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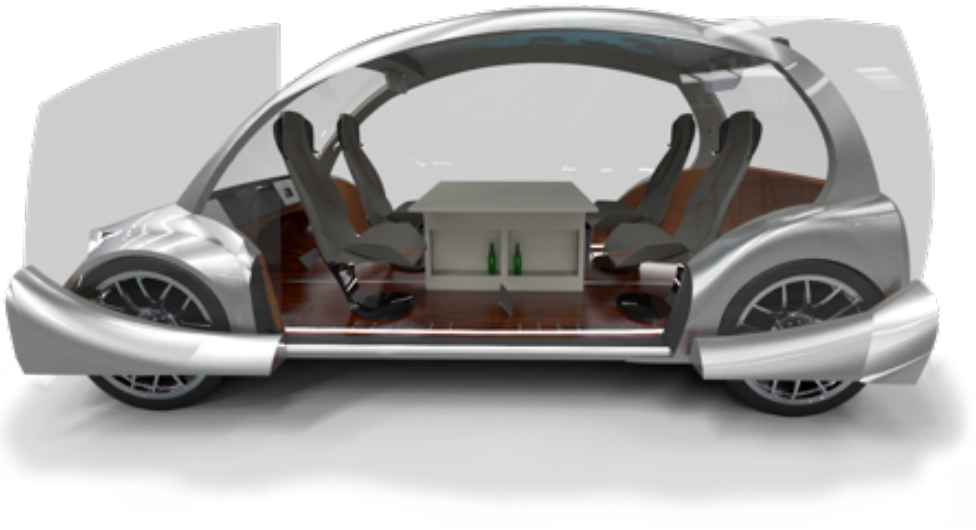

Designing for User Tasks in Shared Autonomous Cars

Development of an Interior Concept for an Autonomous Car in 2028

Master's Thesis in Product Development

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Department of Industrial and Materials Science
CHALMERS UNIVERSITY OF TECHNOLOGY
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MASTER'S THESIS 2019

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User Tasks in Autonomous Driving Vehicles
Designing the Interior of an Autonomous Car in 2028
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MAIK SCHOCKENHOFF

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Cover: Interior Concept of an Autonomous Car Designed for a Ridesharing Service.

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Abstract

This master thesis report is the result of a cooperation project between Chalmers University of Technology and CEVT (China Euro Vehicle Technology). The goal was to develop an interior concept for an autonomous car in 2028 based on user needs identified in the present. CEVT is an automotive company with headquarters in Gothenburg and fully owned by the Zhejiang Geely Holding Group. The group encompasses a range of renowned global car brands with different characteristics and audiences. The consumer car brands include Geely Auto, Lynk Co, Volvo Cars, Polestar, Proton and Lotus.

The type of car this paper is focused on is intended to be used for a ridesharing service in big metropolitan areas. The main use case of it is inner city commuting while it provides space for four passengers.

In this project, various systematic Lean Product Development tools were used in order to develop a final concept that addresses both European and Chinese users. These markets are defined by tasks which users would like to perform in ten years from now.

The first part of this thesis project encompassed and focused on user studies that mapped and defined potential user tasks in autonomous cars, so that the findings could be translated into requirements. These built the basis for the second stage of the project, namely the concept development phase.

The final concept is characterized by two different variations: A premium version and basic version. Both versions share the same exterior, which was designed to accommodate a fundamentally different interior compared to those of traditional cars. The major aspect that was attempted to be covered was flexibility, since the consumers' wishes differ not only between cultures but also between target groups and even seasons. The final vehicle concept was sketched and modelled in AutoDesk Alias AutoStudio 2018. The model was rendered with VRED AutoDesk and transferred into a virtual reality environment for a better visualization and evaluation of the concept.

Keywords: Autonomous Driving, User Study, User Tasks, Concept Car, Ridesharing, Virtual Reality, Chinese Culture.

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Thank you.

Alejandro Robles Díez & Maik Schockenhoff, Gothenburg, March 2019

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Abbreviations

ADAS	Advanced Driver-Assistance Systems
CEVT	China Euro Vehicle Technology
EV	Electric Vehicle
GCIE	Global Cars Manufacturers Information Exchange Group
HVAC	Heating, Ventilation and Air Conditioning
NHTSA	National Highway Traffic Safety Administration
NVH	Noise, Vibration and Harshness
OEM	Original Equipment Manufacturer
VR	Virtual Reality

1

Introduction

1.1 Background

The race to provide autonomously driven vehicles has begun and will completely change the way vehicles are perceived and used in the future. Today the user tasks are almost entirely centred on driving, but what will cars look like, when driving is no longer the primary user task? In order to investigate this question, this master thesis project was carried out in cooperation with CEVT (China Euro Vehicle Technology), a highly ambitious, Gothenburg based joint research and development centre. *Figure 1.1* shows CEVT's role within the Zhejiang Geely Holding Group in which it acts as an in-house consultancy firm. The group includes a wide range of renowned global car brands with different characteristics and target groups. The consumer car brands include Geely Auto, Lynk & Co, Volvo Cars, Polestar, Proton and Lotus. Commercial vehicle brands include London Electric Vehicle Company (previously known as London Taxi) and YuanCheng Auto. CEVT supports these brands in the development of cutting edge technologies that will address future market needs.

Figure 1.1: CEVT's Role within the Zhejiang Geely Holding Group

The vision of CEVT is to "redefine automotive engineering for a different tomorrow" and to fulfill this, it is crucial to understand and predict future user needs and behaviours in the context of car use. It takes several years to develop a car but fundamental structures as well as a new way of thinking which allow new forms of user experiences in future vehicles need to be initialized already today.

1.2 Autonomous Driving

"Fully autonomous cars and trucks that drive us instead of us driving them will become a reality" according to the National Highway Traffic Safety Administration (2018). Fully automated vehicles are about to circulate on public roads in the near future and several car manufacturers have already entered the automotive market with the release of their highly automated vehicles (Strömberg et al., 2017). More than 40 companies were working on autonomous vehicles in 2018, including OEMs like Toyota, Volkswagen, Hyundai/KIA, General Motors or Tesla (CB Insights, 2018). In order to be prepared for the future and to continue producing competitive cars, these companies have established the goal of implementing autonomous driving technologies and developments of new concepts are already on their to-do lists.

The various kinds of autonomous driving technologies have been defined by the National Highway Traffic Safety Administration (NHTSA) by diving them into six levels for automated driving systems, ranging from complete driver control to full autonomy. This scale is outlined in the SAE International's J3016 document (see *Figure 1.2*).

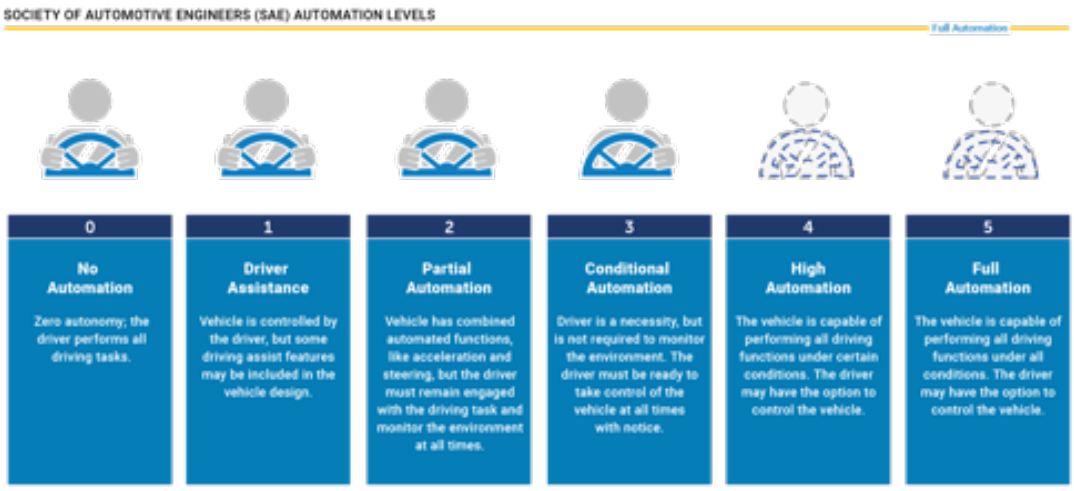


Figure 1.2: Automation Levels as Defined by the National Highway Traffic Safety Administration (2018)

Autonomous driving technologies will bring benefits of improved convenience for the user and opportunities to pursue other activities than driving, but it will especially have a significant impact on safety for both the vehicle occupants and other traffic participant. According to the National Highway Traffic Safety Administration (2018) 94% of serious crashes are caused by human errors. It is expected that the implementation of fully automated vehicles where the user no longer has to interfere in the driving system will reduce the total number of crashes significantly. As stated by the National Highway Traffic Safety Administration (2018):

"Automated vehicles have the potential to remove human error from the crash equation, which will help protect drivers and passengers, as well as bicyclists and pedestrians". A noticeable decrease of crashes will also lead to significant economic and societal benefits. For instance, in 2010 motor vehicle crashes cost $ 242 billion, including $ 57.6 billion in lost workplace productivity, and $ 594 billion due to loss of life and decreased quality of life due to injuries (National Highway Traffic Safety Administration, 2018). Therefore, reducing the number of motor crashes will not only save lives and prevent injuries but also help to lower these costs.

Apart from increased safety and convenience, autonomous vehicles entail many other potential benefits, like e.g. lower fuel/energy consumption and CO_2 emissions due to optimized utilization of cars and interconnected traffic systems (Maurer et al., 2016). Automated vehicles circulating on the roads could lead to a smoother traffic flow and thus reduce traffic congestion (Gruel and Stanford, 2016). According to a recent study conducted by the National Highway Traffic Safety Administration (2018), automated vehicles could liberate as much as 50 minutes each day that were previously dedicated to driving. Instead, the commuting time saved daily could be used to leave work early or live farther away (Gruel and Stanford, 2016).

New mobility options can also be provided by automated vehicles, resulting in increased mobility and flexibility for many people. For instance, users who have some form of disability could benefit from the new automated ways of mobility. In addition, implementing AD will enable users with lack of driver licenses to use the mobility service and move around more independently (Chan, 2017).

Furthermore, the convenience for the users and society in general cannot only be improved by releasing one of the driving tasks and giving the occupants the change to focus on other activities during the ride. Scenarios in which the vehicle moves around without any occupants could also have positive effects. Automated valet parking, vehicle on demand services as well as the transportation of goods are just some examples (Maurer et al., 2016).

1.3 Aim

Since autonomous driving is assumed to completely change our idea and perception of what vehicles are and how we use them, it is essential to try to reach an understanding of how user needs and behaviours might change given such a scenario, what activities users potentially want to perform, which activities can be triggered and promoted, as well as how these activities can be enabled by the interior design of the car. Hence, this thesis project was not driven by the idea to develop a fancy-looking, technology-driven concept but focused on following a user-centered design approach in order to develop an innovative and well-founded concept based on extensive user studies in which profound methods and tools were utilized.

The expected outcome of the thesis project was a concept for the interior of an autonomous car visualized in form of a digital model and depending on its nature and limitation, it was also supposed to be tested in form of a physical mock-up or role play (staging) in order to proof its functionality and validity. However, a fully functional prototype or the like was not within the scope of the project.

With the intention of reaching this aim the thesis project addressed the following research questions which divided the project work into several work packages:

- **RQ1 - What methods are suitable to investigate user behaviours and requirements in future scenarios?**
  In order to develop innovative concepts that satisfy user needs and behavioural patterns in future scenarios, it is essential to select appropriate methods that help to predict these. Since the context of use is about ten years in the future it had to be determined how participants of the study can be enabled to envision this scenario, how relevant reactions could be triggered, and what kind of mediating tools could be used to enhance reflection and discussion among the participants.
- **RQ2 - What kind of activities would future users like to perform in an autonomously driven car?**
  To create the best possible foundation for developing an innovative and future-oriented solution, future users' needs, behaviours, and requirements had to be investigated, analyzed and understood. With the aid of the previously investigated methods, user studies had to be designed in order to determine what activities users in future scenarios, where they no longer have to drive the car themselves, would like to perform in the car.
- **RQ3 - What is needed in terms of interior design and features in the car to enable these user activities?**
  After mapping future user needs, it had to be determined how the desired activities can be enabled by the interior design of the car. In this context, it was also of great significance to take the needs and preferences of many different types of users into consideration in order to develop an as universal solution as possible that can be modularized and which can attract a wide range of potential customers.

1.4 Limitations

Due to the future-oriented character of this master thesis project as well as interactions with further developments within the automotive industry (e.g. electromobility, connected mobility, carsharing etc.) the development effort could have taken numerous different paths. It was therefore all the more important to define the scope and limitations of the project.

The definition of the project's scope was not a onetime act but rather a continuous development throughout the project. While some requirements and limitations were set from the beginning others have been constantly questioned, reevaluated and developed until halfway into the user study. The most relevant guiding

parameters are depicted in *Figure 1.3*.

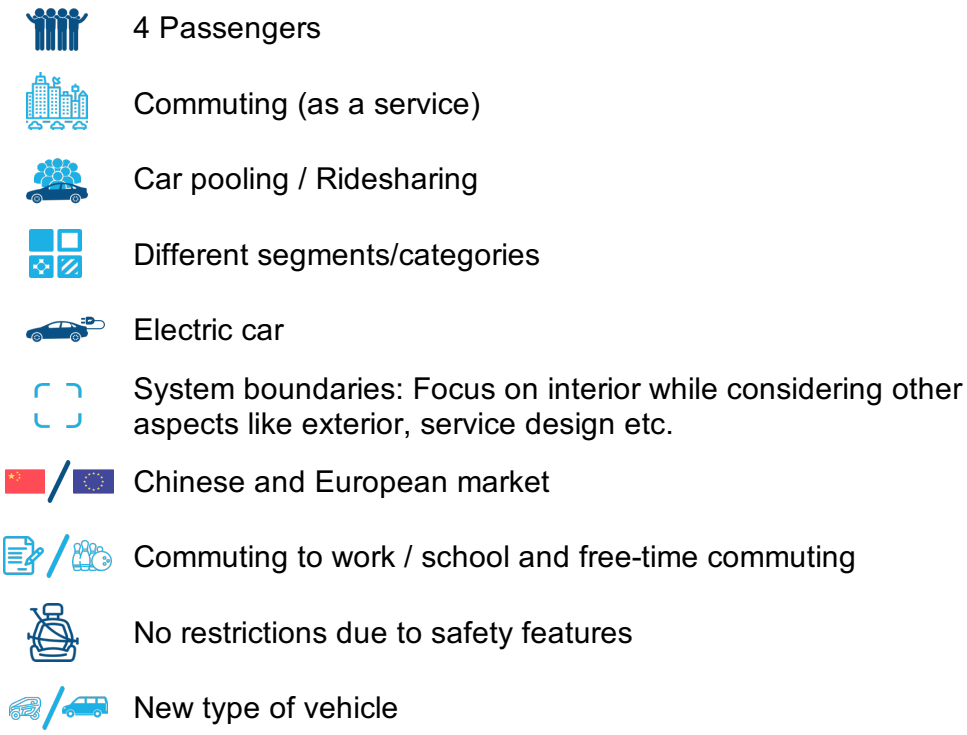


Figure 1.3: Key Parameters of the Project Scope

The car concept focused on urban commuting since all the experts that have been interviewed for this thesis project agreed that this is the area in which autonomous driving technologies will benefit users and society the most (see *Section 3.3.1*). Commutes to work/school and free-time commutes, such as grocery shopping, going to the gym or simply meeting friends in another part of the city, have been identified as use cases. Furthermore, the concept was designed to be used as part of a ridesharing service since the experts expected that the desire for owning a car will decrease significantly in the future and that many users will prefer to spare costs and obligations of owning and maintaining a car.

In order to be able to plan the user studies it was important to set a target for the number of passengers that would share the interior space. Hence, it was determined to develop an interior concept which could accommodate a maximum of four passengers since a larger number of passengers would complicate the ridesharing aspects. The more users share the car the more difficult it would become to plan and predict routes and arrival times to the desired location of each user. A smaller number of passengers, however, would decrease the energy efficiency and lead to a bigger environmental impact per passenger.

For similar reasons, it was decided that the car will be powered electrically. Electric vehicles are seen as a solution to many major energy, environmental, and economic problems facing society today (Muneer et al., 2017). Moreover, the

simplified platform structure of EVs without a drive shaft but with a completely even surface provides more design freedom and enables a better use of the interior vehicle compartment. In addition, the exterior of a car defines the shape and appearance of the interior to a great extent. Therefore, it was determined that the new interior concept could not simply be placed into an existing car exterior and hence would require a new type of vehicle. While the focus remained on the interior, aspects like the exterior design or the design of the ridesharing service also had to be taken into account.

Both Chinese and European markets were targeted for the project, since CEVT develops technologies for both of them and therefore takes a great interest in possible differences and similarities between these cultures.

Last, existing safety restrictions were not considered during the project because their development in the context of autonomous driving is difficult to predict and would only limit the design outcome.

1.5 Process

The project work was performed in an agile way of working, including several interactions and loops. Furthermore, the development process is inspired by a Lean Product Development approach, i.e. spending comparably much time on the user study and concept generation phases in order to gain as much knowledge as possible in the earlier stages of development and develop well-founded and highly promising concepts.

The project's process, which is illustrated in *Figure 1.4*, can be divided into three major phases with three expected outcomes.

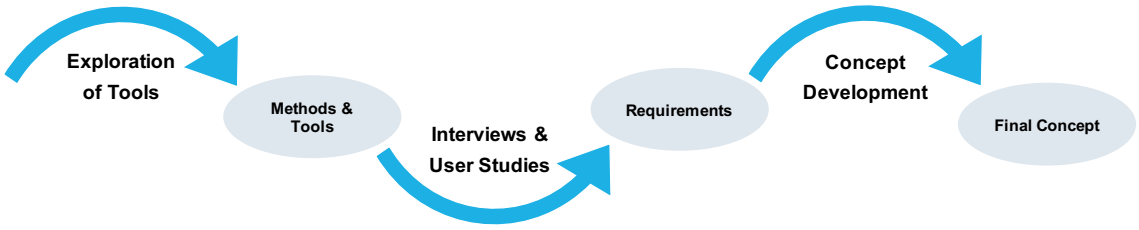


Figure 1.4: Illustration of the Process

The project started with an *Exploration of Tools* in which suitable methods and tools for the investigation of user behaviours and demands were identified and evaluated (*Chapter 2*). The selected methods and tools were then combined to design user studies and interview guides so that *Expert Interviews* and *User Studies* could be conducted (*Chapters 3 & 4*). The different investigations yielded a wide range of *Requirements* related to functions, design aspects, usability etc. (*Chapter 5*). These requirements could subsequently be utilized during the *Concept Development* phase, assuring that the concept addresses the user needs

identified before (*Chapter 6*). The result of the concept development phase and the process in general was the *Final Concept* which would enable future users to pursue various activities they would like to perform in an autonomously driven car (*Chapter 7*).

In terms of time management, it can be stated that the available time for this thesis project was divided equally between tool exploration and user studies on the one hand, and the concept development phase on the other hand. A detailed time plan created at the beginning of the project can be found in *Appendix A*.

2

Exploration of Tools

As a first step in the design of the user study an investigation of suitable tools had to be conducted. This built the foundation of the entire data collection and also addressed the first research question stated in *Chapter 1*: *What methods are suitable to investigate user behaviours and demands in future scenarios?* The investigation of methods and tools was of particular interest for the company since a specific need exists for knowledge regarding how such data can be collected.

2.1 Aim

The aim of this exploration phase consisted of two major parts. First, to investigate what kind of tools and methods can be used to identify user needs and behaviours and second, to screen these and select the most suitable ones for this master thesis project. However, it was important that those tools that were chosen complemented each other in a certain way so that the mentioned research question could be examined from a multitude of different angles, resulting in a comprehensive picture of what activities users would possibly like to perform in a shared autonomous car.

2.2 Method

The various tools that were regarded to be promising in the context of this thesis project have been found by literature studies and online research. For the literature studies Chalmers Library's search engine has been used since it gives access to a wide variety of articles, E-books, printed books, E-journals, and databases. For the online research Google has been the preferred search engine.

Keywords for the exploration of tools were mainly related to the research field of user behaviour and human centered design. Some words and terms utilized were user needs, user experience, user-centered design, interaction design, design research methods, usability, and future workshop. Furthermore, studies about user research related to the particular field of autonomous driving could be identified by adding keywords like automotive, autonomous driving, cars, vehicles, transportation etc.

2.3 Results

The search yielded a number of various potential tools. The most promising ones in context of this project are presented and explained in the following *Sections 2.3.1 - 2.3.9*.

2.3.1 Analogous Inspiration

The *Analogous Inspiration* is an interview method developed by IDEO (2018). The underlying idea is to shift the focus of the interview to completely new but still comparable contexts. This is done in order to broaden the horizon of the topic at hand and to avoid any form of biases that the interview participants might have with respect to the matter of conversation.

In the context of this master thesis project it could mean that one does not make the car the main issue of the conversation but rather shifts the context to travelling and commuting with other means of (public) transport. Moreover, it can be addressed how the interviewees behave in public areas or how they spend their free time.

2.3.2 Collage

The *Collage* is a widely spread tool that is utilized in many user studies within all kinds of areas. According to IDEO (2018) it is a simple way to encourage people to create something tangible that can afterwards be used to explain and demonstrate specific aspects of the issue. However, not only the result is of importance but also the design process itself since a participant's approach to it might also reveal something about their values and thought processes.

The kind of pictures and their type play a key role. In general, there are two ways of providing materials for the people that create the collages. First the pictures could be digital, which would imply giving them access to either a previously prepared library of pictures or to an online image search engine. The other option is to provide analogue materials in form of catalogues, magazines, or a collection of pictures that have been selected beforehand.

The digital version has the advantage that the selection of images is very easy and convenient for the participants since they do not have to cut them out of magazines and the like. Further, depending on the application of this method, the design process of the collages could even be done online which would in turn mean that a huge number of people could be reached. On the downside, the use of digital images might require specific software and is not as intuitive as simply working with scissors and paper.

The main advantage of the analogue version is that the assembly of the collage is extremely easy and can be done by anyone that is able to use scissors and glue

sticks. On the other hand, each of the provided pictures in catalogues etc. can only be used once and the type of magazines can have a significant influence on the results.

Some images of items that could be useful in the context of an autonomous car interior are:

- Luggage (backpacks, messenger bags, handbags etc.)
- Smartphones
- Coffee cups
- Screens (TVs, monitors etc.)
- Speakers
- Lights
- Seating/resting options (seats, couches, hammocks etc.)

One study that has been conducted with the context of autonomous driving and could be taken as a reference is described by Pettersson and Karlsson (2015). In this study images of currently existing car models, concepts, and cityscapes were used to stimulate the participants' fantasy and to enable them to express their vision of autonomous driving in terms of values, worries, activities and expected design changes.

2.3.3 Conversation Starter

Conversation Starter is practically just another name for mediating tools. They act as a stimulus and are used as part of an interview to get the conversation going and spark reactions (IDEO, 2018). The purpose is to enhance reflection and discussion in an interview.

In the context of the present study conversation starters could e.g. be pictures of already existing concepts for autonomous cars or of situations, objects etc. related to commuting and travelling in general (e.g. vehicles, bus/train stop, airport, parking lot etc.)

2.3.4 Draw It

Draw It is not more than another term for a pretty straight-forward approach during an interview: Providing pen and paper and encouraging the interviewee to visualize his or her thoughts and ideas by sketching them.

Sometimes it can be helpful to give the interviewee some concrete hints of what kind of drawings are expected of him or her (IDEO, 2018). Moreover, some people might feel uncomfortable or intimidated to draw something since their sketching skills might be rather limited. In that case one can break the ice by sketching something very simple to demonstrate that no piece of art is expected in this situation.

2.3.5 Future Workshop

The *Future Workshop* is a method developed by Vavoula and Sharples (2007) that is used to help workshop participants to visualize and design the interactions between present and future technology and activity. The general intention is to shift the participants' focus from current problems to imagining alternative solutions by creative thinking.

A future workshop with a number of groups consists of several major steps. First the participants are made familiar with the future scenario and relevant aspects and terms related to the topic. Then, a discussion among the group members follows to get the participants on equal footing and ensure that they are all discussing the same issues. Once the overall topic is clarified, groups are formed and given specific scenarios for which they are supposed to come up with a solution. The groups then design various concepts that would be suitable to address the issue at hand. Finally, all participants come together again in order to discuss functions and attributes the different groups have chosen for the concepts and to compare and contrast them between common scenarios.

A study that has utilized this *Future Workshop* method and could be adopted in similar fashion is described by Gkouskos et al. (2014). The intention of the study was to enable the participants to suggest designs for future vehicles and characteristics of future vehicles and is therefore similar to one of the main goals of this project.

2.3.6 Lego

Lego is similar to the tool *Draw It*, an aid to visualize and express ideas and thoughts. In this case the participants use LEGO's interlocking plastic bricks to build simple 3D mock-ups as mentioned by Pettersson and Ju (2017). In comparison to the sketching method, participants are usually less reluctant to use the blocks since they do not have to create something from scratch and just have to assemble their idea. On the other hand, the creations are limited by the amount of variation of building blocks provided.

2.3.7 Photo Journal

The *Photo Journal* tools as described by IDEO (2018) consists of asking participants to document their thoughts, feelings, behaviours etc. in certain situations or while doing previously defined things in their everyday life for about a week before they are interviewed. This documentation however is not necessarily limited to photos but could also consist or be complemented by voice recordings, notes, sketches etc. The idea behind this is to sensitize the participants with respect to details that might be relevant for the issue under investigation. Furthermore, the volunteers come prepared to the actual interview so that the discussion is less spontaneous and aspects can be discussed in much greater detail.

In the context of this master thesis project, participants could be asked to document their daily commutes to work or school and note down their thoughts as well as what they are doing meanwhile. Further, it should be stressed that they also have to actively think about what else they might want to do in these situation and what they might not be able to do due to the lack of respective means or the like.

The participants are therefore supposed to experience and realize, themselves, what their daily commuting routine is like and how their ideal commuting concept might look like before they are interviewed with respeect to these topics.

2.3.8 Role Play

The method *Role Play* as described by IDEO (2018), also known under other names like e.g. *Staging* as referred to by Pettersson and Ju (2017) is used to facilitate the participants' imagination by actually putting them into an extremely simplified situation of the future scenario.

The participants are usually prepared by first asking them about their current daily routines and then introducing them to the future scenario and its characteristics. Afterwards they are encourage to envision this scenario and act it out in order for researchers to observe their behaviour and to discuss their thoughts and ideas with them.

For the present project participants could first be questioned about their current daily commutes and after being introduced to the autonomous driving theme a role play could be conducted to determine what kind of tasks they would like to perform in an autonomous car in the future.

2.3.9 Story of Evolution

Another tool that can be used to facilitate the explanation of a technology and to spark the imagination of participants is the so called *Story of Evolution*. As part of this tool the participants are informed about the history and possible future developments of a certain object of investigation with the aid of a time line and by highlighting innovations and breakthroughs. This way a feeling for innovation and developments in the respective field can be conveyed which will make it easier for the interviewees to talk about it and bring in own ideas.

In the context of this master thesis project, a time line, as presented in *Figure 2.1*, could be used to illustrate the various steps in which autonomous driving features have been developed in the past and what developments are expected for the future.

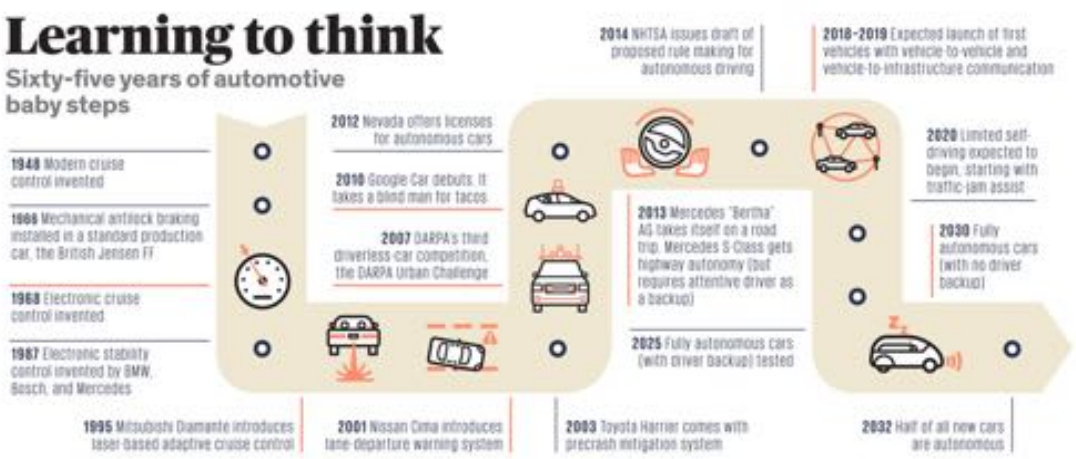


Figure 2.1: Evolution of Autonomous Driving Features acc. to Kurzweil Network (2015)

2.4 Selection of Tools

After the identification of tools that could be used to perform a user study, a selection had to be made in order to identify the most appropriate ones for this specific research effort. There were mainly three factors that determined the tool selection: The expected outcome, the complexity, and the expected effort.

The expected outcome is perhaps the most important evaluation criteria since a method is only as good as the results that it can possibly yield. Therefore, it had to be determined what kind of results could be obtained by the application of a specific tool (e.g. qualitative vs. quantitative), how reliable or representative they might be, and if they were relevant at all for answering the research questions.

The level of complexity regarding a tool is another significant factor. Some tools might require a certain level of expertise for the definition of procedure and tool execution while others are more straight-forward and can be implemented and used effortlessly. Complexity also depends on the perspective. A survey e.g. is seen as something quite simple by a participant since it often only takes a few minutes to fill in and for most questions it is just checking some boxes. However, for the researcher that is preparing and designing the survey it is an immense amount of work. Every question has to be phrased cautiously and it can be difficult to determine the ideal survey length. On the one hand, a long survey provides more data and insights but on the other hand, it can not only increases the number of non-responses but also affect the data quality since participants might not give much thought to answering the questions anymore if it is taking to long and they just want to get it over with. This has to be taken into account when rating a tool with respect to complexity. A tool that looks simple at a first glance might actually be pretty hard to master.

Last but not least the effort that a certain tool is expected to entail is also a decisive factor with respect to the scope and allocated time for the study. This effort might correlate with the previously mentioned complexity but also has other dimensions. A tool can e.g. be very simple to execute on the one hand, but require a tremendous amount of material preparation and planning on the other hand. Moreover, methods for quantitative data collection can deliver precise numerical estimates but they usually require a high number of study participants in order to produce reliable and statistically valid results.

Another evaluation criteria that is not applied to each individual method but certainly has to be considered, is the extent to which tools can be combined. Some tools might work better together than others and create synergies that can eventually make them superior to an outstanding but non-combinable, standalone tool.

After a qualitative assessment of the tools and assessing their pros and cons, those depicted in *Figure 2.2* were eventually selected and found to be the most promising ones for the intended user study due to their strengths and compatibility. How they were combined to actual studies is described in *Chapter 4*.

Tool	Advantages	Disadvantages
Analogous Inspiration	• broadens the perspective • might yield a lot of information about more subtle, secondary factors of influence • avoid any form of biases that the participants might have	• it is not assured that results can be transferred to the main investigation
Collage	• can easily be performed by participants • participants can mediate and explain ideas better • more interactive than an inquiry	• selection of materials can influence outcome
Draw it	• easy way to visualize thoughts and ideas • can easily be combined with most other tools	• participants might feel uncomfortable due to lack of sketching skills
Role Play	• closest to the actual situation in the future • can give insights about non-obvious user needs, behaviours etc. that participants might not be able to put into words themselves	• requires a lot of preparation • very time intensive with respect to execution and analysis

Figure 2.2: Selected Tools

3
Expert Interviews

Expert interviews built the base of the entire investigation. Not only have experts deep knowledge about a particular aspect of the topic but they are also often able to put certain developments, discoveries etc. into context. Therefore, experts have been consulted in order to get an overview of related topics and collect comprehensive data.

3.1 Aim

While study participants might provide unfiltered, first-hand information, experts can usually help to understand the bigger picture and give advice regarding what to focus on. Furthermore, based on their experience they are often able to formulate possible future developments and where current trends might lead which is of high value especially for this project. Therefore, it was decided to interview several experts in order to benefit from their knowledge and obtain guidance for the project development.

3.2 Method

The quality of the results depends mainly on two aspects: The selection of participants, i.e. what information they are able to provide and the quality of questions and in which way they are posed. However, what one makes out of the received information is just as important, which means that the analysis approach also has to be emphasized. All three facets are presented in the following.

3.2.1 Participants

In order to get a comprehensive picture of a topic, it is crucial to interview various experts from different fields and with different specializations. Therefore, nine professionals from both industry and research were interviewed to investigate their view on potential user tasks and behaviours in vehicles as well as autonomous driving. From the field of academic research, a researcher within interaction design and with focus on automotive user experiences as well as a researcher of future mobility were selected for interviews. For insights from the industry, interviews were conducted with three vehicle interior designers, two Tesla dealers, and an expert within safety regulations. In addition, another employee with an extremely interesting background with respect to the project was interviewed. He

lived for four years in China, worked there as a teacher and director of studies, was married to a Chinese woman and still has a lot of connections there. In respect of the focus on the Chinese and European market, he seemed to be the perfect person to provide insights from and comparisons between the two worlds.

3.2.2 Data Collection

The interviews were all conducted in calm and neutral settings; in most cases in small meeting rooms at the interviewee's workplace. Moreover, each interview was recorded to allow an unimpeded focus on what the interviewee had to say and to enable a smooth flow of questioning. Furthermore, all expert interviews were prepared and conducted as semi-structured interviews, i.e. interview guides with specific questions were prepared beforehand to guarantee that certain topics were covered while the conduction itself was characterized by a certain degree of flexibility and adaptability in form of changes of order, follow-up questions on what the interviewee had to tell etc.

To obtain different thoughts and perspectives on the overall topic, a basic set of questions had been prepared and posed to all interviewees. Some of these questions were:

Field 1: Autonomous Cars

- What do you think are the biggest problems regarding travelling and commuting with cars nowadays?
- What is the biggest social benefit that you see in a driverless metropolitan city?
- Do you think existing released concepts of autonomous cars from different companies address the future needs and requirements of the user?

Field 2: User Tasks in Autonomous Cars

- From your experience: What do most people expect to be able to do in an autonomous car?
- Can you describe your personal vision of what it might be like to use a car in 2030?
- Are there significant differences in user tasks with respect to how much time the user spends in the vehicle?
- Have you considered possible differences between various cultures (European vs. Chinese) in your daily work? How do you address these issues in your projects?

Apart from these general questions, each interviewee was asked questions addressing issues from his or her specific field of expertise. Some of the posed questions are exemplified below:

Field 3: Conducting User Studies & Collecting Data

- How can an understanding be conveyed to the participants that not all current trends and developments are desirable? (Isolating oneself through technology, not interacting with other people / the environment and surroundings)
- To what extent should one listen to the study participants if they just want to reinforce these developments by asking for more screens, better WiFi, means to consume music, TV shows, movies etc.?
- How could one counteract these trends?

Field 4: Interior Design

- For a multipurpose car that has to fulfill the needs of people travelling and/or commuting over short as well as long distances: On what would you put the focus regarding the following trade-offs?
  - Entertainment: Short interactions (e.g. use of smartphones) vs. entertainment system
  - Comfort: Easy access vs. comfortable seats and positions
  - Sharing space: Privacy vs. interaction with other people
  - Tasks: Working vs. relaxing
- How would you ensure:
  - Proper maintainability and cleanability of the interior?
  - Proper resistance for high level of usage?
  - Privacy for the passengers and a feeling of social security among other, unknown passengers inside in the vehicle?
  - Feeling of ownership of the vehicle when multiple people use it?

Field 5: Future Mobility

- Carpooling services are on the rise and will most likely play a significant role in future transport systems. Still, at least at the moment the car is something that a lot of people consider as something quite private and personal and they are not always willing to share it with others. How could this discrepancy be resolved and what is a way to create a sense of comfort and safety while sharing the car with strangers at the same time?
- How could one create a feeling of privacy through the interior arrangement?

Field 6: Current State-of-the-art Cars

- What do users like most about the Tesla Model X?
- What are they missing?
- What surprises them the most when they drive this car for the first time?
- How would the car look like when there is no need for a driver? (shape, interior etc.)

Field 7: Differences between Chinese & European Culture

- How does the everyday life in China differ from the one in Sweden in terms of:
  - Living in communities?

  - Daily meals and food (breakfast, lunch, dinner)?
  - Perception of shared space?
  - Privacy?
- What do you think are the most significant cultural differences when it comes to travelling/commuting to work/school? What about free-time commuting (groceries, gym, meeting friends, other activities?)?
- How do Chinese people behave on the train/subway/as a passenger in the car? What do they do?
- What do you think Chinese users would like to do in an autonomous car? In what way would you expect it to be different from European users?
- What attitude do Chinese people have towards technology (in comparison to Swedes/Europeans)?
- How does aesthetic design differ? (colours, materials, shapes)
- From your experience would you say that carpooling services are also becoming more and more important in China or is the car still something like a status symbol for many?

Field 8: Safety Regulations

- Being realistic, what kinds of rules and regulations do you expect to be in place for autonomous driving vehicles (level 4) in 10 years from now?
- Do you think the concepts that have been released already would fulfill these possible requirements?
- What are the differences between European market regulations and Chinese market regulations nowadays? Do you think these regulations will become more similar and more universal in the future or will there still be significant differences?
- Are there already any regulations or guidelines regarding how to steer a level 4 autonomous driving vehicle?

3.2.3 Analysis

In order to make sense of the collected data and to separate the relevant findings from the negligible ones, it is recommended to follow a general structure for the analysis. The overall analysis approach that was used for the interpretation and translation of the collected data in this project is depicted in *Figure 3.1*.

First the data was reduced by summarizing the audio recordings. In the second step the summarized data was screened and analyzed in order to identify the most important aspects for the development of a user-centered concept. This was followed by an interpretation and comparison, i.e. various findings and statements from different experts within a study were compared with the goal to identify typical and untypical values as well as common problems, needs, wishes, requirements etc. Last, these findings were then translated into requirements that the concept has to address and fulfill (see *Chapter 5*).

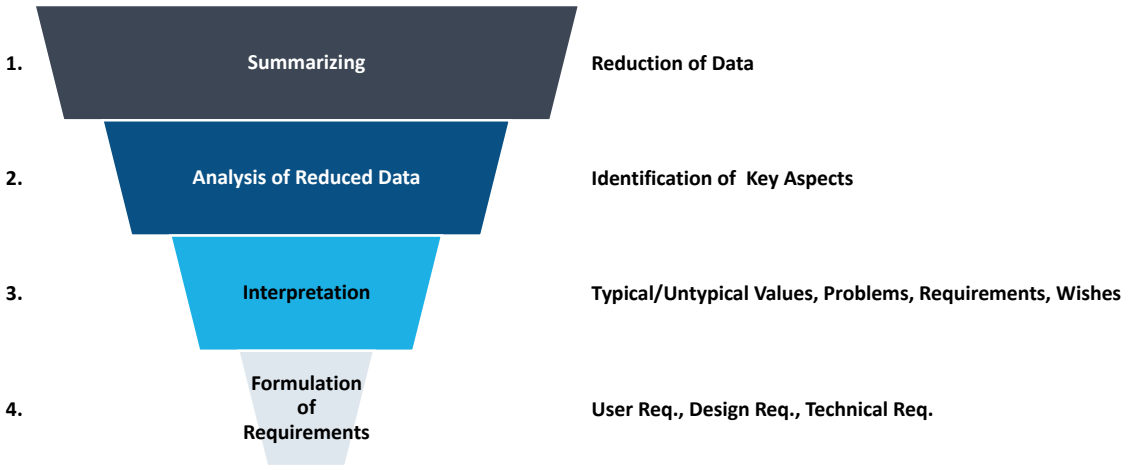


Figure 3.1: Analysis Approach for Collected Data

For the second and third stage of the analysis process, a matrix system was utilized to identify the most significant similarities and differences across the different participants and topics. Thus the answers and comments were analyzed in two dimensions as depicted in *Figure 3.2*. On the one hand, the statements of each participant regarding different topics were investigated to gain an understanding of the individuals' opinions, preferences, tendencies etc. while on the other hand, statements about specific topics from different participants were compared to spot agreements and disagreements among them as well as apparent patterns and trends.

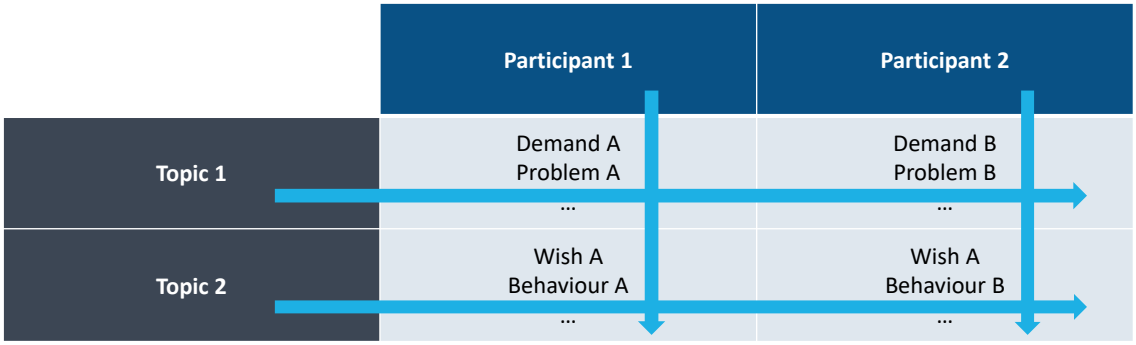


Figure 3.2: Analysis Approach for Interviewee and Participant Statements

The results of the expert interviews are presented in the following *Chapters 3.3*. The focus lies on presenting summarized outcomes of the analysis process instead of going into details with all analysis steps as shown in *Figure 3.1*.

3.3 Results

The expert interviews gave a lot of insights and conveyed a deeper understanding of both the general topic of autonomous driving and the challenges and opportunities related to it as well as field specific aspects regarding interior design, interaction design, cultural differences etc. The findings can be categorized into six themes: *General Aspects regrading Autonomous Driving*, *Future Mobility*, *User Tasks in Autonomous Cars*, *Interior Design Aspects*, *Vehicle Safety Regulations*, and *Cultural Differences and Similarities between China & Europe*. The results with respect to the different themes are described further in the following sections.

3.3.1 Autonomous Driving – General Aspects

In order to develop a concept for the interior of an autonomous car it is essential to understand how this technology will affect not only the overall design of vehicles but also its use by the people. Therefore, all experts were asked what they expect from autonomous driving, what benefits it will bring, and when and in which form we will see these changes implemented.

The first thing regarding autonomous driving that was mentioned by almost all interviewees was safety. On the one hand, it was expressed how concerned many people still are about the reliability of autonomous cars but, on the other hand it was also highlighted what a positive impact on safety they all expect from this technology since cars in the future will navigate more accurately and make decisions much faster than any human being. Nevertheless, it would be naive to think that just because of autonomous driving there will no longer be any accidents at all since the impact of external factors can never be controlled or predicted entirely (see also *Section 3.3.5*). However, especially the researchers in this field indicated that the acceptance of autonomously driving cars among society will be quicker than many expect. One researcher said: „The acceptance [of autonomous cars] will be quicker than we expect. [...] It's like when we trust our kind of personal data with mobile phones. Once we do it and feel the benefits of it we just do it and I think it is the same thing here." The majority of people generally trusts data collecting online services or is at least willing to give access to plenty of their personal data in exchange for the conveniences that these products and service can provide. Hence, the expert stated that similar to this, the value people will get out of autonomous driving technologies will be so big that they will be willing to accept minimal risks which eventually leads to trust and acceptance of the technology.

Related to this, convenience was another discussion point in practically all interviews. Overall it is expected that – compared to the situation with cars today – autonomous cars will cause much less hassle for the users. The improvements with respect to convenience range from automatic parking and easier payments to not having to take care of cleaning or maintenance operations in case of a pure service design that excludes any form of individual car ownership.

Regarding the implementation of autonomous driving features most experts from research and from industry made predictions that we will first see full autonomous drive modes for long-distance travelling on highways. Most likely it will start as a quite expensive extra feature in the premium segment of cars. The utilization for inner-city rides will be a challenge not to be underestimated and it is still not expected to work absolutely reliable for many years. People often misunderstand that it will not be a sudden breakthrough that changes everything over night but rather a step-wise development with a lot of problems and setbacks on the way. However, the benefits that almost all experts saw for autonomous vehicles was exactly in this setting of urban commuting. Once the technology is mature enough, the interviewees argued that taxi services will replace the traditional, manually driven cars with autonomous once to save labor costs. Some experts pointed out that the cost of using such a service will drop to such an extent that it will price-wise compete with other means of public transports like busses and subways while offering a much higher level of comfort and convenience since one can go straight from A to B and not just from one scheduled stop to another. With regard to intercity travelling however, these major benefits were less relevant which meant that autonomous cars will still face a much tougher competition from e.g. trains.

3.3.2 Future Mobility

In addition to the autonomous driving technology and its impact on future car developments, a possible transformation of the entire transportation sector also came up in interviews with various experts. This included not only cars but also other means of transport, how they might compete against or perhaps even complement each other in the future. While some experts said that autonomous cars will have to be linked with other forms of transportation, others stated that the dominance of cars will persist or even grow. At the same time the developments in transportation sector are without doubt influenced by multiple factors which lead to a number of possible scenarios for the future.

The ownership of cars and how it might develop in the future was one of the frequently discussed topics. Overall it was expected that the desire for owning a car will decrease in the future and that ridesharing services will become much more relevant. However, some experts also pointed out that due to the character of the autonomous driving technology it will be possible to personalize the interior space even more than today. People might want to bring more things and devices into their cars, now when they can actually interact with them instead of focusing on driving. One of the experts stated: "Especially if it is autonomous it will be an even more important product that is connected to you as a person. [...] You kind of really want it to be like: 'This is my space, this is my living room on the move.' You do not want to share that space with other people." The car could therefore become something even more personal and users would most likely not like to share it with strangers or even give them access to it. Furthermore, it was brought up by some experts that the freedom that a car brings with it is

something really important for car owners nowadays. Thus, the opportunity of starting at trip whenever one wants and not being forced to adapt to a schedule or even a calculated route is something that a lot of people are not willing to give up yet and some experts were of the opinion that this need will never completely disappear.

There were also different opinions regarding the possibility of driving for fun and amusement in the future. While some experts from the industry said that there will always be an option to drive the car yourself, a researcher disagreed and claimed: "That day will come, that you are not allowed to drive by yourself on public roads." However, this scenario was expected to be placed rather far in the future and will almost certainly not occur within the next 10 years.

The development of the traffic situation was another subject of debate in several interviews. There was no consensus about whether the amount of cars on the streets will reduce or increase due to autonomous driving features. On the one hand, these features would allow a more efficient use of cars but on the other hand, the sheer convenience and probably falling prices could also lead to a replacement of other means of public transport and hereby increase the number of people travelling and commuting by car. Furthermore, when autonomous cars are constantly moving around instead of being parked it also means that the traffic could perhaps increase due to more vehicles on the streets.

3.3.3 User Tasks in Autonomous Cars

In general, there are two possible usage scenarios for autonomous driving: Long-distance and short-distance rides. The user tasks, i.e. the activities that the user gets involved in or engages in in these two scenarios are quite different, not least because of the difference in time spent in the car. Therefore, most experts recommended to separate the two scenarios and not try to address both with the same solution. They are just too different and a comprise that tries to satisfy needs related to both will end up not being really useful for either. This, in combination with the higher chances of implementing a profitable business model as already indicated in *Section 3.3.1*, led to the focus on an urban commuting scenario.

Especially regarding this short-distance commuting, the researchers identified two different types of users: One that expects a personalized experience of transportation with a high level of convenience and one that just wants to get from A to B, no matter how. For the latter one it is of minor importance how the vehicle looks on the inside or outside. What counts is how quickly the destination can be reached.

When it comes to concrete user tasks, most experts agreed that we should not expect completely different user behaviours with respect to what they already do today in a vehicle while travelling, or commuting. Just because people can

use autonomous cars in the future it does not mean that they will change their behaviour entirely. Especially other means of existing transportation where the users do not actively have to focus on driving, such as during train rides, flights etc., should give some indication of probable user tasks and scenarios.

Overall, most experts expected that when people are given the freedom to spend their time in the car in another way than driving, most of them will want to do what they usually do in their everyday lives elsewhere. Since this is highly individual a wide range of possible user task was mentioned and some statements from different experts were even contradicting. While one for example anticipated that people on their way to work in the morning will use the newly gained time to start working in the car in order to be efficient another still believed that people want to separate their private life and working life which means that they might rather want to have breakfast, read news, or relax while listening to music on their way to work. One of the researchers gave some insights from her studies regarding this need for separation of work and free-time. She found that quite many people are concerned that they might be urged to work in the car in the future, especially on business trips. While today the driving time is perceived as an opportunity to disconnect this might change when they become passive passengers due to autonomous driving technologies.

Another possibility of using the "gained" time that was mentioned by multiple experts is enabling the users to make improvements in their lives. This could mean to learn new things (e.g. languages) or spending more time on things that they usually do not find the time for (e.g. reading). Moreover, the car should enable the passengers to do more fun activities like playing games, individually or together with fellow passengers. However, regarding social interactions between the passengers different viewpoints could be identified among the experts. One group stated that the interaction with others will become much more important in the future and that people will turn away from their extensive smartphone usage that can be observed nowadays. It was argued that at the moment smartphones are still in an evolution phase where their use is highly attractive since it provides us with so many opportunities that we did not have before but that they will loose their appeal which will then lead to an increase in social interactions. The other group was convinced that social experience – especially between strangers that share a ride – is overrated and that a seat arrangement which forces the them to face each other will be awkward, even on short trips.

Considering all the different aspects regarding possible user tasks in autonomous cars it was also discussed in each interview how future concepts from big car manufacturers are seen. The general opinion was that most of the existing concepts do not really address the user needs since they are not based on user studies. Instead they are rather technology oriented and have the purpose to show what could be technically feasible. Especially for short trips entire entertainment systems were perceived to be grossly overstated and instead it is expected that passengers will stick to short interaction devices like their own smartphones. Fur-

thermore, it was questioned whether a focus on technology could cause more social isolation and whether it is really desirable to facilitate such a development. One of the interviewees argued: "You see these images of people sitting in autonomous cars with VR glasses on and that is completely sad." Instead technology should be seen as a complementary component (like a TV in a family living room) rather than the center of attention. In addition to this, it was mentioned that the car design should not depend too much on entertainment devices and features due to the fact that those will become outdated quickly. If these devices are then not constantly upgraded, the service will loose its appeal.

Another aspect that comes into play with the use of technology in form of screens, displays etc. and was mentioned several times in the expert interviews is motion sickness. Although it is hard to predict how smooth a car ride will be in the future and to what an extent this will remain a problem, it is certainly something that can not be disregard for the development of an interior concept.

3.3.4 Interior Design Aspects

One thing that all experts could agree on was that the interior appearance of an autonomous car will most likely be quite different from what it looks like nowadays in manually driven cars. The fact that a traditional and permanent steering wheel will no longer be necessary, as well as the assumption that most cars in the future will be electric create a lot of additional space for the interior design. The basic layout will be a flat floor with electric motors positioned right next to the wheels which make a drive shaft obsolete (see *Figure 3.3*). Not only does this result in a completely even surface as a base for design but it also means that there is no longer a traditional engine compartment as for combustion engines.
As already indicated in *Section 3.3.3* the intended use of an autonomous car was expected to have a significant impact on the interior design. Whether the car is designed for urban commuting or long-distance travelling influences the expected amount and complexity of integrated features as well as the choice of materials. Various experts stated that the less time a passenger spends in the car, the more he will engage in short-term interactions like smartphones usage and the less important become luxury materials. Nevertheless, many experts believed that even for daily commuting people will expect more of an autonomous car ride experience than e.g. one they have when using public transport. Customization and feeling of ownership were key words used in this context.

The design and functionality of the seats in an autonomous car were another topic that came up in multiple interviews. To facilitate social interaction it is often expected that at least the seats in the front row should have the ability to rotate. This however is much trickier than one might think and also entails some downsides. At least according to current standards, every rotation feature of the seats will add a significant amount of weight. One of the experts said that a seat with a 360° rotation will add 10kg of mass while a seat with a low degree of lateral rotation opportunity will still add 2kg. These are of course numbers that must

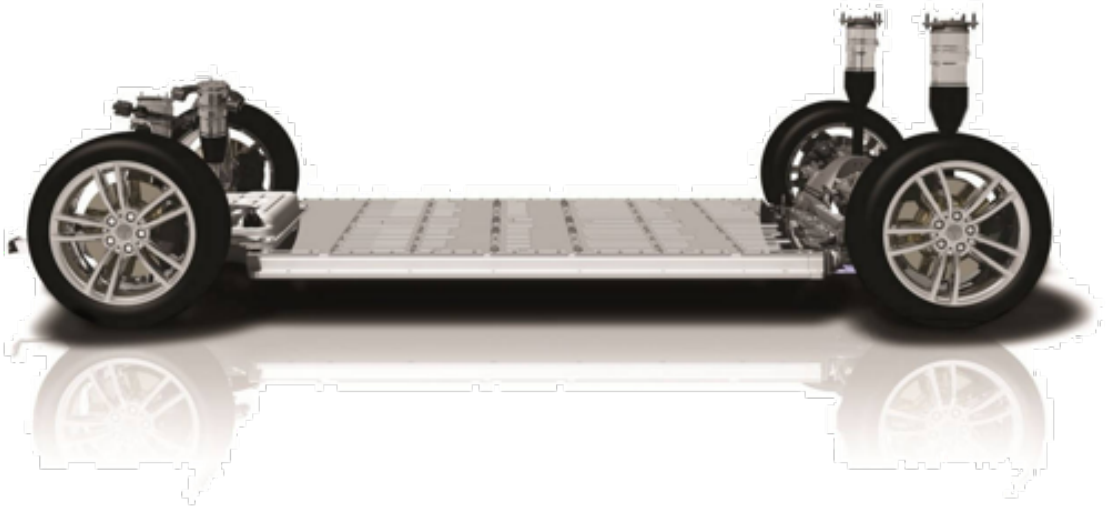


Figure 3.3: "Skateboard" Chassis of an Electric Car Including Batteries, Motor and Suspension (Tesla, 2018)

not be neglected in the case of electric cars where every kilogram counts significantly against the range. In addition to this, it was also pointed out that just like an extensive use of screens etc. (see *Section 3.3.3*) the seat arrangement also has a significant impact on motion sickness. The overall question that none of the experts could answer with certainty was therefore how big the benefits of an implementation of rotating seats will eventually be and whether it would be reasonable to have these at all.

3.3.5 Vehicle Safety Regulations

As mentioned in *Section 3.3.1*, it is generally expected that transportation will become much safer in the future due to autonomous driving. This is according to one expert actually the main driver of this development since 90% of all accidents today are considered to be caused by humans. The overall question in this context is how safety regulations regarding the car interior might develop in the future and to what extent they will continue to restrict the design degrees of freedom.

Some experts were still a bit hesitant to say that all traditional safety features like seat belts, airbags etc. can be dropped in autonomous vehicles since it can never be assured that absolutely no accidents will occur anymore once this technology is fully implemented. The question is what accident rate would be acceptable to let go of certain safety features in order to enable other activities. Moreover, a question that was raised during one of the interviews was whether this decision should be left to the user or if it should be regulated by legislation, like mandatory seat belt wearing nowadays.

There are various aspects that have to be considered regarding this topic. Beside the implementation or omission of interior safety features (like seat belts and airbags) the design itself also influences the degree of safety. In case of an accident, passengers could collide with interior elements like tables and further all kinds of accessories could turn into flying objects and therefore pose a substantial security risk. Hence, one of the experts e.g. suggested that for every task that the user desires to do it would be better if the respective features are actually integrated into the car, reducing the number of loose objects inside. Another subject in many conversation was the design of the seats. Currently the seats always have to be in a fixed position during a crash which is the reason why the range of motion is usually constrained. The lowest leaning position to still survive an accident e.g. is 120° whereas a comfortable resting position for relaxation and sleep requires at least an angle of 140°. A similar situation applies to the lateral rotation of a seat. When the front row seats are turned around to facilitate a conversation among the passengers, the airbags in their current positions will no longer have any effect and the chances of those passengers to survive a potential crash are vanishingly low.

However, it is self-evident that these issues are more serious for long-distance travelling on highways and with higher speeds than they are for urban commuting scenarios. Experts stated in the interviews that the lower the speed is, the lower becomes the risk for accidents which in turn means that the design of the car could change in a way that parts of the metal structures are replaced by windows and more panoramic glasses.

Nevertheless, it is important to note that such design changes might also influence the perceived feeling of safety among the passengers. This factor is one that many experts saw as even more critical (especially in the early stages of autonomous cars) than safety aspects themselves. Even if an autonomous car is safe, no one will use it if people are not convinced of this fact. Although researchers stated that trust will be no issue in the long term (see *Section 3.3.1*), we still have to reach that state. Two experts claimed that people in general do not like to relinquish control and put themselves in a situation where a machine and not a human being takes care of their safety. Therefore, it would be important to keep the passengers of an autonomous car in the loop and to show them in real time what the system is currently doing and what kinds of decisions are made by it.

However, the safety and legislation expert concluded that it is incredibly hard to predict how regulations regarding autonomous driving will develop and what laws will eventually be passed. It is beyond debate that the regulations will have to change according to development in technology. Seat belts, airbags and other safety systems need to be adapted to the new situation. At least the expert expected that in the future, regulations of different countries will merge together and become more alike. European, American, Asian and other countries' regulations will become more and more similar and at some point perhaps even identical.

3.3.6 Cultural Differences and Similarities (China vs. Europe)

Since the interior concept that was developed during this project is supposed to fit the European as well as the Chinese markets it was essential to look into cultural differences between these two nations. Hence, the main questions with respect to this project was whether it is possible to eventually have the same interior concept for both regions. It is needless to say that the findings regarding this topic represent just a fraction of what would be necessary to fully understand this complex subject matter. A full investigation would probably require several studies and many years of research. Furthermore, it must be said that China is a huge country and the differences among the people from different cities or regions might just be as big as between persons from e.g. Scandinavia and southern Europe. The purpose of this thesis project was rather to obtain an insight into the topic and what kind of factors could possibly influence the interior design of an autonomous car.

Regarding the main question – whether it would be possible to develop one interior concept for both markets – the experts had quite differing opinions. One group said that it should be possible to have the same interior design for the two regions in the future or at least one that only needs minor modifications to fit either of the markets. They identified the aesthetic design to be the most relevant difference and implied that user behaviours and demands will become similar to a great extent. Other experts, including the interviewed China expert, believed that it will not be possible at all to have the same interior design for the Chinese and European market since they have completely different values and expectations with respect to this. However, all experts agreed on the assumption that due to globalization mentality and mindset of Chinese and European users will get more and more alike in the future.

One of the most relevant aspects is the role that cars play in China; what people see in them and how they are used are undoubtedly of high importance for this project. Several experts stated that the car has a very special role in the Chinese society a status symbol. The overpopulation leads to a desire among the citizens to differentiate oneself and stand out from the rest by owning rare and often expensive products and showing them off. This is also the reason why luxury brands, no matter of what product category, are selling so well. The China expert even mentioned that many Chinese think about investing in a big car even before they buy a place to live. The interviews also calridied that the Chinese really love all kinds of services. The ridesharing service Didi Chuxing – the Chinese equivalent to Uber – is extremely popular, especially among those that cannot afford a car. The expert on Chinese culture stated the trend in big cities goes towards not owning cars any longer since e.g. the cost for a Shanghai license plate can already be as high as 10.000€.

According to two experts there is a third scenario that has to be mentioned in this context. Chinese couples, especially those of middle age often travel with their whole family including their (usually only) child as well as the grandparents. This

means that a car needs to have a minimum of five seats and in addition often a high degree of convenience and practicality. To cover all extremes, some experts said that a segmentation might be unavoidable. Three categories could be:

- "Luxury Car" especially for company managers and wealthy people;
- "Family Car" for users that have to move three generations in a car (children, parents, grandparents); and
- "Commuting Service" for getting around the city in a convenient way

Another interesting aspect to consider is the mindset of Chinese people when it comes to commuting in cities. Particularly interesting was one statement of the China expert according to whom free-time commuting does not really exist in China. Especially people in big cities like to live in huge building complexes – also called "communities" – where they can find everything that they need (massage, favourite restaurants, karaoke etc.). Supermarkets and grocery stores can usually be found on the bottom level(s) of the building that they live in and these shopping options are complemented by open markets with fresh, regional food. Chinese people really like the convenience of having everything nearby and in general they are quite reluctant to travelling or commuting anywhere, if not to work. From a Chinese person's perspective, going into the city is only something for foreigners while they prefer to stay in their communities for most of the time.

Moreover, for this project it seemed relevant to know what attitude Chinese people have towards privacy and sharing space, e.g. how they behave while using public transport and whether they are bothered in any way by crowds of people. According to several experts the short answer to this is: "Privacy does not exist in China." People usually live with multiple generations under one roof and the number of single households is very low. The huge population leads to seemingly overcrowded places everywhere which seems to have made the people resistant to any feelings of constriction while e.g. using public transport. However, the interviewed China expert pointed out that trends are developing which might change this picture, at least with respect to the housing situation. Younger generations that live in the city seem to value privacy more and more, which means that they seal themselves off from others and tend to become more like Europeans who cherish the opportunity to have private moments if the want to.

With respect to one thing, Chinese and Europeans are still fundamentally different: Technology affinity. While Europeans might show a certain degree of enthusiasm or excitement for technology, it is firmly anchored and embedded in the lives of Chinese people. According to the experts, the use of smartphones for instance is socially absolutely accepted in almost every situation. This means that at company meetings e.g. half of the people present are more or less perpetually looking at their phones and even when people are on a date they spend more time interacting with their devices than talking to each other. It seems that Chinese are not critical towards this extensive usage at all. Rather, being connected and online are absolutely essential for them and at the moment there is no tendency that

this behaviour will change anytime soon. The expert on Chinese culture said that "Their lives are basically centralized into their smartphones", which is also the reason why they always want to have the latest phones and why they update their personal models every year. Further, he pointed out that there is no such thing as a second-hand culture for any kind of products since anything that has already been used by someone else has a significantly lower value for them. He indicated that this insistence on owning brand-new products is also a sign of a lack of environmental awareness compared to most European citizens and especially to those living in the Nordic countries.

Finally, the interior design of cars in the context of Chinese users was another subject of conversation in several interviews. It became clear that Chinese users are extremely demanding. They want what European people have in their cars but even more, true to the motto "more is more". Moreover, features are in general really important and just the fact that special features are available increases the value of the entire car significantly, even if they are not used and do not contribute to or enhance the overall functionality or usability. (Examples could be a built-in karaoke machine or a machine that allows the user to get a hot cup of tea in the car.).

Another interesting fact in this context is that, according to two of the experts, Chinese users like to discover and test out features. They want to explore them with their eyes and hands. It should therefore be possible to unfold, uncover, swing out, open up or move things. In comparison, for European and American users automated solutions are much more appealing. This could mean that something moves, opens up, or moves towards the user once he or she gets close to it. Further, Chinese users seem to be much less fond of systems like voice assistants and the like that can give recommendations or suggest things.

In terms of aesthetic design, Chinese people seem to prefer dark colours. One of the interviewed experts said that in hotel rooms the colour scheme and materials used like woods etc. are usually quite dark, creating an ambience which could almost feel oppressive for people who are not used to it. The Swedish minimalist design however, would lack details and extravaganza and look rather unfinished to Chinese people.

Further findings regarding cultural differences between Europe and China are presented in *Section 4.3.1.5* where the results from this section and the role plays with Chinese participants are also summarized (see *Figure 4.8*).

3.4 Implications

The expert interviews yielded many insights that were of high relevance for the project. Among the most beneficial outcomes were the findings that helped to reshape the scope of the project. Hence, due to the input from various experts, the entire development process could be built upon a much more solid basis.

Especially the advice to focus on the development of a concept that is aimed at urban commuting and that car sharing might be much more common in the future had a big influence on the direction in which the project eventually went. Furthermore, the input on potential user tasks was very helpful. Even if concrete user tasks are better determined by conducting user studies (see *Chapter 4*) the experts could at least provide guidance by pointing out what one should focus on while investigating user tasks and what has to be kept in mind during the process (e.g. the risks of implementing too much technology and that people will not change their behaviours and activities completely just because they use autonomous cars). On the other hand, findings from the expert interviews regarding interior design aspects were considered to be more specific and better defined than those obtained from the user studies. The three vehicle interior designers who were interviewed are professionals in this field and could therefore give much more concrete advice than participants of the user studies (e.g. on arrangement, rotation, and leaning angles of seats). Moreover, the China expert was not only able to provide broad insights into Chinese culture but also to put things into perspective, compare them to the European culture and way of living, and point out specific differences. Such reflected thoughts could not be expected from Chinese participants that can only refer to their own culture.

However, findings from all themes presented in this chapter were incorporated into the *Specification of Requirements* which will be presented in *Chapter 5*.

4

User Studies

Conducting user studies is absolutely essential if one wants to fully understand user behaviours and needs. Even though other studies could be found with results that are certainly relevant and can point in the right direction, user studies specifically tailored to this project had the best possible prospects of success in answering the second research question: *What kind of activities would future users like to perform in an autonomously driven car?*

4.1 Aim

The overall goal of the user studies was to determine what activities and tasks future users might like to perform in an autonomously driven car in ten years time. It was of particular interest how they might behave and act when they do not have to drive themselves anymore and can shift their focus in the vehicle to something completely different.

4.2 Method

The user studies were divided into three major activities, namely the planning of data collection, the data collection itself and the data analysis.

In terms of the methodology that was applied throughout the project, the planning phase was of particular interest. Starting with the tool exploration, suitable tools for the purpose of collecting relevant data were investigated and screened (see *Chapter 2*). In the next step the remaining tools had to be combined and arranged in a way that the individual studies complemented each other and led to the most promising results.

Overall, it has to be kept in mind that the entire design of the user studies was not a straight forward process. While working on the different phases of the user study new ideas were constantly developed, priorities within the project changed and especially the study design was constantly altered and adjusted in order to maximize the outcome.

In order to determine what kind of activities future users would like to perform in an autonomously driven car the selected tools were combined in a way that they formed independent studies which not only examined various facets of the topic

but also shed light on it from different angles. This way it should be possible to get a holistic picture while at the same time being able to compare various opinions and sentiments regarding certain aspects.

Apart from the expert interviews described in *Chapter 3*, two different types of investigations were designed for this purpose: A user study that aimed at creating a link between the present state and a future scenario as well as another study that had the goal of broadening the perspective by shifting the subject of investigation to another context.

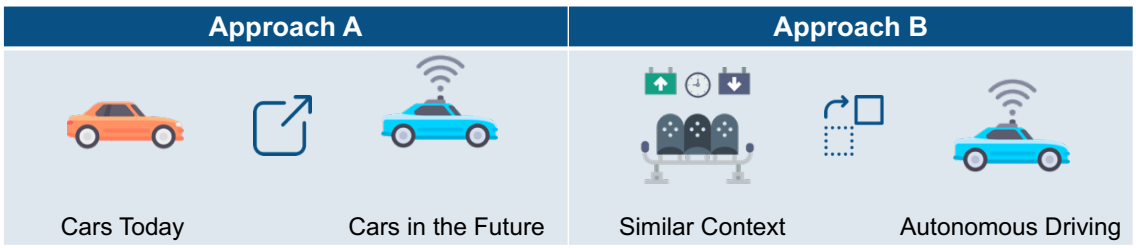


Figure 4.1: Two Different Study Approaches

The difference between the two user studies is illustrated in *Figure 4.1*. The first study focused mainly on how cars look today and how they will change in the future as well as how these changes have an effect on the users and their everyday life. The approach of the second study, however, was of a completely different nature. Instead of focusing on cars right from the beginning, the study was based around another but still similar context. The findings were then transferred to the context of autonomous driving in the next step. The different investigation types will be explained further in *Sections 4.2.1 & 4.2.2*.

After setting up the structure of the studies, the data collection itself was carried out by conducting the user studies and was eventually followed by a data analysis. The analysis approach was similar to the one used for the expert interviews (see *Section 3.2.3*). This meant that all audio and video recordings were first summarized so that subsequently an identification of key aspects could follow. In the next step the findings obtained from different participants were compared, assessed and sorted in order to determine the relevance of each aspect and detect typical and untypical problems, needs, and requirements. Finally, the findings were translated into specific user requirements that could be used for the concept development process (see *Chapter 5*).

In addition, the so-called KJ Method was applied in order to combine the findings from the expert interviews and the user studies and to gain a better understanding of the key aspects and especially their relation to each other (Scupin, 1997).

The application of this method consists of three major steps: Label making, label grouping, and explanation. Therefore, the most relevant findings were written onto labels (post-its) and then grouped according to their level of relation, i.e.

Figure 4.2: Illustration of the KJ Method

their dependency and influence on each other. The closer the post-its are placed to each other, the higher the relation between them. Then, the different groups can be named and colorized. In order to clarify how this method looks in practice, *Figure 4.2* shows an illustration of the KJ model for this project.

4.2.1 From Present to Future

The first study is based on the *Role Play* method (presented in *Section 2.3.8*). The intention of this study was to study and investigate user needs and behaviours in autonomous cars by putting participants into a situation that simulates the scenario of using an autonomous car. It is expected that acting out such a situation enhances the participants' involvement and reflection on the topic so that certain requests, needs, wishes etc. might show that would not be possible to detect in e.g. interviews, where the scenario is just discussed hypothetically.

The role play took place in the Usability Lab at Chalmers, which is a room that is equipped for observations as part of a study like this. The entire role play

could be filmed from 4 different angles so that no movement or indication of the participants would fade into obscurity or remain unnoticed during the analysis phase. As preparation for the role play, the floor was covered with a large piece of paper. To indicate the dimensions of the prospective car, a square was drawn onto this paper. Its measurements of 2 x 3,7m however were on purpose bigger than those of an average car nowadays in order to give the role play participants enough space to move around and express their ideas. The paper on the floor also served as a canvas for the users as they were encouraged to draw whatever they would like to use or have access to in this situation on it.

The future scenario presented to the participants was aligned with the parameters that defined the project scope (presented in *Chapter 1.4*). This mainly meant that four persons participated per role play, that they would share the car at the same time and that the focus was less on long-distance travelling and rather on commuting. To be exact one role play dealt with commutes to work or school while another one was about free-time commuting trips. The time that the users spent in the car was about 30 minutes. Since the prospective concept(s) should suit the European as well as the Chinese markets, two role plays were conducted with European participants and another two with Chinese, which means that overall four role plays took place.

In order to facilitate the communication and to make it easier for the participants to relate to the future scenario the role play started with a discussion on the present daily commuting routines of the participants. This way, they might become more aware of problems that they are facing nowadays and shortcomings of the current transport solutions. Moreover, due to the association with their daily lives, it enhances the chance that the conversation and expressed ideas will be much closer to reality and addressing actual needs rather than just focusing on technology or very futuristic features. As soon as the participants' current commuting routines had been discussed sufficiently, a future scenario of passenger traffic was presented by showing them a picture by Bosch and Daimler (2017) which illustrates how a city with autonomous vehicles might look like (see *Figure 4.3*). In addition, terms like *Autonomous Driving*, *Car Pooling*, and *Ridesharing* were explained to the study participants and they were also told that they should not feel restricted by current safety regulations in cars.

In the next step the actual role play took place where the participants were encouraged to envision the future autonomous driving experiences, how they would spend their time and how their daily commutes might change. As already mentioned, the participants could draw design elements, features, devices etc. on the paper to elaborate on their thoughts and ideas. (The detailed plan with all probing questions for the two different role plays can be found in *Appendix B*.)

Overall, four groups with four participants each took part in the study. Two of the groups consisted of European participants while the other two comprised Chinese people. All participants were between 20 and 40 years old with a slight majority

Figure 4.3: A Future City Scenario as Presented by Bosch and Daimler (2017)

of students over employed persons. The limited number of participants does of course not allow statistically representative results and the study is not meant to provide such. Instead, the intention was to have a dialogue with the participants and to observe behaviour patterns which combined might eventually indicate what is of importance from a user perspective for the interior design of an autonomous car.

As shown in *Figure 4.4* all role plays were recorded from four different angles. Two of the role plays dealt with commuting trips to work or school while the other two were about free-time commuting. The overall procedure was to start with having a conversation with the participants for about 30 minutes about their current daily commutes and routines, which was followed by a brief introduction of five to ten minutes about autonomous driving, the scenario and what aspects were most important with respect to the study. The actual interactive role play with assigned roles took around one hour. In addition to this, refreshments in form of sandwiches or muffins as well as coffee were served to the participants during or after the role plays to facilitate a relaxed atmosphere and thank them for their help.

4.2.2 Context Shifting

The second user study was a combination of different tools that had been previously selected (see *Chapter 2.4*). While the character of the study was mainly inspired by the *Analogous Inspiration*, it was complemented by the design of a

Figure 4.4: Role Play with Two Different Groups of Participants

Collage which then again was supported by the tool *Draw It* in case that participants wanted to include something that was not among the provided images.

The purpose of this study was to broaden the perspective on the topic and spur creative thinking. This was achieved by shifting the focus from autonomous driving and car interiors to another context that did not elicit any associations with these topics but was still comparable on many levels. The participants were therefore not biased when they came to the interview and did not only express unconventional ideas but were also less tempted to say what they think is expected from them with respect to the discussed topic. Thus, the study got the name "Interviews with Deviating Focus" during the project, reflecting the unusual approach behind it.

Just like the expert interviews this study was conducted in an environment familiar to the participants (in this case their university). Further, all interviews were recorded to release the interviewers from the obligation to take notes. The study was conducted in form of semi-structured interviews with two participants at a time. Not only may the interview be more fun for the participants if they can do it with another person but it could also make them more comfortable with the fact that they could not be told beforehand what the interview was about. The interview consisted of two main parts. First the interviewees were asked a number of questions regarding their daily lives and behaviours and in a second phase they were asked to participate in a small creative task.

In the context of this project two main themes have been identified to be of relevance: *User Tasks* and *Privacy & Sharing Space*. The various topics within these themes and around which the posed questions revolve are stated below. The complete interview guide can be found in *Appendix C*.

User Tasks

- Losing time
- Daily routines
- Free time
- Stress
- Travelling & Commuting
- Online services
- Learning something new

Privacy & Sharing Space

- Behaviour in public spaces
- Working in public
- Talking to friends & family
- Talking to strangers
- Waiting room scenario

In the second part of the interview the interviewees were asked to create some kind of a collage. More precisely they were supposed to design a waiting room for four people in which these would spend about 30 minutes. For this they got an A3 piece of paper with a simple black rectangle on it as well as four sheets with various items which had been selected beforehand and which they could use for their design. As shown in *Figure 4.5* these items ranged from food and beverages to entertainment objects and furniture and services. In addition to this they could make sketches of whatever they were missing in the provided materials and also for clarification purposes. Further, it was crucial to instruct the objects to choose the items according to their functionality and not their aesthetic appearance. That the room was actually supposed to represent the interior of an autonomous car was not revealed to the interview participants until the very end. However, once this ulterior motive was disclosed, they were asked how this change might affect their design and whether they would like to change certain things as a consequence of this revelation.

In total four interviews were conducted with two participants each. All of them were students at the Gothenburg School of Business, Economics and Law and between 20 and 25 years old. The group of participants represented an international mixture. While all of them are living in Sweden at the moment, their backgrounds were highly diverse. Two participants were from Brazil, one from Canada, three from Spain, one from Italy, and another one from the Netherlands. However, as with the role plays from the first study, the low number of participants does not allow to draw conclusions on a general level but is intended to detect overall tendencies and trends.

The procedure consisted mainly of two parts. First a 45 minutes interview about topics related to the themes of *User Tasks* and *Privacy & Sharing Space* was conducted. After this the participants got the task to design the interior of a waiting room on paper for which they were allocated 30 minutes. This was rounded off

by a brief presentation of their work and finally shifting the context to the original topic of autonomous cars in order to see how this would affect their design.

Figure 4.5: Provided Materials for the Design Task

4.3 Results

In this chapter the results of the different investigation approaches, i.e. of the two user studies as described in *Sections 4.2.1 & 4.2.2* are presented. In total 24 people participated in the two different studies which resulted in 13 hours of recorded material.

4.3.1 From Present to Future

The first user study yielded results regarding many different areas, from general expectations, to product and service design features, and even social and cultural aspects. Many statements where directly related to the design challenge of the project while others even surpassed the scope of the project but are nevertheless worth mentioning for understanding the overall context of autonomous driving and also for further investigations in the future.

In the following *Sections 4.3.1.1 - 4.3.1.4* the results of the role plays are presented according to different subareas. The focus is on the input of the European participants and on those aspects that were similar between both cultures. The differences between Chinese and European demands and expectations will, however, be described separately in *Section 4.3.1.5*.

4.3.1.1 General Expectations

There was a whole range of expectations that the participants had regarding the interior of an autonomous car that they would share with other users. Some of these expectations could be verbalized immediately, others required a discussion between the participants to reach a conclusion and some were of such a subtle character that they could only be obtained by interpreting the behaviour and statements of the participants.

One of the basic prerequisite that the participants had was that the use of the car and the related service have to be safe. This does not only include physical safety in case of an accident but also being safe from and protected against theft, aggression and other forms of crime by fellow passengers.

Two other aspects that were of high importance were convenience and reliability of the service. Almost all participants expected a higher level of convenience than e.g. one that busses, subways, or trams can offer. This convenience was however not necessarily interpreted in terms of comfort but rather regarding the availability and flexibility of transportation. They expected e.g. that they can travel from door to door instead of just between defined stops and not only in a scheduled manner but whenever they want. Furthermore, the service has to be reliable and guarantee a certain arrival time, especially on the way to work. However, if they would arrive around five to ten minutes earlier that would be totally fine.

As already mentioned, due to the fact that the role play revolved around the interior of a future car, comfort played a certain role in the discussions. However, most of the participants did not demand an excessively high, luxurious-like level of comfort since they were aware of the fact that this would also drive up the price of the service. Instead most participants expressed that the comfort level should be "appropriate" which meant some sort of "cushioning" but no multi-element seats. Perhaps they could be a bit wider and slightly more comfortable than seats in a bus.

What was much more important to all participants than the comfort was the cleanliness inside the car. No matter how many people have used the car before the participants always wanted to have the feeling that it is clean so that they can be comfortable, somewhat like in a hotel room. The filthiness and dirt on seats in many busses and trams were e.g. a reason why some participants preferred to stand whenever they took the bus or tram. In an autonomous car however, they would expect a cleaner interior.

With respect to motion sickness the reactions were quite mixed. While some stated that they never experienced any problems others explained that they cannot read in a moving vehicle or sit on a seat that is facing backwards. Nevertheless, all agreed that it should be up to the user to decide whether he or she wants to ride backwards, read something or use devices or screens.

The idea of implementing new features in the car that enable the user to spend the time more wisely or efficiently did not generate a lot of positive responses among the participants. Unlike statements in the expert interviews (see *Section 3.3.3*), some study participants were rather skeptical about the idea of learning something new or using the newly gained time for things that they actually would like to spend more time on, like e.g. reading. They said that while this might certainly be a desirable and good idea, they might finally just end up watching video clips on YouTube or spend more time on social media.

4.3.1.2 Specific Design Features

The setup of the study also allowed the users to come up with and express more concrete ideas regarding the interior design. In terms of the style and aesthetic design most people expected something minimalist and simple forms. The materials should be durable but do not have to be fancy or luxurious. This works conveniently well with the demand for cleanliness mentioned before.

For the seats, none of the participants liked the idea of a couch-like seating opportunity that could accommodate two or more passengers. Instead everyone was in favour of individual seats according to the distribution of two in the front and two in the back. Moreover, most people said that the front row seats should at least have the option to rotate 180°.

The same applied to the access to the car. Most participants preferred individual

doors over e.g. common doors on each side in order to not be disturbed by the opening of doors for other passengers, especially in bad weather. Moreover, the doors should not require much space to open and do this automatically if requested, so that one can get into the car smoothly.

Furthermore, many participants expressed the desire for bigger windows on each side of the vehicle. In addition to this, a panoramic sunroof would also be a nice feature. As reasons for this they named the improved view, the positive effect on the amount of natural light inside the car during the day as well as a better opportunity to experience the city by night. Moreover, they mentioned feelings of openness and dynamics which they would enjoy.

Regarding storage opportunities only one of the participants expressed a need for a trunk in the car. The rest said that in the scenario of urban commuting, sufficient space for one or two bags in a compartment or somewhere under or around the seat would be more than enough.

Most participants also had relatively low requirements with respect to (device) holders, tables or connection opportunities. The presence of cup holders and an option to charge one's phone would be much appreciated. On the other hand, solid tables to place bigger items or devices were perceived as unnecessary for a 30 minute commuting trip. The only participants who requested such a table were those that had been assigned the role of a manager since they might have to prepare something for work in the car and would therefore appreciate an opportunity to use their laptop in a convenient way. The availability of WiFi, however, was considered an essential feature by all users.

In terms of entertainment in an autonomous car, most people would like to do what they are already doing today while riding the bus or subway which is mainly listening to music and using apps on their smartphone (social media, news etc.). Almost all would prefer to listen to their own music individually and most participants would try out a music service offered by the car but perhaps just stick to their own music collection or subscribed streaming service. Watching short video clips could be an option but mainly on commuting trips that take more than 20 minutes and most participants stated that their smartphone would suffice in that case. Further, magazines and newspapers available in the car would be nice-to-have to pass time or catch up on certain interests that they have.

4.3.1.3 Service Design

A lot of discussions during the role plays revolved around the service behind the product and how it can increase convenience, provide entertainment etc. However, the focus of this project was on the physical design so that ideas regarding the service design will only be elaborated briefly and on a quite general level. Nevertheless, it is considered as advantageous to present at least the most significant findings with respect to the service expectations since they can also influence the interior concept to a certain extent.

The first question was always how potential users would order the car in the first place. While some referred to the method of ordering it by a phone application (like the ridesharing service Uber) others came up with the idea of calling it like a taxi indicating with their arm or hand. Most participants would order the service just-in-time although some said that for going to work or going home, a scheduled pick-up time (perhaps even linked to a work schedule) would also be a convenient solution. Most important in this context would again be the convenience and reliability as mentioned in *Section 4.3.1.1*.

Another service related discussion topic was that a pretty wide range of people might use such a service so that quite different requirements and wishes might have to be fulfilled. According to the participants, it would therefore be wise to offer different categories of cars in terms of comfort, functionality, features etc. Furthermore, it was even more important to them that the people that are co-using the car have a similar attitude in terms of acceptable noise level. This means that if a person wants to work in the car or maybe just relax, he or she should not have to share the ride with people that want to have a conversation or make any kind of noise. Therefore, it would be beneficial to have differently themed cars, like e.g. a "Silent Car" for those who want to focus on something or relax.

Another service demand was that the car should always keep the passengers informed about the route that the car is taking and which users will be picked up or dropped off where and when. Related to this was the idea that each user of the service should have a user profile that is minimum partially visible for other users. This profile should at the minimum show a picture and a name but could also contain information about hobbies or interests in order to possibly serve as a conversation starter between two or more occupants.

Last but not least, a few participants expressed a wish for having access to small meals, snacks and/or beverages in the car. This way they could e.g. save some time in the morning by having breakfast in the car. However, overall this feature was rather seen as something nice-to-have than a request but according to some participants it could certainly be a distinctive feature of this kind of ridesharing service and help to stand out.

4.3.1.4 Social Aspects

Since the prospective concept is based on a ridesharing service, certain social aspects and how people interact with each other also have to be considered. In general there were some concerns among the participants about sharing the car with strangers (see also *Section 4.3.1.1*). Since the number of passengers is quite low and even situations of being alone with just one additional person might occur, participants had the feeling that there is a potential threat of harassment or violent assaults. Unlike in busses, subways etc. there is no crowd of people around that usually prevents such things from happening. None of the participants had objections to the idea of having a security camera inside the car in

order to increase the level of security. The issue of possible harassment and assaults became even more severe when participants who had been assigned the role of a mother or father thought about using this kind of service to send their kids to school, football training etc. They were quite clear about the fact that they would not let their children use the service if there is a chance that they might end up being alone in the car with an adult person. Another theme for a car (as presented in *Section 4.3.1.3*) could therefore be "School Bus" or "Kids" in order to prevent any form of child abuse. The participants stated that the interior design might then also need some other, child-oriented features.

One additional aspect that was of relevance in the context of sharing the car with unknown fellow passengers was privacy. Most participants said that it would be nice to have some privacy if desired but that, due to the fact that the car is supposed to be based on a ridesharing concept, they would not expect to be completely isolated and be protected from any form of human interaction. In case they were not interested in having a conversation with another occupant they would simply indicate this by using their ear- or headphones. Measures that could provide a higher degree of privacy like (raisable) walls, curtains or the like were perceived as too extreme and the participants stated that they would not use such adjustable solutions since closing a curtain or pulling up a wall would appear extremely rude to the other passengers. However, one concern that could be determined was that one passenger could see the screen of another user if this one is e.g. writing a mail but most did not mind much about this since it is similar to being in other situations in public.

4.3.1.5 Cultural Comparison

The results so far represent the opinions and ideas of the European participants and those of the Chines ones that were more or less congruent. However, with respect to some aspects the statements of the Chinese participants differed quite a lot which is why these findings will be summarized in this section.

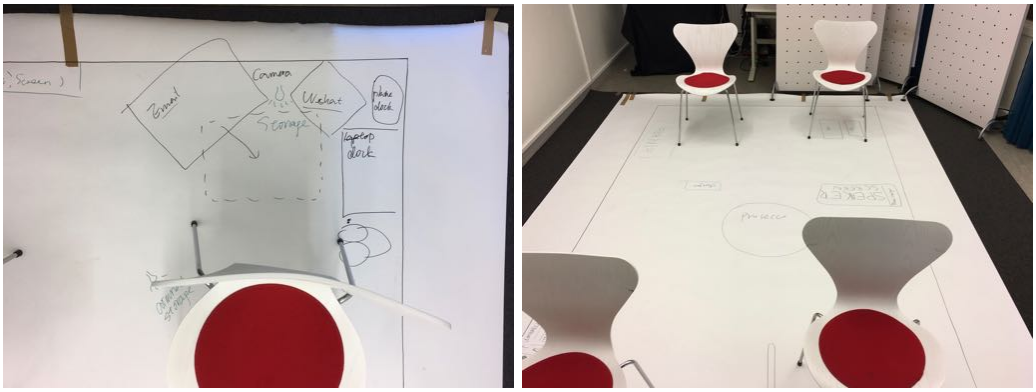
The most unexpected discovery during the second role play about free-time commuting was that these kind of trips do not really exist in China. Most people prefer to stay in their communities where they can find everything that they need within walking distance (see also *Section 3.3.6*). This basically eliminated the chance to identify any distinctive characteristics in comparison to the situation of commuting to work or school with respect to Chinese users.

With respect to the general expectations regarding a ridesharing service with autonomous cars, it became apparent that reliability was even more important for Chinese users than it was for European users. Being on time is absolutely essential and arriving later than planned due to the route that the car took or other passengers who had to be picked up along the way would be absolutely unacceptable. Being a few minutes early would however be acceptable.

In terms of a possible trade-off between comfort and cleanliness it was mentioned

that – similar to the statements from the role plays with European participants – cleanliness has a higher priority. Nevertheless most of the Chinese participants had higher demands for comfort. One participant e.g. predicted that people in the future will be even more stressed than they are already today which will make it more important for them to be able to relax and be comfortable when they get a chance to rest. Therefore, adjustable chairs with user identification and feet rests would be desirable. However, also here the need for different product segments for different target groups came up.

The biggest difference regarding specific interior design features was the expected level and amount of integrated technical features for entertainment purposes. As shown in *Figure 4.6a*, several Chinese study participants drew several electric devices on the provided paper. Among the mentioned devices, gadgets, and features were screens (at least one per passenger but if possible multiple ones), virtual and augmented reality headsets, video games, and cameras for video chatting. In addition to this they would prefer to read magazines and newspapers in a digital form instead of picking up physical copies. The perfect solution according to them would be to have access to a digital library to browse through on a screen or hand-held device.



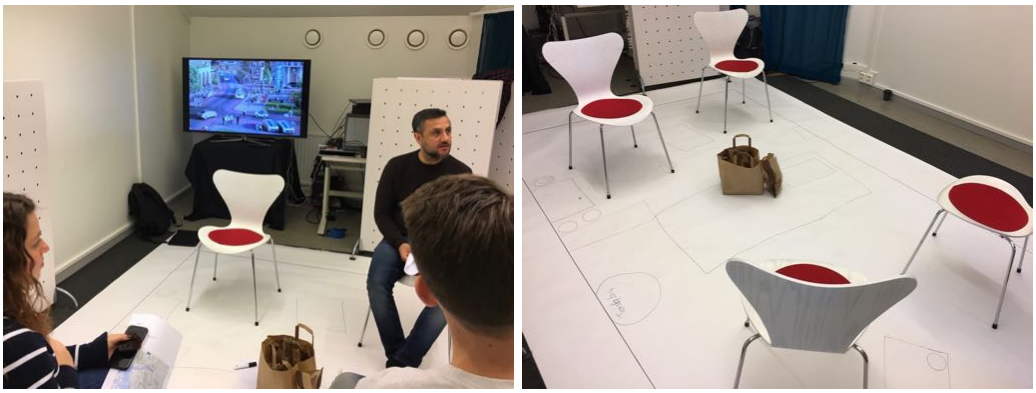
(a) Sketches from a Participant **(b)** Seat Arrangement of One Group

Figure 4.6: Chinese Role Play Snapshots

Another interesting detail was that the Chinese participants did not see a need for cup holders or the like since (at least nowadays) it is not common at all to see Chinese citizens walking around with takeaway coffee cups.

With respect to the service design, there was one noteworthy distinction when it came to offered goods in the car. For the option of providing beverages, it should be considered that Chinese people almost only consume warm beverages and hardly ever cold drinks. This means that in case such a service would be included in the car it should contain freshly brewed tea or coffee.

In terms of social interaction between passengers one significant behavioural difference could be identified. While one of the two groups consisting of European



(a) Participants Having a Conversation

(b) Seat Arrangement of the First Group

Figure 4.7: European Role Play Snapshots

people switched into a conversation mode with seats facing each other quite quickly during the course of the role play (see *Figure 4.7*), the Chinese participants decided themselves to sit in a conventional position with the seat facing forward (see *Figure 4.6b*). When asked whether they would also consider turning around and speaking to another passenger they stated that they would prefer to be left alone and not interact with other occupants as long as they do not know them from before. It would be nice though to have this option in case they were sharing the ride with friends or work colleagues.

The main cultural differences that were found during this study and from the expert interviews in *Section 3.3.6* are briefly summarized in *Figure 4.8*.

Europe	China
• Commuting is a natural part of life	• Free-time commuting is of almost no relevance (in general they do not like to commute)
• Commuting = Getting from A to B	• Cars = status symbols, “showing off” is very important
	• Heavy focus on entertainment & connectivity (Use of smartphones is accepted in *every* situation)
• Rather puristic design & functionality	• Very demanding, “more is more”, they love features
• Focus on automation	• Focus on interactive features & exploration
• More awareness of & concern about sustainability issues (reuse, reduce, recycle)	• Being up to date with technology is extremely important
	• No second hand culture

Figure 4.8: Summary of Cultural Differences between Europeans and Chinese

While there are certainly many differences between China and Europe, it has to be noted once more that several experts predicted that the mentality and mindsets of both cultures will become more and more similar in the future. Nevertheless, due to the sheer distance and completely different histories there will always be some form of differences, especially within the project’s intended time frame of the next 10 years.

4.3.2 Context Shifting

Just like the first user study, the *Context Shifting* study also produced a lot of valuable results. Due to the character of the investigation the results are overall less detailed and not only related to autonomous vehicles but rather on a holistic level and less biased by the image of current automotive concepts. Thus, the statements revolved more around general issues like free time activities, privacy, sharing space, and relaxation. All these results provide ideas that go beyond of what is currently possible in an non-autonomous vehicle and how people might behave in a shared autonomous car.

4.3.2.1 User Tasks

The questions regarding user tasks in the participants' free-time or in waiting situations were of particular interest since they could reveal what kind of tasks could be transferred into to the car if one has no longer to drive oneself.

The situations that were mentioned the most by the participants in this context revolved around daily routines. Basically there were two different types of user tasks that were particularly interesting for the context of this project: Those that the participants like to because they are related to hobbies or interest and those that are performed in order to relieve stress or make an inconvenient and stressful situation more pleasant.

Regarding their hobbies, the interviewees were especially probed for those that they (can) pursue indoors and/or while sitting down since those could later on more or less easily be transferred into a car. Some examples that were brought up were watching movies, TV shows, or documentaries, listening to music, reading, online shopping, using social media services, and talking to friends or family either in person or by phone.

As necessary but annoying or stressful daily routines, the most frequently mentioned examples were waiting in line for the bus or for a lecture to start, grocery shopping, cooking, doing laundry, and cleaning. To make these more pleasant activities, listening to music or podcasts, watching a TV show episode in the background, checking the news or social media, learning Swedish by using an application, as well as messaging or calling friends were strategies that were named most often. It is important to point out that the participants' smartphones played a central role for these kind of situations since they can enable almost all of the mentioned activities.

Two more scenarios that were found worthy to be investigated were travelling and commuting with other means of transport than driving a car. The participants were asked what kind of activities they pursue whenever they are taking a bus, the subways, a tram, or a plane. Once again the use of their smartphones and whatever activities these allow to perform ranked highest on the list. Some activities however were quite dependent on the duration of the journey. Hence, on

longer trips some would also watch a movie or try to sleep. Some participants also said that they like to get some work done if the conditions are good with respect to noise level and allow a comfortable work posture. In general being somehow more productive by e.g. studying for school was something that many interviewees would like to do more often in situations where they have time to kill anyway. However, in most situations they are simply missing the means to do this.

4.3.2.2 Privacy & Sharing Space

Since the interior concept developed for this project will be part of an autonomous car that is used for a ride-sharing service it seemed wise to investigate how the interviewees behave in public situations, what attitude they have towards privacy, and how they shared limited space. In general most participants stated that they do not necessarily mind being around people but that they prefer to be left alone and not interact with strangers. To signalize that they do not want to talk to anyone many said that they put in their earphones or simply express their disinterest by means of their facial expression or posture.

Another activity that could be accomplished in an autonomous car is working, whereby work refers to desk work in this context. Therefore, questions about working in public places like libraries, cafes, or in hallways of public buildings were posed to the interviewees. Most of them found it quite difficult to focus on something in a public area due to movements and especially sounds. With respect to noises, people having a conversation nearby were distracting but not as bad as music or repetitive sounds since these have some sort of rhythm that catches one's attention even more. Strategies to prevent such distractions were listening to calm music or natural sounds (rain, ocean, forest) with headphones or wearing earplugs.

Talking to a friend was the preferred activity for most participants whenever they were waiting or going somewhere. Since they do not always have company in such situations they often message or call a friend or family member instead. It was interesting to find that while all participants said that they do not mind having a conversation on the phone while being on the move (e.g. walking in the streets), most of them tried to avoid the same whenever they were standing or sitting still and when others around them could listen to their conversations. (Unless they spoke a language that they were quite sure no one around understands.) For more private matters and delicate conversations however, all of them preferred to make calls at home where they can assure that it is quiet and where they have more privacy.

As mentioned earlier most participants would in general prefer not to interact with complete strangers in public spaces or at least not initiate a conversation themselves. However, if they enter a room some of them would test a potential conversation partner by greeting them and ask an insignificant question. Depending on the initial reactions they would then decide whether they would continue the dia-

logue or not. In general, how open one is towards starting a conversation with an unknown person depends on the number of people in the room. The more people around the less likely it becomes. Therefore, in a bus, none of the participants would talk to a stranger while the probability are higher in a waiting room.

Another influencing factor was the time that the participants would spend together with an unknown person. If both cannot really connect at the beginning they might end up in an awkward situation for multiple hours which was something that the participants wanted to avoid at all costs. This is the reason why most participants said that they would not initiate a conversation e.g. on a long-distance flight. However, theses are individual differences. The behaviour in these kinds of situations is dependent on the individual personality and the level of shyness and introversion.

4.3.2.3 Design Task Results

The design task aimed at determining how the participants would like to spend 30 minutes in a waiting room which is a similar situation to a 30 minutes commute with an autonomous car. Two examples of such collages designed by participants are depicted in *Figures 4.9 & 4.10*. All other can be found in *Appendix C*.

Figure 4.9: Design Task Result of Participant 1

What most of the participants had in mind when working on this task was a waiting room at the doctor's or dentist's. The designs of various study participants,

Figure 4.10: Design Task Result of Participant 2

however, turned out to be quite different from each other. The design in *Figure 4.9* is rather focused on privacy and individual pastime judging by the type of seats, while the design depicted in *Figure 4.10* also offers the opportunity for occupants to sit right next to each other on couches and interact with each other. According to the participant that created this design, a table with an integrated screen is also supposed to make the persons in the room interact with each other by offering games or displaying fun facts or quizzes. Board games placed on shelves have the same purpose.

Overall, the first design is also much more minimal and simple with just few magazines and newspapers, one common screen and otherwise the occupants' smartphones and individual headphones for entertainment purposes. The second design offers all these things plus the already mentioned screen table, common speakers, board games, and tablets. Other similarities were the demand for (wireless) phone chargers and that some hot and cold beverages would be appreciated. In addition, some small meals or snacks would also be desirable (see the second design).

Regarding possible changes for the interior of an autonomous car, motion sickness was once again a concern that was mentioned multiple times. Some participants said that they would remove the magazines and newspapers and perhaps even TVs and screens since they would not be able to read and use them in a car

anyway without feeling queasy or dizzy. As a solution for this issue two participants suggested that the magazines etc. could be replaced by a service similar to audio books since listening to the content instead of reading it would be possible for everyone.

Further, the question was raised to what extent it would be possible to consume at least certain kinds of food that had been chosen for the waiting room in a moving vehicle.

With respect to the selected seating opportunities all participants that chose couches for their designs said that in a car they would prefer individual chairs for each passenger.

Especially during the first few rides with such a novel car some of the study participants expected that people might be more interested in interacting with each other and exploring it as part of a group. However, doubts were also expressed how long this effect might persist and if the passengers might still be as engaged over time when the service becomes part of their everyday lives.

Moreover, the participants stated that the size and position of windows would become much more important since looking out of the window might be a form of entertainment itself. While all other changes meant reducing the waiting room design by elements, this was the only thing mentioned by the participants that could add value and enable something that was not really possible in a static room in a building.

Overall, however, all participants were of the opinion that their designs could be transferred to the context of an autonomous car to a considerable extent and that just some minor changes would be necessary due to the fact that the car, unlike the waiting room, is moving and that this will most likely have an impact on the kind of user tasks that can be performed.

4.4 Implications

Due to the two user studies conducted during this master thesis project, profound insights on user behaviours and needs could be obtained. In comparison to those results of the expert interviews, which were for the most part either kept general or addressed technical issues, the user studies led to first-hand impressions regarding what future users would actually like to do in an autonomously driving car. These findings were essential for the mission to develop truly relevant concept ideas and, therefore, guided the concept design process significantly.

In terms of activities that could be supported by the interior design, it turned out that most participants – especially the European ones – did not expect or need features that cannot already be found in common means of transport today (e.g. big screens, VR headsets etc.). Instead most stated that the use of their personal

smartphones would suffice for commuting trips of 30 minutes since it allows them to do things like listening to music, checking the news, making phone calls or using social media. However, among the Chinese participants, technology had a higher priority, which confirmed the statements made by the expert on Chinese culture. Hence, technical features were mentioned more frequently, most of them aimed at facilitating and extending the use of their smartphones (e.g. through additional screens, speakers etc.).

Apart from concrete activities, the participants also provided expectations regarding the interior design. While a trunk was found to be dispensable for commuting trips, all participants were in favour of individual seats as well as bigger windows compared to today's cars. In addition, it could be determined which design aspects could facilitate certain activities or promote the overall well-being. Among the most important aspects for the users was cleanliness which was described as much more important than comfort. For the concept design this meant that simple component shapes, accessible surfaces and easy to clean materials should be implemented. A feeling of privacy was another frequently expressed desire, which according to some participants could be a distinguishing feature compared to other forms of public transport used inside a city, like e.g. busses, trams etc. Unlike statements made by some vehicle interior design experts, the implementation of elements that promote or encourage the use of new features was rather viewed with skepticism by most participants. According to some of them it could be helpful to promote the service in the beginning but would not necessarily add much value in the long term. However, in general, a modular design was determined to be of high value in order to adapt the interior to the needs of various target groups and cultures or even to season throughout the year.

The formulation of requirements based on the findings in this chapter as well as those of the expert interviews will be presented in the following *Chapter 5*.

5

Specification of Requirements

Before the concept development phase could begin, the discoveries of the expert interviews and user studies had to be translated into specific design requirements. Therefore, a specification of requirements was conducted, starting with a function analysis based on the insights gained from the user studies and expert interviews. Thus, the most significant discoveries as well as demands, wishes, and needs were translated into functions which had to be fulfilled by the interior design of the car. These functions were then combined with other design requirements, resulting in a list of requirements that could serve as a basis for the concept development.

5.1 Functional Analysis

The functional analysis was an essential intermediate step between user study and concept creation. The methods and tools used in this stage served as an aid to translate the study findings into design parameters as well as guidance for the concept generation. Further, the structural approach helped to maintain a holistic perspective and to not disregard or neglect certain aspects. Since the interior of a car is exceptionally complex and contains a huge number of partially very different components and design elements an underlying structure was particularly helpful.

5.1.1 Function-Means Tree

A Function-Means Tree displays the hierarchical order of a functional structure. Starting with the main function at the top, the functions are broken down into sub-functions by going downwards level by level. At least one possible solution has to be identified for each sub-function, which can either fulfill this function alone or in combination with other means for the same sub-function. These means then lead to the next sub-functions and the procedure starts over again until eventually a function can not be broken down any further or the level of detail is sufficient enough for the purpose.

The Function-Means Tree produced in this thesis project has been divided into two parts. The first part depicted in *Figure 5.1* shows the main tree while the second part in *Figure 5.2* focuses on the core function with respect to this project which is enabling user tasks.

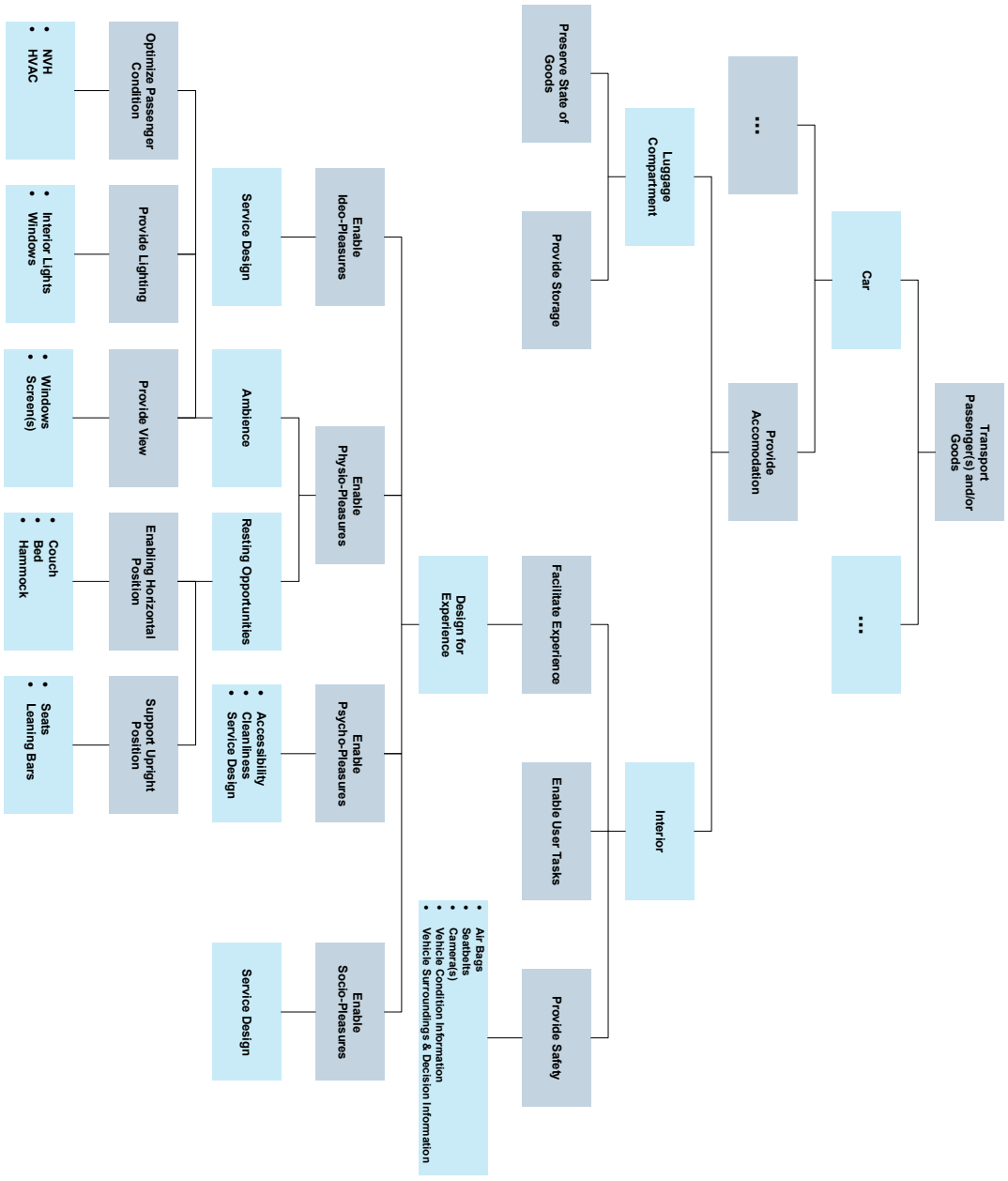


Figure 5.1: Function-Means Tree Part 1

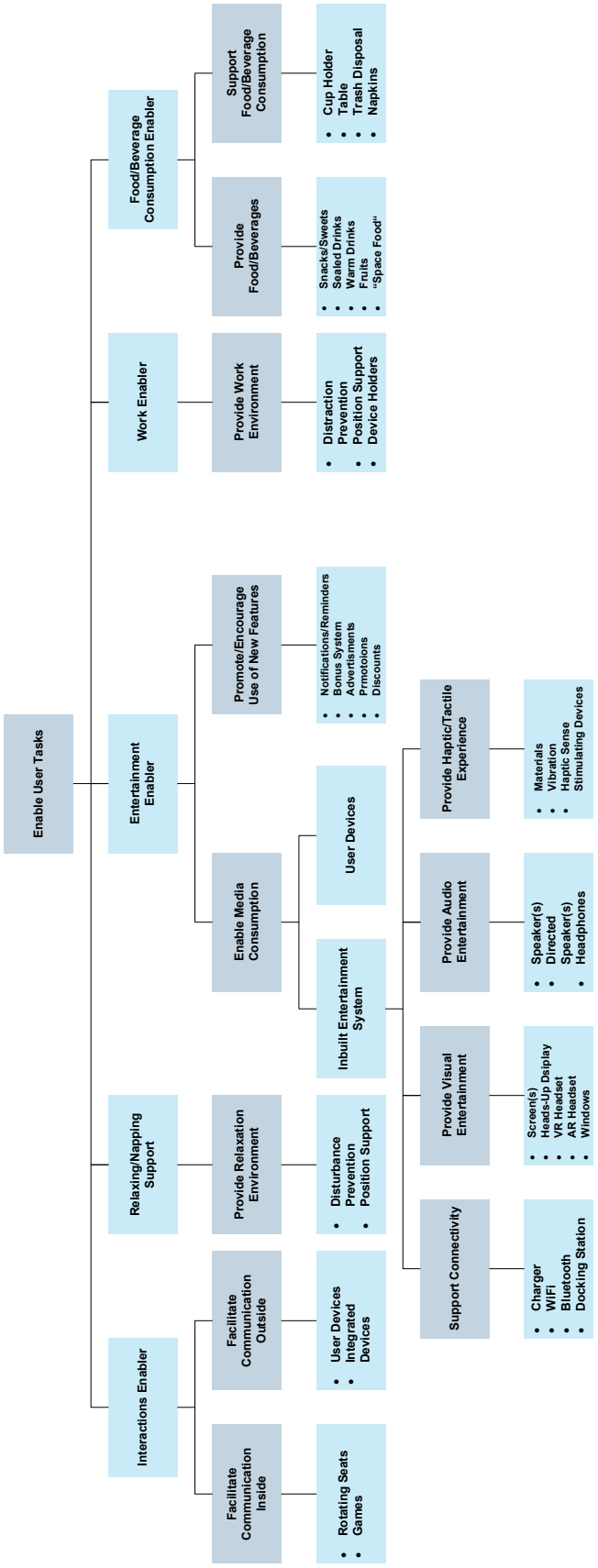


Figure 5.2: Function-Means Tree Part 2

The tree starts at the top with the main function of a vehicle, namely to transport passenger(s) and/or goods. This can evidently be fulfilled by a wide range of vehicles but due to the scope of the project the focus is on the car. The next level of functions is determined until eventually the level of the interior as a solution is reached which in turn has three functions: To facilitate experience, enable user tasks and provide safety. Especially the second aspect is in focus since it relates to the focus area regarding the development effort of this project. *Figure 5.2* shows that, based on the findings from the user studies, user tasks can be enabled by five different categories of means, namely interactions enabler, relaxing/napping support, entertainment enabler, work enabler, and food/beverage consumption enabler. These solutions can be broken down even further, eventually leading to concrete applications and features like rotating seats, speakers, cup holders etc.

While the Function-Means Tree method provides a great level of detail regarding the different functions and their interconnections, not all of them could be taken into account during the concept development phase. Therefore, a list of the most important functions with respect to the master thesis project is presented in *Figure 5.3*. The degree of fundamentality of each function is indicated by the assigned level. While level 1 implies that a corresponding function is indispensable, a level 5 function has the lowest priority for the concept.

No.	Function	Level
F01	Provide Resting Opportunity	1
F02	Provide Storage	1
F03	Provide Feeling of Privacy	3
F04	Provide Feeling of Ownership	3
F05	Provide Relaxation Environment	2
F06	Provide Haptic/Tactile Experience	5
F07	Provide Audio Entertainment	4
F08	Support Connectivity	2
F09	Provide Visual Enteratinment	4
F10	Facilitate Communication Inside	4
F11	Facilitate Communication Outside	4
F12	Provide Work Environment	3
F13	Provide Food/Beverages	4
F14	Promote/Encourage Use of New Features	5
F15	Provide Safety	1
F16	Preserve State of Goods	4
F17	Optimize Passenger Condition	2
F18	Provide Lights	2
F19	Provide View	1
F20	Enable Psycho Pleasures	2
F21	Enable Socio/Ideo Pleasures	-
F22	Support Food/Beverage Consumption	4

Figure 5.3: List of Main Functions

5.1.2 Concept Layer Model

The expert interviews as well as the user studies showed that the needs and wishes of different user groups can diverge significantly. Therefore, it was decided to refrain from trying to develop one single concept that is intended to serve all demands. It would most likely just end up as a solution that is not more than an accumulation of trade-offs and that does not fulfill any requirements properly. In addition, the cultural differences between China and Europe add another dimension to the problem since the investigations clearly showed that the expectations from people of the two nationalities can differ with regard to multiple aspects. Ultimately, this meant that several concepts variants had to be developed in order to be able to address different target groups in Europe and China.

Therefore, three different versions of an interior concept were designed. The first one was intended to be a basic version that fulfills the essential core functions and is indented to be used by people that just want to get from A to B in a convenient way. These users do not expect a lot of features in the car since they will most probably use their smartphones to perform most of the user tasks they intent to do in an autonomous car while commuting. The other two concepts were more sophisticated and designed for users that have higher expectations in terms of comfort and functionality, want to travel together with friends, or would like to perform tasks like working on their laptop or having breakfast. However, even though the three concepts differ with respect to a number of aspects it is important to emphasize that they have the same basic structure due to economic and logistical reasons.

In order to address this multidimensional issue and identify what should be included in each concept, the main functions were rearranged in a model with multiple layers, representing the degree of fundamentality of each function. An illustration of the developed model is depicted in *Figure 5.4*. Based on the levels indicated in *Figure 5.3*, four different layers around a core were identified. Thus, the core of each concept consists of solutions that fulfill the basic functions that an interior has to facilitate, namely to provide a resting opportunity (F01), provide storage (F02), provide safety (F15), and to provide a view of the surroundings (F19). The different layers around this core contain solutions regarding comfort, customizability, specific user tasks, as well as aesthetics and might differ for the various concepts. The features of the ridesharing service behind the product are interwoven through the layers since they affect all of them. Hence, as brought up during the role plays (see *Section 4.3.1.3*), the service could allow the selection of a certain theme for the car like, e.g. "Silent Car" which would influence how to provide a suitable work environment or a feeling of privacy (both in the customizability layer). The selection of a "Public Car" could on the other hand, facilitate the communication inside (user tasks layer) since no other passenger can complain about others who want to have a conversation in the car and might disturb him or her with this.

As already mentioned before, the basic concepts for the Chinese and European

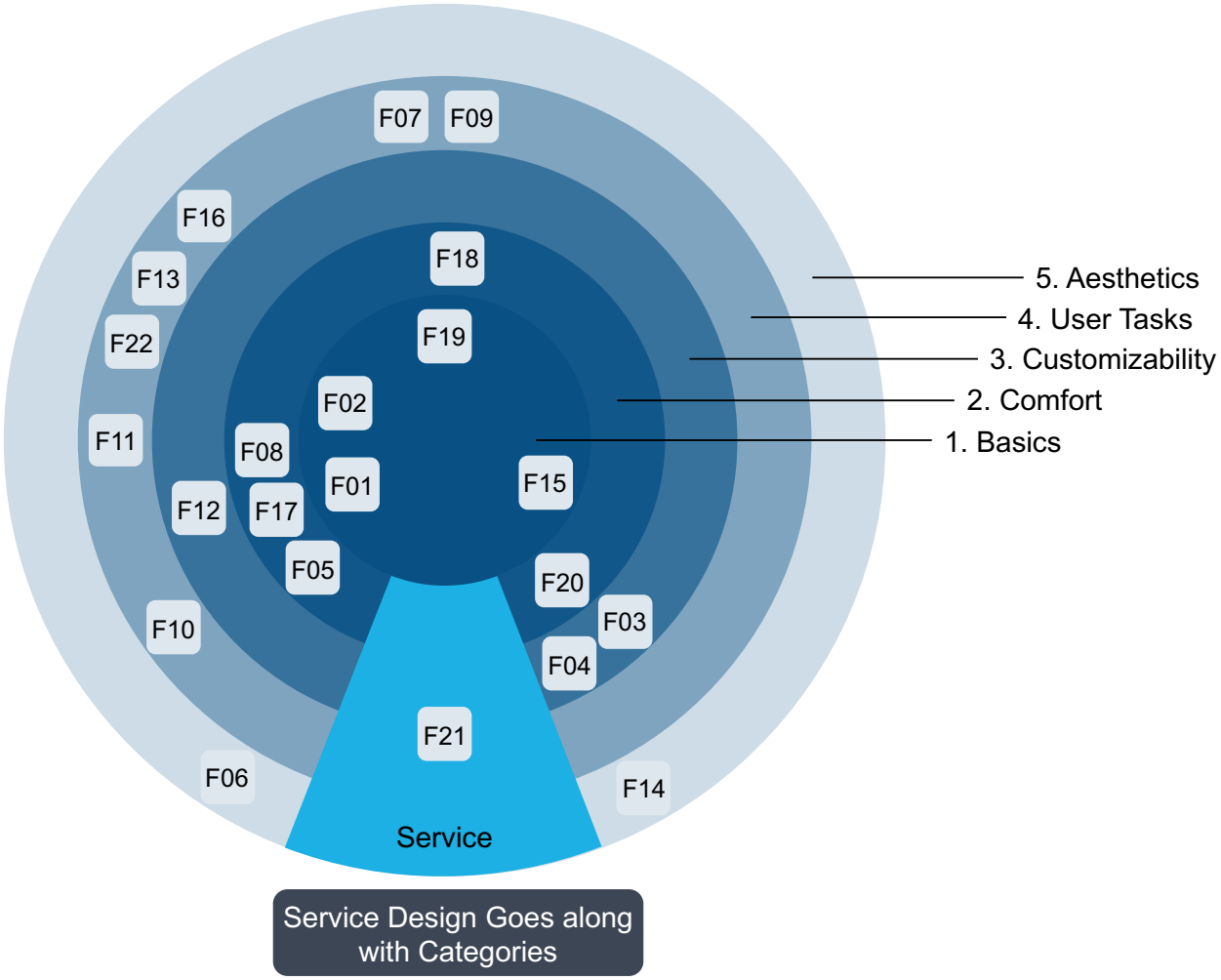


Figure 5.4: Concept Layer Model

users are identical for the most part. The premium models for both markets on the other hand, differ in terms of aesthetic design, functionality and in particular the number of features. Since most Europeans study participants consider themselves to be rather puristic and stated that they find minimal designs appealing and considering the statements made by experts and Chinese study participants regarding expectations of Chinese users (e.g. "more is more"), the number of features is higher for the Chinese premium version. The differences between the three types of concepts developed as part of this project are visualized in *Figure 5.5*.

The structure that was set up helped to determine in what way the concepts should differentiate and what priorities were assigned to various functions. However, due to the effort required to develop multiple concepts, it was decided that the focus would be on the basic concept which was intended to be more or less identical for the European and Chinese market. Furthermore, it was concluded to develop a concept for the European premium version, in order to demonstrate the major differences between the two segments. The European concept was

selected from the two premium options because of its lower level of complexity and amount of expected features compared to the Chinese one. This would make it easier to create a digital model, which was the deliverable of this project (according to the aim presented in *Chapter 1.3*).

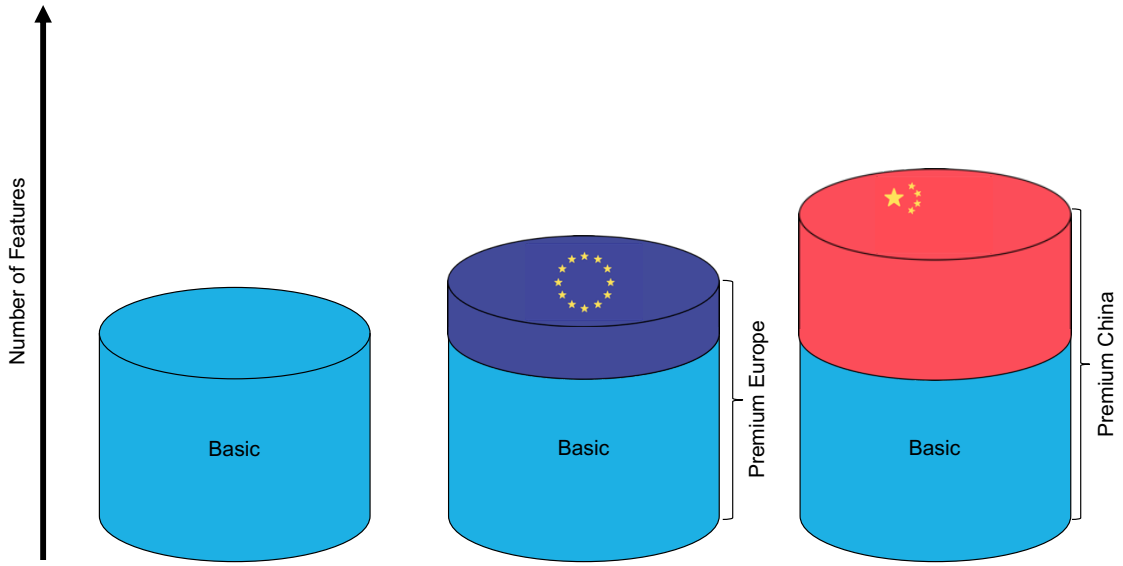


Figure 5.5: Differences between the Basic and the Premium Concepts

5.2 List of Requirements

To summarize the various requirements and prepare the actual concept development a list of requirements was produced, which is depicted in *Figure 5.6*.

The functions previously determined make up the largest part of the list since they are of fundamental interest with respect to the project. In order to complete the list other relevant requirements from areas such as geometry, usability, comfort and convenience as well as design and quality impressions have been added. Due to the futuristic character of the master thesis project which primarily focused on an innovative design, requirements that are usually found in car development projects have been neglected. These included e.g. aerodynamics, NVH, mass, safety etc. The same also applied to requirements that are more relevant for products in later development stages like cost, material, manufacturing, maintenance, environment etc.

Since a specification consists of a metric and a value, a target value for each requirement has been added (Eppinger and Ulrich, 2015). Due to the early design stage, almost all target values were chosen to be binary (Yes/No) and not numerical in order to focus on feasibility rather than fine tuning and optimization. Furthermore, the possible types of evaluations were determined for each requirement. While some can be evaluated by assessing dimensions and po-

No.	Requirement	R/D	Target Value	Evaluation
1	**Function**			
1.01	Provide Resting Opportunity	R	Yes	User/Ergonomic Assessment
1.02	Provide Storage	R	Yes	CAD, Ergonomic Assessment
1.03	Provide Feeling of Privacy	R	Yes	User Assessment
1.04	Provide Feeling of Ownership	D	Yes	User Assessment
1.05	Provide Relaxation Environment	D	Yes	User Assessment
1.06	Provide Haptic/Tactile Experience	D	Yes	User Assessment
1.07	Provide Audio Entertainment	D	Yes	User Assessment
1.08	Support Connectivity	D	Yes	User Assessment
1.09	Provide Visual Enteratinment	D	Yes	User Assessment
1.10	Facilitate Communication Inside	D	Yes	User Assessment
1.11	Facilitate Communication Outside	D	Yes	User Assessment
1.12	Provide Work Environment	D	Yes	CAD, Ergonomic Assessment
1.13	Provide Food/Beverages	D	Yes	CAD, Engineering Assessment
1.14	Promote/Encourage Use of New Features	D	Yes	User Assessment
1.15	Provide Safety	R	Yes	Engineering Assessment
1.16	Preserve State of Goods	D	Yes	Engineering Assessment
1.17	Optimize Passenger Condition	D	Yes	User/Ergonomic Assessment
1.18	Provide Lights	R	Yes	CAD, Ergonomic Assessment
1.19	Provide View	R	Yes	CAD, Ergonomic Assessment
1.20	Enable Psycho Pleasures	D	Yes	User Assessment
1.21	Enable Socio/Ideo Pleasures	D	Yes	User Assessment
1.22	Support Food/Beverage Consumption	D	Yes	CAD, Ergonomic Assessment
2	**Geometry**			
2.01	Volume (HxWxL)	D	< 2x2x4m	CAD
3	**Usability**			
3.01	Easy to Access	R	Yes	User/Ergonomic Assessment
3.02	Easy to Use (Physical Aspects)	R	Yes	User/Ergonomic Assessment
3.03	Intuitive to Use (Cognitive Aspects)	R	Yes	User/Ergonomic Assessment
4	**Comfort & Convenience**			
4.01	Feeling of Being in Control	D	Yes	User Assessment
4.02	Perception of Roominess	D	Yes	User Assessment
5	**Design & Quality Impressions**			
5.01	According to CEVT Design Guidelines	D	Yes	Designer Assessment
5.02	Solid Impression	D	Yes	Designer Assessment

R=Requirement, D=Desire

Figure 5.6: List of Requirements

sitions within the CAD-model or using engineering parameters, others require a user assessment.

Since the list of requirements represents all requirements that are relevant for the concept development, it also served as a basis for the concept evaluation towards the end of the master thesis project to determine which requirements could actually be fulfilled (see *Section 6.3.3*).

6

Concept Development

The user studies were followed by the actual concept development process. Based on the *Specification of Requirements* (presented in *Chapter 5*) various concepts were developed in an iterative process in order to address the third and last research question: *What is needed in terms of interior design and features in the car to enable user activities?* Eventually, the number of concepts was narrowed down by a selection process resulting in a final concept which then was refined and designed in detail.

6.1 Aim

The aim of the concept development phase was to develop solutions for the requirements and to address demands, wishes, and behavioural observations of the study participants by actual design features. Finally, all these solutions had to be combined to a coherent concept.

6.2 Method

Just like the user study phase, the concept development phases can also be divided into several activities. The *Concept Generation* phase which covered an idea generation and a concept visualization stage was followed by the *Concept Selection & Refinement*. This phase included the identification of the most promising concepts as well as an iterative modelling and design process. Last, a *Concept Evaluation* was conducted to verify the utility of the concept and to determine potential improvement opportunities for the future.

6.2.1 Concept Generation

The Concept Generation was mainly based on the functional analysis presented in *Chapter 5.1* since the identified functions were a direct result of the user needs and were therefore the focus of the entire project. In order to elaborate on the solutions already mapped with the Function-Means-Tree in *Section 5.1.1* and to find even more solutions in a structured way, a Morphological Matrix was used. In a subsequent next step this tool also served as a reference for combining the different solutions to concepts.

The borderline between the exterior and interior of a vehicle can be quite blurry since some features and characteristics are shared by both. The overall shape of the car, i.e. the exterior design defines the interior design significantly, especially in terms of space, shape, and lighting. Hence, the exterior design has also to be taken into consideration to a certain extent for the development of an interior concept. Developments like the increasing dissemination of electric propulsion of cars as well as autonomous driving technologies which result in the omission of steering devices, that no longer have to be permanently in place, lead to opportunities to question and redefine the traditional space partitioning of engine compartment, vehicle interior, and trunk. This meant that, in order to tap the full potential of an electric, autonomous car, the prospective interior could not simply be placed in an existing car model or even one that is future-oriented but still based on conventional technologies and user schemes of the present like combustion engines and manual driving. Therefore, a conceptual design of a new type of car was developed which focuses on possible positive impacts that changes to the exterior can have on the interior and hence on the space that the users actively use and occupy during the ride.

When it came to the interior design, it was essential to break the design task down into manageable elements. Since the interior of a car is highly complex with a wide range of diverse and partially very specific components it was crucial to set priorities when it came to the elaboration and refinement of the concepts. The scope of the project did not allow a detailed development of all interior components which is the reason why those elements that could potentially address the most fundamental functions were selected for an in-depth design effort. Therefore, the concept development process for the interior would mainly focus on seats, device holders, and storage opportunities.

6.2.2 Concept Selection & Refinement

Once initial concepts have been developed they have to be screened and compared. To support the Concept Selection process, concept-scoring matrices (also known as Kesselring Matrices) were used to better differentiate among the competing concepts (Eppinger and Ulrich, 2015).

As soon as the most promising concepts were selected, the detailed design could begin. This did not only include the detailed product design of the different components in several steps but also continuous refinement and optimization work of the technical functionality.

6.2.3 Concept Evaluation

The purpose of the in-depth user study at the beginning of this concept development project was to build up a significant amount of knowledge before any solutions to the stated problem were proposed. This way, the concepts that were eventually developed would be much more sophisticated and well-founded even

in earlier stages. Furthermore, the number and length of iterations could be reduced significantly.

Nevertheless, a concept evaluation is inevitable to assure that user requirements have been met and to find out how the concept could be improved even further. Moreover, participants might be able to give more detailed feedback or make remarks of completely other kind than during an interview once they have a visual concept in front of them that they can comment on.

Therefore, a usability test was conducted at the end of the development process in order to gather feedback on the designed concepts. For this, some of the role play participants as well as an expert from the ergonomics department at CEVT were invited to test the concepts in a virtual reality setting (see *Figure 6.1*). This way, the participants could get an impression of how the interior would look like and feel like. Furthermore some animations have been prepared to demonstrate certain technical features of the concept.

Figure 6.1: Evaluation of the Final Concepts in Virtual Reality

The evaluation session consisted of a practical part in which the participants were wearing a VR headset to explore the concept as well as a semi-structured interview that was conducted in parallel while the participants were experiencing the concepts. Some of the questions posed were:

- How do you like the concept overall?
- What do you like most about it?
- Do you have the feeling that something is missing?
- Where would you prefer to sit and why?
- Do you feel safe?
- Do you feel connected to the outside?
- Is the level of privacy sufficient if you fold up the shields?
- Do you feel like you own your own space?
- Do you think that the interior will be (easy to) clean?
- Is the storage space sufficient?

Thus, several questions aimed at determining to what extent functions that have been identified in *Chapter 5.1* (e.g. "Provide Storage", "Provide Feeling of Privacy" etc.) were fulfilled by the concepts.

6.3 Results

In the following section the results of the concept development efforts are presented. First, the process of generating various concepts is described, focusing on the interior design while also considering a redesign of the car exterior. This is followed by the concept selection and refinement process, eventually resulting in a digital model of an interior concept that could be evaluated in an usability test.

6.3.1 Concept Generation

The concept generation was aimed at developing several concept ideas that could address the identified user needs. Since the interior space is significantly influenced by the outer shape of a car, the exterior design was approached first. In the next step, various concepts for the interior were developed and refined in an iterative process.

6.3.1.1 Exterior Design

As indicated in *Section 6.2.1*, the design of the exterior has a significant influence on the shape and design possibilities of the interior simply as it is its container. This is the reason why a redesign of the car exterior – considering what new possibilities this opened up for the interior design – has been carried out for this project. The exterior of the car was supposed to be the same for all concepts, no matter if premium or basic and whether intended for the Chinese or European market.

The overall idea of changing the exterior was to challenge the traditional shape of a car and think beyond the conventions of the industry. The underlying intention was to use the design freedom that results from the use of an electric propulsion system as well as the omission of traditional steering devices in order to change

the exterior in a way that has a positive effect on the interior. While the overall design should not move too far away from the traditional shape, there were certain things that could be improved so that more design freedom for the interior was gained and the user could eventually benefit from these changes.

One important aspect that was discussed during all role plays was the access to the car. Since the autonomous car will be used for inner city commuting the time that a passenger will spend in the car is relatively short. This in turn means that people will constantly have to get into and out off the car. To facilitate this the overall height of the car should be increased so that users do not have to bend down as much in order to enter the car. Besides, they will less likely knock their heads while entering or leaving the car. Since the speed inside cities is relatively low, the impact that this change might have on the aerodynamics of the car is of little relevance. Furthermore, as requested by all role play participants, the car was equipped with four individual doors – one for each passenger. Sliding doors were used to minimize the necessary space for opening them.

As explained in *Section 3.3.4*, the underlying structure was a "skateboard" chassis which is typical for electric cars. This means that the wheels are placed further towards the front and rear part of the vehicle compared to a traditional car with a combustion engine which results in more available space for the interior. Moreover, the expressed desire of the role play participants for bigger windows and a panoramic sunroof are also considered in the design to enable more natural light to come into the car and a better view. The result of the exterior design is presented in form of sketches in *Figures 6.2 & 6.3.*

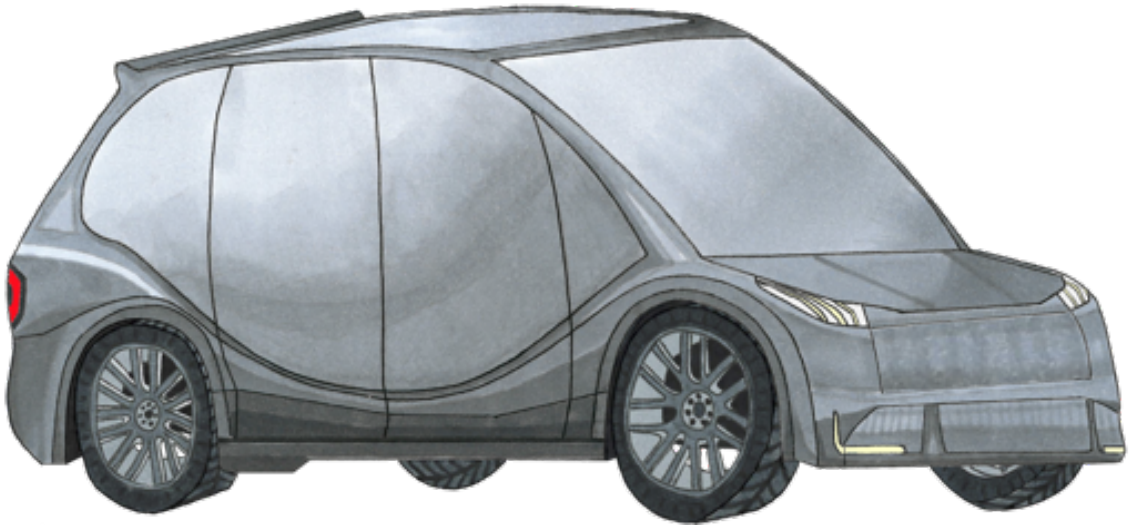


Figure 6.2: Exterior Design Front View

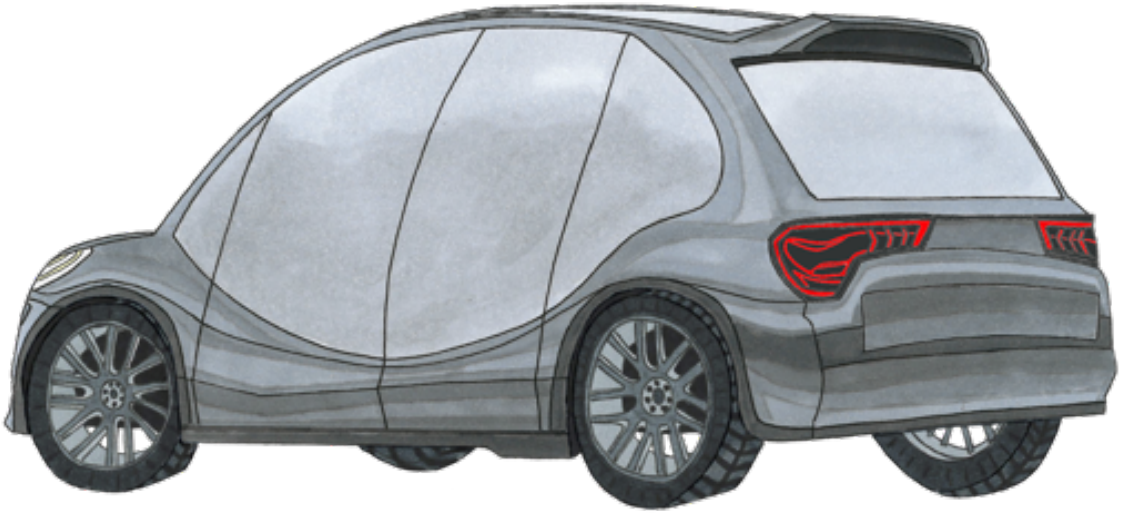


Figure 6.3: Exterior Design Rear View

6.3.1.2 Initial Interior Design Concepts

The development process for the interior concepts went through several iterations starting with the development of *Initial Interior Design Concepts* followed by a *Concept Selection & Refinement* in order to develop the ideas further. The refined concepts were then part of another elaboration cycle in which *Digital Models* were created. Finally, the process was concluded by a *Concept Evaluation*.

For the generation of initial concepts, the functions identified during the functional analysis were used as a starting point (see *Chapter 5.1*). In order to explore as many possible solutions for each function in a structured manner a Morphological Matrix was utilized. The matrix for this project is shown in *Figure 6.4*.

As stated in Section 5.1.2 it was determined that it would not be possible to address the different needs of all user groups with only one concept. Therefore, it was concluded that a segmentation into basic and premium concepts would be the best way to solve this issue. While the functions F15–F22 would be addressed with similar solutions for both concept categories, the basic and premium concepts would mainly differ with respect to the solutions for the functions F01–F14.

The solutions for each function in the columns (S1–S9) are sorted according to how well they are expected to fulfill the function. The solution to the left were expected to be the most rudimental ones, while those to the right were considered to be more sophisticated and complex. Thus, making trade-offs between simple but probably unsatisfactory and sophisticated but perhaps too inordinate and costly solutions were a central challenge during the concept generation. Moreover, some solutions could be in conflict with others addressing other functions so that it could also be necessary to make trade-offs in this regard.

The next step after creating the Morphological Matrix was to combine solutions for each function from it in order to create different concepts. This is mainly done by using common sense and always with the results of the expert interviews and user studies in mind. The different combinations of solutions for the basic and premium segment and made for the two different markets in Europe and China are shown in *Figures 6.5 & 6.6*. They also follow the approach of including more features in the Chinese premium concept visualized in *Figure 5.5*.

Functions / Solutions	S1	S2	S3	S4	S5	S6	S7	S8	S9
F01 Provide Resting Opportunity	Leaning Bar	Seat Shell	2-Component Seat	Hammock Seat	3+-Component Seat	Couch			
F02 Provide Storage	Ceiling Pocket	Door Pocket	Foldable Pocket	Hanger(s)	Side Pocket	Trap Door Pocket	Extra Space	Beneath-The-Seat Pocket	Trunk
F03 Provide Feeling of Privacy	Darkness	Limited Visibility (from outside)	Headrest Shields	Seat Positions	Curtains	Transparent Layer	Space	Walls	
F04 Provide Feeling of Ownership	Seat Memory	Atmosphere (Light) Customization	Service Implementation	Visual Customization	Voice Assistant				
F05 Provide Relaxation Environment	Relaxation Music	Resting Oppprtunity (see above)	Darkness	Noise Cancelling					
F06 Provide Haptic/Tactile Experience	Interactive Projection on Surface	Touch Screen	Touchless Technology	Interior Materials					
F07 Provide Audio Entertainment	Headphones	Speaker	Directed Speaker						
F08 Support Connectivity	Charger	Wireless Charger	Bluetooth	Docking Station	WiFi				
F09 Provide Visual Enteratinment	Window(s)	Heads-Up Display	Screen(s)	AR Headset	Integrated Window Screen	VR Headset			
F10 Facilitate Communication Inside	Daily News/Fun Facts	Rotating Seats	Games						
F11 Facilitate Communication Outside	User Devices	Integrated Devices							
F12 Provide Work Environment	Device Holder	Position Support	Voice Assistant	Eye Tracker	Mind Control (BCI)	Distraction Prevention			
F13 Provide Food/Beverages	Sealed Drinks	Warm Drinks	Fruits	Snacks/Sweets	"Space Food" (in form of tubes, pills etc.)				
F14 Promote/Encourage Use of New Features	Advertisments	Notifications/ Reminders	Promotions/ Discounts	Collaborations	Bonus System				
F15 Provide Safety	Vehicle Condition Information	Vehicle Surroundings & Decision Information	Cameras	Aribags	Seatbelts				
F16 Preserve State of Goods	Insulation	Damping							
F17 Optimize Passenger Condition	HVAC	NVH							
F18 Provide Lights	Interior Lights	Window(s)							
F19 Provide View	Screen(s)	Windows							
F20 Enable Psycho Pleasures	Service Design	Accessibility	Cleanliness						
F21 Enable Socio/Ideo Pleasures	Service Design								
F22 Support Food/Beverage Consumption	Napkins	Cupholders	Trash Disposal	Table					

Figure 6.4: Morphological Matrix

F01 Provide Resting Opportunity	2-Component Seat
F02 Provide Storage	Beneath-The-Seat Pocket + Door Pockets + Extra Space + Hangers
F03 Provide Feeling of Privacy	Space + Seat Positions + Headrest Shields + Lim. Visibility (from outside)
F04 Provide Feeling of Ownership	Atmosphere Custom. + Service Impl.
F05 Provide Relaxation Environment	Relaxation Music + Darkness + Resting Opportunity (see above)
F06 Provide Haptic/Tactile Experience	Basic Materials
F07 Provide Audio Entertainment	Headphones
F08 Support Connectivity	WiFi + Bluetooth + Charger
F09 Provide Visual Enteratinment	Windows + Heads-Up Display
F10 Facilitate Communication Inside	
F11 Facilitate Communication Outside	User Devices
F12 Provide Work Environment	Position Support + Device Holder + Distraction Prevention
F13 Provide Food/Beverages	Sealed Drinks
F14 Promote/Encourage Use of New Features	Notifications/Reminders + Discounts/Promotions + Collaborations
F15 Provide Safety	Seatbelts + Airbags + Cameras + VCI + VS&DI
F16 Preserve State of Goods	Damping + Insulation
F17 Optimize Passenger Condition	NVC + HVAC
F18 Provide Lights	Windows + Interior Lights
F19 Provide View	Windows
F20 Enable Psycho Pleasures	Cleanliness + Accessibility + Service Design
F21 Enable Socio/Ideo Pleasures	Service Design
F22 Support Food/Beverage Consumption	Cupholders + Trash Disposal + Tables

F01 Provide Resting Opportunity	2-Component Seat
F02 Provide Storage	Beneath-The-Seat Pocket + Door Pockets + Extra Space + Hangers
F03 Provide Feeling of Privacy	Space + Seat Positions + Headrest Shields + Lim. Visibility (from outside)
F04 Provide Feeling of Ownership	Atmosphere Custom. + Service Impl.
F05 Provide Relaxation Environment	Relaxation Music + Darkness + Resting Opportunity (see above)
F06 Provide Haptic/Tactile Experience	Basic Materials
F07 Provide Audio Entertainment	Headphones
F08 Support Connectivity	WiFi + Bluetooth + Charger
F09 Provide Visual Enteratinment	Windows + Heads-Up Display
F10 Facilitate Communication Inside	Daily News/Fun Facts
F11 Facilitate Communication Outside	User Devices + Integrated Devices
F12 Provide Work Environment	Position Support + Device Holder + Distraction Prevention
F13 Provide Food/Beverages	Sealed Drinks
F14 Promote/Encourage Use of New Features	Notifications/Reminders + Discounts/Promotions + Collaborations
F15 Provide Safety	Seatbelts + Airbags + Cameras + VCI + VS&DI
F16 Preserve State of Goods	Damping + Insulation
F17 Optimize Passenger Condition	NVC + HVAC
F18 Provide Lights	Windows + Interior Lights
F19 Provide View	Windows
F20 Enable Psycho Pleasures	Cleanliness + Accessibility + Service Design
F21 Enable Socio/Ideo Pleasures	Service Design
F22 Support Food/Beverage Consumption	Cupholders + Trash Disposal + Tables

Figure 6.5: Overview of the Basic Chinese and European Interior Concepts

F01 Provide Resting Opportunity	3+-Component Seat
F02 Provide Storage	Beneath-The-Seat Pocket + Door Pockets + Extra Space + Hangers (automated)
F03 Provide Feeling of Privacy	Space + Seat Positions + Headrest Shields + Lim. Visibility (from outside)
F04 Provide Feeling of Ownership	Atmosphere Custom. + Service Impl. + Seat Memory + Voice Assistant + Visual Costum.
F05 Provide Relaxation Environment	Relaxation Music + Darkness + Resting Opportunity (see above) + Noise Cancaelling
F06 Provide Haptic/Tactile Experience	Premium Materials
F07 Provide Audio Entertainment	Directed Speaker
F08 Support Connectivity	WiFi + Bluetooth + Charger + Docking Station
F09 Provide Visual Enteratinment	Windows + Heads-Up Display + Integrated Window Screen/Screens
F10 Facilitate Communication Inside	Rotating Seats + Games + Daily News/Fun Facts
F11 Facilitate Communication Outside	User Devices + Integrated Devices
F12 Provide Work Environment	Position Support + Device Holder + Distraction Prevention + Voice Assistant + Eye Tracker
F13 Provide Food/Beverages	Sealed Drinks + Warm Drinks + Snacks
F14 Promote/Encourage Use of New Features	Notifications/Reminders + Collaborations + Bonus System
F15 Provide Safety	Seatbelts + Airbags + Cameras + VCI + VS&DI
F16 Preserve State of Goods	Damping + Insulation
F17 Optimize Passenger Condition	NVC + HVAC
F18 Provide Lights	Windows + Interior Lights
F19 Provide View	Windows
F20 Enable Psycho Pleasures	Cleanliness + Accessibility + Service Design
F21 Enable Socio/Ideo Pleasures	Service Design
F22 Support Food/Beverage Consumption	Cupholders + Trash Disposal + Tables + Napkins

F01 Provide Resting Opportunity	3+-Component Seat
F02 Provide Storage	Beneath-The-Seat Pocket + Door Pockets + Extra Space + Hangers (manual)
F03 Provide Feeling of Privacy	Space + Seat Positions + Headrest Shields + Lim. Visibility (from outside)
F04 Provide Feeling of Ownership	Atmosphere Custom. + Service Impl. + Seat Memory + Visual Costum. + Person Recognition
F05 Provide Relaxation Environment	Relaxation Music + Darkness + Resting Opportunity (see above) + Noise Cancaelling
F06 Provide Haptic/Tactile Experience	Premium Materials + Touchless Control
F07 Provide Audio Entertainment	Directed Speaker + Karaoke
F08 Support Connectivity	WiFi + Bluetooth + Charger + Docking Station
F09 Provide Visual Enteratinment	Windows + Heads-Up Display + Integrated Window Screen/Screens + VR/AR
F10 Facilitate Communication Inside	Rotating Seats + Games + Daily News/Fun Facts
F11 Facilitate Communication Outside	User Devices + Integrated Devices
F12 Provide Work Environment	Position Support + Device Holder + Distraction Prevention
F13 Provide Food/Beverages	Sealed Drinks + Warm Drinks + Snacks + "Space Food"
F14 Promote/Encourage Use of New Features	Notifications/Reminders + Collaborations + Bonus System
F15 Provide Safety	Seatbelts + Airbags + Cameras + VCI + VS&DI
F16 Preserve State of Goods	Damping + Insulation
F17 Optimize Passenger Condition	NVC + HVAC
F18 Provide Lights	Windows + Interior Lights
F19 Provide View	Windows + Screen(s)
F20 Enable Psycho Pleasures	Cleanliness + Accessibility + Service Design
F21 Enable Socio/Ideo Pleasures	Service Design
F22 Support Food/Beverage Consumption	Cupholders + Trash Disposal + Tables + Napkins

Figure 6.6: Overview of the Premium Chinese and European Interior Concepts

In *Chapter 5.1* and also in *Section 6.2.1* it was already pointed out that the task to design the entire interior of a car is extremely challenging and should therefore be broken down in into manageable parts. Thus, the concept development focused on certain components.

Those functions that are part of the core of the Concept Layer Model depicted in *Figure 5.4* were selected for an in-depth investigation since they represent the most fundamental functions that had to be fulfilled by all concepts. However, considering the simplicity of the function "Provide View" and the high uncertainty regarding the development of and need for safety features in the future the focus lay on the functions "Provide Resting Opportunity" and "Provide Storage". This meant that two component types were identified: Seats and storage opportunities. This was complemented by looking into solutions for holding various devices since these enable and facilitate multiple user tasks located on the outer layers of the graph. Therefore, a third component type was chosen for a further investigation, namely device holders. In addition, the option to integrate some more functions from the outer layers of the model into one of the three component types was also investigated. To determine what kind of functions would qualify for such implementations, a function distribution table was created which is shown in *Figure 6.7*.

The table shows which of the 22 identified functions could – theoretically – be integrated into the seat (A), device holder (B) and storage (C) respectively. Function F03, "Provide Feeling of Privacy" e.g., could be implemented into all three components while the functions F09, F11, F13, F17, F19, and F21 would be impossible, unreasonable, or inconvenient to integrate into a seat, device holder or storage space. The implementation of solutions to these functions was therefore left for other components that could be placed inside the interior.

In order to avoid repetitions of solutions across the three selected component types (seat, device holder, storage) the remaining 16 functions were categorized into main functions, first level combinations, and second level combinations with respect to the three components (see *Figure 6.8*). The main functions are those that were exclusively fulfilled by one of the three components (A, B, C). For example, it only makes sense for the seat to provide a resting opportunity. The second level of combinations consist of two categories. First the category containing those functions that can be integrated in two of the components at the same time (AB, AC, BC) and second the one for those that either have to be implemented in one or the other but would be repetitive if implemented in both (AB-1, AC-1, BC-1). This means that solutions to provide storage opportunities for items (F02) could be integrated into both, the device holder (B) and the designated storage space (C), whereas an implementation of two audio entertainment solutions (F07) into the seat (A) and device holder (B) would be possible but repetitive and unnecessary. The same line of reasoning applies to the second level combinations just with one more category due to the possible combinations of three components (ABC) and leaving out one (ABC-1) or two (ABC-2) of them respectively.

No.	Function	Seat (A)	Device Holder (B)	Storage (C)
F01	Provide Resting Opportunity	F01 Provide Resting Opportunity		
F02	Provide Storage	F02 Provide Storage		F02 Provide Storage
F03	Provide Feeling of Privacy	F03 Provide Feeling of Privacy	F03 Provide Feeling of Privacy	F03 Provide Feeling of Privacy
F04	Provide Feeling of Ownership	F04 Provide Feeling of Ownership	F04 Provide Feeling of Ownership	F04 Provide Feeling of Ownership
F05	Provide Relaxation Environment	F05 Provide Relaxation Environment		
F06	Provide Haptic/Tactile Experience	F06 Provide Haptic/Tactile Experience	F06 Provide Haptic/Tactile Experience	F06 Provide Haptic/Tactile Experience
F07	Provide Audio Entertainment	F07 Provide Audio Entertainment	F07 Provide Audio Entertainment	
F08	Support Connectivity		F08 Support Connectivity	F08 Support Connectivity
F09	Provide Visual Enteratinment			
F10	Facilitate Communication Inside	F10 Facilitate Communication Inside	F10 Facilitate Communication Inside	
F11	Facilitate Communication Outside			
F12	Provide Work Environment	F12 Provide Working Environment	F12 Provide Working Environment	
F13	Provide Food/Beverages			
F14	Promote/Encourage Use of New Features		F14 Promote/Encourage Use of New Features	
F15	Provide Safety	F15 Provide Safety		
F16	Preserve State of Goods		F16 Preserve State of Goods	F16 Preserve State of Goods
F17	Optimize Passenger Condition			
F18	Provide Lights	F18 Provide Lights	F18 Provide Lights	F18 Provide Lights
F19	Provide View			
F20	Enable Psycho Pleasures	F20 Enable Psycho Pleasures	F20 Enable Psycho Pleasures	F20 Enable Psycho Pleasures
F21	Enable Socio/Ideo Pleasures			
F22	Support Food/Beverage Consumption		F22 Support Food/Beverage Consumption	

Figure 6.7: Function Distribution

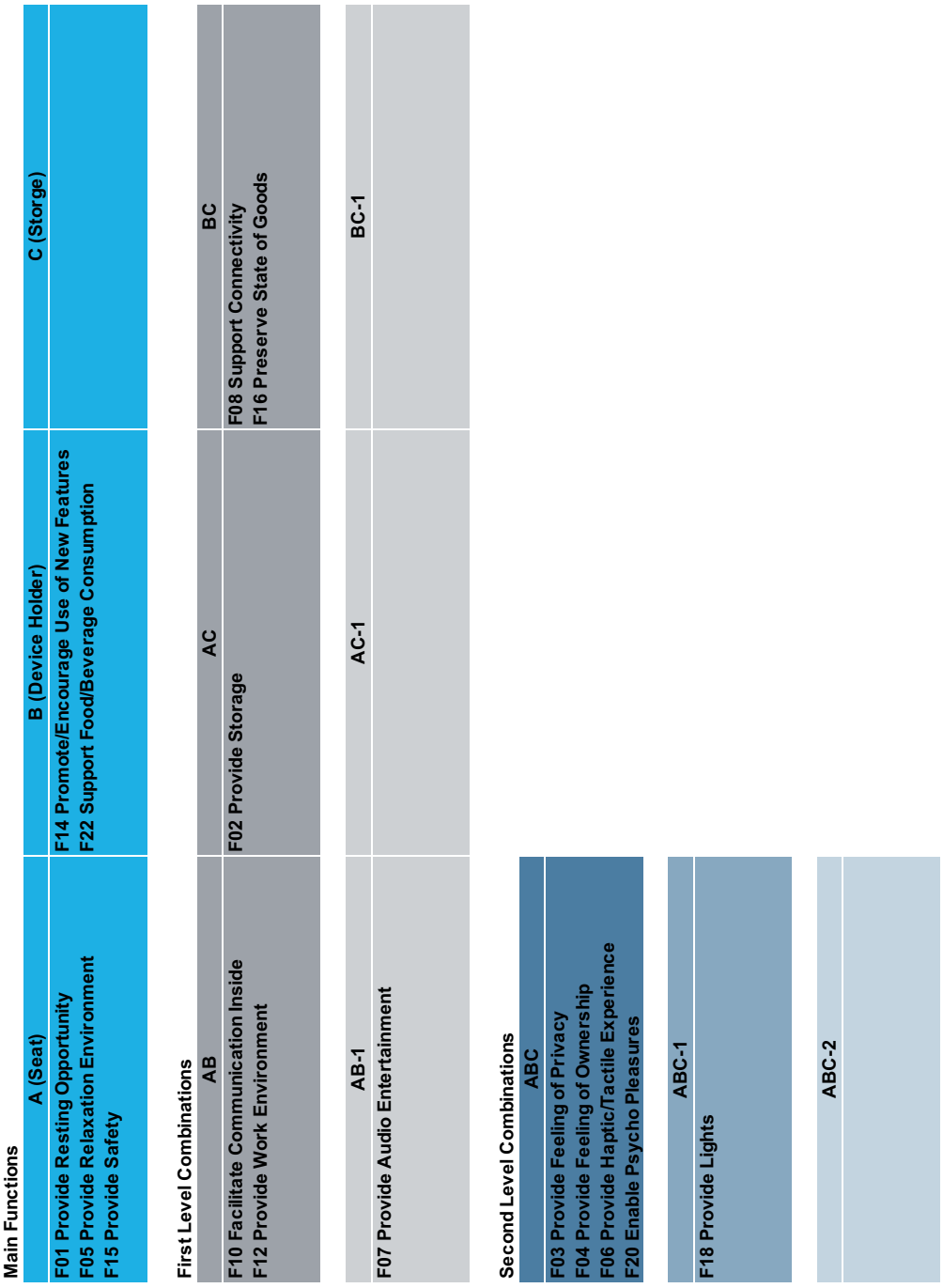


Figure 6.8: Categories of the Function Distribution

After the functions had been allocated to the three different components under investigation, the first set of sketches was created in order to visualize a number of conceptual ideas. The initial concepts for each of the components will be presented and explained in the following sections.

Initial Seat Concepts
In accordance with interior concepts depicted in *Figures 6.5 & 6.6*, the seat should not consist of more than two main components that provide support for the passenger. As shown in the table in *Figure 6.8*, there are three functions that (among the three chosen components) can only be fulfilled by the seats, namely to provide a resting opportunity, provide a relaxation environment, and provide safety.

While the first two are more or less already fulfilled by including a seat in the design place and can perhaps be optimized by the choice of materials, amount of cushioning etc., safety can be provided by adding minimum seat belts but these must be complemented with other safety features of the overall interior and exterior of the car. The functions of providing haptic/tactile experience and enabling psycho-pleasures are also influenced by the choice of materials, design and execution of possible control elements etc.

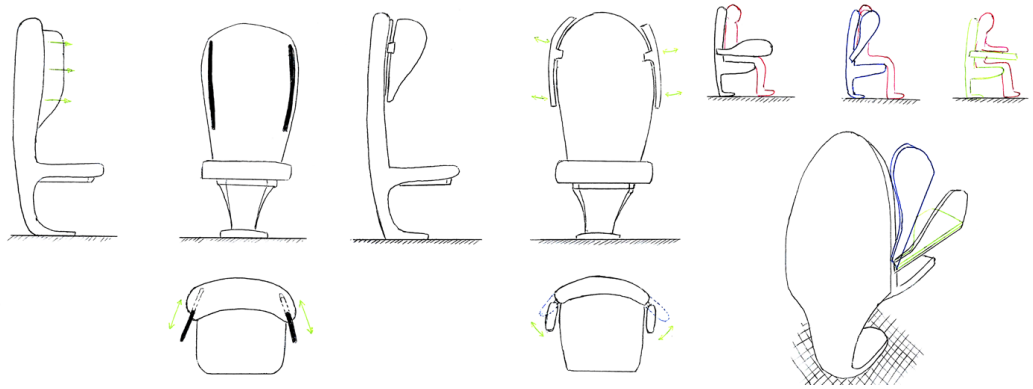
Furthermore, it was found that the seat offers a good opportunity to provide some form of privacy and create a barrier against unwanted proximity to other people which is a particular desire in public transport (Laudenbach, 2018). A feeling of ownership can e.g. be provided by enabling the user to easily adjust his/her seat position.

While the provision of a working environment is related to privacy aspects and the sitting postures that the chair allows, other functions like "Facilitate Communication Inside" can be fulfilled relatively easily if a rotation function is added to the seat designs.

The three most promising concepts depicted in *Figure 6.9* and will be explained in the following.

- *Sliding Shield*: Since privacy is quite important not only for the well-being of a passenger but also for a number of individual user tasks, a shield at eye level was implemented into all seat designs. In case of the *Sliding Shield* concept this shield was not fixed but could be slid into the chair and disappear. Hereby, the shield will not be in the way if a passenger actually wants to have a conversation with a seatmate.

- *Foldable Shield*: The *Foldable Shield* concept pursued a similar approach, but instead of a sliding mechanism the shields could be folded. A significant advantage however was that other features could be implemented into these shields in order to enable other functions. Examples could be reading lights or speakers in order to listen to music, podcasts, or audio books. If directed



(a) Sliding Shield **(b)** Foldable Shield **(c)** School Chair

Figure 6.9: Seat Concepts

speakers (also called parametric speakers) are used the fellow passengers would not even be disturbed since these specific speakers (already available today) only emit sound in one specific directions. Outside of this line one does not perceive any kind of sound (Kuroda, 2016).

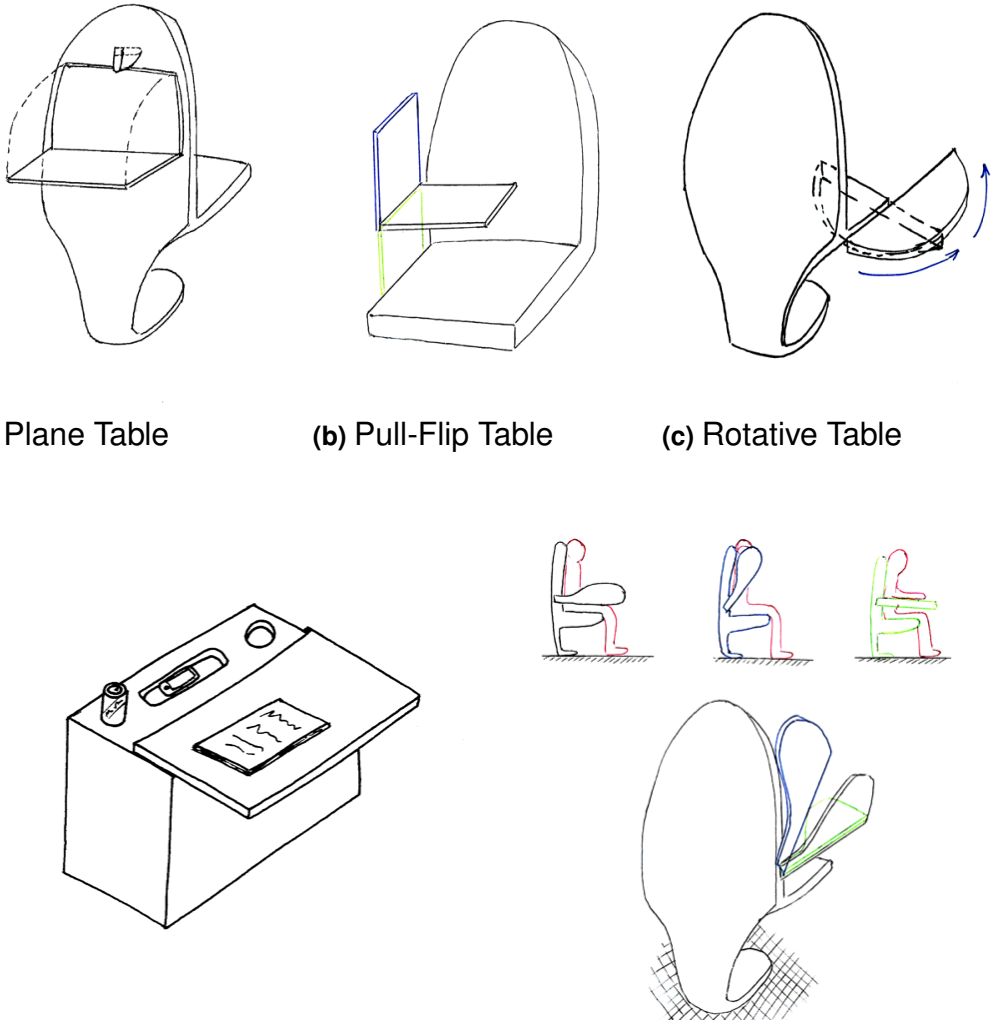
- *School Chair*: The *School Chair* concept was a multi-functional solution. The movable shield at arm height could take three positions and could be used as an armrest, privacy shield, or table. However, the user had to choose between on of these options and cannot use more than one at a time. Due to the fact that this multipurpose solution could also be used as a device holder it is also listed under the name *School Table* under the *Initial Device Holder Concepts* in the next section.

Initial Device Holder Concepts

The term "device holders" is here understood to mean all sorts of tables, holders, trays etc. The functions unique to this component are to promote/encourage the use of new features and support food/beverage consumption. In addition to this, there is an opportunity to address the function of providing storage for smaller items as well as preserving the state of goods, i.e. to protect them as well as to hold them at a desired temperature in case of drinks, food etc. Further, the connectivity can be supported by implementing wired or wireless chargers, docking stations or other types of connectors. The functions "Provide Haptic/Tactile Experience" as well as "Enable Psycho Pleasures" can again be affected by the choice of materials, the design of movable elements, their mass etc.

A total of five initial device holder concepts have been developed (see *Figure 6.10*). An explanation of each concept follows below.

- *Plane Table*: The *Plane Table* concept was a very simple but still effective and space-saving concept for a foldable table which is very common in passenger airplanes and trains. A major disadvantage was however that the availability of the table is dependent on the positioning of the seat in front



(a) Plane Table **(b)** Pull-Flip Table **(c)** Rotative Table

(d) The Pod **(e)** School Table

Figure 6.10: Device Holder Concepts

of it. Hereby, the solution could not be applied to the first and second row seats in the same way.

- *Pull-Flip Table*: The *Pull-Flip Table* was also a well-tried solution that could provide a quite stable table which could be hidden if not needed. In comparison to the *Plane Table* concept it had the advantage that the table is attached to the seat itself.

- *Rotative Table*: The same idea of not having a large, permanently installed table was pursued by the *Rotative Table* concept. A table for placing relatively small devices or items was attached to the side of the seat. However, if necessary the table could be enlarged by rotating it since the complete element was a semicircle with one half hidden in the seating surface (see *Figure 6.10c*).

- *The Pod*: The concept with the name "*The Pod*" was a standalone solution and the only device holder concept that is independent of the seat structure. It was basically a container which would be placed between two seats. Two tables were stored in its center and could be pulled out if needed (see *Figure 6.10d* with one table pulled out and one remaining inside the container). When a table was not pulled out because the user does not need or want a huge surface in front of him or her, the pod still offers a small storage area possibly including a phone charger and/or cup holders at the top.

Initial Storage Concepts

As the name already implies the *Storage* concepts are primarily supposed to provide storage and also preserve the state of the stored goods. However, depending on the execution and a possible implementation of chargers and connectors for external devices this element could also at least partially fulfill the function "Support Connectivity".

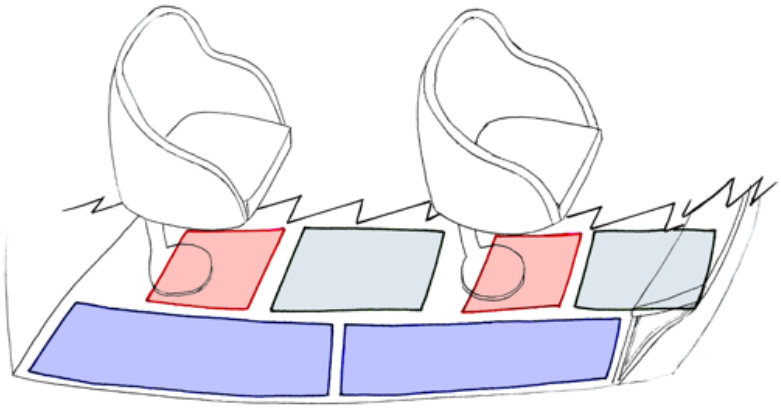
Further, the storage of personal items also touches upon the function of providing a feeling of privacy depending on how much the design can prevent theft etc. Other functions like "Provide Feeling of Ownership", "Provide Haptic/Tactile Experience" or "Enable Psycho Pleasures" are once more influenced by the choice of materials, functionality etc.

Figure 6.11 shows the initial stage of the three different storage concepts that have been developed. They will be explained in the following.

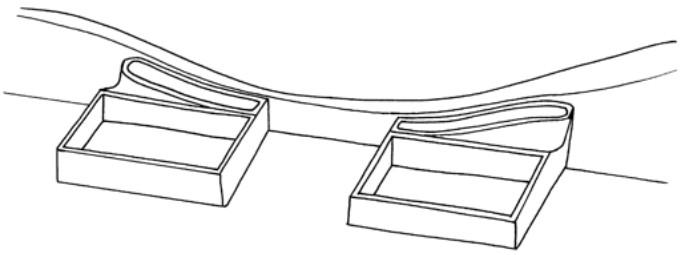
- *Free Space*: The concept of *Free Space* was the most minimal solution possible since it provides storage by actually preventing the placement of too many other components that would take up space. Three areas have been identified for storage opportunities: Under, in front of and next to the seat. It should also be noted that space itself is in general a very valuable feature for most users since it is usually a scarce resource in all types of transportation vehicles that one has to pay an additional price for (compare differences between economy and business class on flights). So, if the passengers do not bring too much luggage they will certainly enjoy the extra legroom.

- *Side Compartment*: The *Side Compartment* concept offered one or multiple separate compartments next to the door. Its advantage compared to the *Free Space* concept was that stored luggage and items would be hold in place much better by the solid structure, preventing them from moving around in the car during the ride.

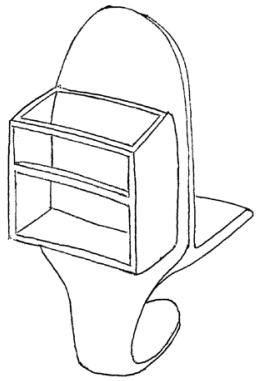
- *Backside Pocket*: The *Backside Pocket* concept was basically a shelf-like structure on the rear side of each seat. While items and smaller bags could be placed at a convenient height with this solution, the placement on the rear side of the seat could be an issue. If the storage belonged to the person occupying the seat, it would be out of sight and the user might fear



(a) Free Space



(b) Side Compartment



(c) Backside Pocket

Figure 6.11: Storage Concepts

that his or her items might be stolen. However, if the shelf was supposed to be used by the user in the second row of seats, another solution for the passengers in the first row would be needed.

6.3.2 Concept Selection & Refinement

The next step in the process was to screen and compare the initial concepts in order to identify the most promising ones. To facilitate the selection process and to enable a structure approach Kesselring Matrices were utilized. The strength and weaknesses of each concept could be quantified by rating the different solutions with respect to how well they fulfill the functions and by considering a weighting that represents the importance of each function. The Kesselring Matrices for the seat, device holder, and storage concepts are shown in *Figures 6.12 - 6.14*.

As *Figure 6.12* shows, there are two concepts which reach more than more 70% of the ideal score, namely the *Foldable Shield* and the *Sliding Shield*. The first solution was hence chosen for the premium concept because it was not only the

Criterion				Ideal		Solution Alternative 1 Sliding Shield		2 Foldable Shield		3 School Chair	
Category	No.	Function	Weight (1-5)	v	t	v	t	v	t	v	t
A	F01	Provide Resting Opportunity	5	5	25	5	25	5	25	5	25
	F05	Provide Relaxation Environment	5	5	25	4	20	4	20	2	10
	F15	Provide Safety	5	5	25	5	25	5	25	3	15
AB	F10	Facilitate Communication Inside	3	5	15	4	12	4	12	5	15
	F12	Provide Work Environment	4	5	20	4	16	4	16	3	12
AB-1	F07	Provide Audio Entertainment	5	5	25	3	15	5	25	4	20
AC	F02	Provide Storage	5	5	25	1	5	1	5	1	5
ABC	F03	Provide Feeling of Privacy	5	5	25	4	20	4	20	3	15
	F04	Provide Feeling of Ownership	5	5	25	3	15	3	15	3	15
	F06	Provide Haptic/Tactile Experience	4	5	20	3	12	3	12	4	16
	F20	Enable Psycho Pleasures	4	5	20	4	16	3	12	3	12
ABC-1	F11	Facilitate Communication Outside	3	5	15	3	9	4	12	3	9
		T = Sum t		265		190		199		169	
		T / T max		1,000		0,717		0,751		0,638	
		Ranking		-		2.		1.		3.	
								↑ Premium		↑ Basic	

Figure 6.12: Kesselring Matrix for Seat Concepts

best solution according to the score but was also found to fit best into a higher class interior by the project members. For the basic concept however, the *School Chair* concept was chosen despite its lower score compared to the *Sliding Shield* concept. First of all all, the score was not significantly lower and second (as it will be shown later) the *School Table* concept in the device holder category is the second best solution, which is why it was decided to select this multi-functional solution and to utilize the symbiosis effect.

Criterion				Ideal		Solution Alternative 1 Plane Table		2 Pull-Flip Table		3 Rotative Table		4 The Pod		5 School Table	
Category	No.	Function	Weight (1-5)	v	t	v	t	v	t	v	t	v	t	v	t
B	F14	Promote/Encourage Use of New Features	3	5	15	2	6	1	3	2	6	4	12	2	6
	F22	Support Food/Beverage Consumption	4	5	20	3	12	4	16	2	8	4	16	3	12
AB	F10	Facilitate Communication Inside	3	5	15	1	3	2	6	2	6	4	12	2	6
	F12	Provide Work Environment	4	5	20	2	8	3	12	1	4	4	16	2	8
AB-1	F07	Provide Audio Entertainment	5	5	25	1	5	1	5	3	15	3	15	1	5
BC	F08	Support Connectivity	5	5	25	3	15	3	15	2	10	5	25	3	15
	F16	Preserve State of Goods	3	5	15	2	6	2	6	2	6	4	12	2	6
ABC	F03	Provide Feeling of Privacy	5	5	25	3	15	3	15	2	10	3	15	4	20
	F04	Provide Feeling of Ownership	5	5	25	2	10	2	10	3	15	4	20	3	15
	F06	Provide Haptic/Tactile Experience	4	5	20	3	12	3	12	2	8	4	16	3	12
	F20	Enable Psycho Pleasures	4	5	20	2	8	2	8	3	12	4	16	2	8
ABC-1	F11	Facilitate Communication Outside	3	5	15	2	6	2	6	1	3	3	9	2	6
		T = Sum t		240		106		114		103		184		119	
		T / T max		1,000		0,442		0,475		0,429		0,767		0,496	
		Ranking		-		4.		3.		5.		1.		2.	
												↑ Premium		↑ Basic	

Figure 6.13: Kesselring Matrix for Device Holder Concepts

Among the device holder concepts *The Pod* turned out to be the by far superior solution due to the fact that so many features could be implemented (see *Figure 6.13*). Thus, it was selected for the premium concept. All the other concepts were not too far apart from each other; all of them achieved between 43% and 50% of the ideal score. Still the *School Table* had the second best score overall and as stated earlier, the fact that it was identical to the *School Chair* concept and that one solution can be used for two components was an excellent opportunity to simplify the overall interior concept and to save costs in the basic version.

Criterion				Ideal		Solution Alternative 1 Free Space		2 Side Compart-ment		3 Back-side Pocket	
Category	No.	Function	Weight (1-5)	v	t	v	t	v	t	v	t
AC	F02	Provide Storage	5	5	25	5	25	3	15	2	10
BC	F08	Support Connectivity	5	5	25	1	5	3	15	2	10
	F16	Preserve State of Goods	3	5	15	2	6	3	9	3	9
ABC	F03	Provide Feeling of Privacy	5	5	25	4	20	4	20	1	5
	F04	Provide Feeling of Ownership	5	5	25	4	20	3	15	2	10
	F06	Provide Haptic/Tactile Experience	4	5	20	3	12	2	8	3	12
	F20	Enable Psycho Pleasures	4	5	20	4	16	4	16	1	4
ABC-1	F11	Facilitate Communication Outside	3	5	15	1	3	2	6	2	6
			T = Sum t		170		107		104		66
			T / T max		1,000		0,629		0,612		0,388
			Ranking		-		1.		2.		3.
							↑ Premium & Basic				

Figure 6.14: Kesselring Matrix for Storage Concepts

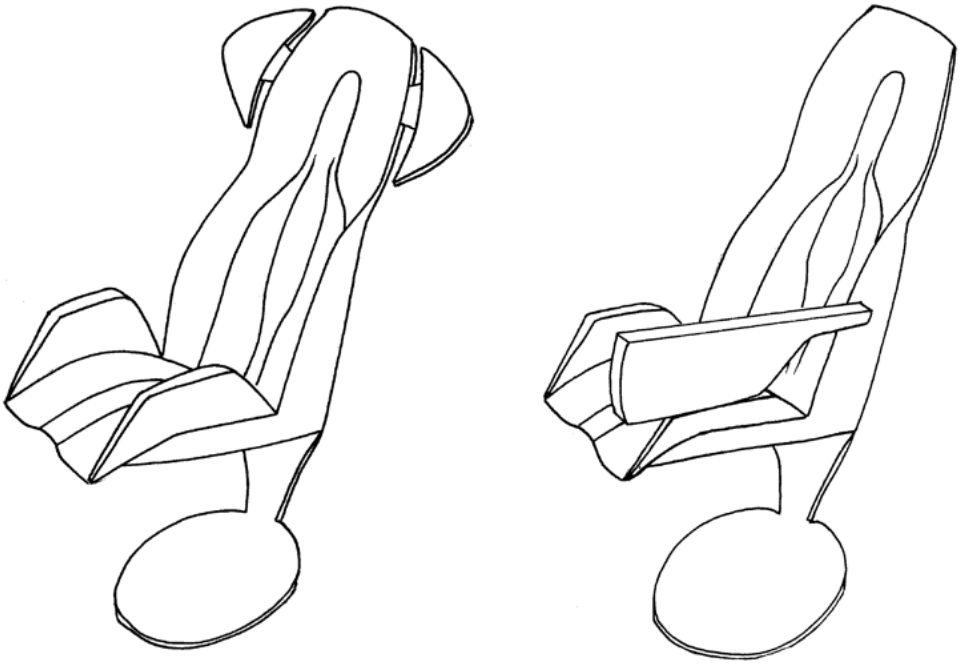
Regarding the storage solutions, the *Free Space* and the *Side Compartment* concept outscored the *Backside Pocket* concept by far (see *Figure 6.14*). The *Free Space* concept scored slightly better then the second placed one. Due to the fact that the concept did not contain any components and therefore nothing was added to the costs it was selected for both the premium and the basic interior concept.

After the most promising concepts had been selected, they had to be refined and developed further. Therefore an elaboration of the concept sketches was the next step in order to define shape and design of the components further. These are presented in *Figures 6.15 - 6.17*.

Refined Seat Concepts

In order to reduce the amount of variants and keep the costs low it was decided that both seat concepts were to have the same basic structure. Moreover, it should be possible to rotate the front row seats of the premium concept. This was enabled by a rotating mechanism under the circular base of the seat.

- *Foldable Shield for Premium Segment*: As already implied in *Section 6.3.1.2*, directed speakers were implemented in the foldable shields on the sides of



(a) Refined Foldable Shield **(b)** Refined School Chair

Figure 6.15: Refined Seat Concepts

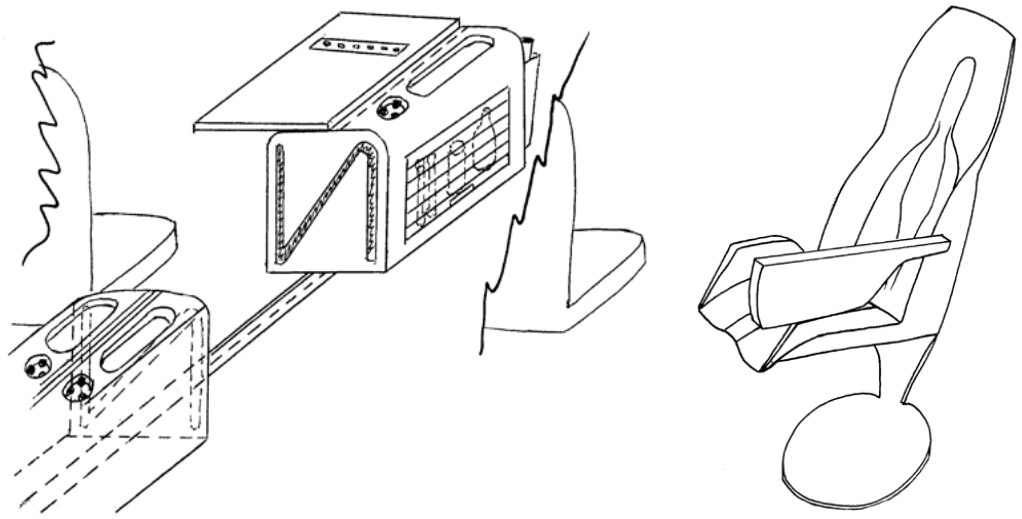
the seat. These can be activated once the user folds the shields towards him/her. In addition to this, reading lights were implemented in the lower part of the shields.

- *School Chair for Basic Segment*: The refined *School Chair* concept still had the same functionality as the initial concept with three positions enabling different tasks. As indicated in the role plays and expert interviews, some people just want to get from A to B with a ridesharing service for which this vehicle was intended and therefore the table in this concept for the basic version was kept rather small. Some smaller items or devices could be placed there but it is not meant to hold a laptop or the like.

Refined Device Holder Concepts

The two device holder solutions were an important distinctive feature between the basic and the premium segments, which are aimed at different target groups. While the basic concept was intended to be for users who just want to reach their destination in a quick and convenient way, the premium concept is also to allow e.g. managers and other people in need of proper means to be productive and work with their laptop. Furthermore, acquaintances would be able to interact much better with each other as they can to face each other if they want to.

- *The Pod for Premium Segment*: One of the main advantages of *The Pod* concept is that it had a modular character and was predestined for implementing various features. Depending on the area of application, local user



(a) The Refined Pod **(b)** Refined School Table

Figure 6.16: Refined Device Holder Concepts

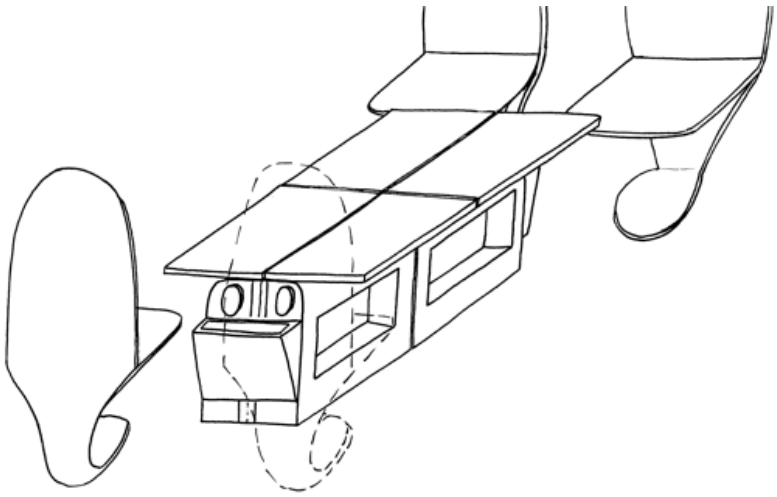


Figure 6.17: The Pod in Conversation Mode

preferences, season etc. the pod could offer different features and could also easily be exchanged once the implemented technology becomes outdated. Therefore, it could e.g. contain a slim fridge or storing compartment on the sides so that snacks and/or drinks could be provided (see *Figure 6.16a*). Furthermore, a wireless charging strip was integrated into the table for laptops etc. Depending on technical developments this might even be a plugless docking station strip, making it possible to connect the computer to screens in the car. Moreover, the two pods between the first row and second row of seats were both placed on rails, which allowed moving them between the rows. This does not only enable a position adjustment according to the users' preferences but also allows a rearrangement into a conversation mode. *Figure 6.17* shows the two pods attached to each other with the aid of magnetic strips. In this position they can act as a common

table and facilitate a conversation, once the passengers in the front row turn around. Further, speakers were attached on the front and rear side respectively of each pod to enable the group of passengers to listen to music together in this arrangement. This is also where a selection of magazines could be found in a container.

- *School Table for Basic Segment*: The refined *School Table* concept corresponds to the *School Chair* concept, so that its description can be looked up under the section *School Chair for Basic Segment*.

Refined Storage Concept
Since the *Free Space* concept, which was chosen for both the basic and premium segment, did not contain any components that could be revised, a refinement of the initial concept was superfluous. The concept would thus be applied as described in the section about the *Free Space* concept under *Initial Storage Concepts*.

As a concluding visualization of the combination of all refined components *Figures 6.18 & 6.19* show the concepts for the premium version of the interior placed into the car concept from *Section 6.3.1.1*. The sketches indicate the arrangement of the seats and pods in the initial position. Furthermore, one can get an idea of the spacious feeling that this solution conveys as well as the amount of natural light coming in to the car.

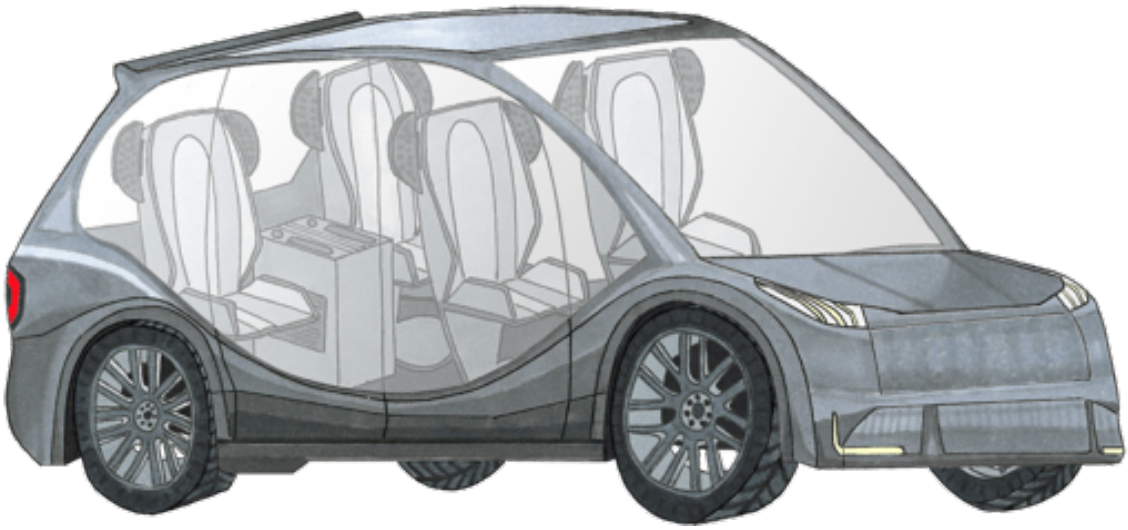


Figure 6.18: Exterior Front View with Translucent Windows

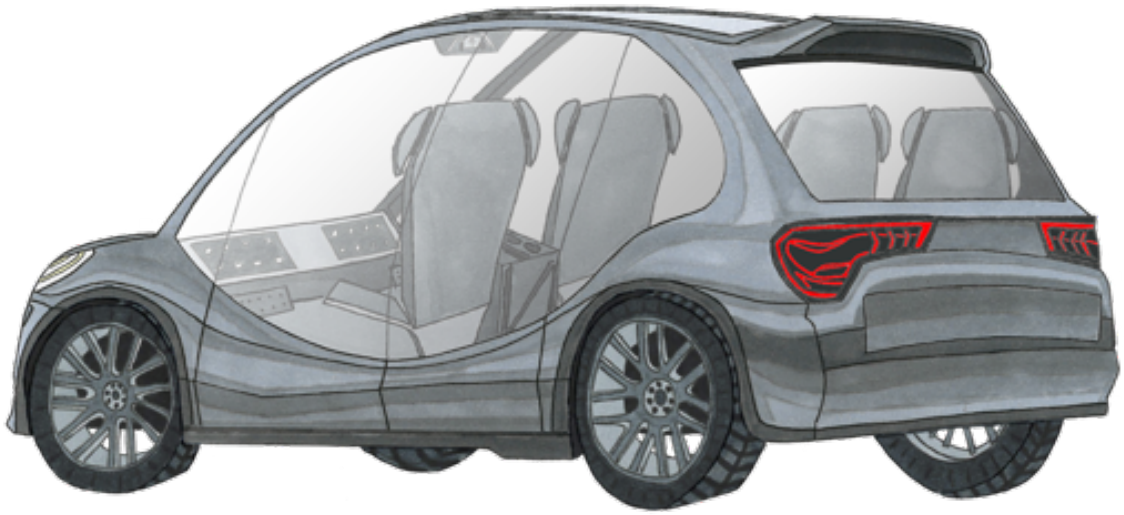
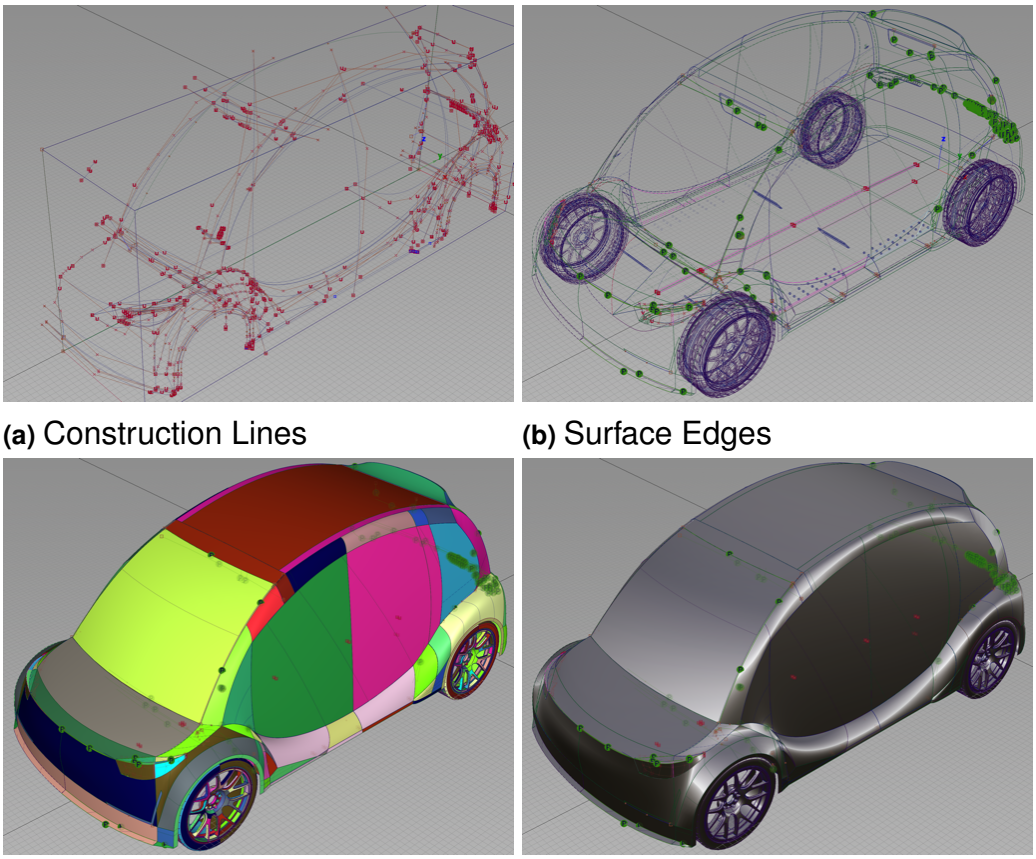


Figure 6.19: Exterior Rear View with Translucent Windows

After all decisions regarding the concept selection had been made, it was time to elaborate the concepts and create the digital model which was the deliverable of this master thesis project. For the digital design the CAID software Autodesk Alias was used.

Figure 6.20 shows the major steps of the evolution of the digital car model. The process started with splines that define the overall shape of the car and were modeled according to scanned technical drawings. Since the car is symmetric only half of the car had to be designed this way. In the next step the lines were converted into surface edges and the model was mirrored in order to obtain a complete structure. These edges were then closed to create surfaces and eventually the surfaces were connected to generate a solid body.

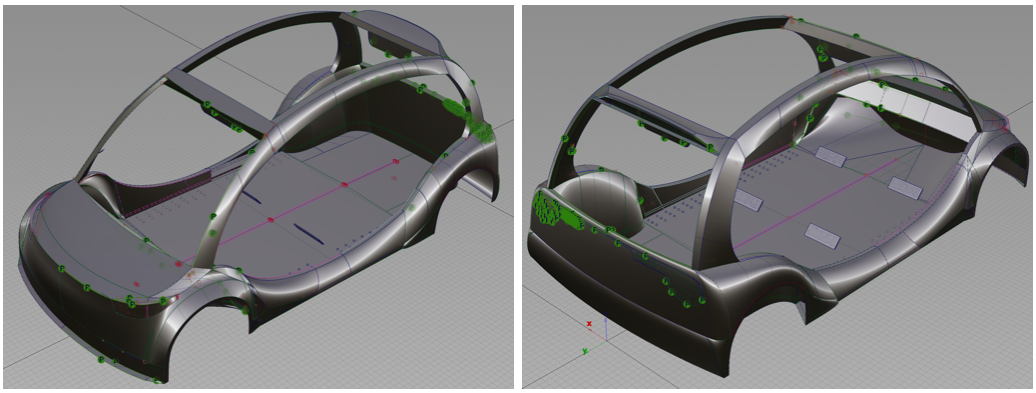


(a) Construction Lines **(b)** Surface Edges

(c) Surfaces **(d)** Solid Body

Figure 6.20: Design Evolution of the Concept Car

The car frame was a central result of the design process and can be seen in detail in *Figure 6.21*. This illustrates how much more space the interior provides compared to a traditional car.



(a) Front View **(b)** Rear View

Figure 6.21: Car Frame

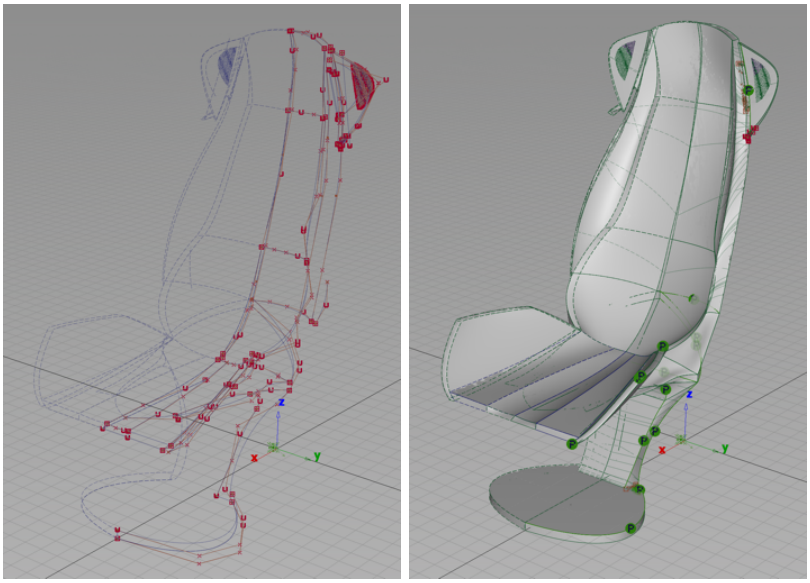
The general exterior dimensions assigned for the final model are, according to the standard packaging nomenclature defined by the Global Cars Manufacturers Information Exchange Group (GCIE) (Renault Astier, 2010):

Geometry	GCIE-Code	Dimension [m]
Vehicle Height	H100-B	1.800
Ground Clearance (max. Load)	H157	0.260
Cowl Point to Ground	H120-1	0.910
Vehicle Length	L103	3.916
Overhang – Front	L104	0.627
Overhang – Rear	L105	0.477
Wheelbase	L101	2.813
Tire Size – Front	L102-1	0.735
Tire Size – Rear	L102-2	0.735
Vehicle Width	W103	1.990

In addition to these exterior dimensions, the interior room dimensions are provided in the following:

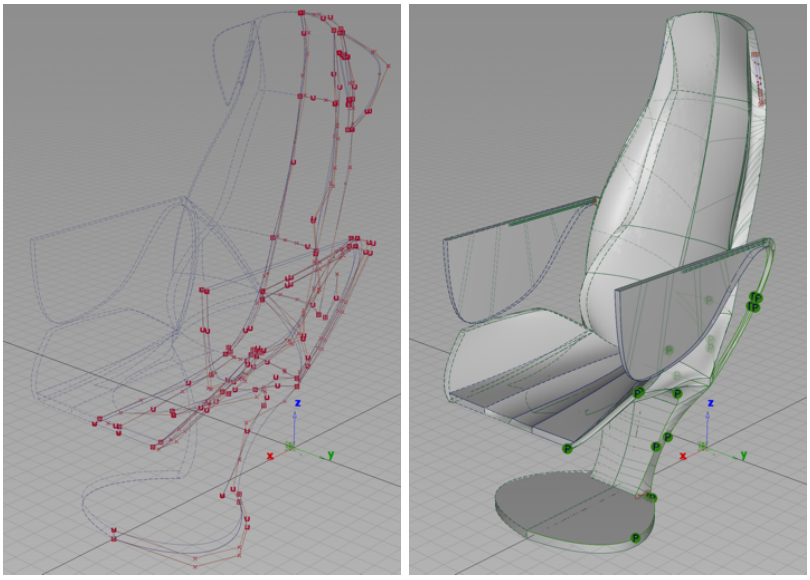
Geometry	Dimension [m]
Maximum Interior Width	1.610
Maximum Interior Length	3.630

In the next step, the selected concepts for the seat and device holder in both, the basic and the premium version were modeled. The evolution of each component is implied in *Figures 6.22 - 6.24*. The same design steps were followed as described earlier.



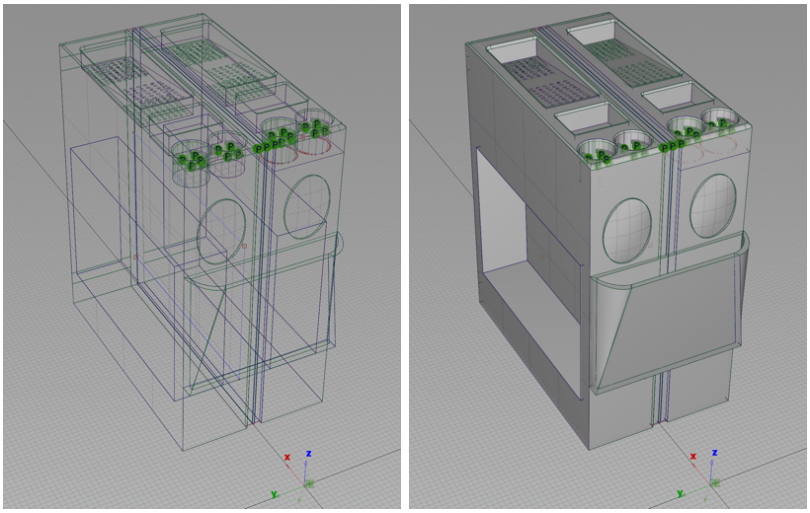
(a) Construction Lines **(b)** Solid Model

Figure 6.22: Design Evolution of the Foldable Shield Seat Concept



(a) Construction Lines **(b)** Solid Model

Figure 6.23: Design Evolution of the School Chair Seat Concept / School Table Table Device Holder Concept



(a) Construction Lines **(b)** Solid Model

Figure 6.24: Design Evolution of the Pod Device Holder Concept

During the design process smaller refinements were still made. For example an additional shield on the other side of the *School Chair* was added in order to allow the use of two of its functions at the same time, e.g. one of them as a privacy shield and the other one as a table (see *Figure 6.23*). Another example is the addition of small rubber dots next to the door as depicted in *Figure 6.21b*. These are intended to increase the friction in the designated storage area in order to prevent objects from moving around too easily.

Furthermore, several additional features, like a dashboard screen, footrests, or a semi-transparent sunroof screen, were implemented to refine the concept during the final design iterations. However, the description of these details is part of the *Final Concept* presentation in *Chapter 7*.

Once all digital models were finished in Alias the models were exported into the 3D visualization software VRED AutoDesk to create renderings and videos of the final concept and to prepare the concept evaluation with the aid of VR. After arranging all components inside the car model and placing everything in a virtual world, rendered pictures were generated. These can also be found together with the description of the final concept in *Chapter 7*.

6.3.3 Concept Evaluation

As a final step of the concept development phase an evaluation session was conducted. For this some participants of the previously conducted role plays as well as a CEVT employee who works in the ergonomics department could experience the digital model in virtual reality setting.

Overall, the participants were satisfied with the result and really liked the concepts. Especially the innovative design with its huge panoramic windows elicited positive responses. Moreover, the flexibility and adjustment options of the concept stood out to several participants.

However, some concerns were expressed regarding various aspects related to the design. For instance, some participants stated that the footrests might not be necessary for short commuting trips and that it would be more convenient if the footrests were adjustable. The lights attached to the shielded seats could be adjustable so that the user can manipulate the angle for reading since not everyone reads in the same position or height. Further, if the doors are completely transparent it might occur that people can either not see them and possibly bump into one of them. The front seats appeared to be more popular than the rear seats due to the better view and access to the dashboard screen. Consideration should therefore be given to features that could be added for the rear seats in order to counteract this imbalance.

The remaining things that were pointed out can be divided into two main categories:

Design Aspects:

- The roof looks higher than the one of a normal car which one might have to get used to.
- From a cleanliness perspective, a white interior might not be convenient for carsharing depending on the material.
- It is possible to see a lot from the inside but people around will also constantly look at the passengers from the outside.
- The vision and dynamic feeling inside the car must be wonderful. ("It feels that you are surfing the city.") Compared to traditional means of public transport, like trams or busses, the concepts convey a completely new idea of urban commuting.
- If it is sunny outside it might get too warm in the interior due to the size of the windows.
- The seats look sporty and nice but maybe not so soft and comfortable.
- The space under the chair and next to the door looks convenient and practical.
- From a safety perspective the concept raises concerns. Safety aspects must definitely be considered in order to create trust in the concept.

Technical Features:

- All the windows could be used for screen displays since that technology already exists and it might add value for the user.
- The concept with the pods seems very flexible and adaptable to various user needs.
- A slot for the phone charger would be more convenient than just a tray area.
- A tilted surface in the wireless charger towards the user could be better than a flat surface.
- The dashboard screen might not be used for watching a movie but it can be used for connecting your devices and work from there.

In addition to the evaluation with the help of participants, the list of requirements presented in *Chapter 5.2* was also used to determine which requirements could or could not be fulfilled by the final concept in this stage as well as which ones were not possible to be evaluated yet.

As shown in *Figure 6.25*, a significant number of requirements could already be fulfilled by the concept while only the implementation of one desired function, namely the promotion/encouragement of new features in the car, failed. However, several requirements could not be evaluated at this point. Some requirements, like e.g. the function "Provide Haptic/Tactile Experience", was simply not possible with a digital model. To evaluate such functions, the construction of a physical prototype is inevitable. Furthermore, a reliable assessment of some requirements, like e.g. "Intuitive to Use", would require more sophisticated methods and means such as devices for eye-tracking or facial expression recognition. For other requirements, like "Enable Psycho Pleasures" or "Feeling of Being in Control" another in-depth user study would be necessary.

Nevertheless, the concept evaluation conducted as part of this thesis project was of considerable help in order to reassert and determine to what extent the identified functions were expressed by the modelled concepts. After the evaluation session some minor changes and improvements suggested by the participants were implemented in the concept models. However, due to the limited time not all issues could be addressed which means that the final model has still room for improvements.

No.	Requirement	R/D	Target Value	Evaluation	Fulfilled
1	**Function**				
1.01	Provide Resting Opportunity	R	Yes	User/Ergonomic Assessment	Yes
1.02	Provide Storage	R	Yes	CAD, Ergonomic Assessment	Yes
1.03	Provide Feeling of Privacy	R	Yes	User Assessment	Yes
1.04	Provide Feeling of Ownership	D	Yes	User Assessment	Yes
1.05	Provide Relaxation Environment	D	Yes	User Assessment	Not Evaluated
1.06	Provide Haptic/Tactile Experience	D	Yes	User Assessment	Not Evaluated
1.07	Provide Audio Entertainment	D	Yes	User Assessment	Yes
1.08	Support Connectivity	D	Yes	User Assessment	Yes
1.09	Provide Visual Enteratinment	D	Yes	User Assessment	Yes
1.10	Facilitate Communication Inside	D	Yes	User Assessment	Yes
1.11	Facilitate Communication Outside	D	Yes	User Assessment	Not Evaluated
1.12	Provide Work Environment	D	Yes	CAD, Ergonomic Assessment	Yes
1.13	Provide Food/Beverages	D	Yes	CAD, Engineering Assessment	Not Evaluated
1.14	Promote/Encourage Use of New Features	D	Yes	User Assessment	No
1.15	Provide Safety	R	Yes	Engineering Assessment	Not Evaluated
1.16	Preserve State of Goods	D	Yes	Engineering Assessment	Not Evaluated
1.17	Optimize Passenger Condition	D	Yes	User/Ergonomic Assessment	Not Evaluated
1.18	Provide Lights	R	Yes	CAD, Ergonomic Assessment	Yes
1.19	Provide View	R	Yes	CAD, Ergonomic Assessment	Yes
1.20	Enable Psycho Pleasures	D	Yes	User Assessment	Not Evaluated
1.21	Enable Socio/Ideo Pleasures	D	Yes	User Assessment	Not Evaluated
1.22	Support Food/Beverage Consumption	D	Yes	CAD, Ergonomic Assessment	Yes
2	**Geometry**				
2.01	Volume (HxWxL)	D	< 2x2x4m	CAD	Yes
3	**Usability**				
3.01	Easy to Access	R	Yes	User/Ergonomic Assessment	Yes
3.02	Easy to Use (Physical Aspects)	R	Yes	User/Ergonomic Assessment	Not Evaluated
3.03	Intuitive to Use (Cognitive Aspects)	R	Yes	User/Ergonomic Assessment	Not Evaluated
4	**Comfort & Convenience**				
4.01	Feeling of Being in Control	D	Yes	User Assessment	Not Evaluated
4.02	Perception of Roominess	D	Yes	User Assessment	Yes
5	**Design & Quality Impressions**				
5.01	According to CEVT Design Guidelines	D	Yes	Designer Assessment	Yes
5.02	Solid Impression	D	Yes	Designer Assessment	Yes

R=Requirement, D=Desire

Figure 6.25: Fulfillment of Requirements

7
Final Concept

As stated in the aim in *Chapter 1.3*, the expected outcome of this master thesis project was a concept for the interior of an autonomous car, visualized in form of a digital model. In the following, the final concept is presented in detail. However, the description is rather a summary of the concept while the reasoning behind the majority of design decisions can be found in *Chapter 6*.

The final concept consists of two variations in order to address different user groups. The main differences between the two versions are the aesthetic design, functionality and the number of implemented features. While the premium version (see *Figure 7.1*) of the concept is more versatile and offers more supporting measures for various activities, the basic version (see *Figure 7.2*) is aimed at users who simply want to get from point A to point B as quickly as possible. Further information about the different concept versions can be found in *Section 5.1.2*.

As shown in *Figure 7.1*, the premium version of the concept includes the *Foldable Shield* seats with directed speakers and reading lights implemented into the shields. Moreover, the seats are rotatable which in combination with the movable *Pods* allows a switch into "conversation mode" with all passengers facing each other (see *Figure 7.1c*). This arrangement would be suitable for meetings between work colleagues, business partners, or friends that are commuting together to a destination.

In contrast, the *School Chair* seats of the basic concept version are fixed and all facing forward. *Figure 7.2* shows the three different modes in which the shield of this multi-functional solution can be used. It can either serve as an armrest, a privacy shield, or a table for small devices, magazines etc. For both the premium and the basic version the *Free Space* concept was applied by providing storage opportunities under, in front of and next to the seats. Additional benefits are the enhanced roominess of the interior and extra legroom for the occupants.

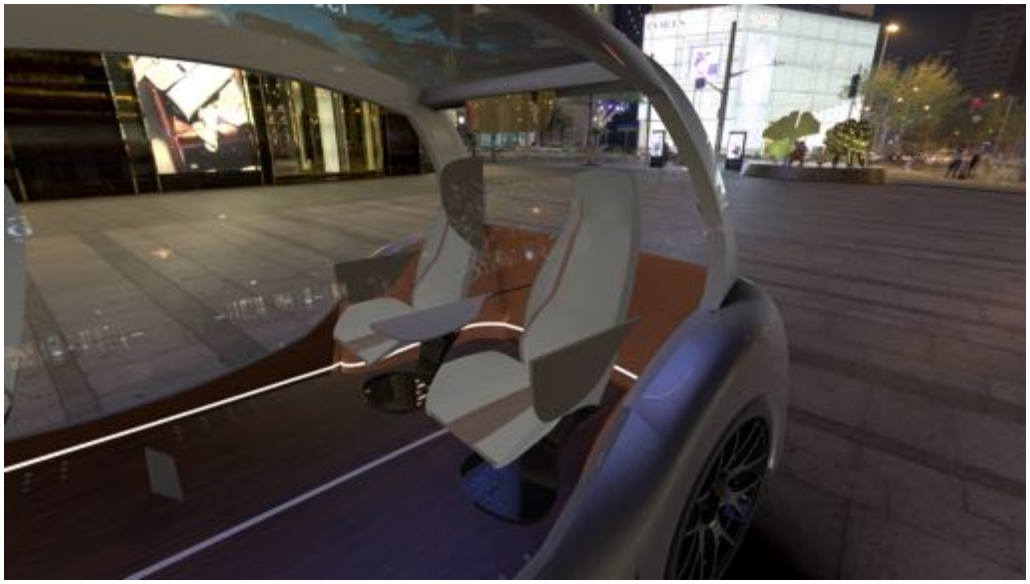
(a) Overview Perspective

(b) Side View with Seats Heading Forward

(c) Side View with Rotated Seats

Figure 7.1: Premium Version

(a) Perspective view with Seats in Different Modes



(b) Detail of Seats in Different Modes: Armrest, Shield and Table

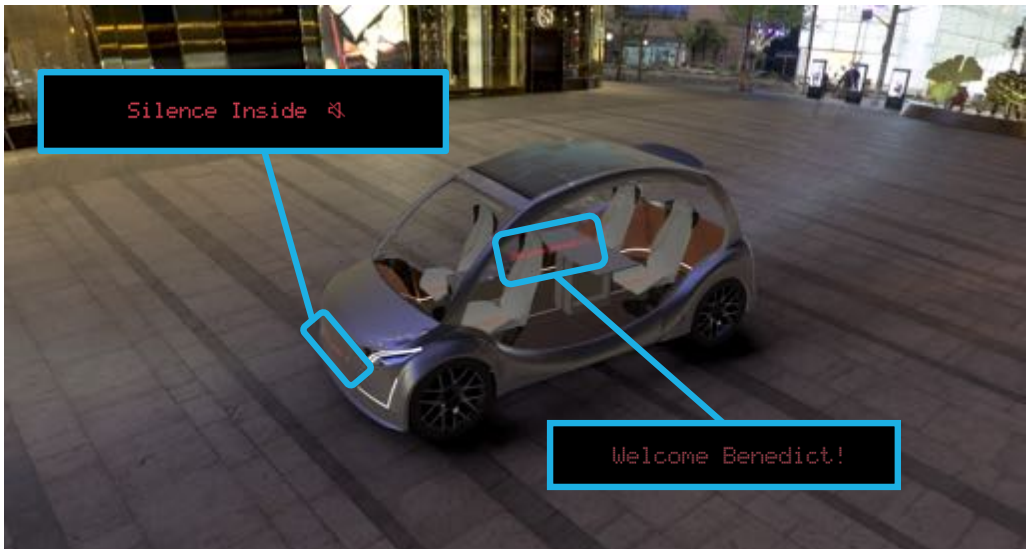
Figure 7.2: Basic Version

In addition to all the implemented features already described in Chapter 6.3, some further refinements were made to optimize the concept and with the intention to incorporate even more wishes and desires expressed by participants of the user studies.

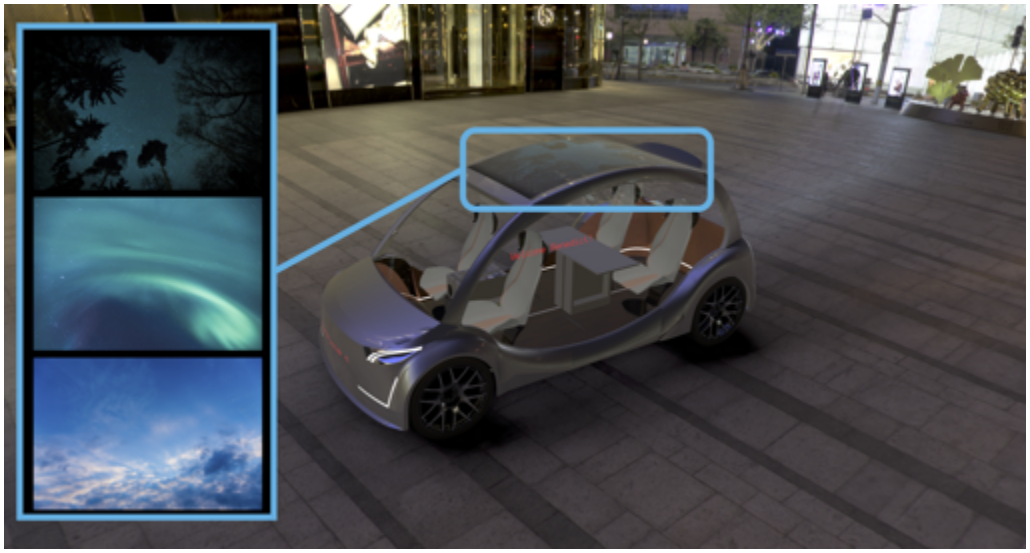
Figure 7.3a shows that a head-up display was implemented in the windows of the doors to greet the user that approaches the vehicle. This is intended to increase the customizability and could address functions like "Provide Feeling of Ownership" or "Enable Socio/Ideo Pleasures". Also, simple screens were added on the front and back of the car in order to display the current mode of the car, e.g. by displaying "Silence Inside" (compare user study results in *Sections 4.3.1.3 & 4.3.1.4*). Furthermore, a semi-transparent screen was integrated into the sunroof glass of the premium version in order to once again increase the customizability by creating a special ambience for the passengers by e.g displaying a star-spattered night sky (see *Figure 7.3b*).

In terms of the features inside the car, a long dashboard screen for entertainment purposes as well as two small common screens on the front and rear beam were added to show what the car will do next and where it is going (see *Figures 7.4a & 7.4b*). This is rooted in the desire of users to be "kept in the loop" as stated in the role plays and expert interviews of the user study.

Other details that were added to increase comfort and convenience are the footrest and the coat hangers on the A and C pillars that can be folded in and out (see *Figure 7.4c*). The folding mechanism could either be automated for the European version of the car or manual for the Chinese one. This refers to the different preferences of the user groups of which one wants to have automated solutions and the other is keen to discover features manually (compare *Section 3.3.6*).



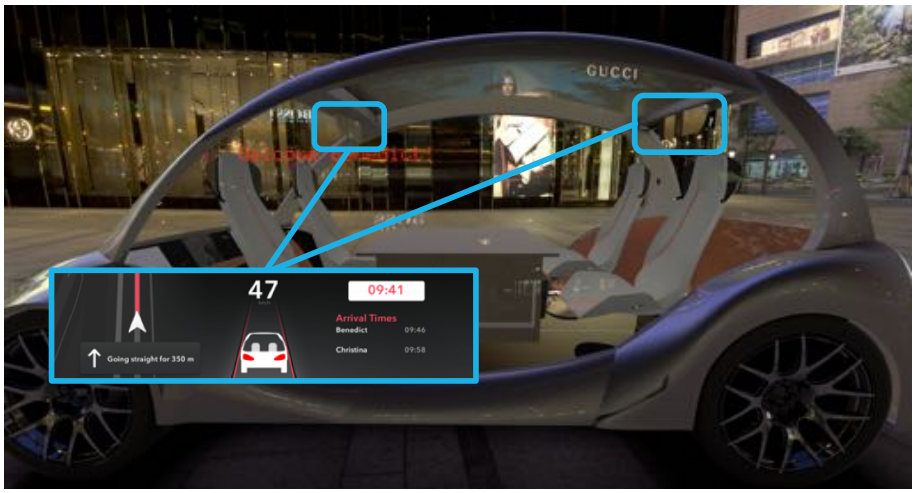
(a) Indication Screens



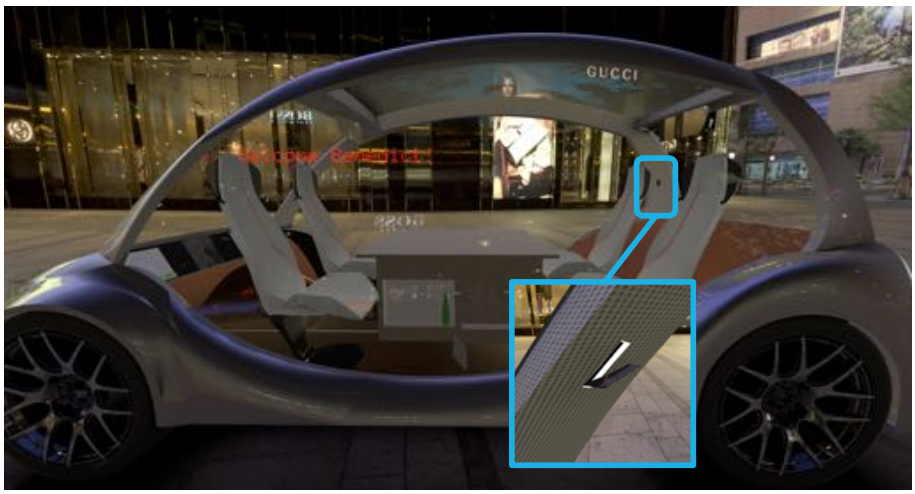
(b)

Figure 7.3: Exterior Details

(a) Dashboard Screen



(b) Screens Displaying Route Information



(c) Coat Hanger

Figure 7.4: Interior Details

8

Discussion

Throughout the project a lot of decisions were made with respect to the scope, methods, tools, participants etc. The purpose of this chapter is to look back on these decisions and to question their validity and highlight possible weaknesses.

8.1 Overall Approach

The overall approach and project structure had perhaps the biggest impact on the result of the project. Therefore, those decisions made during the planning phase (see *Chapter 1.5*) have to be assessed first.

8.1.1 Allocation of Time

The allocation of time has a major influence on the direction in which a project is going and to what extent or how detailed something can be examined. For this project it was found immensely important to come up with an interior concept that is actually based on user needs by determining what would be useful during everyday commutes for passengers of a car. In order to achieve this, half of the time available for the conduction of the project was allocated to an in-depth user study without which the result might just have been yet another concept solely based on technological development instead of addressing user needs. Certainly the final model would have been much more sophisticated if the user study would have been completed in a shorter period of time. However, without this solid foundation it would most likely just have been cosmetic and superficial work without an underlying purpose to improve the users' situation.

8.1.2 Defined Project Scope

As described in *Chapter 1.4* the scope of the project was under continuous development until the middle of the user study phase. Especially insights from the various expert interviews affected what exactly was investigated and what should be considered for this thesis project. A fully defined scope right from the start might have led to less confusion along the way and the time used for redefining the scope could have possibly been utilized for other research or design tasks. Nevertheless, the continuous adjustment of the scope was seen as a vital part of the project since it by definition deals with predicting the future which brings a high degree of uncertainty with it. Figuring out what aspects of the topic would be most relevant, which ones were most practical to investigate and which could

have the biggest potential for the future was an elementary part of the project and any cutback of it could have led to the project going astray.

8.2 Selected Tools & Designed Studies

With respect to the tool selection (*Chapter 5*) and the user studies (*Chapter 4*) it can certainly be argued that both could have been investigated even further. More time spent on the tool exploration might have revealed even more suitable tools and other combinations of those and/or the identified once would have been possible and might have yielded other results. Nevertheless, the designed studies were found to be complementary because they helped to examine the topic from different angles.

8.2.1 Conducted Expert Interviews

The selection of experts is always a tricky task and as pointed out before it can even have a significant impact on certain details that are investigated. It has to be kept in mind that experts are often pretty much focused on their specific area of expertise which certainly influences their opinions towards certain topics and can make them biased in some way. Therefore, it was particularly important to get a good mixture of experts and especially the fact that some from the industry and others from research institutions have been questioned benefited the project without any doubt. While people from the industry are usually able to provide a lot of in-depth knowledge to certain topics they sometimes tend to focus on short-term changes and sometimes do not see the bigger picture. Researchers on the other hand, often think in completely different time intervals and try to find answers to the big questions which is great to keep an overview and understand the underlying reasons but can be less helpful with practical issues.

8.2.2 Conducted User Studies

As already pointed out in the results, the number of participants was relatively low due to the scope of the project. Therefore, the results have to be treated with caution since they might not be representative.

For the design tasks of the context shifting study it is of course possible that the provided material had an impact on the designs that the participants created. More material might have caused more diversity between the designs but nevertheless, looking back the amount is still considered to be reasonable since more of it would have had the potential to overwhelm some participants.

Further, both studies were conducted with multiple participants at the same time which of course stimulated the debate but possibly also led to participants influencing each other, so that some did not state or stick to their true opinion. This might have especially occurred when single participants had a very dominant appearance or persuasive reasoning. In fact this phenomenon could partially be

observed during one of the role plays in which some participants revised their previous ideas during the course of the discussion. However, these kind of mutual influences can in general not be avoided and should also not solely be seen as something negative. Interactions between people and letting them respond to their ideas are the essence of a constructive discussion culture that often leads to more sophisticated results than the comparison of individual statements.

8.3 Data Analysis

The analysis of collected data is always at least partially subjective and can yield different outcomes depending on the chosen analysis approach and the person(s) conducting the analysis. Already by summarizing the data in the first step certain noteworthy elements can possibly get lost. When it comes to the identification of key aspects and interpretation of gathered information the outcome can vary even more.

However, in order to provide a high level of transparency and substantiate the origin of the various assumptions and conclusions later on, the results were presented in rather great detail in *Chapter 3.3 & 4.3*.

8.4 Development of Concepts

The functional analysis was a central part of the concept development process and had the purpose of providing a structure for the generation of solutions for the design challenge. As with the data analysis, the functional analysis is also highly dependent on individual choices in methods and models. While the *Function-Means Tree* e.g. is a quite common tool in product development processes, the *Concept Layer Model* (see *Section 5.1.2*) is a rather customized approach that lacks scientifically proven validity but was found to work well in this context.

Regarding the interior design, the approach is once again a decisive factor for the final outcome. Breaking down a problem by focusing on what seems to be the most important (as done in this project) usually results in a much more comprehensible and manageable development effort. It should, however, be taken into account that such a reduction of complexity can cut away other possibly relevant parts. Nevertheless, the level of complexity that was chosen for this master thesis project seemed like a reasonable trade-off between these two extremes.

Last but not least, the results of the concept evaluation have to be treated with caution since the demonstration in virtual reality might, on the one hand, be the most realistic option for digital models that is currently available, but on the other hand, it has to be considered that the use of VR technology is still a completely new and exciting experience for many people. This could have influenced the participants' judgment and lead to overly positive feedback. Therefore, the concepts might have been perceived as better as they really were by the participants.

Perhaps, a functional mock-up of the vehicle concept might be beneficial for a further evaluation in the future. It would enable the participants to experience and explore the model physically and also allow an assessment of other requirements which could not be evaluated so far.

9

Conclusion

The goal of the project was to develop a concept for the interior of an autonomous car based on actual user needs. In order to determine whether this goal could be achieved, the research questions posed in *Chapter 1.3* along with the answers that can be given to them at the end of the project are used as assessment criteria and to conclude the project. Moreover, future prospects are presented and necessary next steps are highlighted.

9.1 Project Assessment

The research questions posed in *Chapter 1* are stated once more and answered individually in the following.

RQ1 - What methods are suitable to investigate user behaviours and requirements in future scenarios?

The *Exploration of Tools* presented in *Chapter 2* yielded nine different tools that can be used in order to investigate ambiguous user needs in the future. Moreover, synergies can be created by combining these within the context of user studies. The approach of such studies can differ with respect to context and time. While one of the studies conducted during this thesis project is aiming at predicting the future by examining the present first, the other study focuses on similar but unrelated contexts and a transfer of the findings into the main context afterwards.

RQ2 - What kind of activities would future users like to perform in an autonomously driven car?

Overall, the activities that future users will most likely perform in such a scenario will not be so much different from those they are already pursuing today as non-driving passengers in cars or public transport. Beside the fundamental things like resting in a comfortable position, storing their luggage or other belongings and simply enjoying the view most people will be satisfied with some form of light entertainment, such as listening to music or reading. In addition to this it was found that users might appreciate the opportunity to do some light office work like writing mails etc. It has to be pointed out that cultural differences certainly have an effect on the expectations regarding certain activities. While, for example, European users seemed to be very comfortable with using their smartphones for

music and media consumption and often preferred physical printed media, Chinese users seemed to be much more in favor of having additional entertainment media available and focused on consuming digital content. Furthermore, being connected to the outside world via (video) chats and social media turned out to be very important to them.

RQ3 - What is needed in terms of interior design and features in the car to enable these user activities?

In order to reduce the complexity of the design task the concept development was focused on three main components which addressed the most fundamental functions and further allow the integration of various additional functions. Those components were the seat, device holder, and storage opportunities. Two aspects that were related to many activities and also had to be addressed in some form by the design were flexibility and privacy. While the flexibility was achieved by applying a modular and versatile component design, a feeling of privacy could, for example, be conveyed by the use of foldable shields at eye level as well as directed speakers.

These research questions which were used as guidelines during the entire project were characterized by a user-centred design approach. Therefore, it can be concluded that an interior concept for an autonomous car could be developed that distinguishes itself fundamentally from most existing concepts for interiors of autonomous cars. By putting the user at the centre of the investigation the final concept is not as much led by technological developments as by the intention to create something truly useful and practical for the everyday life of future users.

9.2 Future Outlook

Autonomous driving will not only change the car industry but also the way we perceive transportation dramatically. This will of course have a significant impact on the users in terms of their behaviours, needs, expectations, and how ownership models might develop and change over time. Nevertheless, the technology is still in the early stages of development and no one can say with certainty how the transportation sector will look like in the future and how people will use different means of transportation.

This project made an attempt to predict user behaviours and needs for the use of an autonomous car in ten years. Extensive user studies were carried out with the intention to create a solid foundation from which various concepts could be developed and explored. The concept evaluation showed that the developed concepts seem to point in the right direction. However, there are still many aspects that can be improved and a lot of influencing factors with respect to which more research has to be conducted. Among the things that have to be investigated further are:

- Research methods with the purpose of identifying user needs in future scenarios
- Cultural differences between China and Europe and how they affect user behaviours and needs
- Rules and regulations for autonomous driving in its different levels and how they will dictate and shape the design of cars
- Interactions between the development of infrastructure and autonomously driving vehicles

The high level of complexity and vast number of influencing factors are incredibly challenging, but at the same time it is absolutely exciting and fascinating to work with such an innovative technology. Experts from different fields have to work together in order to design the future of transportation one step at a time but the potential of autonomous driving technologies is enormous and the future prospects of the transportation sector are promising.

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A

Appendix

The Gantt Chart is a popular project management tool which displays the sequence of activities necessary to achieve the outcome in form of bars along a time axis. As shown in *Figure A.1 & A.2* there are two major phases apart from the report writing, namely the user analysis and concept development. Both are divided further into sub-tasks. Furthermore, four milestones are defined at the beginning of the project in consultation with the supervisors from the company as well as those from Chalmers to assure a general consensus about decisions taken along the way.

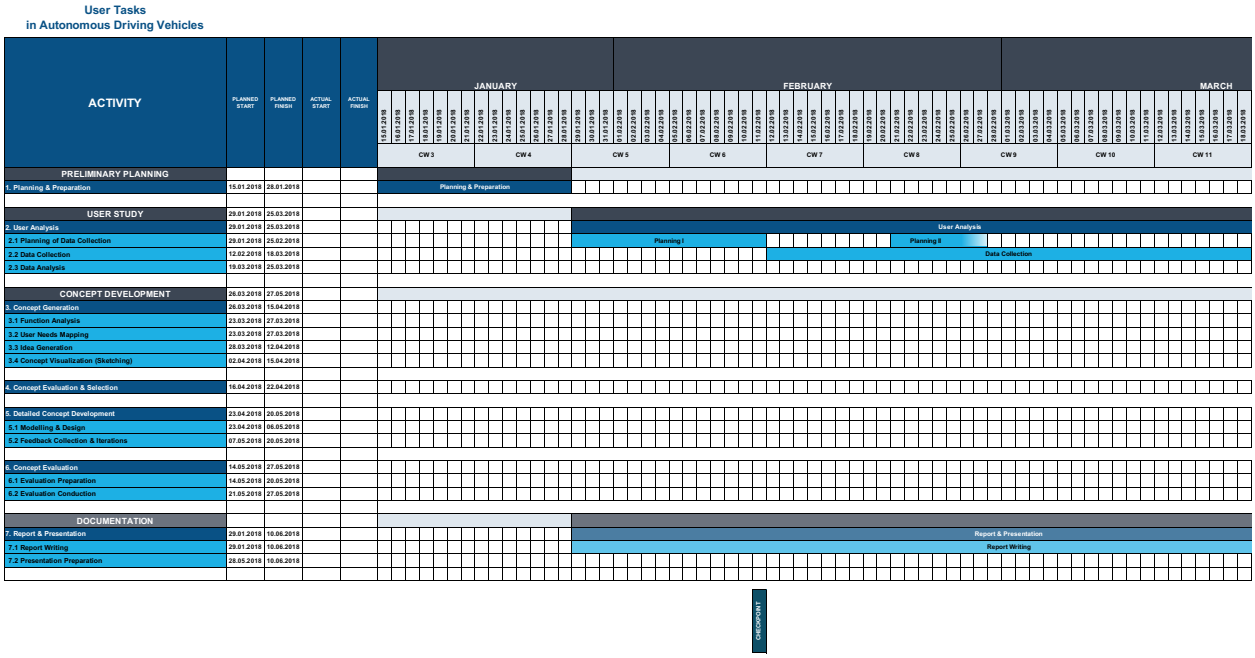

Figure A.1: Gantt Chart Part 1/2

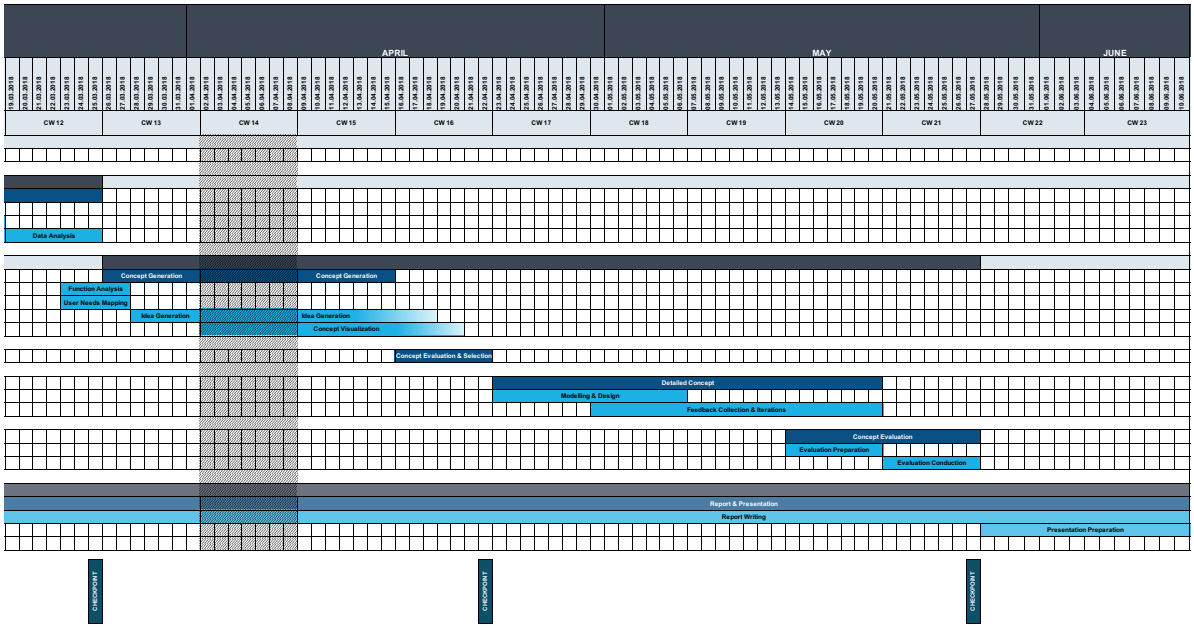

Figure A.2: Gantt Chart Part 2/2

B

Appendix

Both of the different types of role plays follow a rough time schedule which shows the procedure that has to be followed. The plans for the role play "Commuting to Work/School" as well as for the one "Free-time Commutes" can be found below.

Furthermore, the hand-out sheets for one role within the two different role plays which are given to one of the participants each is also included as an example.

Commuting to Work/School: Group 1

13:00-13:05
Introduction

13:05-13:30

1. Asking for current daily commute trips
   → having an open dialogue with all participants about their daily routines
   → sharing experiences
   - You get up in the morning. What is the first thing you do?
   - What do you have for breakfast?
   - Do you read the news / check your phone or the like?
   - Do you take the car to school/work, do you use public transport or do you cycle/walk?
     i. Car:
     - Do you have to free your car of snow and ice in the winter?
     - What is the first thing you do when you get into the car? What is the second/third.
     - Do you get into traffic jams / slow traffic often?
     - How do you react to those situations? Does it increase your stress level? What is it that makes it so stressful?
     - Do you park your car in the same spot every time? If not, do you remember easily where the car is located?

     ii. Public Transport:
     - Are you usually in a hurry to reach the tram/bus stop in time?
     - How long do you usually have to wait at the stop?
     - What do you do in the meantime?
     - Do you have to switch busses/trams on your way to work/school?
     - How do you spend your time on the bus/tram?
     - Do you sit or stand on the bus/tram? Why?

     iii. Walking/Cycling:
     - How long does it take to get to your destination?
     - Do you always take the same route?
     - Do you do something else while you walk/cycle? (e.g. listening to music)
     - Does the weather have a significant impact on your mood or did you get used to changeable conditions?
     - Do you lock your bike?
     - Are there enough places where you can lock it to something?

   - What do you do on your way back? Is it similar to what you do on the way to school/work or completely different?

13:30-13:40

2. Presenting the future scenario
    - Picture: Bosch & Daimler: Driverless Systems
    - Make them familiar with other relevant aspects like
        - Car sharing & Car Pooling
        - Number of seats: 4
        - How would commuting shape the interior design?
        - Neglect regulations etc.

13:40-14:30

3. Encourage participants to envision future autonomous driving experiences, how they would spend their time and how their daily commute might change.
    - Relate daily commutes in the present to how it could be like in the future.
    - Participants can draw future design elements to elaborate on their thoughts and ideas.
    - Ask them what they currently cannot do while travelling/commuting but what they would like to do.

Role 1:

- 40 years old
- Engineer
- Manager of a small group
- Married
- Has 2 kids: 2 year old son, 6 year old girl
- Social and likes to practice sports
- Active lifestyle. Ambitious
- Female

Role 2:

- 25 years old
- Newly arrived company employee
- International
- Loves to travel
- Loves nightlife and music
- Was living in a rather small town before
- Male

Role 3:

- 23 years old
- Master programme student
- Loves to hangout with friends
- Curious and energetic
- Female

Role 4:

- 30 years old
- Works in retail, liquor/beverage store
- Hectic job and on his fit the entire day
- Helpful and social. Communicative
- Single
- Goes often to the gym
- Male

Scenario:

Commuting trip of ~30min

"The city is growing strongly to make space for 700,000 residents by the year 2035 – that's 150,000 more than at present." (Annual report, goteborg.se)

a. First person: Car picks up the first passenger at the person's home
    - How do you order the car?
    - What will you do first?
    - How do you want to sit?
    - What is on your mind in that moment?
    - Do you want to prepare for work or just relax?

b. Second person (orders a vehicle and vehicle stops due to convenience)?
    - Would you like to know beforehand that you won't be alone in the car?
    - Would you like to know who is in the car? (gender, age, interests)
    - Where do you (person 2) want to sit?
    - How do you want to sit?
    - How does person 1 change his behaviour?
    - Do you want to talk to each other?
    - Do both of you mind sitting next to each other?
    - What if you were always commuting together? (so you somewhat know each other)

c. Third person:
    - Where do you (person 3) want to sit?
    - How do you want to sit?
    - How do person 1&2 change their behaviour?
    -

d. Fourth person:
    - How do you want to sit?
    - Do you feel comfortable there and considering that you could not choose the seat and that you are with three other strangers? How could that be improved?

e. The trip (details):
    - How do you expect the interior to look like? (equipment, materials etc.)
    - How could the comfort be increased as much as possible? (type of seats, massage etc.)
    - Is comfort even important for a 30 min trip?
    - How much privacy do you expect?
    - You gained 1h in total that you spent on driving before. Would you like to use the time for something that you never did before? (Learn a new language, how to play an instrument)
    - (Assuming that you could commute with friends/colleagues to work:
        - Would you pay extra for such a feature?
        - Would it be really worth it on a commuting trip?
        - How would you like to spend your time together?)

f. Passengers leaving the car:
    - Do the remaining ones change their behaviour?

14:30-14:45

4. Summarizing
   → let everyone express what is most important to him/her

   - Express in a few words: What should we as designers consider? (a few minutes per person)
   - Additional question: If you would not only commute with the car but also use it for short-distance traveling:
     - How would the interior design have to differ?
     - Or could the design we discussed also be used for this?
     - Do certain aspects become more relevant (materials, privacy etc.)

Examples of other scenarios that might be relevant:

Aspect	Scenario 1	Scenario 2	Scenario 3
Setting	Metropolis	Metropolis	Intercity
Distance	Short Distance	Short Distance	Long Distance
Passengers	Strangers	Group of Friends (3-4) + Strangers (2-3)	Strangers

   - Let them discuss how this would influence the design

Free-time Commutes: Group 2

15:00-15:05
Introduction

15:05-15:30

1. Asking for current periodically recurring routines which include commuting
   → having an open dialogue with all participants about commuting trips in their free time (grocery shopping, going to the gym etc.) → sharing experiences

    - Starting in the present: How do these routines look like for you nowadays?
        - What do you take with you when you go grocery shopping/to the gym (e.g. bags)
        - When do you usually go to do the groceries/to the gym? e.g. in the weekend, straight after work or do you go home first? Why?
        - How often do you go?
        - Is it a pleasure or a duty?
        - Do you do it alone or accompanied with friends/flatmates?

15:30-15:40

2. Presenting the future scenario
    - Picture: Bosch & Daimler: Driverless Systems
    - Make them familiar with other relevant aspects like
        - Car sharing & Car pooling
        - Number of seats: 4
        - How would commuting shape the interior design?
        - Neglect regulations etc.

15:40-16:30

3. Encourage participants to envision future autonomous driving experiences, how they would spend their time and how their daily commute might change.
    - Relate recurring free time commutes in the present to how it could be like in the future.
    - Participants can draw future design elements to elaborate on their thoughts and ideas.
    - Ask them what they currently cannot do while commuting but what they would like to do/be able to do.

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- Engineer
- Manager of a small group
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- Social and likes to practice sports
- Active lifestyle. Ambitious
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Role 2:

- 25 years old
- Newly arrived company employee
- International
- Loves to travel
- Loves nightlife and music
- Was living in a rather small town before
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- Master programme student
- Loves to hangout with friends
- Curious and energetic
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Role 4:

- 30 years old
- Works in retail, liquor/beverage store
- Hectic job and on his fit the entire day
- Helpful and social. Communicative
- Single
- Goes often to the gym
- Male

Scenario:

a. First person: Car picks up the first passenger at the person's home
    - How do you order the car?
    - What do you bring with you?
    - What will you do first?
    - How do you want to sit?
    - What is on your mind in that moment?
    - Do you do something related to your planned activity or something completely else?

b. Second person (orders a vehicle and vehicle stops due to convenience)
    - What do you bring with you?
    - What will you do first?
    - How do you want to sit?
    - Where do you (person 2) want to sit?
    - Do both of you mind sitting next to each other?
    - How does person 1 change his behaviour?
    - What is on your mind in that moment?
    - Do you do something related to your planned activity or something completely else?
    - Would you like to know beforehand that you won't be alone in the car?

- Would you like to know who is in the car? (gender, age, interests)
- Do you want to talk to each other?

c. First person leaves
   - Do you (the remaining person) change your behaviour now that you are alone in the car?

d. Second person leaves

e. Third person enters:
   - What do you bring with you?
   - What will you do first?
   - How do you want to sit?
   - Where do you (person 3) want to sit?
   - What is on your mind in that moment?
   - Do you do something related to your planned activity or something completely else?

f. Fourth person:
   - What do you bring with you?
   - What will you do first?
   - How do you want to sit?
   - Where do you (person 4) want to sit?
   - Do both of you mind sitting next to each other?
   - How does person 3 change his behaviour?
   - What is on your mind in that moment?
   - Do you do something related to your planned activity or something completely else?
   - Would you like to know beforehand that you won't be alone in the car?
   - Would you like to know who is in the car? (gender, age, interests)
   - Do you want to talk to each other?

g. The trip (details):
   - How do you expect the interior to look like? (equipment, materials etc.)
   - How could the comfort be increased as much as possible? (type of seats, massage etc.)
   - Is comfort even important for a 20 min trip?
   - How much privacy do you expect?
   - Would you like to use the newly gained time for something that you never did before? (Learn a new language, how to play an instrument)
   - Assuming that you are going with three of your friends from one location to another:
     - Would the interior design have to be different? In what way?
     - Would it really be that important for a 20 min trip?

16:30-16:45

4. Summarizing
   → let everyone express what is most important to him/her

   - Express in a few words: What should we as designers consider? (a few minutes per person)
   - Additional question: If you would not only commute with the car but also use it for short-distance traveling:
     - How would the interior design have to differ?
     - Or could the design we discussed also be used for this?
     - Do certain aspects become more relevant (materials, privacy etc.)

Examples of other scenarios that might be relevant:

Aspect	Scenario 1	Scenario 2	Scenario 3
Setting	Metropolis	Metropolis	Intercity
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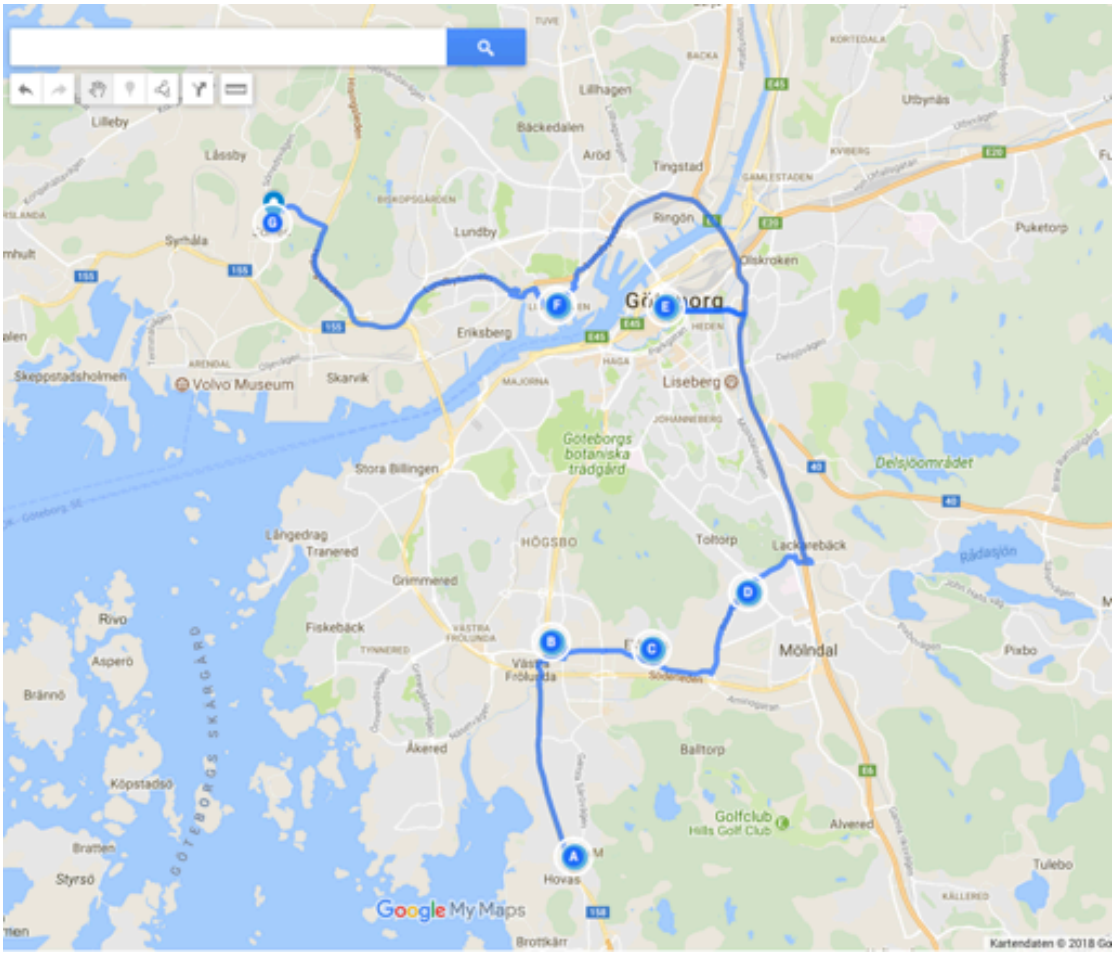
Passengers	Strangers	Group of Friends (3-4) + Strangers (2-3)	Strangers

   - Let them discuss how this would influence the design

Role 1

- 40 years old
- Female
- Engineer
- Manager of a small group
- Married
- Has 2 kids: 2-year-old son, 6-year-old girl
- Social and likes to practice sports
- Active lifestyle
- Ambitious

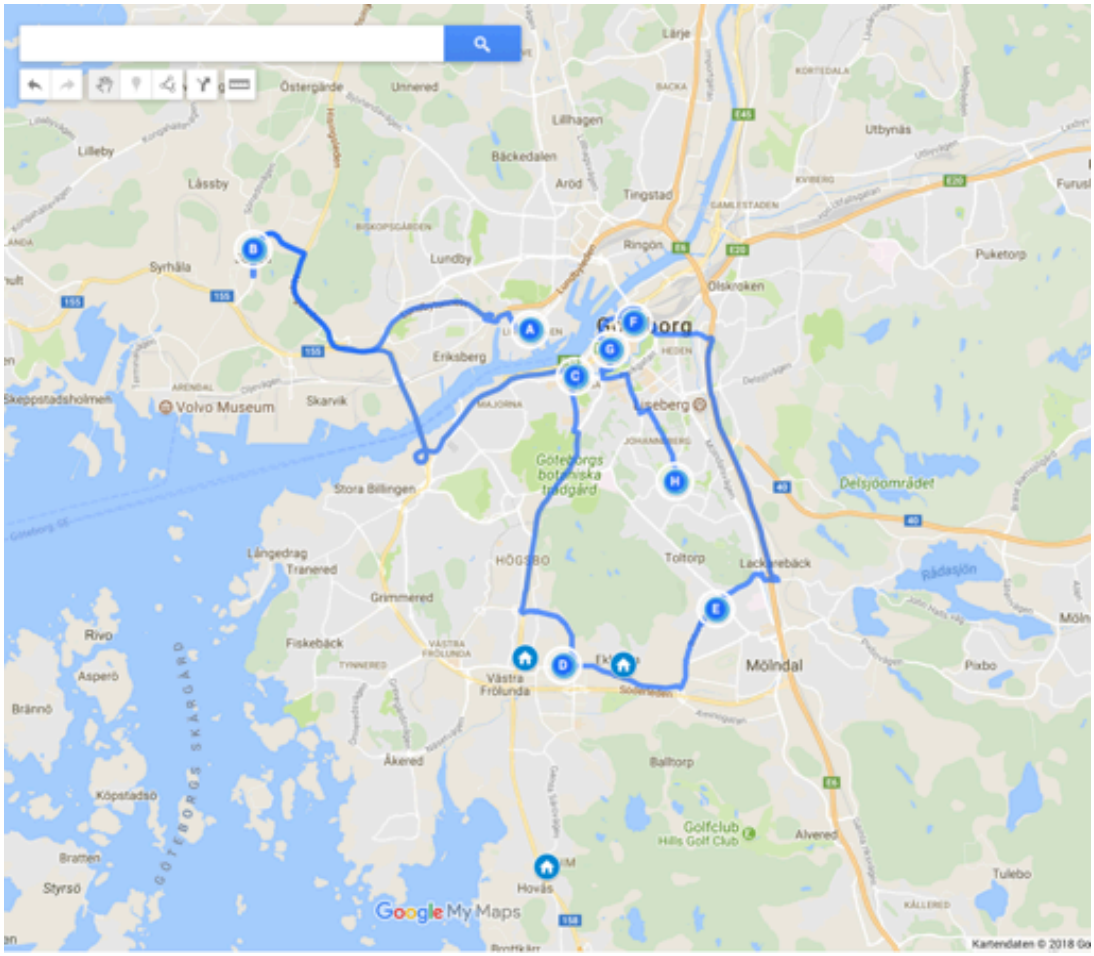
- Lives in Askim **(A)**
- Works at Volvo **(G)**



Role 1

- 40 years old
- Female
- Engineer
- Manager of a small group
- Married
- Has 2 kids: 2-year-old son, 6-year-old girl
- Social and likes to practice sports
- Active lifestyle
- Ambitious

- Lives in Askim
- Works at Volvo **(B)**
- Has to do the groceries at ICA Maxi on her way home **(D)**



C

Appendix

Interview Guide

Part 1

User Tasks:

Losing time

- Do you ever find yourself in situations where you are losing time because you e.g. have to wait for something? (“What takes up too much of your time?”)
    - e.g. standing in line
    - e.g. in a phone queue
- What kinds of situations are these?
- Do you do something else while your waiting?
- Is there something that you would like to do in such situations where you have the feeling that you are losing your time?

Daily routines

- Are there any daily routines and recurring duties in your life?
- What are your strategies for making these routines more pleasant?
    - e.g. doing the laundry
    - e.g. grocery shopping
    - e.g. cleaning the house/apartment
    - e.g. going to the gym when you are not in the mood
    - e.g. cooking when you are hungry but don’t want to cook

Free time

- What hobbies do you have and how do you like to spend your free time?
- Which of these activities do you usually do indoors?
- For which do you sit down somewhere?

Stress

- Are you stressed often? If yes, because of what?
- How do you usually deal with this stress? Do you have any strategies to lower your stress level?
- Do you have a morning routine? What does it consist of?
- What do you do when you get home after a long day of work/at school? How do you relax?
- What are the small things that make your day better?

Travelling

- Do you like travelling?
- Do you also travel around your area?
- How often do you travel long distances e.g. to other cities around your area? Which means of transport do you usually use for that? (car, train, bus)
- How often do you go on vacation? Which means of transport do you usually use for that? (plane, car, train, bus)
    - If you go by car, do you drive yourself or are you a passenger?
- How do you spend your time during the trip?

Commuting

- How do you usually get to work/school?
    - Public Transport:
      What kind of activities do you do when commuting with public transports or as a passenger?
    - Car:
      Are you the one driving?
      What do you do while driving?
    - Walking/Cycling:
      What do you do while going somewhere? What are you thinking of? Are you listening to music?
- How do you usually go around the city when for example you go shopping/groceries or for going to the gym? What about the weekends when you meet your friends or have any other nice plans?

Online services

- Do you like to check the news? How (radio, newspaper, digital app, tv?
- Did you subscribe to any services? (Netflix, Spotify, Duolingo, Babbel, magazines etc.)
- Do you use these services only at home or also when you are on the go?
    - If yes, how?
    - If no, why not?

Learning something new

- Is there something that you would like to do/learn but you don't find the time for?
- What do you wish you knew more about

Privacy and Sharing Space:

Behaviour in public spaces

- Are you a person that in general feels comfortable around other people, especially strangers or do you need your own space?
- How do you share limited space and how do you behave among others in such a situation?
    - e.g. on a crowded bus/tram
    - e.g. in an elevator/lift
- How do you usually try to gain privacy in public?
- How do you signalize that you do not want to interact with others?

Working in public

- Do you have troubles to focus (e.g. on work) when other people are around/close to you?
    - If yes, what is it that disturbs/annoys you?
    - If no, what is your secret to focus?
- What is the most annoying habit that other people in public spaces have?
- How could that be addressed?

Talking to friends & family

- Do you consider yourself to be a social person that enjoys being around other people often?
- How often do you speak to your friends and family?
- Do you speak to them over the phone or in person?
- Why do you do it that way? Is it your prefered way to communicate? If yes, what is the reason for that? (time, convenience)
- Do you mind to speak in public (over the phone or in person)?
    - If yes:
        - Is it because you feel uncomfortable that others can hear what you are saying? Or do you not want to disturb the people around you?
        - Do you have a strategy to address or even solved this issue?
    - If no:
        - Are you not concerned about the fact that others can hear what you are saying?
        - Do you not mind that you might disturb other people around you?

Talking to strangers

- Do you talk to strangers often?
    - If yes:
        - Is it usually because you are curious or because you need help?
    - If no:
        - What stops you from speaking to strangers?
        - Would you like to do this more often? (Are you concerned that you would bother people with that?)
- How do you start a conversation with strangers?
- Can you think of anything that could make it easier to start a conversation?

Waiting room scenario

- Assuming you had to spend 30 min with someone in a room. Would you start a conversation or mind your own business and wait for the time to pass?
- Would you appreciate to know something about the other person beforehand? (e.g. common interests) (What about common dislikes?)
- What would you say is okay for strangers to know about you?
    - e.g. job
    - e.g. hobbies & interests
    - e.g. where you have been living / where you have been on vacation before
    - e.g. what your favourite movies/TV shows/songs/artists are
    - e.g. what you are passionate about
    - e.g. idols and role models

Part 2:

“What would your perfect room look like?”

Instructions for the participants:
You have to design a waiting room. You can choose objects that you would like to have in the room from the library. Moreover, you can of course also write notes to explain your ideas.

However, the following restrictions have to be considered:

- The dimensions are 2x3m
- 4 people have to fit in there. In some situations it might be your friends, in others unknown people.
- Keep in mind that it is not about the aesthetics of the objects that you select but rather the functionality and what you can do with them.
- Also keep in mind that you will spend around 30 min in this room.
- You might carry objects with you, maybe because as a student you have your backpack or because you went groceries or will go to the gym later on.
- If you cannot find an object that you would like to have in the room, feel free to draw it.

After finishing the collage:

- Why did you choose those objects?
- Why did you disregard the rest?
- Now assume that the room is actually the interior of an autonomous car: Would you change anything?

Figure C.1: Further Design Task Results Part 1

Figure C.2: Further Design Task Results Part 2

Figure C.3: Further Design Task Results Part 3