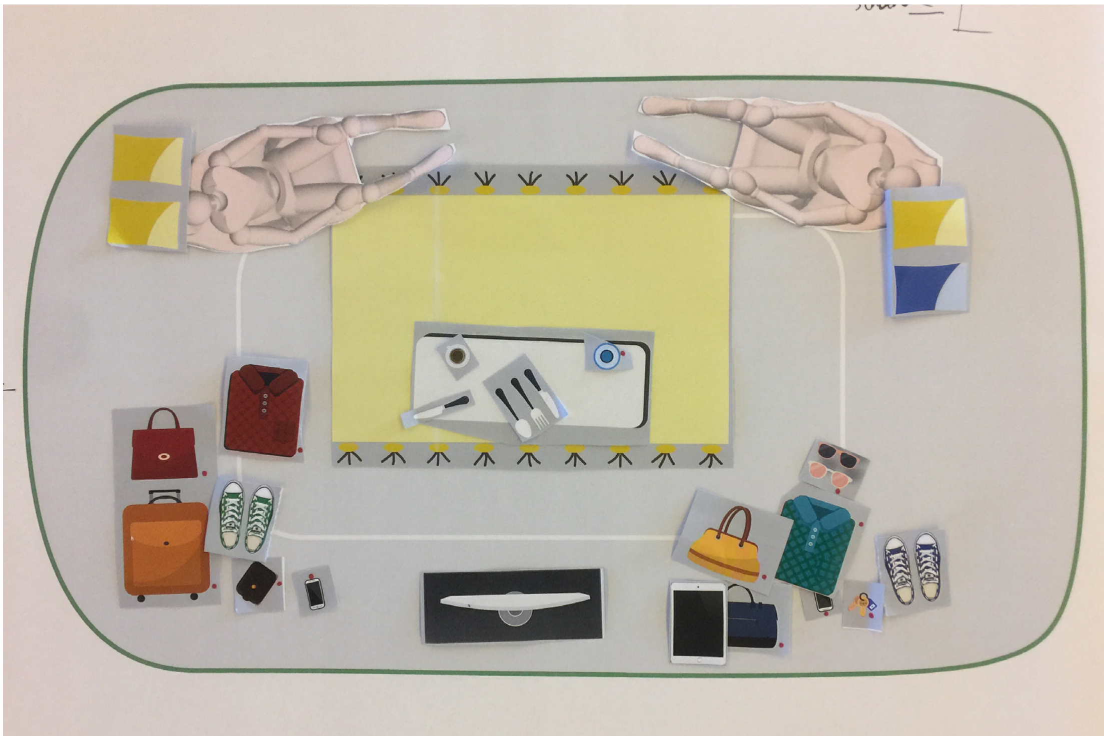


Figure 73: Creative Session, Participant 2, scenario: Socializing

05 / CREATIVE SESSION:

5.1 CREATIVE SESSION: INTRODUCTION

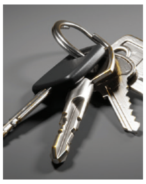
So, how could an occupant enjoy the cabin experience? The market analysis shows that a lot of OEM's believe that this space should be designed like a future second living room in which people feel at home and could relax. Examples are the Icona Nucleus, Renault Symbioz, and Audi Aicon. The assumption is made that occupants can enjoy this cabin when it enables them to fulfill similar rituals (as what they would do at home while doing activities like eating or sleeping) with the items they need for these rituals. The following questions were answered before setting up the procedure for the creative session:

- Which items are frequently used during daily commute currently?
- Which items are frequently found within a living room that makes a living room, your living room?

Frequent use of items in the daily commute

The experimental exploratory study showed the activities and seating positions that future users of a shared autonomous car will want. To be able to do these activities a couple things are required. Wagner (Wagner et al, 2016) researched the most frequent objects found during different driving situations (daily commuting, leisure, etc.) and also looked at the placement of these objects within the current interior. The following things are used and placed within the cabin frequently during daily commute (figure 74-75):

11.1%



9.1%

8.1%

7.5%

7.5%

5.3%

4.0%

3.8%

1.6%

1.6%

Figure 74: Things that are used during daily commute

Table 2
Frequency distribution of personal objects stored on or close to seats

Seat	Maps	Jacket/ coat	Tablet PC	Bottle	Supplies	Hand-bag	Bag work	Laptop	Smart-phone/ mobile	Sports equipment	Suits	Shoes	Umbrella (wet)
Seating backpanel	16.7%	8.3%	8.3%	0.0%	0.0%	0.0%	0.0%	8.3%	0.0%	0.0%	0.0%	0.0%	0.0%
Front seats	2.4%	4.8%	0.0%	18.3%	15.9%	15.9%	6.3%	6.3%	5.6%	0.0%	0.0%	0.0%	0.0%
Rear seats	0.0%	21.7%	0.0%	5.6%	4.2%	3.5%	4.9%	6.3%	0.0%	8.4%	5.6%	0.0%	0.0%
Under the seats	12.5%	0.0%	12.5%	0.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Floor front driver	0.0%	0.0%	0.0%	31.3%	12.5%	6.3%	0.0%	0.0%	0.0%	6.3%	0.0%	25.0%	18.8%
Floor front passenger	0.0%	0.0%	1.0%	23.0%	17.0%	19.0%	6.0%	2.0%	0.0%	2.0%	0.0%	9.0%	4.0%
Floor rear driver	0.0%	0.0%	0.0%	11.4%	10.0%	8.6%	14.3%	8.6%	0.0%	5.7%	0.0%	12.9%	2.9%
Floor rear passenger	0.0%	0.0%	0.0%	25.0%	21.9%	3.1%	12.5%	3.1%	0.0%	0.0%	0.0%	12.5%	3.1%

Table 3
Storage use cases of the door compartment

	Tissues	Sun glasses	Wallet	Bottle	Keys	Umbrella (dry)	Smartphone
Door compartment	10.1%	9.2%	8.3%	8.3%	7.3%	5.5%	5.5%

Table 4
Sersonal belongings stored in various spaces close to the middle console

Centerconsole	Smartphone	Keys	Wallet	Sun glasses	Tissues	Glasses	Gum/mints	Supplies	Bottle
Centerconsole front	23.1%	13.1%	12.3%	9.2%	6.9%	4.6%	2.3%	0.0%	0.8%
Centerconsole middle	14.8%	9.3%	13.0%	5.6%	5.6%	9.3%	7.4%	5.6%	0.0%
Centerconsole sideways	0.0%	0.0%	11.1%	0.0%	0.0%	0.0%	0.0%	0.0%	44.4%

Figure 75: placements of objects within a BMW 7 series (Wagner et al, 2016)

While it is expected that the interior will drastically change because of the introduction of level 4 autonomy, the usage of these items will most likely still remain. This means that people will still use these items but may place them somewhere else than that it is currently done (so the information displayed in figure 75 will most likely change). An example is that there might not be any center console or floor beneath the seat anymore to put stuff in.

Items found at home that make your living room, your living room
To give an answer to this question, a desk research was done in which a lot of pictures of living rooms found online were compared:

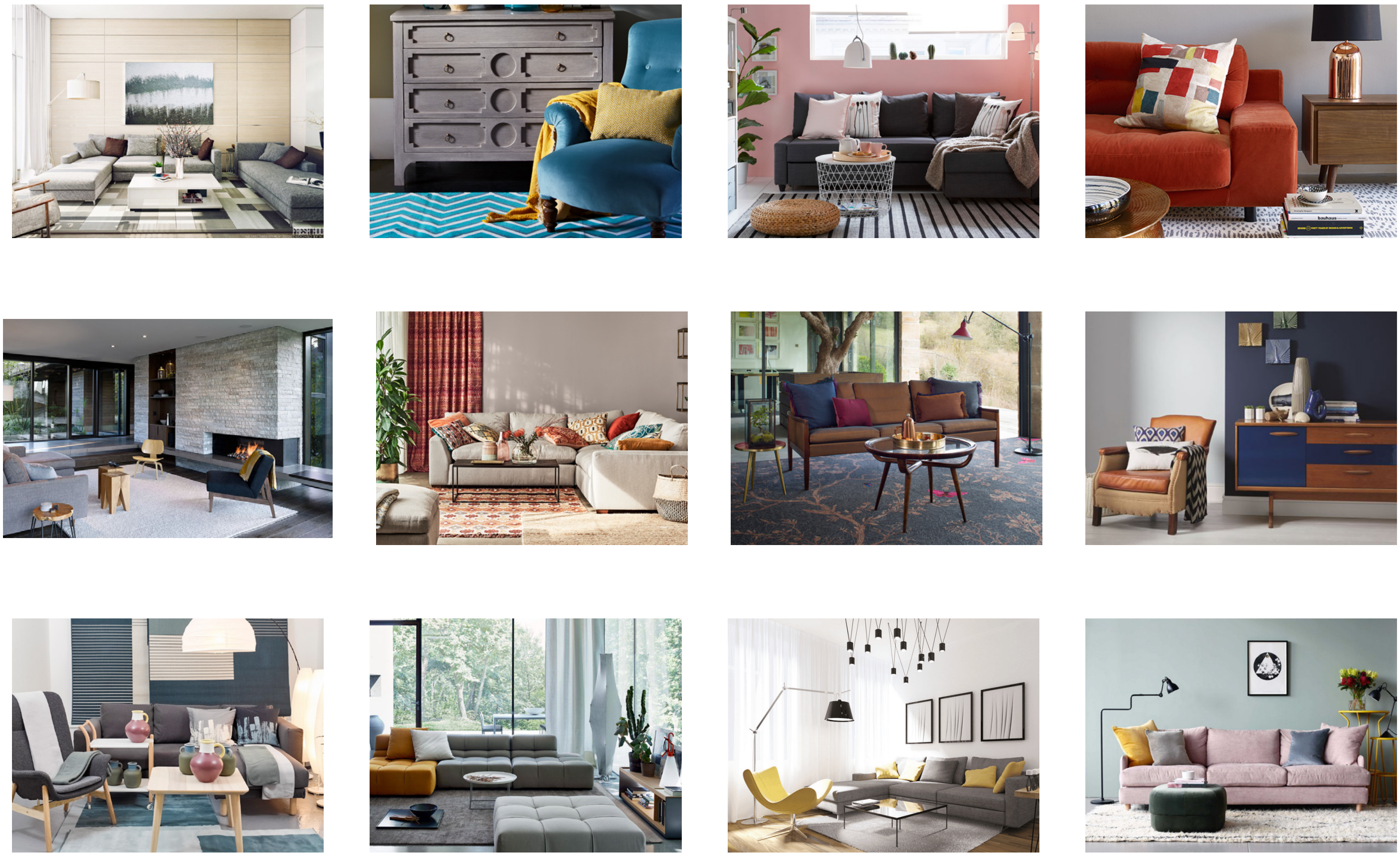


Figure 76: Comparing modern living rooms

From these pictures, it appears that it a lot of cases a central point is created with a table and carpet in the middle of it while there are couches around it. Most rooms are decorated with cushions, plants, art, books or light. Furthermore, in most rooms, specific objects can be found that serve or maintain social ties and relationships. Examples are gifts that are received by family or friends that are put on a display which makes us remember certain memories (Money, 2007). These objects are different for everyone and are difficult to place within a shared autonomous car, thus are excluded from this creative session.

Besides these items, the literature shows that one core theme centered around the role of rooms is the creation of a home-ness feeling for the family, by using technology. An example is the use of the TV which is found in almost all living rooms and suggests that entertainment at home should be enjoyed together. Furthermore, a TV fits aesthetically in the decoration of a living room and is associated with fun (Elliott et al, 2003).

5.2 CREATIVE SESSION: PROCEDURE

This creative session exists of two parts: An interview and an experiment in which the participant was asked to place the items within the cabin during different scenario's while thinking of their rituals.

The interview

The interview questions are about personal rituals that people have while eating or sleeping at home and how they would like to be welcomed (see figure 77). The participants were asked to think loudly about the answer to these questions and draw while thinking about it. This method is based on the idea of context mapping which shows that when participants 'draw' they unconsciously think about the deeper reason for their decisions.

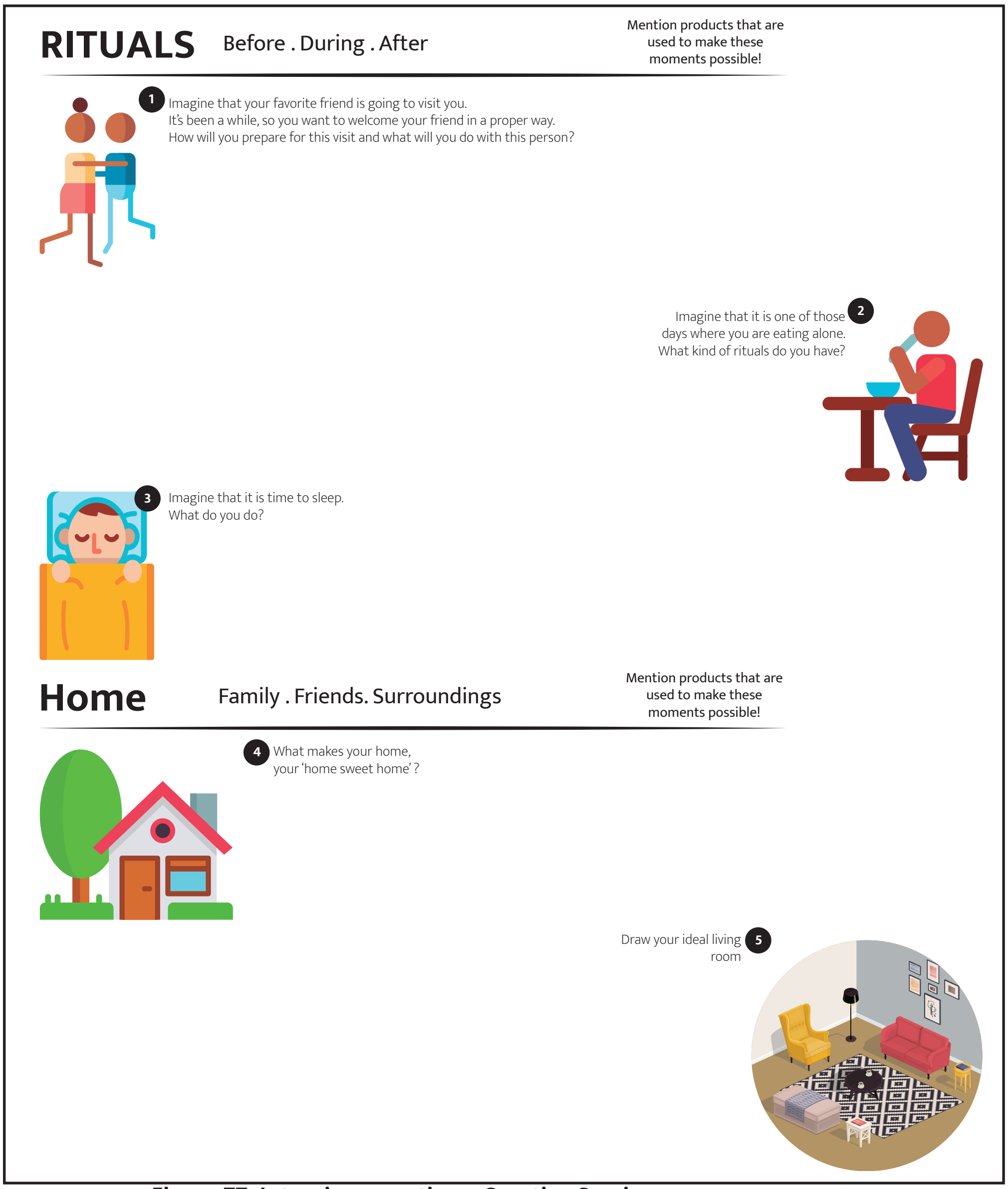


Figure 77: Interview questions, Creative Session

The experiment

After the interview questions, the participants were asked to first think about what makes their homes, their 'home sweet home' and then draw their ideal future living room. These questions were asked to make sure that everything was thought of by the participant before doing the actual experiment.

Shin (Shin et al, 2018) did a study in which he observed how couples decorate a living room and the motives they have for doing so. They found out that couple's design based

on functionality and think in groups/areas such as a "tv area" or "office area" rather than individual furniture items. The TV area was the most important and well thought out area for these couples (see figure 78).
This shows that there is a level of importance between areas and within this experiment, I looked at the placement sequence of things to see if some things were more important than others.

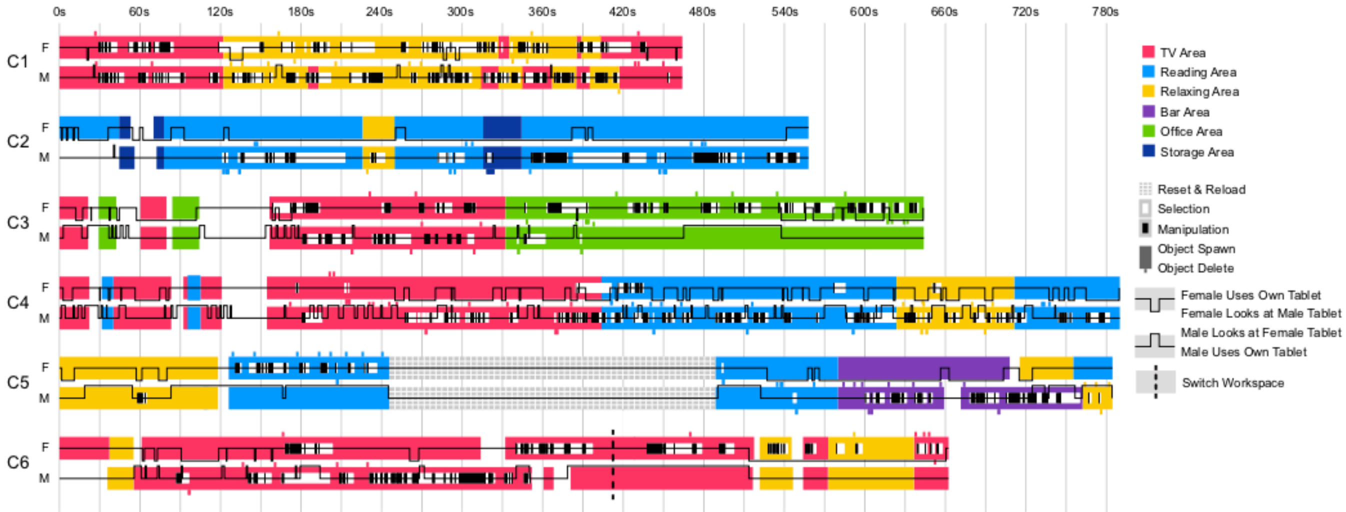


Figure 78: Visualisation of the design activities over time (Shin et al, 2018).

So this experiment is partly inspired by this study and the same methodology was used. The difference is that this study was done with virtual reality and I did not have this luxury. There were a couple ways to solve this:
1) make the participant draw the required things within a 3D-outline of the cabin
2) make the participant place illustrated isometric items within an isometric box
3) make the participant place top view illustrated items into a top view outline of the cabin

Before performing this creative session, some pilots were done to make sure that the interview questions that were asked were understood and it became clear that placing items in top view was the easiest way for participants to realize the space of the cabin during the experiment.

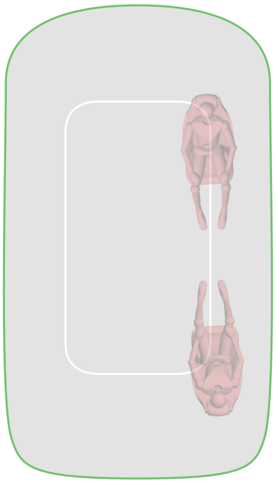
This session was done with 5 separate participants (male students, age 23-25). The participants were first shortly introduced to the project and then were asked to answer the interview question by thinking out loud and sketching. For the second part, participants were asked to imagine themselves in the following three scenarios and think about the rituals that they would perform:

scenario 5: socializing with a familiar person
scenario 3: sleeping with a familiar person
scenario 7: eating with a familiar person

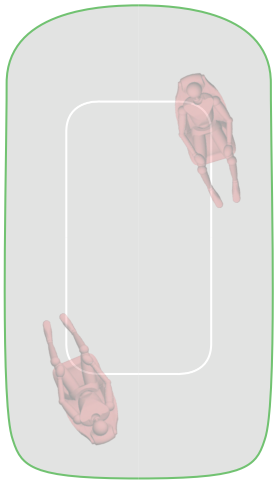
The main reason to do these three scenarios (instead of the seven scenarios found from the experimental exploratory study) was to reduce the time of the creative session and these scenarios seem to have the largest influence to the cabin experience.

The researcher reminded the participant that the session was being recorded and that items found by Wagner (Wagner et al, 2016) were obligated to be placed somewhere within the cabin while all other items were optional. Figure 79 shows all the items that could be placed within the different scenario's.

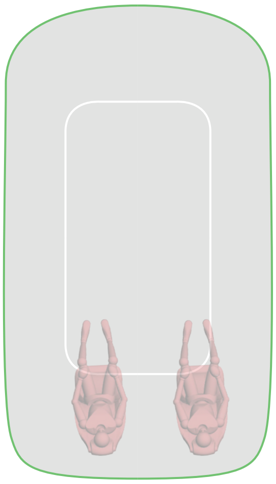
Figure 79: All items that could be placed within the cabin. These items are based on the findings of the previous paragraphs



Cabin outline: socializing



Cabin outline: sleeping



Cabin outline: eating

5.3 CREATIVE SESSION: RESULTS

Some of the interview results gave clear directions while others were misunderstood or not valuable after all. The first question, in which it was asked how the participant would welcome a familiar person varied a lot. The only common things were that participants would pick this person up from the airport and go somewhere to eat while talking about nostalgic- or actual stuff that's going on. The given answers could not really be adapted into the cabin experience besides the possibility to put something as a display that shows nostalgic moments of these people together, but this does not seem like something that would be put into a shared autonomous car.

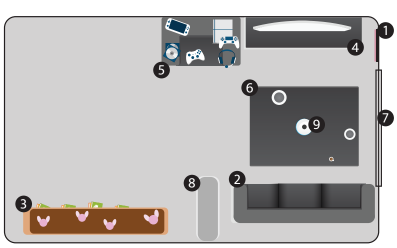
The second question asked about the rituals that people have while eating alone. All participants mentioned that when they eat alone, they would like to multitask in some way. Examples that were given were entertaining themselves with content on the smartphone/ tablet or read something.

The third question asked about rituals before sleep. Here most participants mentioned that they needed a kind of distraction stimulus to fall easier asleep. Examples were music sounds or a movie in the background. The second and third question shows that people need technology while doing these activities.

The forth question asked about what makes their homes special for them. This question gave either unclear answers or answers about specific objects were given and like described earlier, these were for everyone quite different thus difficult to adapt into the interior of a shared autonomous car.

Next the participants were asked to sketch their ideal future living room. Because some participants had difficulty while sketching, I visualized what they told into one coherent visualization (see figure 80).

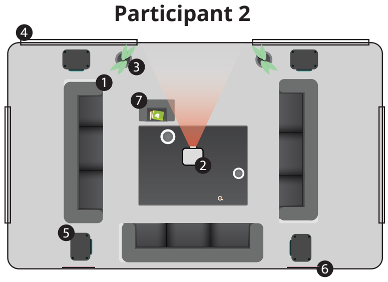
Participant 1



Placing sequence

1. Art, it makes your home personal and shows to others who you are
2. A simple sofa to chill on
3. A bookcase with my personal stuff on it like merchandise and books
4. A tv to watch movies with and game on
5. A crazy collection of game consoles. Fun when people visit
6. A coffee table
7. A window to look outside occassionally
8. A mini fridge to take drinks out without going to the kitchen
9. A lamp and heating: basics that belong to all rooms

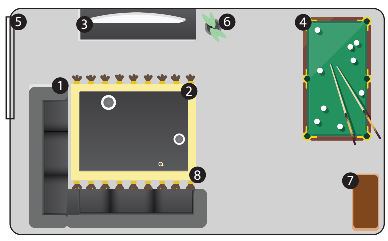
Participant 2



Placing sequence

1. A 3 part U shaped sofa, to create the group feeling vibe
2. A projector. It doesn't need to be on the whole time
3. A lot of plants. Makes your room less homely but more connected to the outside nature
4. Open windows which keeps everything fresh
5. A good surround sound system
6. Art and books. Gives more personality to a otherwise characterless room
7. Picture frames to bring back old good memories

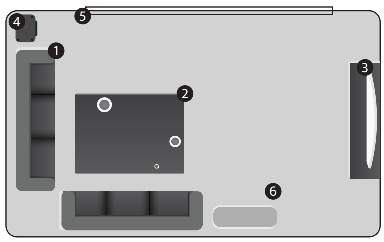
Participant 3



Placing sequence

1. A long loungesofa to relax on
2. A big table that has muliple options
3. A tv
4. A snooker table or ping pong table to relax with friends
5. Windows to have fresh air inside
6. Plant will give the living room a fresh look
7. A closet to keep important stuff in it
8. A carpet that gives the room a cozy feeling

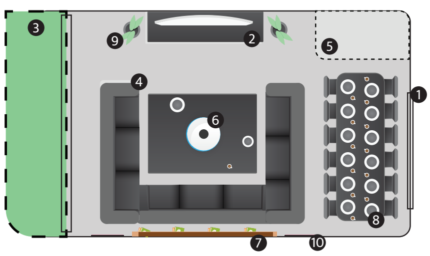
Participant 4



Placing sequence

1. Multiple sofas that should make the living room more cozy
2. A table to put stuff on it
3. A tv
4. A sound system used for entertainment
5. Windows with opague curtains that give privacy but at the same time provides enough light, to prevent that the room feels too narrow
6. A mini fridge to take drinks out without going to the kitchen

Participant 5



Placing sequence

1. Big windows that give enough daylight. Daylight gives me energy, makes me happy
2. A big tv for entertainment
3. Living room should be close to the garden and make you one with nature and give you rest after a hard day of work
4. A 3 part comfortable U shaped sofa, to create the group feeling vibe what you can find in lounges
5. There should be direct access to the kitchen for when something is needed
6. A big decorative lamp in the middle of the living room. Thislamp should create a atmosphere where the focus is to get a peace of mind
7. A bookcase just for decoration
8. A big dining table where you can invite a lot of friends of family and have dinner together
9. Plants next to the tv
10. A picture frame where you can see your old moments with family or friends. All other things mentioned could be in a restuarant but such a picture frame is unique to your living room.

Figure 79: All items that could be placed within the cabin. These items are based on the findings of the previous paragraphs

During this exercise important quotes and the placing (sketching) sequence of things were noted. Most participants started to first sketch a (lounge) sofa, then an TV opposite to the sofa, a big table in-between and a lot of windows that give enough daylight or fresh feeling. Like argued by Elliot (Elliot et al,2003) the TV is still the central point of the living room and this set-up seems to represent the average living room set-up between the participants. Less often mentioned were plants, closets, sound systems, carpets, picture frames, art and books.

The last exercise was to put items that were needed for rituals during the different scenario's. Within this exercise, there does not appear to be a common placement sequence (see appendix 19) like with the earlier exercise. Still, a lot of common things were found (appendix 20):

During socializing:
Most participants noted that the phone should be kept away and that stuff like bags, jackets, and umbrellas should be kept out of view. Technology (tablets and TV) is used as an additional option during socializing when occupants do not want to look at each other or just to hear something in the background. Shoes and small luggage like keys and sunglasses were placed at the door trim and cushions were used to make conversations more comfortable. Most participants desired to have a small table next to the seat where they could leave their wallet or a bottle of drink on. A carpet was used to give it more of a homely feeling and there

socializing

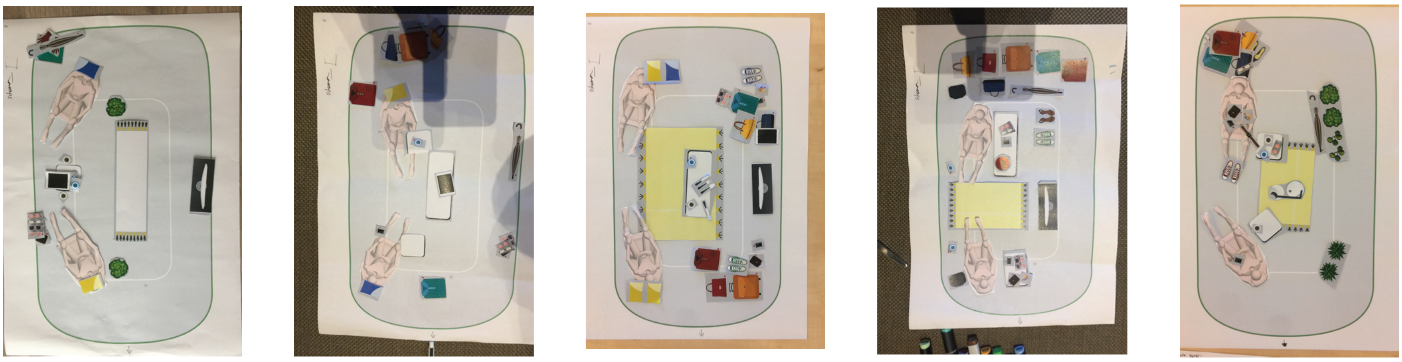


Figure 80: Things that are needed during socializing (n=5)

seemed to be no strong desire for plants.

While sleeping:
Almost all participants used a night table to fulfill the ritual earlier mentioned (to put a tablet on it and watch or listen to something as a stimulus to sleep). As during socializing, luggage should be dumped somewhere where it's not visible to the occupant. A participant noted that they wanted to organize everything cleaner and give the cabin a more spacious feeling. The phone is also kept on the night table and additional entertainment like books should be within reach of the occupant. A carpet was used to give it more of a homely feeling and there seemed to be no strong desire for plants.

sleeping

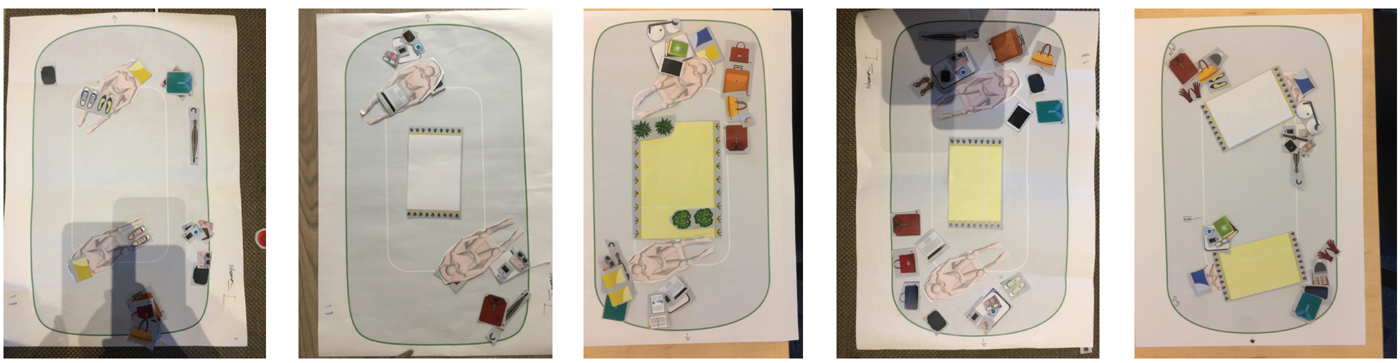


Figure 81: Things that are needed while sleeping (n=5)

While eating:
Like the exercise in which was asked to draw their ideal living room, the same set-up of the sofa, big table, and a TV was desired while eating. This shows that people desire a relaxed dinner like feeling while eating. The big table is used for food and bottles, while the tv is placed at the front of the car. Luggage is again stored in a dump area (in this case either behind the seats or behind the TV) and the phone is kept away. A carpet was used to give it more of a homely feeling and there seems to be a small interest in plants that were put next to the tv.

eating

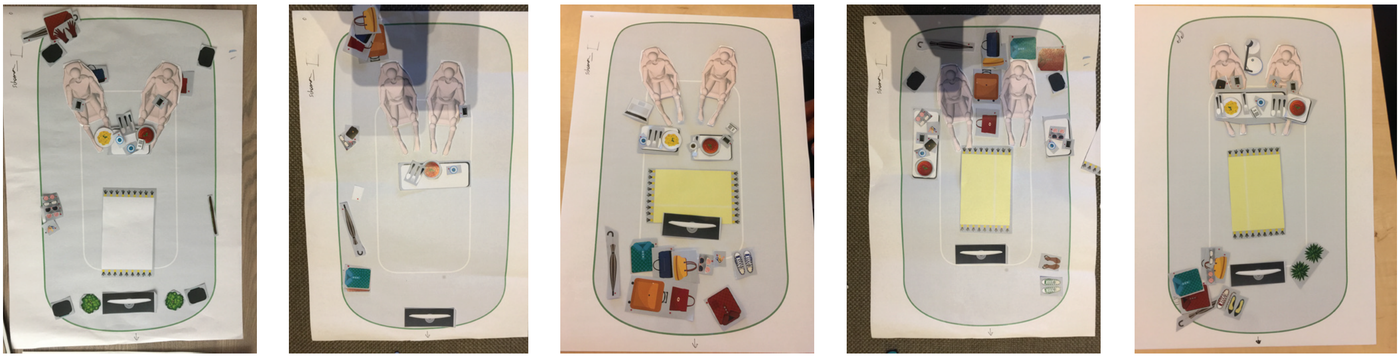


Figure 82: Things that are needed while eating (n=5)

While participants were doing this exercise they mentioned a couple metaphors that could be used to give the cabin and interior an additional emotional value. This value could make the dynamic seats more, than just dynamic seats. The following metaphors were mentioned:

- The seat should take your jacket like a butler would do in a fancy restaurant before you take a seat.

- Like entering most of the houses, the car should give a possibility in which you can take off your shoes and embrace the cabin by tactile experience with your feet

- Like with most houses, when you enter, you leave most of your bags and jackets in the designated area for it. One participant even mentioned “dumping stuff at your cellar at home.” And “There should still be a luggage room in a self-driving car like in current cars” This desire came back while placing stuff.

5.4 CREATIVE SESSION: CONCLUSION

When all of these results are taken into account, the cabin layout beneath seems like an appropiate solution. On the next two pages, a total cabin experience is described (see figure 84-85) and concludes this chapter. This experience does not include all scenario’s found during the exploratory study but I believe that the most important onces are described.

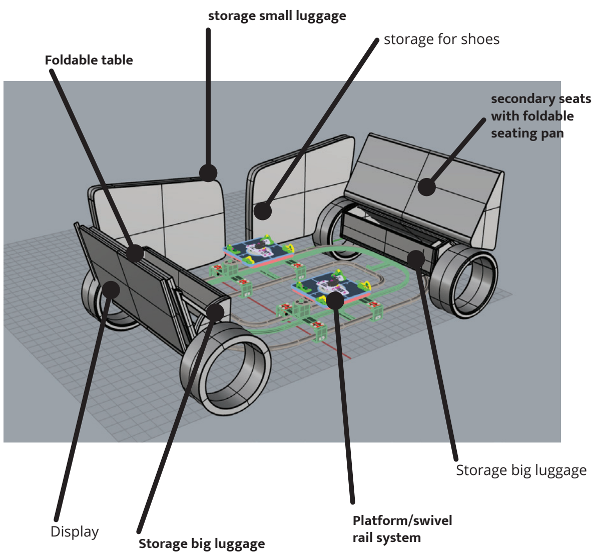
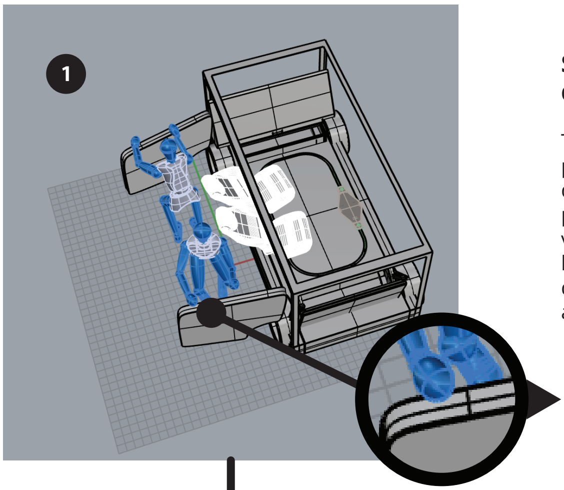


Figure 83: Resulting new cabin layout

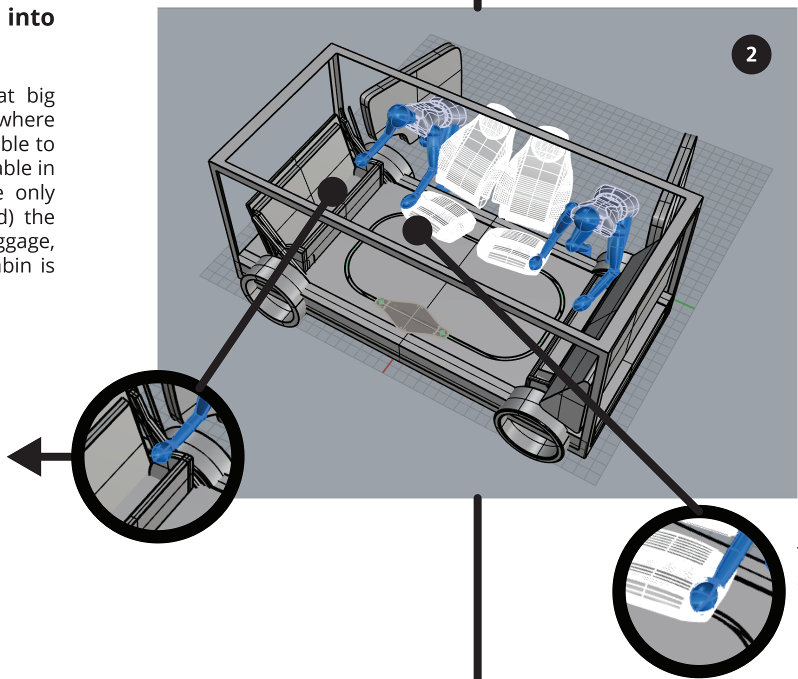


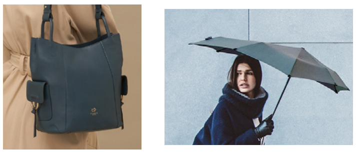
Step 1: Place small luggage into door trim

The creative session has shown that most participants do not need this small luggage during their commuting in the car and prefer it to be hidden. When leaving the vehicle, they should be reminded of this lugage like when you leave your house and do a final check to see if you have your keys and other stuff with you.

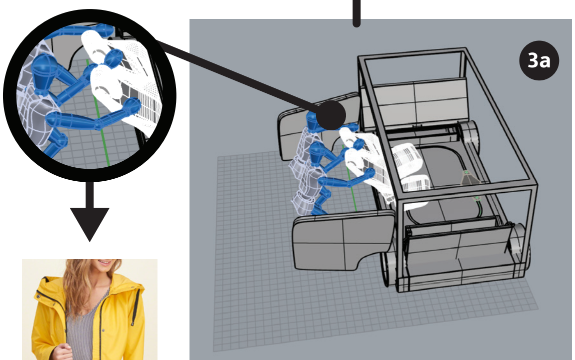
Step 2: Place big luggage into luggage area

The creative session has shown that big luggage should be hidden somewhere within the vehicle without it being visible to the occupants while still being accessable in case that something is needed. The only area for this is beneath (and behind) the seats. By not seeing this big luggage, occupants get the feeling that the cabin is more spacious and neat.



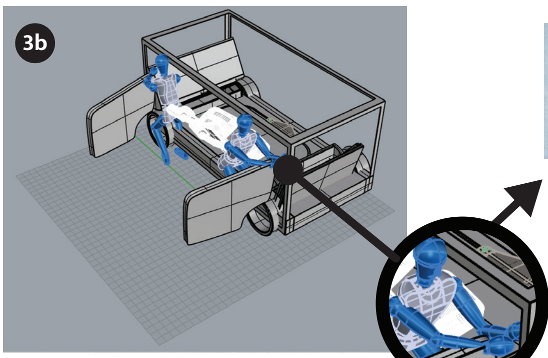


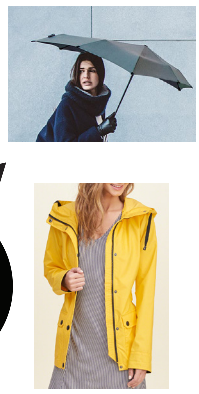
The dynamic seats support the occupants while occupants place their luggage



Step 3: Hang the coat on the seat

The creative session has shown that one of the first thing that people do when they arrive at home, is hanging their coat. The dynamic seats (3a) could 'take' the coats from the occupants like how a butler would take your coat in a fancy restaurant. This could add additional emotional value to these seats.

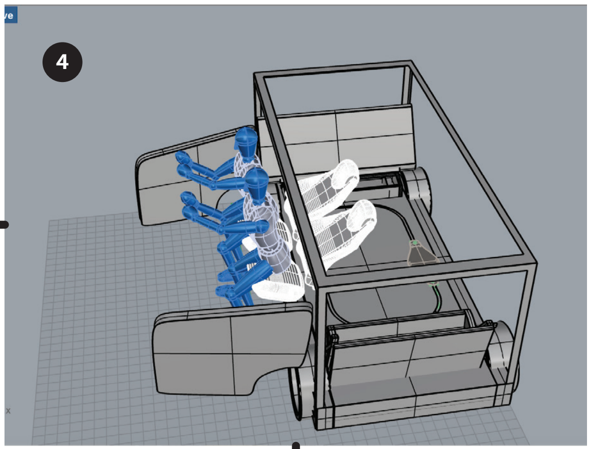




Step 3: Hang the coat in the corner

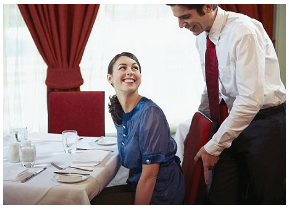
A alternative is to hang the coat (and the umbrella) in the corner of the vehicle during ingress/egress. This simulates the current ritual that we do at our homes.

Figure 84: A total cabin experience (part 1)



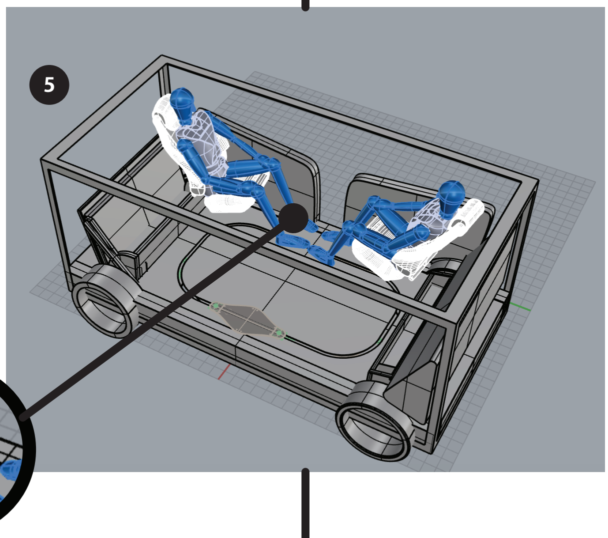
Step 4: ingress/egress dynamic seats

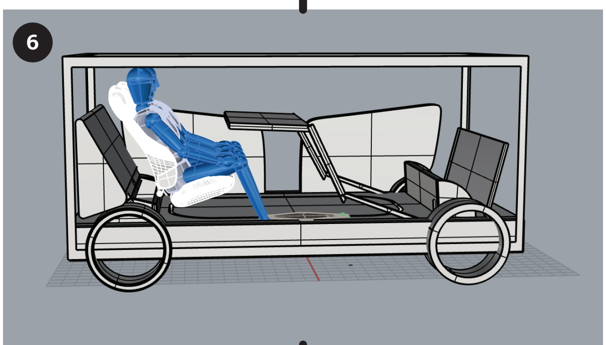
Now the seats turn around and the occupants can take place. This movement is similar to a butler that shoves the chair for you, so that you can take a sit.



Step 5: place shoes in door trim

The creative session has shown that people want to take take shoes off in their own home. This gives them a feeling that it is really their place and the tactile interaction that people get with their feet and carpets increases this





Step 6: eating mode

When asked how participants ideal living room looked like, there was always a big table in front of the sofa and a big screen at the wall. This came back also during the creative session while participants were 'eating'. So during this scenario, there should be a table that pops out either from the floor or ceiling of the cabin and a display that occupants can look to if they want

Step 7: 4 occupants mode

When 4 occupants are taking place in the self-driving car, all things are hidden. The foldable table, big luggage, small luggage, display and shoes. The idea is to focus on the interaction between occupants and make the cabin feel spacious.

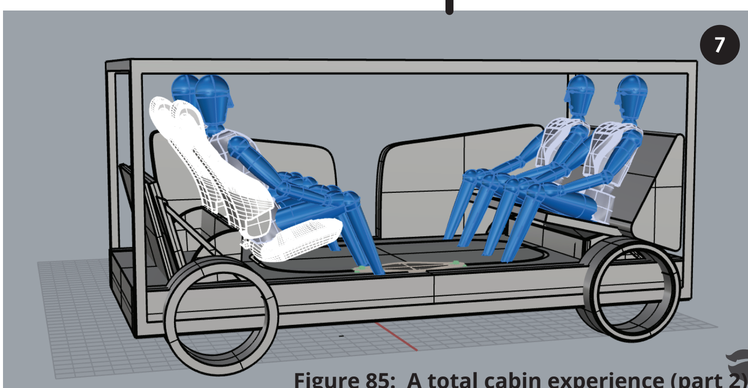


Figure 85: A total cabin experience (part 2)

06 / STYLING

The creative session concluded with a scenario in which things are placed at certain places inside the interior. This scenario is used as a reference point during the styling phase. The styling phase starts with a selection of a brand, ideation, collage and jumps into concepts that are modeled in Alias Speedform. At the end of this chapter recommendations about the dynamic seat and a final visualization of the scenarios are given.

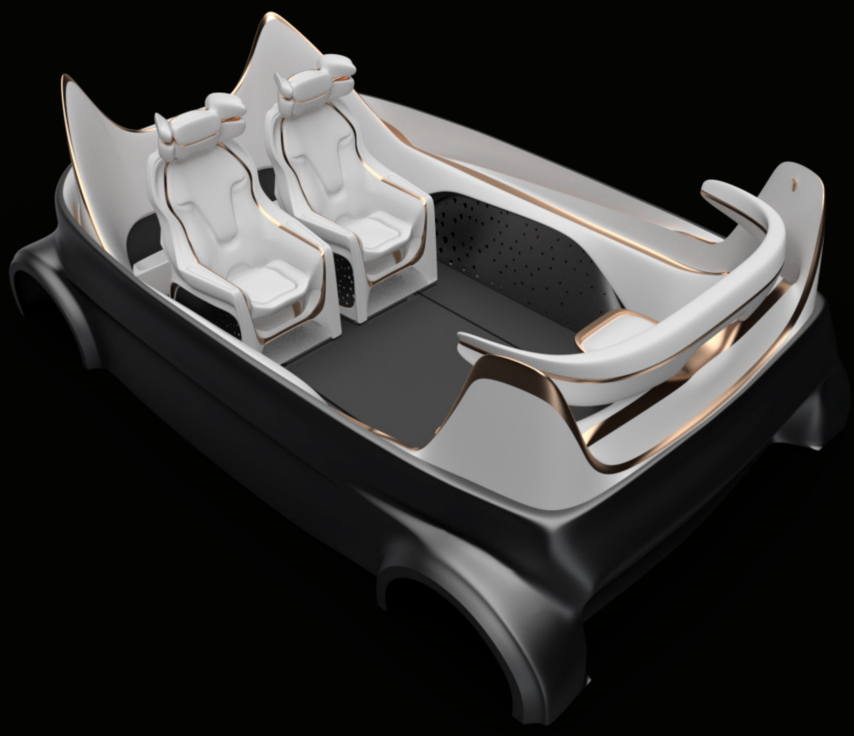


Figure 86: A total cabin experience (part 1)

06 / STYLING

The scenario on the previous pages shows guidelines to how this private shared autonomous car could be. For example, in the door trim, there should be room for small luggage like keys, cards, and others that resemble the metaphor of leaving and entering your house. This chapter explores the different styling possibilities while keeping this scenario in mind and proposes a final design.

Choosing a target group

When this project just started a company analysis was done into Martur and it became clear that they are a first tier supplier which means that they do not have direct customers like you and me, but instead deliver to big brands like Renault and Ford. Because of this, there was not a clear indication of what the target group should be. Desk research showed that the first users of autonomous vehicles probably will be males with above-average incomes that live in urban cities and love tech (see figure 11). They desire this autonomous car to be safe, personal and practical. Nevertheless, I believe that ride-sharing will be used by everyone thus there is no reason to reduce the target to this group. Still, characteristic as providing a safe feeling that is personal (see figure 16 & 26) and comfortable (see table 1) to the individual (when desired) should be one of the main aims of the interior design. The interior design still focuses on providing the personal space required for up to two occupants to do the different activities that they desire while also having a layout for four occupants (figure 6 shows that only 1.4 car seats are used in daily commuting averaged).

6.1 STYLING: CHOOSING A BRAND

After a discussion with Peter and Martijn, we came to the conclusion that choosing a brand would be a wise thing to do. There was a possibility that this project could be presented to BMW (with the agreement of Martur) so BMW has been chosen as a brand. When looked at BMW's production interior it becomes clear that they have a tremendous amount of detailing (like stitches and patterns) at the right places while still keeping it clean. Strong bolsters are used to reflect the sportiveness found in BMW's philosophy with an intimate touch to it. Dark colors are used, and most interior parts use the BMW layering principle in which levels are made of different materials that are visually 'stacked' on top of each other to bring surfaces to life (BMW Group,2012).

Figure 87: BMW 5 series 2018

When looked at the concepts of BMW, the interior seems slightly different. For sportive cars like the BMW 6 grand coupe more organic and fluid shapes are used while the luxury concepts like the BMW X7 uses more geometric shapes. The whole cabin (like the door trim and instrument panel) seems lively yet calm and has dynamic, fluid forms that create a balanced and harmonious organic surface. The use of the subtle horizontal flow of lines create a sense of space and the exploratory study and creative session suggested that people want to experience this cabin as spacious as possible. Furthermore, these concepts seem light (by using floating elements) and futuristic

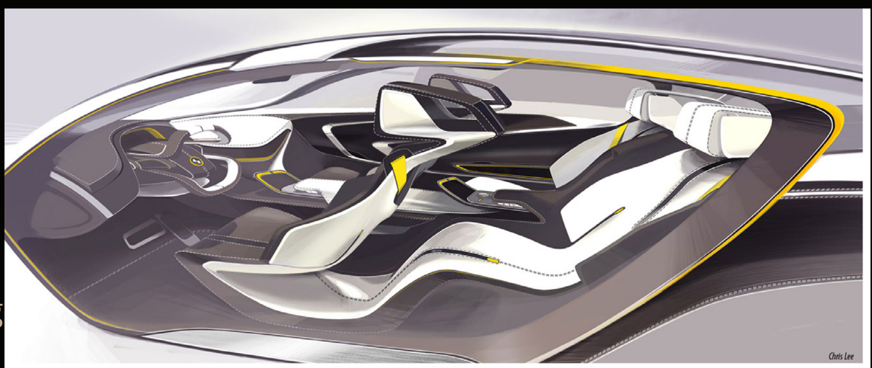


Figure 88: BMW i6 series concept 2022

(see appendix 22 for more examples).

These brand characteristics should be combined with the trend in which OEMs expect these shared cars to feel more like a second home. When looked at the interior of the living room (see figure 76), it becomes clear that soft simple shapes with cushions and high armrests are used mostly with a lot of light neutral colors.

6.2 STYLING: CHARACTERISTICS

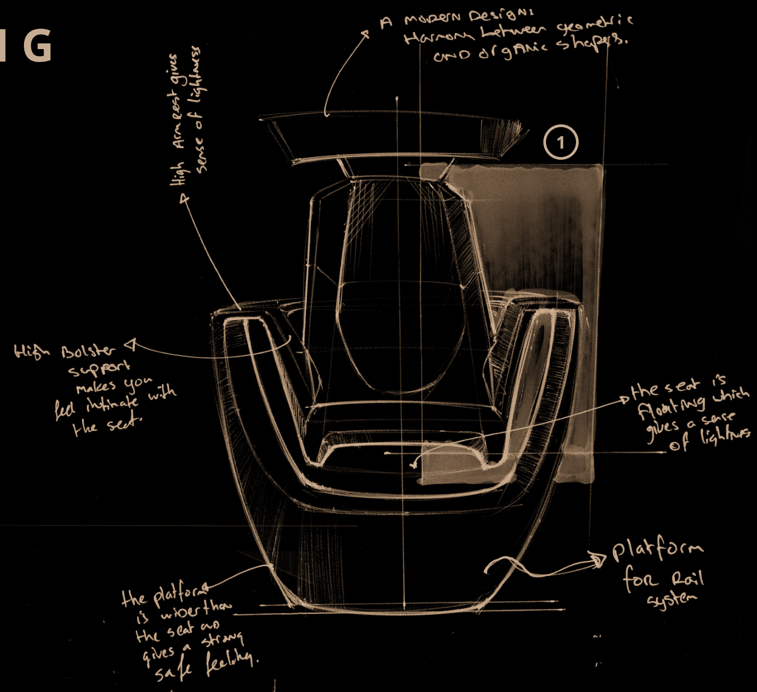
So, from this total analysis the following characteristics are expected from the interior:

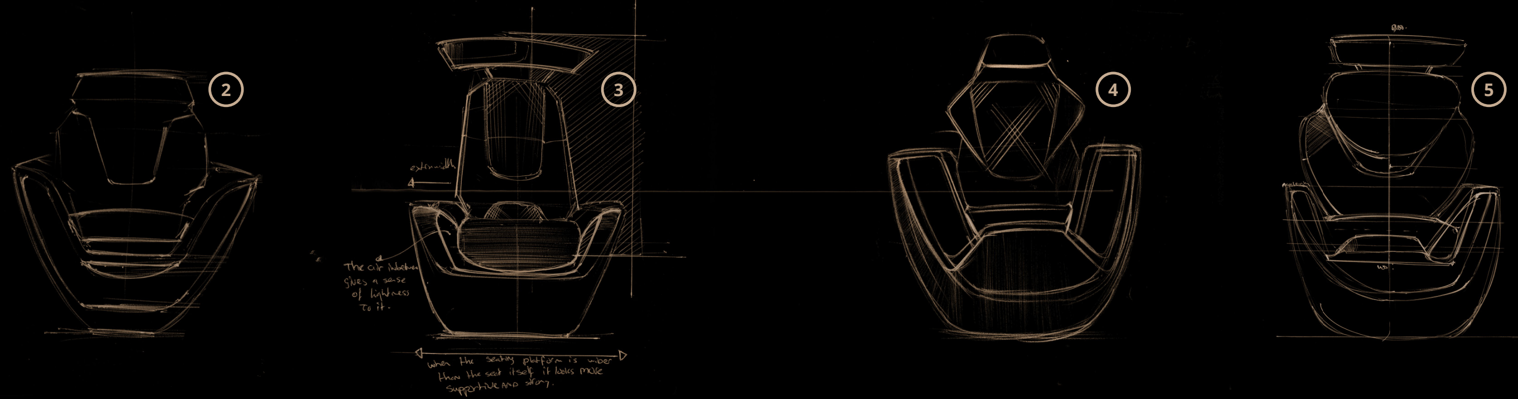
Dynamic seats:
- should have a nice balance between geometric and organic shapes
- should have a harmony between simplicity and complexity, by using details at the right places
- should have a balance between looking safe and light
- should look comfortable
- should look futuristic

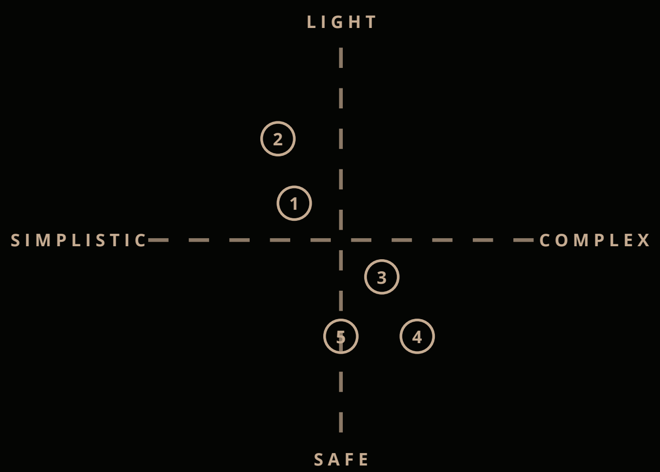
Cabin interior:
- should use horizontal organic lines to make it feel more spacious
- should have a harmony between simplicity and complexity, by using details at the right places
- should look luxurious

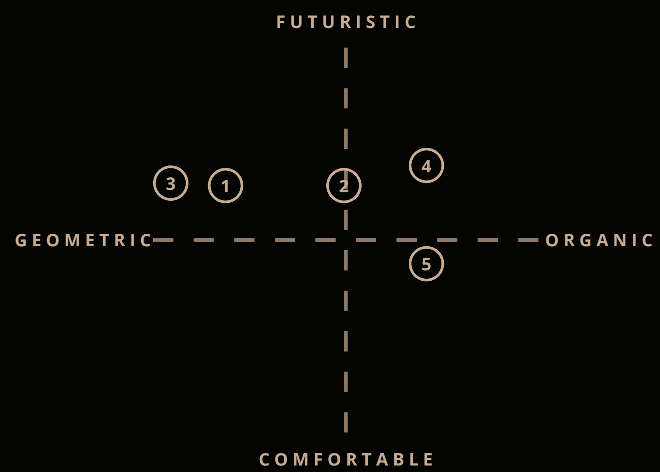
These characteristics were used during the ideation and conceptualization of the final design together with a collage (see beneath, originally existed of more pictures but these onces gave the most inspiration). The idea of this collage was to get inspired by various products (some made by BMW) that have a harmony in simplicity and complexity.

Figure 89: Collage



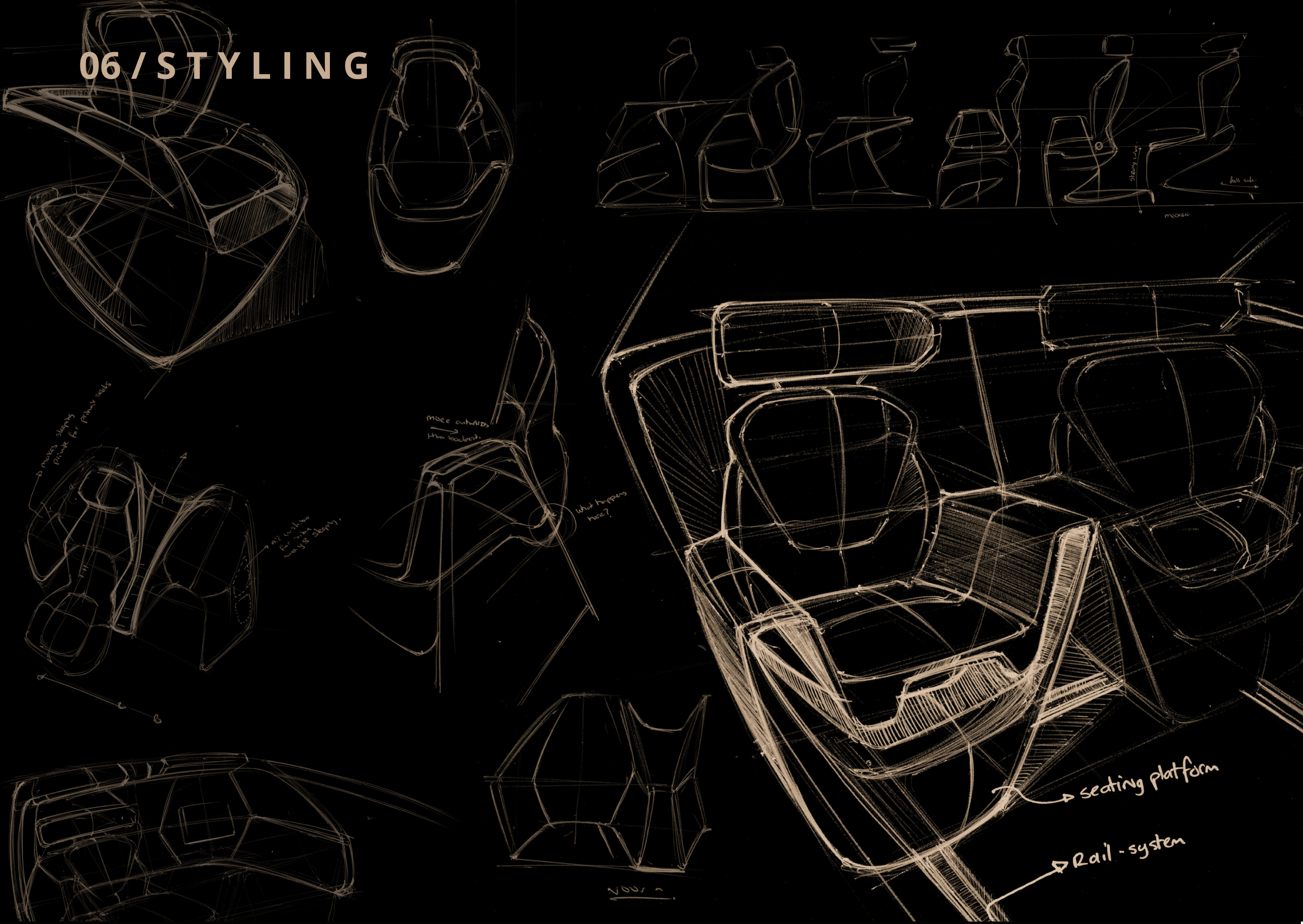


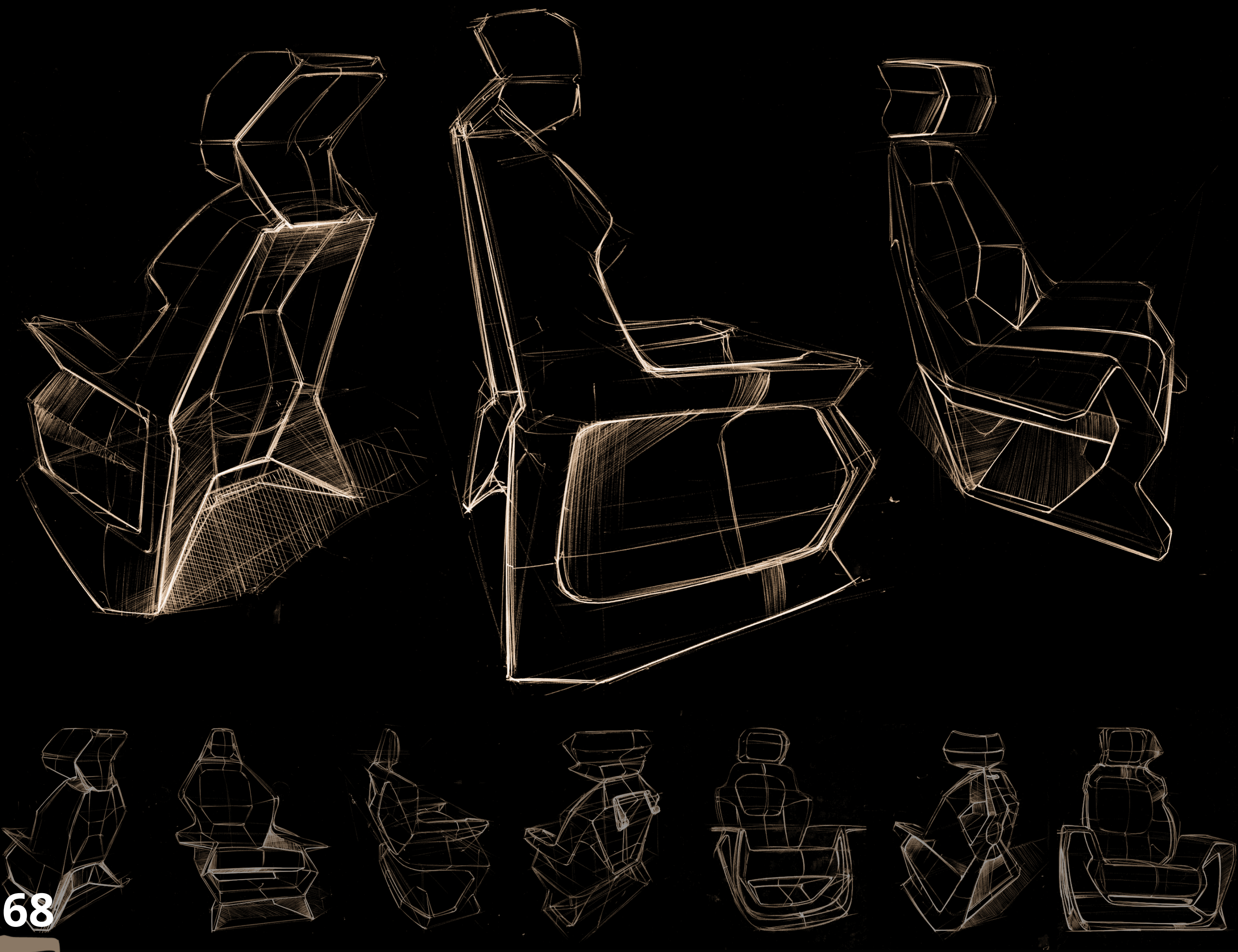




6.3 STYLING: IDEATION & CONCEPTUALIZATION

At the beginning of the ideation, the focus lied on making the seat look light and safe at the same moment. These five designs rely on the idea that the seat ‘floats’ from the platform. Different proportions in height and width were tested out. The different geometric or organic shapes in the designs show different levels of comfort while some are more simplistic than others. Geometric designs look more futuristic while organic designs look softer, thus more comfortable.


seating platform
Rail - system



06 / STYLING

These ideas were then taken into side view sketches (see previous page) to understand how the shape of the platform influences the stance of the seat (lay back, strong, weak, etc.). A couple perspective drawings were made and things started to look good until the Martur Seat underlayer was used (see appendix 22). It became clear that the seating platform as sketched was way too high (the chair height of the seating pan was too high) and when correcting this and lowering the height, the floating effect which created a sense of lightness disappeared.

So the attention for lightness became less and the aim was more to provide a seat that looked more stable, thus feel safer, while still providing a nice balance between geometric vs. organic, simplistic vs. complex, be futuristic and still be perceived as comfortable. The resulting design can be displayed beneath. The next page shows orthographics of this resulting design. These orthographics were used as a reference for the CAD model. I was not sure about the headrest design yet, so I kept it vague until the CAD modelling.

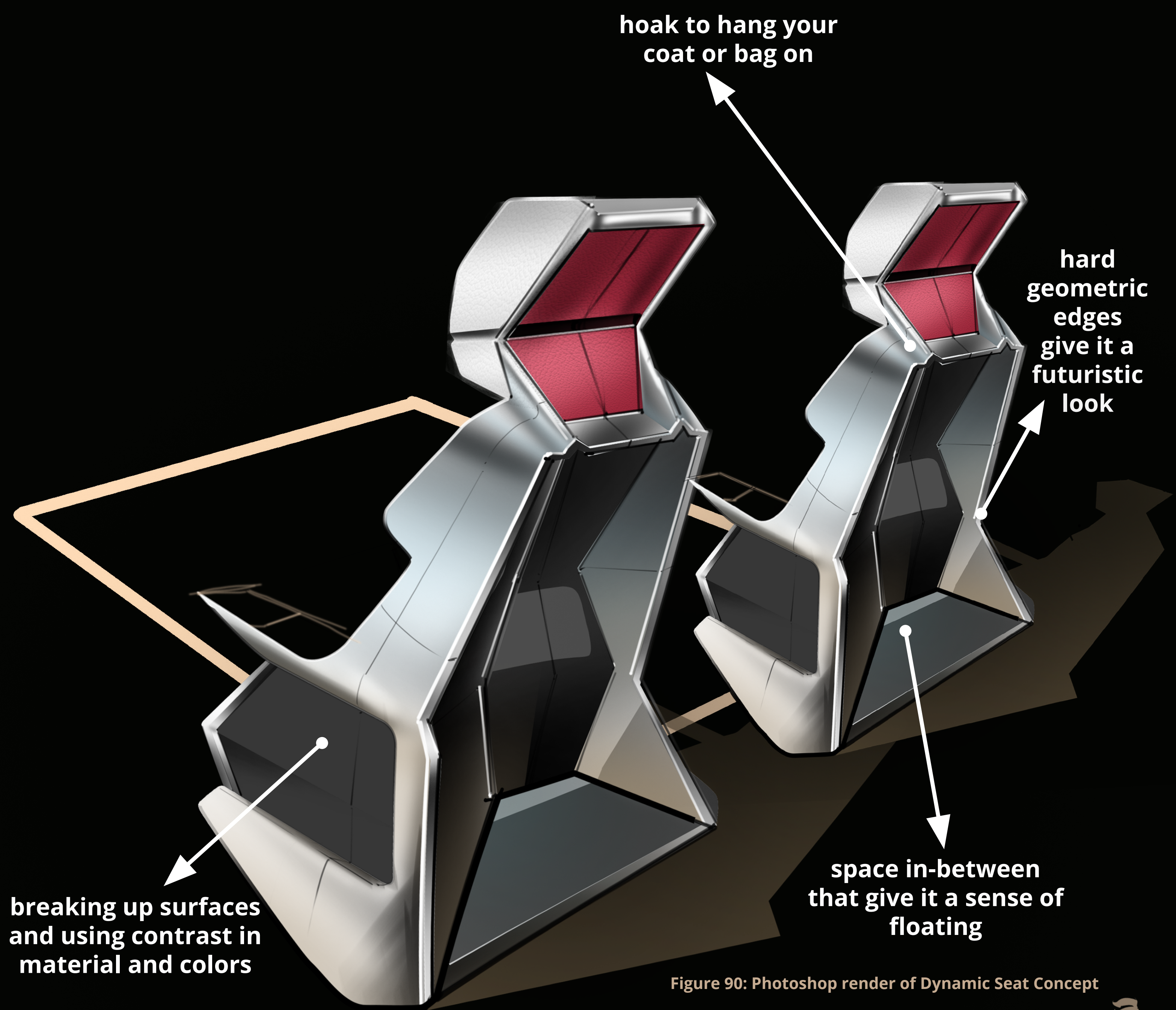


Figure 90: Photoshop render of Dynamic Seat Concept

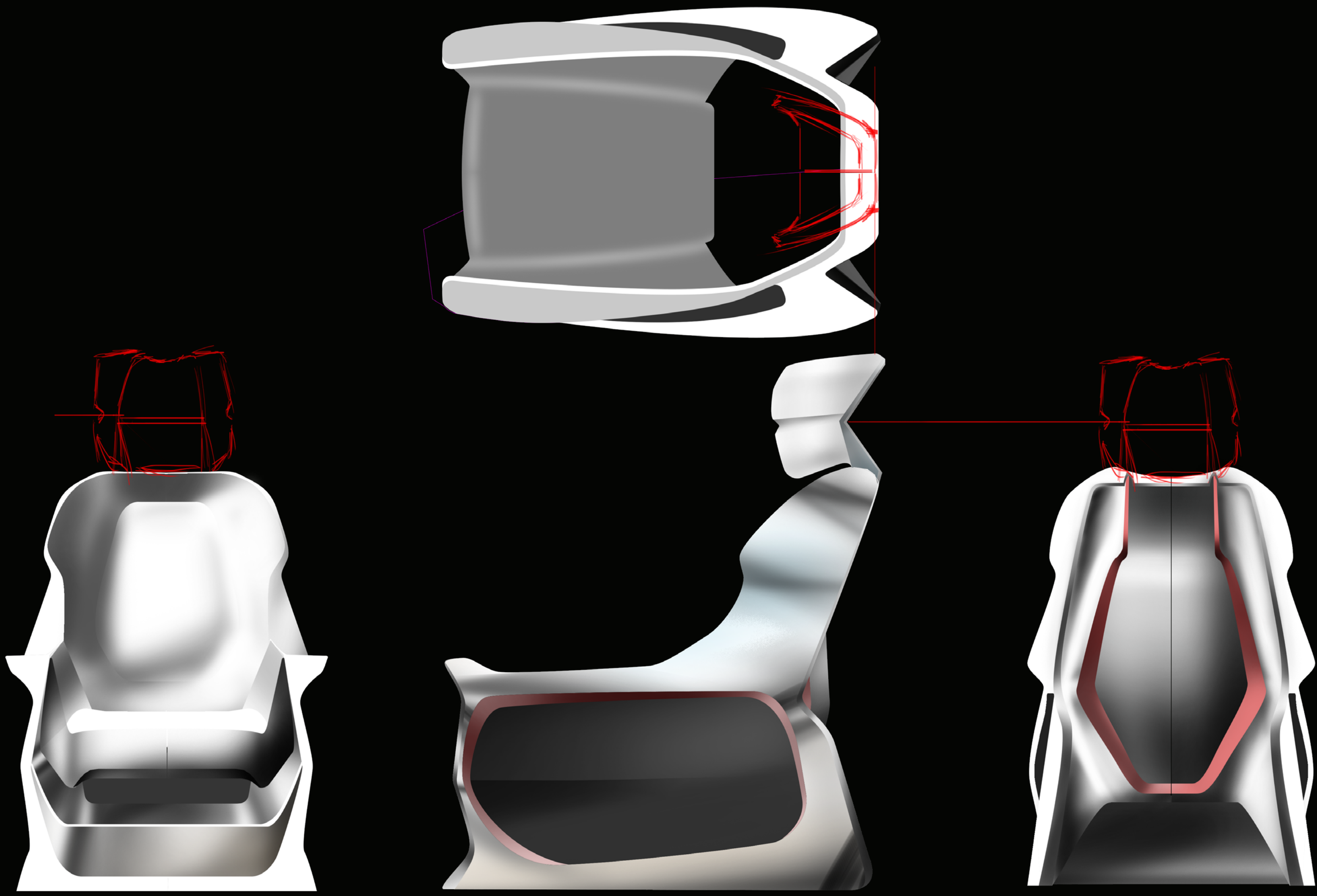
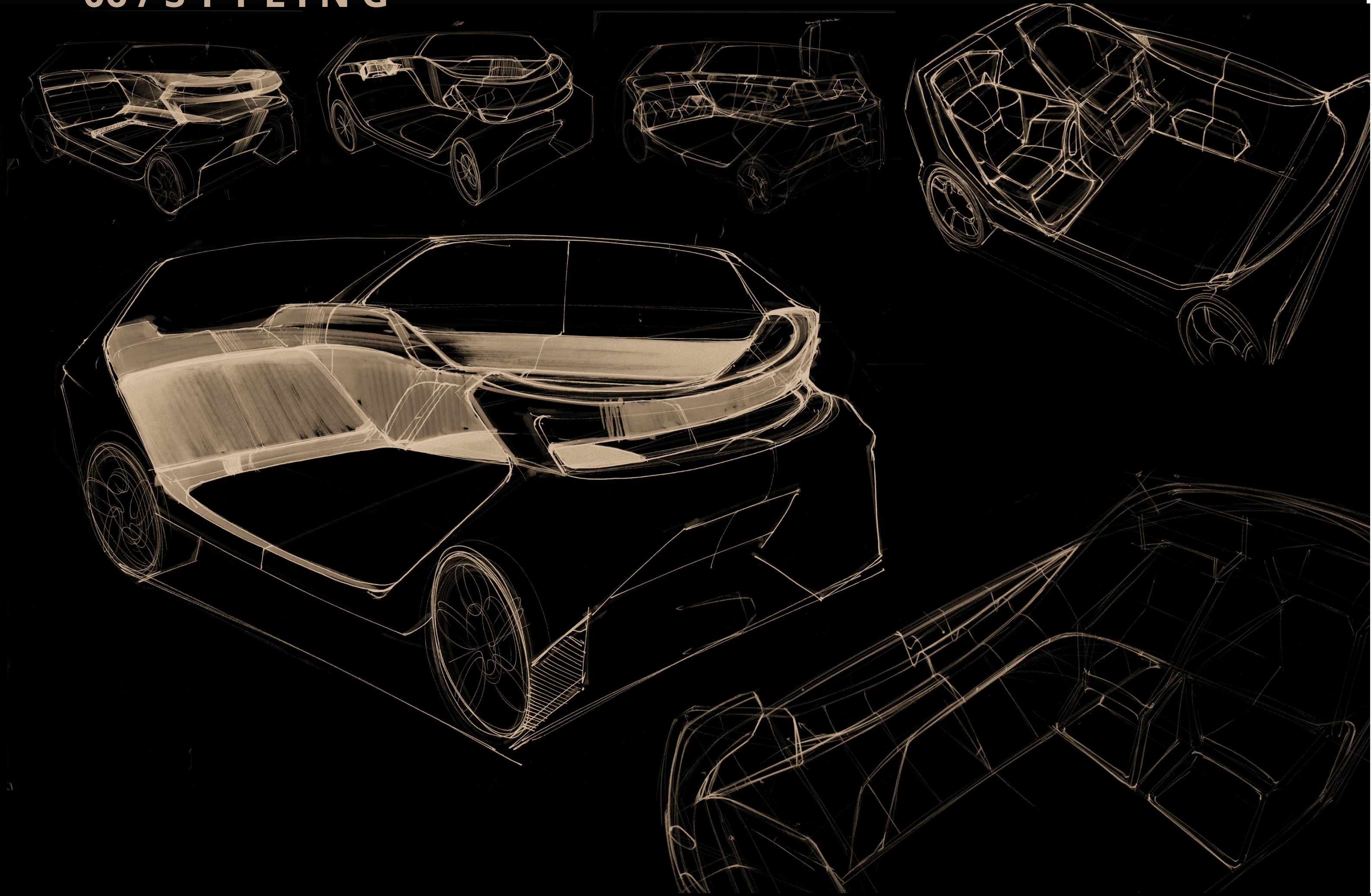
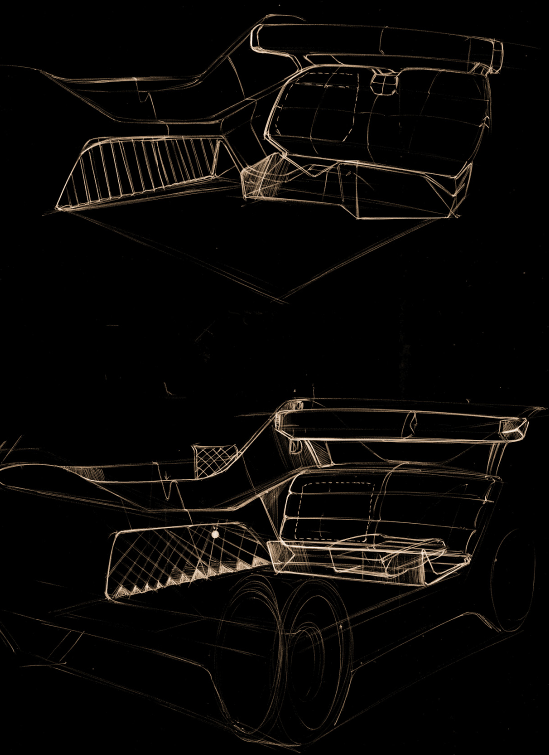


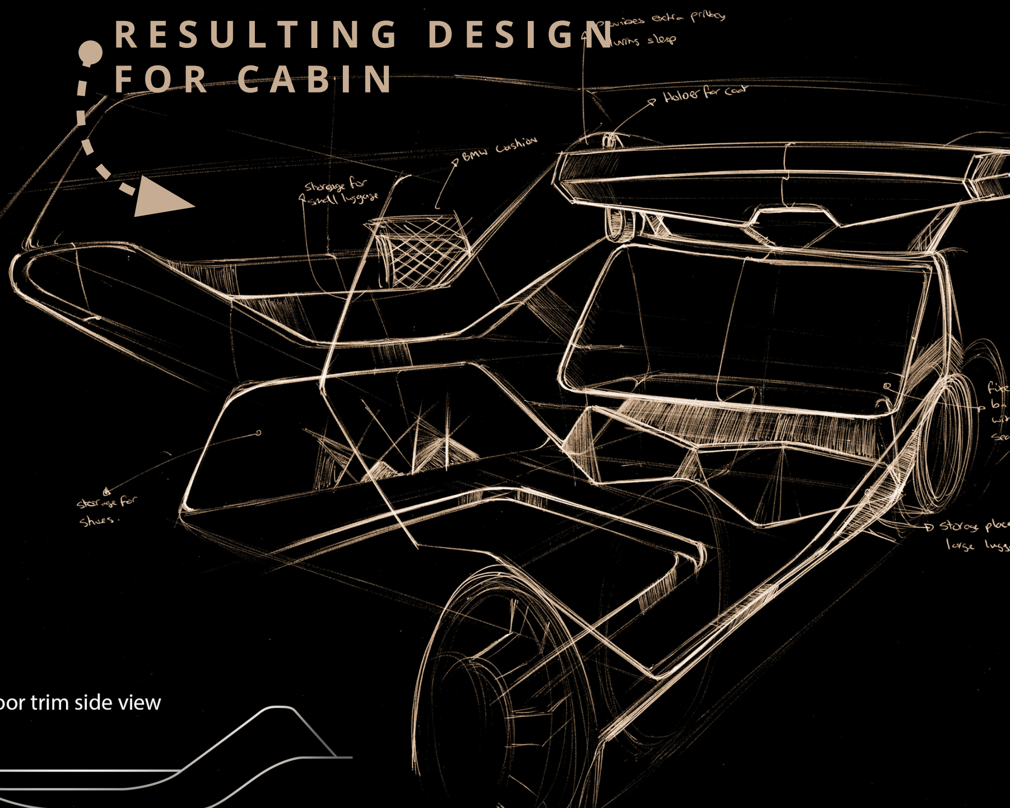
Figure 91: Orthographics of Dynamic Seat Concept

Parallel to designing the dynamic seats, cabin sketches were made. At first, I used a lot of current interiors as an example but realized that a bathtub design gave more design freedom. The upper sketches on the next page show different bathtub designs. I tried lines with different curvature (some more horizontal while other curves had more vertical elements to it) to see what worked best while keeping the scenario's mentioned in figure 84 & 85 in mind. The sketches beneath on the next page show a resulting design of the cabin and these sketches have clean minimalistic flowing lines which proportionally break nicely. Different patterns were thought off on these surfaces (based on the collage in figure 88) and different shapes were thought for the backrest of the rear fixed seats and storage room. These designs were used as a reference for the CAD model.

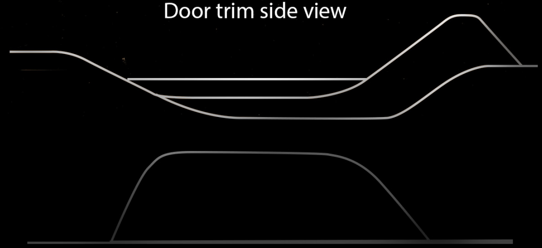




RESULTING DESIGN FOR CABIN



Door trim side view



6.4 STYLING: CAD MODEL DYNAMIC SEATS

The first step in this process was to select the right CAD program. When we look at the design of the seat and cabin, it seems too organic to build this with a polygon software like Solidworks. Instead, a t-spline software was used (Autodesk Alias Speedform). The benefit of the t-spline software is that the user is able to model in a sculpting way. To get used to this program some tutorials and exercises were done first.

Figure 93 shows the process of modeling the dynamic seat. The first two versions were built quite fast and then the second version was discussed with Martijn. Martijn explained that the transitions and linework in some parts were too complex and that it did not go well with the design of the cabin (which was build simultaneously). Examples are the armrest and the proportions in the side view between elements. So between the second and final version, a lot of design iterations were made within the CAD model to simplify the shapes and make it more coherent with the cabin design. Besides that, the second version had a backrest and seating pan which was based on the underlayer car seat model delivered by Martur (see appendix 22), but these dynamic seats should be more similar to an airplane or train seats because the driving posture found in car seats does not exist anymore. so a new backrest and seating pan were designed which was based on the latest research done about the ideal comfortable contour found while sitting (Hiemstra-van Mastricht, 2015). This paper compared ideal sitting positions of participants on vacuum bags and delivered several section views, but some sections were still missing.

A new research (Wang et al, 2018) released this year, used 52 cylinders to mimic a seat and the additional section views that resulted from this research was used. Using these sections made it possible to reduce the thickness found in current day car seats to 55mm (p5-p95 range, section views).

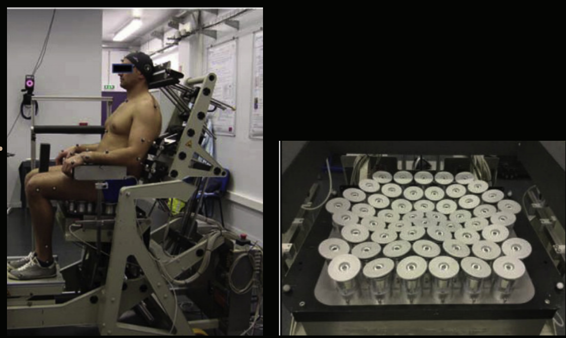


Figure 92: Using cylinders to find the ideal sitting contour (Wang et al, 2018)

To make sure that the dynamic seat could be used by everyone some check-ups were done (Dined) and corrected in the design:

- The front of the seating pan (in its standard position) was lowered to 375 mm heigh to accomondate for the p5 60+ female popliteal height.
- The headrest should have a moving range of 100 mm to accomondate for the height difference between a p5 60+ female and a P95 20 years old Dutch male when sitting.

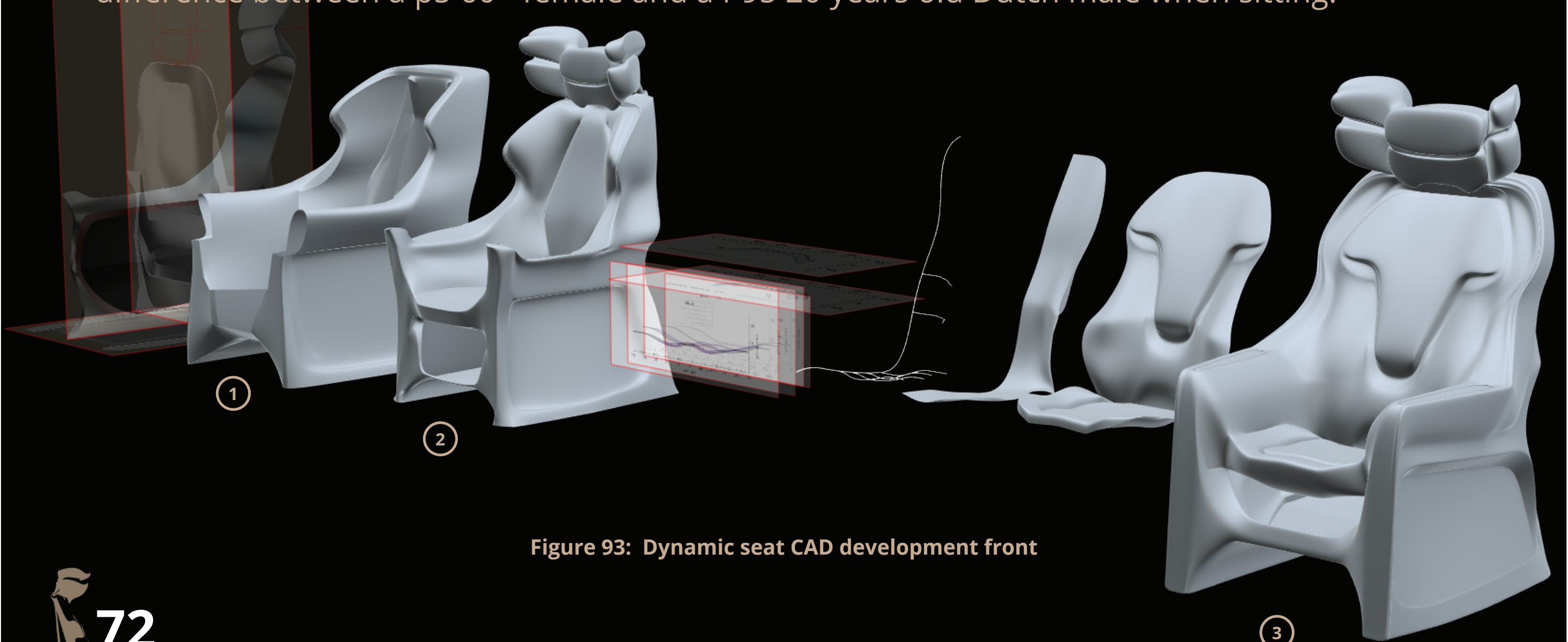


Figure 93: Dynamic seat CAD development front

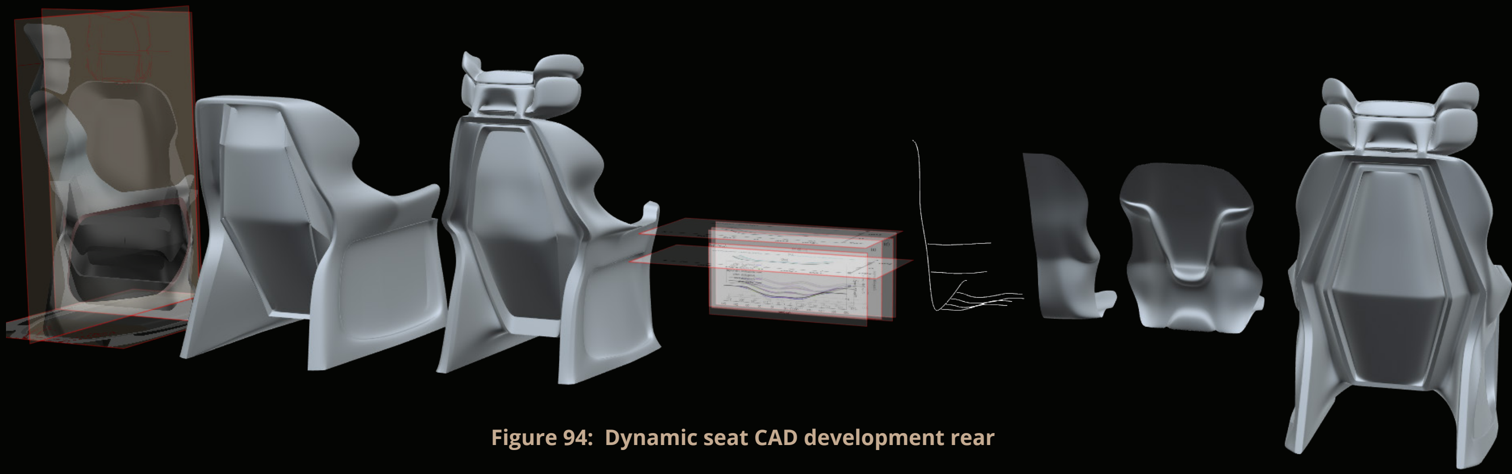


Figure 94: Dynamic seat CAD development rear

6.5 STYLING: CAD MODEL CABIN

While making the underlayer the following things found in H-point (Macey, 2009) and Dined were used as reference:

- After placing a P95 occupant in an 8-degree backrest angle, 102mm headroom should be added to accommodate the movability of the occupant in the cabin
- The current chair height, 340mm (which is based on chairs used at home to deliver a living room experience) belongs to the minivan, SUV category
- The height of the DLO (window line) has been chosen in such a way that a P5 60+ female can look outside while being in the relaxed posture (as looking outside is always important, see chapter 3)

Figure 95 shows the development of the cabin. The global surface was made quite fast but the detailing and space optimization was quite difficult. An example is the fact that shoes are placed in the door trim and that the swiveling of the dynamic seats took more space than expected (because of the armrest that it has) which takes a lot of space in the width. The cabin still holds it's original length and height but the width increased with 500mm to a width of approx 2.10 meters. While designing the additional parts (like the storage boxes and heightened surfaces a lot of indexing was used (parallel lines between elements or all lines moving to a certain point), this is done a lot in automotive design to keep everything more coherent. The next pages show renders of the final interior.

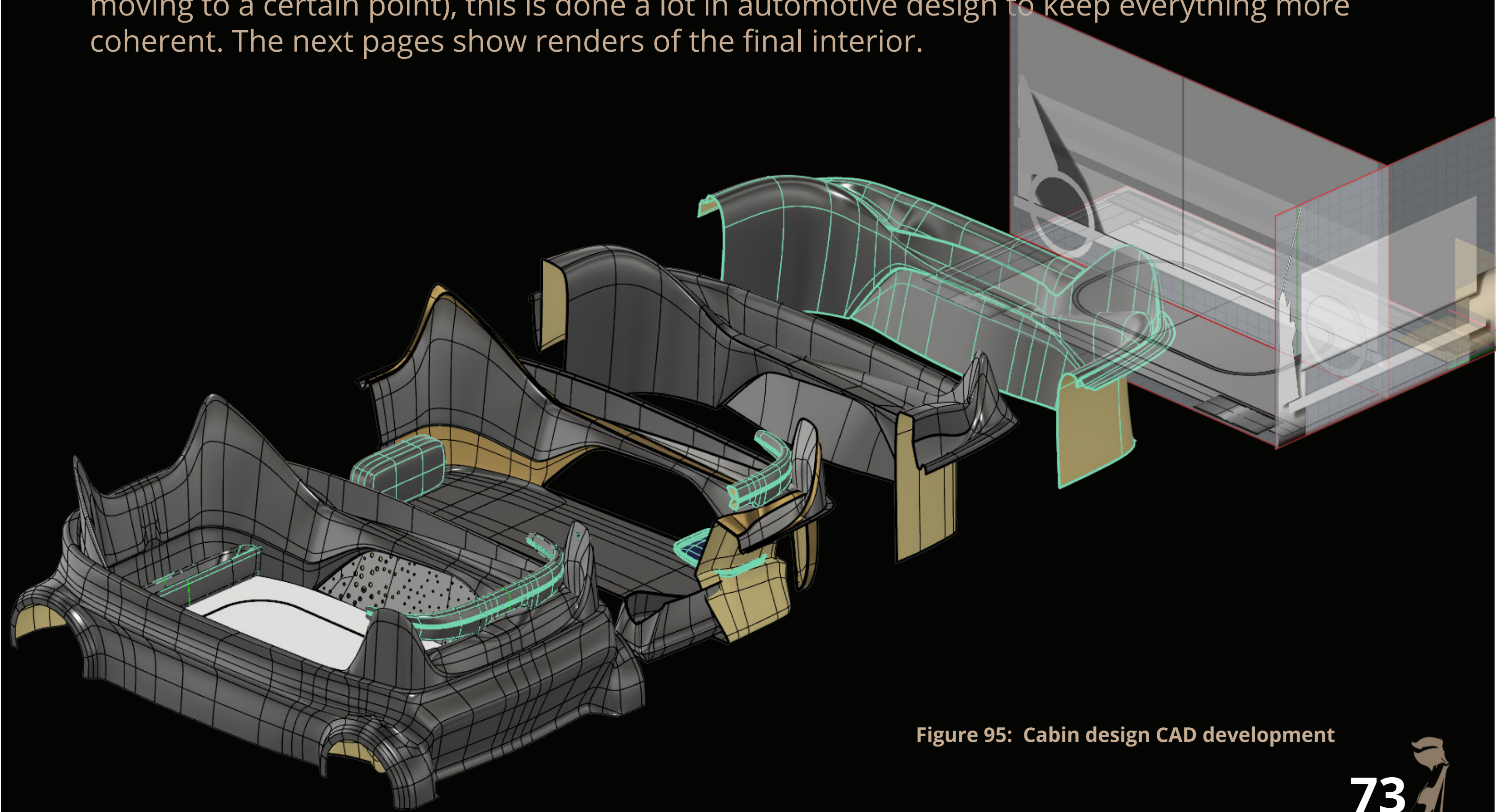
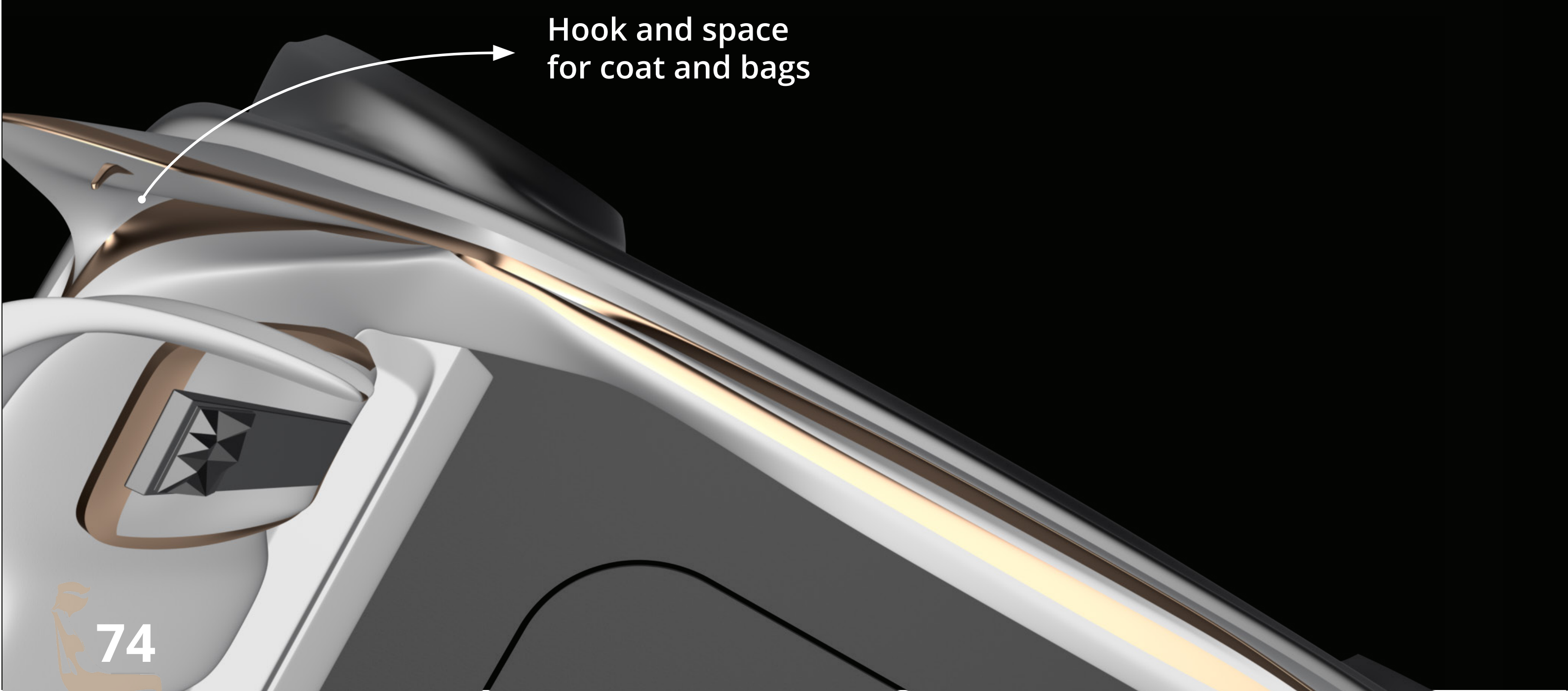
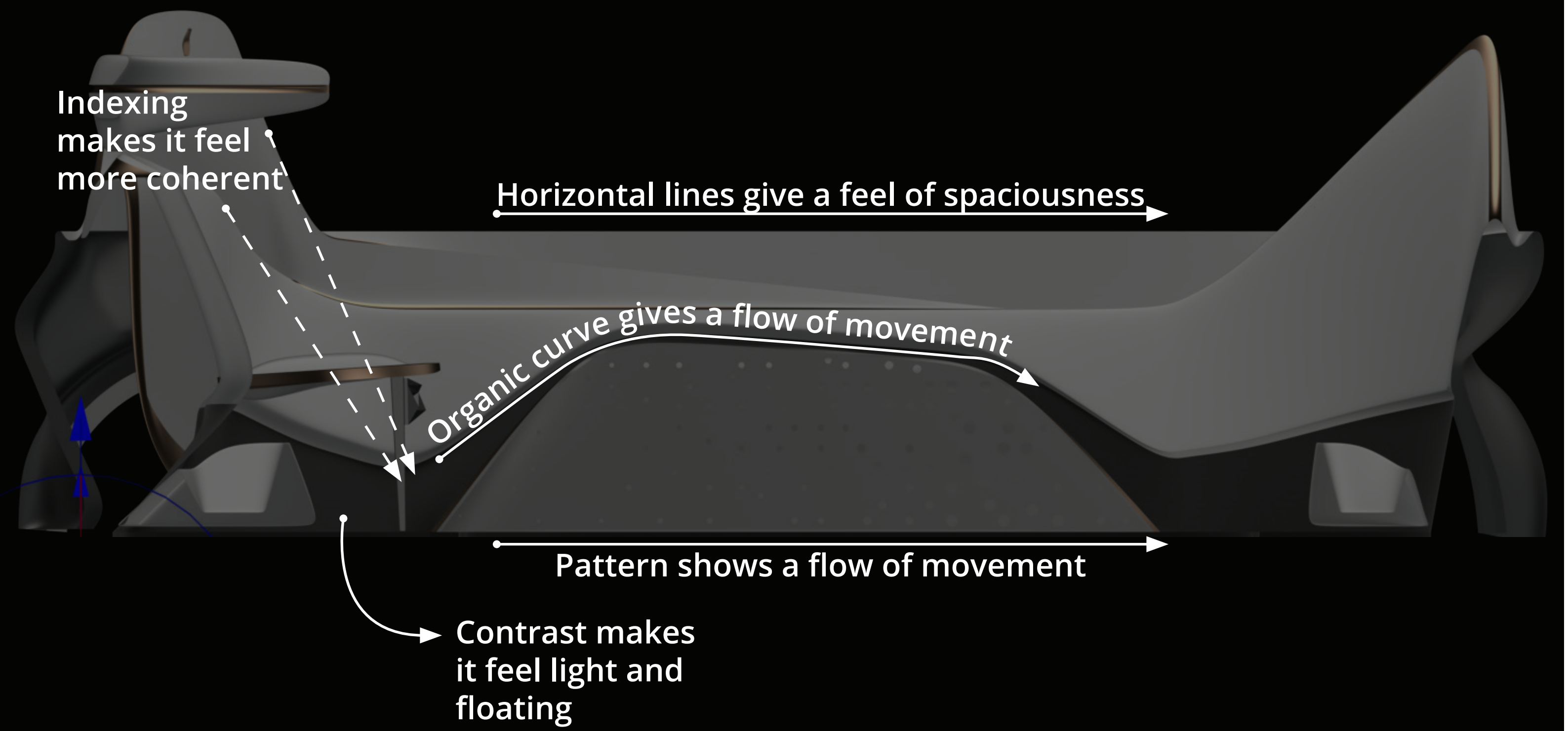


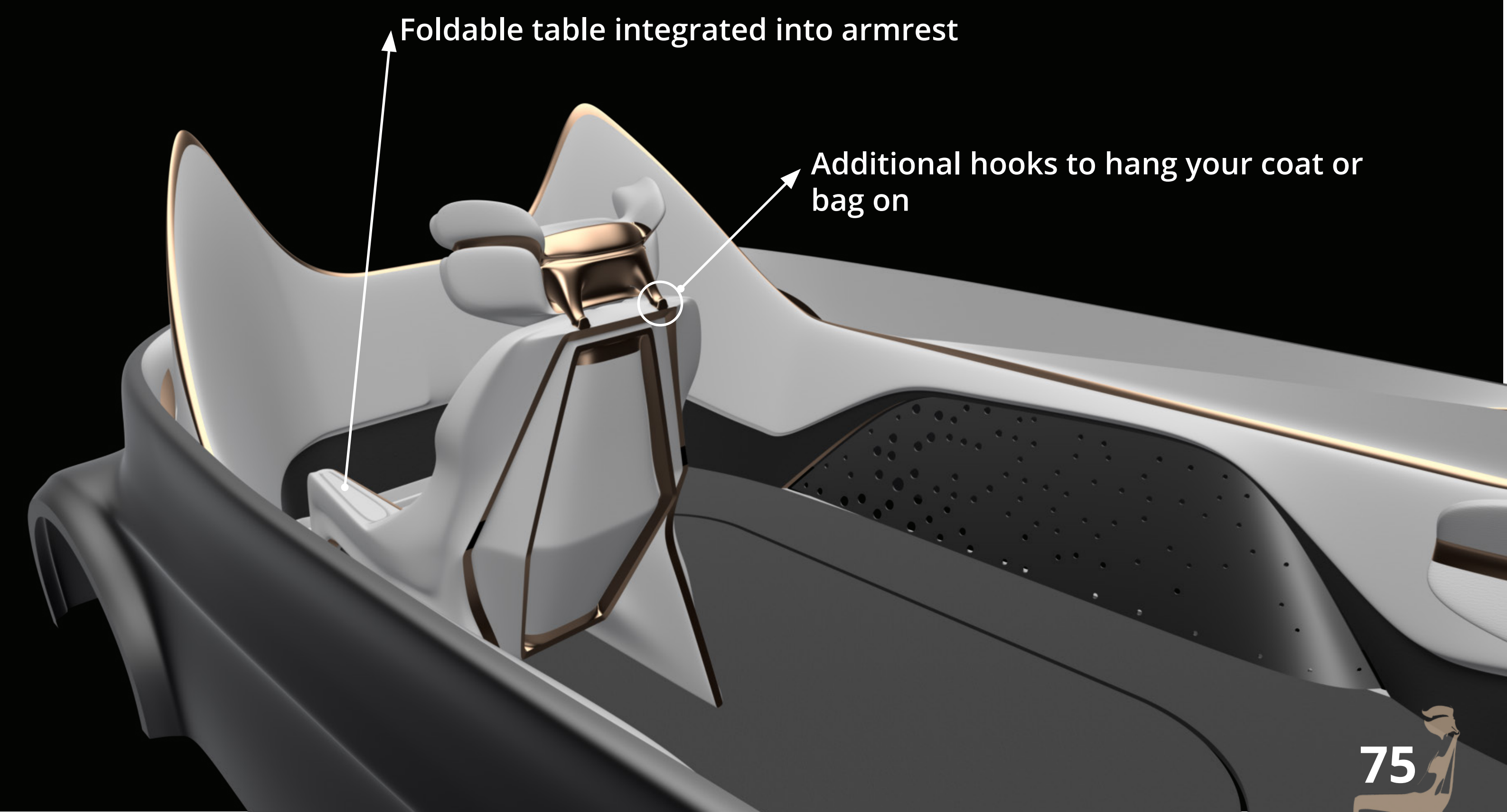
Figure 95: Cabin design CAD development

06 / STYLING

6.6 STYLING: PRESENTING THE INTERIOR




Indexing
makes it feel
more coherent
Horizontal lines give a feel of spaciousness
Organic curve gives a flow of movement
Pattern shows a flow of movement
Contrast makes
it feel light and
floating


Foldable table integrated into armrest
Additional hooks to hang your coat or
bag on

6.7 STYLING: RECOMMONDATIONS FOR DYNAMIC SEATS

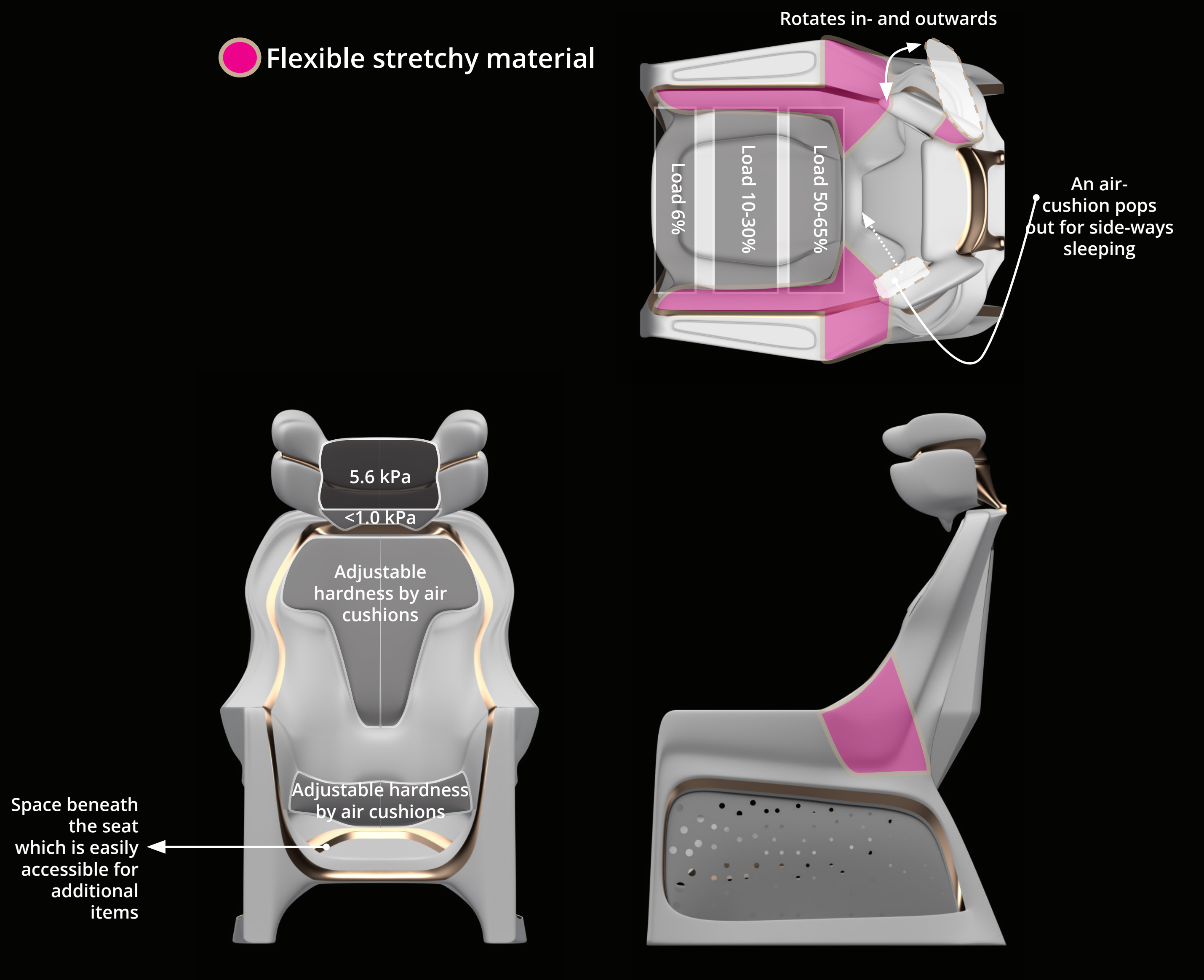


Figure 96: Recommondations for dynamic seat

To make this dynamic seat work, a flexible stretchy material should be used, which allows the backrest and seat pan to rotate while the design is still coherent. When occupants want to sleep side-ways, parts of the headrest can rotate in or outwards and air cushions within the headrest can deliver extra support. This headrest should at least use two foam hardnesses, 5.6 kPa for the head and less than 1.0 kPa for the neck support (Franz, 2012). Furthermore, in order to optimize comfort, the ideal load distribution of Zenk (Zenk,2012) should be used together with air-cushions that allow adjustable hardnesses in the shoulder area and the front of the seat pan (Lips, 2017).

For the foldable table a Origami table was build in Rhino with Grasshopper but the algorithm did not work. The table when both occupants are eating together and the TV projection have not been designed because of lack of time.

6.8 STYLING: FINAL SCENARIOS VISUALIZED

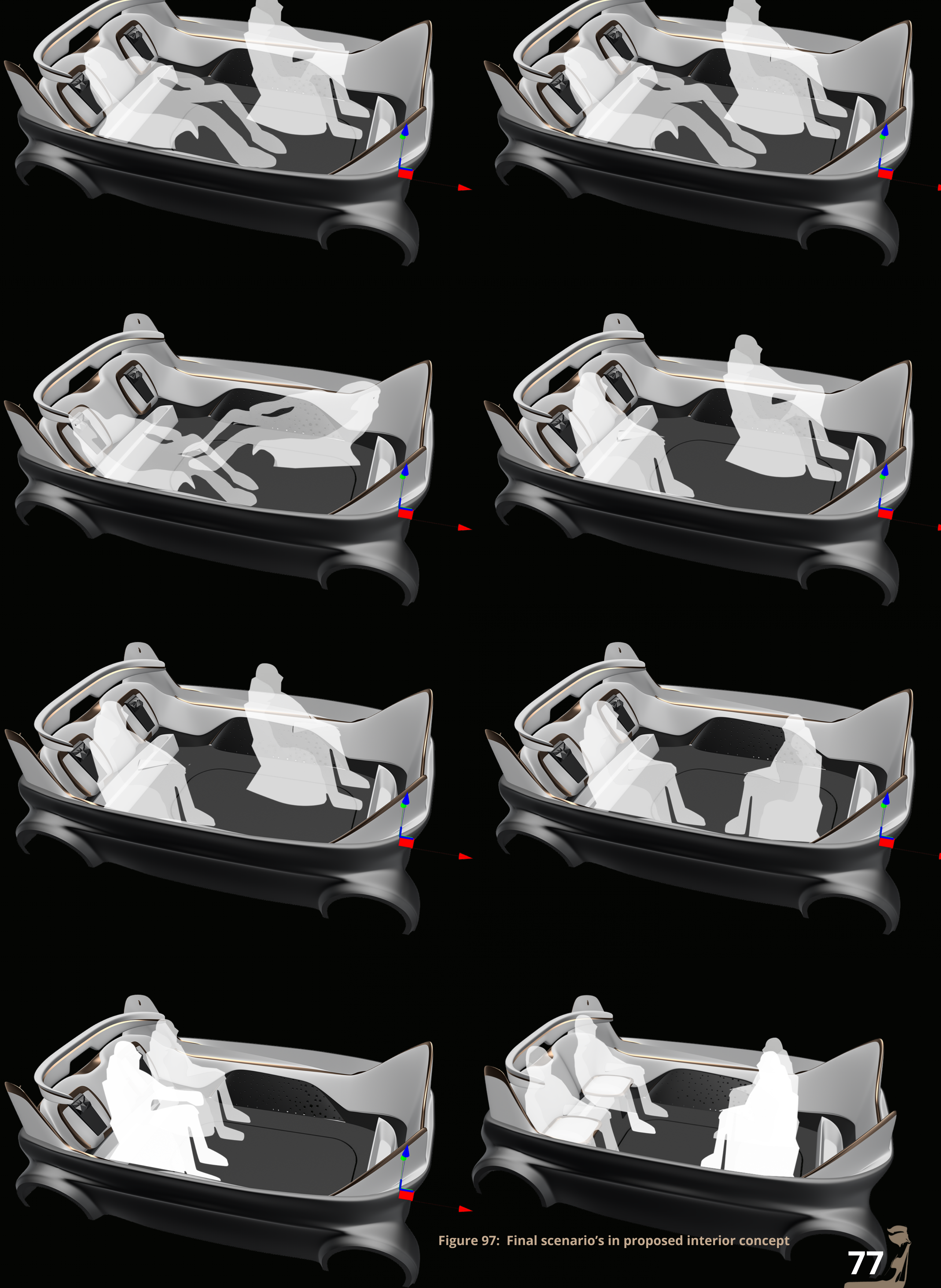


Figure 97: Final scenario's in proposed interior concept

07 / CONCLUSION

This project started with a question proposed by Martur: “How will the interior change when cars will drive themselves?” And this question could be answered in multiple ways. The future market analyses showed that all major OEMs already have a view regarding this and I proposed my own view. This view is based on designing inside out and it became clear that when cars have level 4+ autonomy, people desire to spend their time by doing activities like sleeping, eating, socializing, working, using in-car entertainment or being private. These activities have led to an experimental exploratory study in which new seating positions and SgRP Couple distances were discovered. All activities were possible by implementing a mechanical rail system that allows the dynamic seats to move in a rectangular path and swivel around their own origin. This mechanical system is based on professional equipment delivered by Rollon and others but should be tested in real life to see if it fulfills the safety requirements set by the industry.

Future autonomous cars do not have a clear target group so instead the choice was made to choose a brand as inspiration. Martur does not have a direct target group (they deliver to OEMs instead of individuals) so instead BMW was chosen as brand and the interior philosophy of BMW is used while designing the dynamic seats and the rest of the cabin. This philosophy is focused on a harmony between simple and complex shapes with details added at the right spots. Besides BMW, a lot of desk research was done into what makes a living room a living room. The reason for this is that there is a clear trend that shows that these new users want a shared vehicle to feel like their secondary living room. Chapter 5 researched the ‘stuff’ and rituals that people need and do, to make it feel like a living room and the right placement for them. These were additional input used for the final design. This final design should be tested together with the mechanical system to see if the seating positions found for the different activities are valid and if people want to make the effort to change between these positions when they want to do another activity.

08 / GENERAL RECOMMONDATIONS

Chapter 3: experimental exploratory study
This study was built on assumptions like that in-wheel motors will happen and that car suspension will take less space in the future to optimize the space available. This already is a big ‘if’ and influences the outcome of this interior proposal. Furthermore, the study had multiple preliminary surveys and an experiment conducted with 9 groups of two people. It was quite difficult to create 1 target group and search participants that reflect this target group. Instead, I have been asking students around the faculty and friends or family members to participate. So, an improvement to this whole study is to really select your participants for the target group that you are designing for (with the help of a budget). Besides this, the SgRP Couple distance was not measured during the study but later with top view videos, because I was doing the experiment alone and this would make the experiment even longer (thus participants would be less enthusiastic). When checking the top view videos, it became clear that there was still distortion, even if GoPro settings were put to linear so a advice would be to do this experiment with at least 2 researchers and measure the SgRP Couple Distances in real time. As last, this study was limited to a couple activities, while there are clearly more activities that people will perform while commuting in the future.

Chapter 5: conceptualizing the mechanism
A lot of conversations had taken place with Mesut, an engineer at Martur, to optimize the proposed mechanical rail system concept. As discussed before, I did not want to focus on this, but I needed to satisfy all stakeholders, so this took additional time in my project and left less time over for the actual design of the interior. After a lot of iterations, I proposed a concept which could be built with professional parts, but this concept still misses stuff like invertors (for the DC motor) and electronics. Beside this, space (in height) is not really optimized (1 motor vs. multiple motors could be researched) and the gear ratio between the rack and pinion is randomly chosen. Basically, the concept is there but it’s just a start. To make this concept more realistic, a small team of mechanical- and electrical engineers is needed who optimize this and build it.

Chapter 6: styling
While doing the ideation, no real measurement was tested to see if the proposed concept reflected the characteristics that I wanted to show (harmony between simplicity and complexity, details at the right places, etc.). So, if there was a bit more time in-between a user-group test could be done to see if people perceive the design the same way as I intended. Beside this, multiple CAD programs were used on two laptops and a PC to make all this possible while a little bit more research into CAD programs could have led me to Autodesk Fusion 360 which has everything SolidWorks, rhinoceros and speed form has. Using different programs led to not perfect alignment between the mechanical rail system and the interior (clearly seen in the 3d printed model) and this could be redone by a professional modeler. As last, not enough attention was given to parts like the big table, foldable table and the cushions and carpet found in chapter 5 were neglected in the final design because of the time limit.

So within my interior, I propose a concept in which people can change their sitting positions based on the activity they would like to do. There are at the moment 5 positions discovered but these should be revalidated to see if these are actually the best positions for the activity and to see if people really want to take the effort to even change their sitting positions while commuting. There might be a chance that people prefer to just stay in that one sitting position regardless of the activities they perform.

With ride-sharing a big question unanswered is how to keep everything clean and which materials to use. These topics were beyond the scope but should also be considered.

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