# Entwicklung von technischen Lösungsmöglichkeiten zu Herausforderungen bei der Mobilität einer zukünftigen „Sharing Economy“

**Development of technical solutions for challenges of the mobility of future sharing economies**

Sven Höhl | Bachelor-Thesis | 2019
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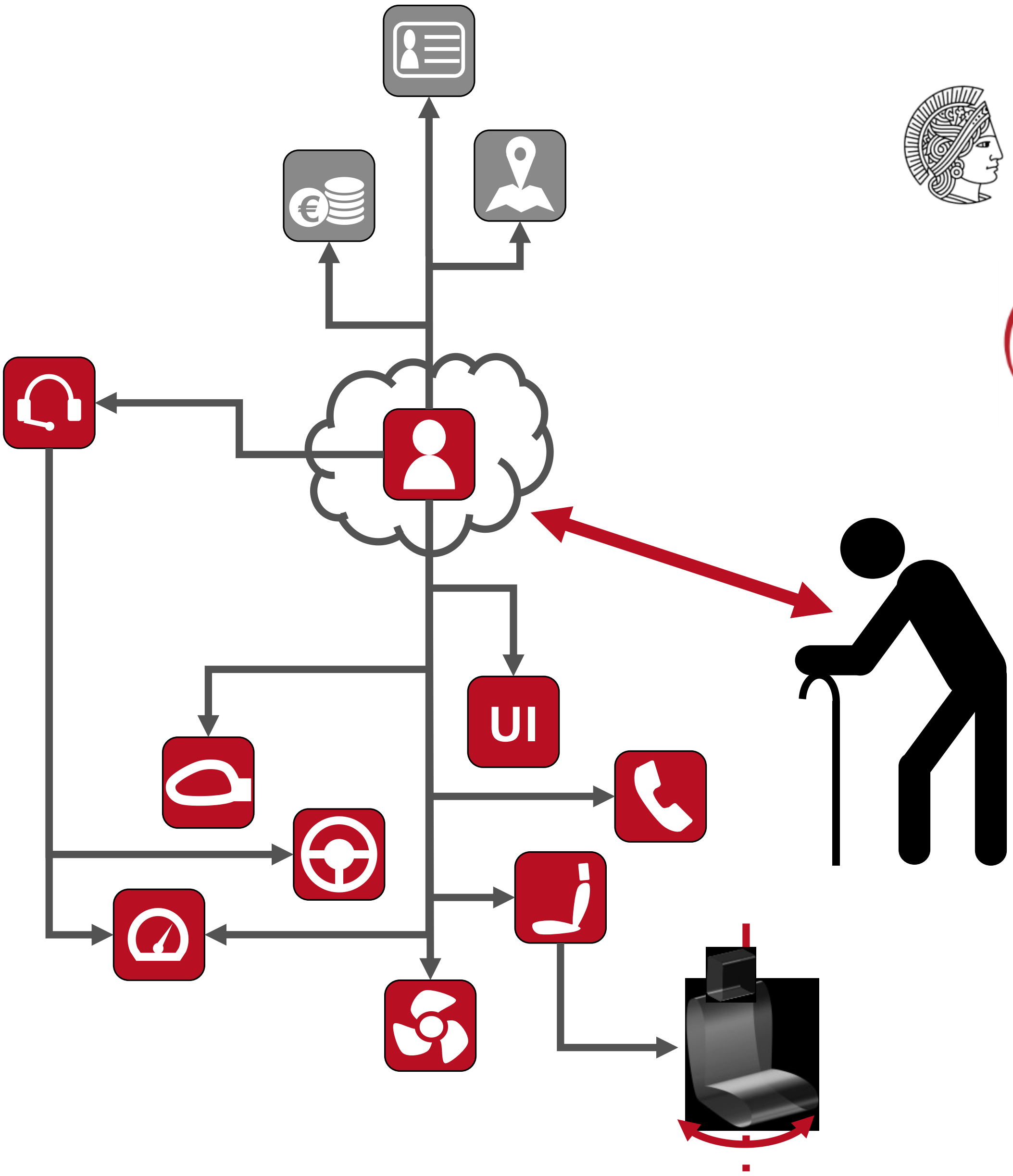


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Bachelor-Thesis
Entwicklung von technischen Lösungsmöglichkeiten zu Herausforderungen bei der Mobilität einer zukünftigen “Sharing Economy”
Development of technical solutions for challenges of the mobility of future sharing economies

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## Task description

## Abstract

The intention of this thesis is to develop technical solutions for challenges of future sharing economies, with the goal of generating two to three product features that enhance customer experience in the context of shared mobility and are relevant in the timeframe of 2025-2035. At the start, a research phase is conducted, to determine a viable methodic approach for product development and to obtain a market review. During the following development process, the scope is narrowed down in each step to find a clear focus for the product features. First, customers are identified as the main stakeholder, followed by the determination of their requirements. Therefore, a customer survey is conducted. The results are used to generate customer profiles using the Persona-method. In the next step, a car is identified as the overall product to focus on, and a functional analysis is carried out. After choosing elderly people as the customer segment to concentrate on, the results of the functional analysis, in combination with the generated Persona, are utilized to generate concept ideas. Finally, the three best ideas are selected and further specified into product features. Due to narrowing the scope of the thesis during the development process, all three features focus on enhancing customer experience for elderly people in regard to carsharing. The first feature eases access to the vehicle by implementing rotatable seats. It can also be beneficial to people suffering from injuries or parents buckling their child's seatbelt. The second feature uses teleoperated driving as a service for old people who are suddenly unable to continue the drive, e.g. due to exhaustion, dizziness or loss of orientation. Such a safety feature to fall back on allows people, who otherwise avoid using cars, to stay mobile. Other customers can benefit from teleoperation as well, i.e. by being able to order a vehicle to their current location. Finally, the third feature eases handling and provides a more familiar environment in carsharing vehicles through the use of a digital profile. This profile fulfills two main functions, namely providing a senior-friendly user-interface in the car, as well as a memory function for systems determining the driver's environment, like the seats or the mirrors. Automatically adjusting components like the seats to the customer's needs is beneficial for all user groups, not only old people. All three features show ways to offer senior-friendly mobility and make carsharing more convenient for elderly people. At the same time, other customers do not suffer any disadvantages, if anything the developed features benefit them as well. Therefore, they can be an option to meet the challenges of demographic change.

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## Kurzfassung

Die Intention dieser Arbeit ist die Entwicklung von technischen Lösungsmöglichkeiten für die Herausforderungen von zukünftigen „Sharing Economies”, mit dem Ziel 2-3 Produktkonzepte zu entwerfen, die das Nutzererlebnis im Kontext von „Shared Mobility“ während des Zeitraums von 2025-2035 verbessern. Zu Beginn wird eine Recherchephase durchgeführt, um ein geeignetes methodisches Vorgehen bei der Produktentwicklung zu ermitteln und einen Marktüberblick zu erhalten. Während des folgenden Entwicklungsprozesses wird die Zielsetzung immer weiter eingegrenzt um einen klaren Schwerpunkt für die zu entwerfenden Konzepte zu finden. Zunächst werden die Kunden als die Hauptanspruchsgruppe identifiziert und anschließend werden ihre Anforderungen ermittelt. Hierfür wird eine Kundenbefragung durchgeführt. Die Ergebnisse davon werden genutzt um mit der Persona-Methode Kundenprofile zu erstellen. Im nächsten Schritt wird das Auto als das zu betrachtende Gesamtprodukt festgelegt und eine Funktionsanalyse durchgeführt. Nachdem Senioren als Hauptkundensegment gewählt sind, werden die Ergebnisse der Funktionsanalyse, in Verbindung mit den erstellten Personas, zur Erzeugung von Konzeptideen genutzt. Schließlich werden die drei besten Ideen bestimmt und zu Produktkonzepten ausgearbeitet. Durch das Eingrenzen der Zielsetzung konzentrieren sich alle drei Konzepte darauf, das Nutzererlebnis von Senioren beim Gebrauch von Carsharing zu verbessern. Das erste Konzept erleichtert das Einsteigen in ein Fahrzeug durch den Einbau von drehbaren Sitzen. Davon profitieren neben Senioren auch Menschen die an einer Verletzung leiden oder Eltern, die ihr Kind anschnallen. Das zweite Konzept nutzt teleoperiertes Fahren als Service für Senioren, die sich plötzlich außerstande sehen die Fahrt fortzusetzen, z.B. wegen Erschöpfung, Schwindel oder Orientierungsverlust. Solch eine Funktion als Sicherheit erlaubt es Menschen mobil zu bleiben, die sonst den Gebrauch eines Autos vermeiden müssten. Andere Kunden können von Teleoperation ebenfalls profitieren, z. B. durch die Möglichkeit ein Fahrzeug zu ihrem aktuellen Standort zu bestellen. Das dritte Konzept schließlich erleichtert durch die Verwendung eines digitalen Profils die Bedienung und bietet ein gewohnteres Umfeld in Carsharing Fahrzeugen. Dieses Profil erfüllt zwei Hauptfunktionen, nämlich die Bereitstellung einer senioren-gerechten Benutzeroberfläche im Auto, sowie eine Speicherfunktion für die Einstellung der Fahrerumgebung, z.B. die Position von Sitzen und Spiegeln. Diese automatisch nach den Anforderungen des Kunden einzustellen ist nützlich für alle Kundengruppen. Alle drei Konzepte zeigen Möglichkeiten auf, um altersgerechte Mobilität anzubieten und Carsharing angenehmer für Senioren zu machen. Gleichzeitig erleiden andere Kunden keine Nachteile, sondern können von den Konzepten profitieren. Deshalb stellen sie eine Option dar, um den Herausforderungen des demographischen Wandels zu begegnen. Diese Bachelor-Thesis wurde durch das Horizon 2020 research and innovation programme der Europäischen Union unterstützt (grant agreement No. 693651, Science2Society). Der Autor bedankt sich für die Unterstützung.

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# 1 Introduction

The goal of this thesis is to develop two to three product features for mobility products that enhance the user experience in the context of future sharing economies, with a targeted timeframe of 2025-2035 and a focus on Germany. Those features are to address challenges of future mobility. To gain an idea of such challenges, three current trends in society, other than the trend towards sharing economy itself, can be identified to presumably affect mobility during the targeted timeframe. First is an increasing ecological awareness, due to the necessity to contain the effects of climate change. Man-made climate change is caused by the emission of greenhouse gases, the most prominent being carbon dioxide. And since transportation is responsible for roughly 20 percent of the greenhouse gas emission in Germany, new concepts and regulations are developed to reduce emissions [1]. The second trend is digitalization. In the context of mobility, this results in increasing connectivity of the vehicles, as well as advancements in automated driving. The last trend is demographic change. People in Germany live longer than before, and so over time the society contains a larger percentage of old people [2]. Therefore, many aspects of daily life, including mobility, must increasingly consider their needs. Considering these trends, future mobility can be expected to be greener and more connected. It will also have to pay more attention to old people. Sharing economy, regarding mobility for example in the form of carsharing, benefits from the first two trends, since it requires connected vehicles and can be a way to reduce overall emissions. However, it currently fails to address old people [3]. To conclude, the developed product features should address problems within the field described above.

To systematically develop those features, this thesis consists of four phases; the research phase, the definition phase, the concept phase and the specification phase. The research phase determines an approach for methodical product development and obtains an overview of the state of the art. Following is the definition phase, which helps to specify the task by determining requirements. In the subsequent concept phase, product concepts are generated. Finally, the most promising concepts will be further specified and detailed in the definition phase. Basis for this development process is the VDI guideline 2221, along with its supplement sheet 2.

The structure of the following text follows the stated approach. In chapter two, the results of the research phase are presented, including information on the chosen model for product development, a discussion of the term sharing economies, as well as an overview on trends in society and technology. Chapter three explains the development process, beginning with the determination of stakeholders and requirements, followed by a functional analysis and subsequently the generation of concept ideas. In the last section of the chapter, the three final product features are presented in detail. The thesis closes with a conclusion in chapter four.

## 2 State of the art

In order to develop product features for future mobility products, the state of the art, as well as relevant future developments, need to be considered. To acquire the necessary knowledge, a literature research is conducted. The results of this research are documented in this chapter. First, the methodical approaches for product development used for this thesis are presented. Since the task is to develop solutions in the context of sharing economies, the term is discussed in the second section of this chapter, and it is defined which aspects of it are considered for this thesis. Along with this, relevant current business models for shared mobility are introduced. In the third section, trends in society that can be expected to affect mobility in the timeframe of 2025-2035 are presented. Finally, technological aspects are examined. The products that fit in the scope of the thesis are introduced, and an overview of major technological developments concerning these products is given. This includes information about the state of the art, as well as an outlook on the future of these technologies.

### 2.1 Methodical product development

To provide structure and transparency for the development process, a methodical approach needs to be followed. There are several basic models for product development that are generally fitting for the purpose of the given task description. In the following, the models chosen for this thesis are introduced.

#### VDI guideline 2221

Issued by the Verein Deutscher Ingenieure (VDI), the purpose of this document is to provide a generally applicable model of product development for mechanical engineers, which is not sector-specific [4, p. 2]. In this model, the development process starts with the task description and ends with the documentation of the finished design. Actions concerning production are not considered in this approach.

Its main idea is that the development process can be divided into seven stages. Each stage builds upon the previous and ends with achieving a particular documentable result. Although the seven stages are consecutive, iterations between them are possible and intended [4, p. 9]. Figure 1 shows a depiction of the model.

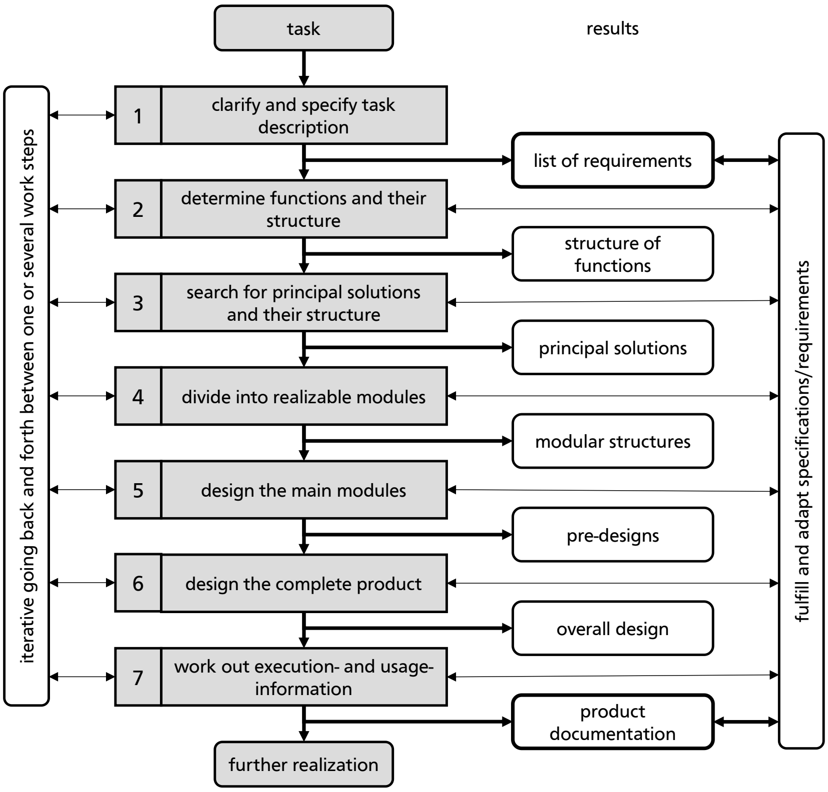



Figure 1: depiction of the process model for product development introduced in the VDI guideline 2221 (based on [4, p. 9])

Due to its fundamental approach, this model is applicable to almost all scenarios of product development. However, it is best suited for projects that have clearly defined product requirements, since it has no stage devoted to research or determining requirements. The first stage of the model is only intended to translate the given task description into a more technical language, in form of a list of product specifications. This means it focuses heavily on the design process, and is therefore not ideally suited for the scope of this thesis, which does not include a finished design. Another downside of this model is that it only describes the stages of the process and specifies their results, but neither are particular tasks stated, nor any specific methods introduced.

#### VDI guideline 2221 sheet 2

Sheet 2 is a supplement to the original VDI guideline 2221, and provides several examples of the basic model applied to projects from different sectors. One of these examples is a student project. The core idea of the model, namely the development process consisting of several steps, from analyzing functions, to finding principal solutions, to a detailed design, is kept.

However, the linear approach is replaced with a two-dimensional one. It now also includes time as an axis and the project is therefore divided into five phases. Through the resulting matrix, each step of the development process can be connected to a phase or amount of time in the project. Just like in the basic model, iterations are intended, but in this adaptation, several steps of the process are worked on simultaneously. Another difference is that this adaptation of the model includes other activities as well, i.e. production or marketing. However, these are not relevant for this thesis [5].

Apart from the benefit of the two-dimensional model and several steps happening simultaneously, the biggest advantage of this approach over the original model is extra information about the individual project phases. Unlike the basic guideline itself, supplement sheet 2 explains what to do in each phase and gives specific tasks.

## 2.2 Sharing economies

Following is an introduction of different aspects of sharing economies that are of relevance for mobility services. To establish a foundation for this thesis, the first section will differentiate between different models of sharing economies and give specific definitions. Based on these definitions, product models that fit into the scope are introduced in the second section.

### 2.2.1 Definition

Shared or sharing economy is a trend that affects different aspects of society and consumption. The basic idea behind it is for individuals to lend or share unused assets, in order to enable a collaborative consumption [6]. Assets can include anything from workforce, over capital to objects and apartments. Those can be provided by individuals, but also by companies.

However, beyond this lose description there is no precise definition for the term sharing economies. It has become a buzzword, much like digitalization, is currently very popular, and seems to stand for something new and innovative. Therefore, many companies and institutions feel obliged to use it, oftentimes with little-to-no regard towards a precise definition. Hence, the term now covers a broad spectrum of meanings. As a recently conducted study shows, even more specific terms related to sharing economies are defined differently by different authors [7, p. 179].

Since there are no generally accepted precise definitions in scientific literature, the terms used as the basis for this thesis are established in the following. The definitions stated here are mostly consistent with the ones given by GÖRÖG [7]. Figure 2 depicts the relationship between the different terms as they are established here, with general concepts in rectangles and the specific ones in circles. The specific concepts identified to be applicable for the thesis are red.

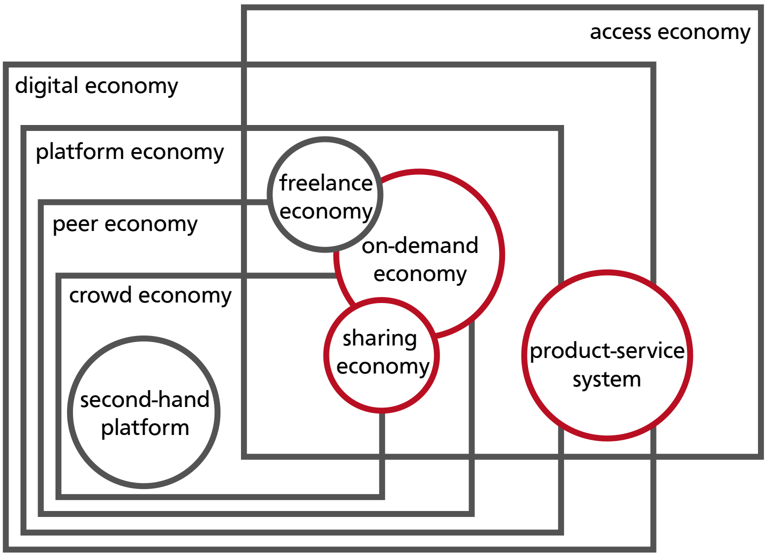



Figure 2: different terms regarding sharing economies in relation to each other

Since only the ideas and models applicable to mobility are of relevance for this thesis, they are grouped into three categories, which are explained in the following. Those categories are general concepts, inapplicable concepts and applicable concepts.

**General concepts**

The first category consists of general concepts related to sharing economies. These are generally applicable to mobility, but are not specific enough to result in a particular business model. Instead, they are rather umbrella terms that include the more specific concepts and business models. Nonetheless, they are introduced to allow a better understanding of the other models. The general concepts are all ideas that are not exclusive to sharing economies.

- **Digital economy**
  This term basically stands for any business model that uses digital technology. Therefore, almost all of today's business can be categorized as such. Since an increase in digitalization until the targeted timeframe of 2025-2035 is to be expected, this concept is assumed to generally apply for this thesis. It is also a requirement for all of the other concepts.
- **Platform economy**
  Directly connecting supply and demand is the main idea of this concept. The platform provides a space where customers and retailers can meet, eliminating the need for intermediaries. A classic example is eBay. Since this concept is generally applicable to mobility services, it is of relevance for this thesis.

- **Peer economy**

  Peer to peer economy means that consumers are doing business amongst themselves. This usually involves a platform as introduced above. Likewise, the peer economy is generally applicable for mobility services. But because of legal regulations and insurance costs, mobility services are not ideally suited for this form of business [8].

- **Crowd economy**

  Crowd economy describes a business model in which the "crowd" provides the necessary resources. This can be capital (crowdfunding), as well as physical products. The concept can principally be the foundation for mobility services such as carsharing, with the crowd making their private cars available for use. However, due to insurance cost and major corporations already dominating the market, it is unlikely to be relevant in this field in the future.

- **Access economy**

  Access economy lets the consumer pay for the access to a good or service rather than for its ownership. This implies that several customers use the same product, so the concept usually requires some form of sharing. A conventional example is car rental.

#### Inapplicable concepts

All the specific concepts and business models that cannot be applied to, or do not describe mobility services as developed in this thesis, are listed in this category.

- **Freelance and gig economy**

  Both terms essentially mean that instead of regular employment, people work as freelancers, offering their services through digital platforms. These concepts are the most criticized aspects related to sharing economies, because of their lack of regulation and worker rights. Since they are concerned with the provision of labor instead of goods and services, they are not directly related to mobility products. For instance, whether a car is driven by a professional taxi driver, or by a freelancer working for uber, does not influence the properties of the car. Since the thesis is concerned with product development, this form of sharing economies is therefore not relevant.

- **Second-hand platform**

  This concept is based on consumers selling their used products when they have no need for them anymore. While it can be applied to mobility, e.g. online platforms to buy and sell used cars, it is not suited for mobility services, since a service cannot be second-hand.

#### Applicable concepts

The final category consists of specific concepts that are applicable to shared mobility. They are the basis to later determine which business models are in scope and which are not.

- **Product service systems**
  This term describes a business model where the consumer pays for the use, instead of the ownership of a product. Companies rent their products to customers instead of selling them. Neither specialized products are necessary, nor does the traditional relationship of company and customer need to be changed. Examples of this business model are car leasing and conventional car rental.
- **On-demand economy**
  Online platforms that provide instant access to goods or services to the customer are described by this term. This allows the customer to not be forced to own the required assets, but still be able to use them whenever he desires. It is typical for this concept to increase the user’s options considering the desired product or service in comparison to conventional ownership. A good example are streaming platforms. By using their service, the customer can watch movies any time he wants to, but does not have to own a copy of the film.
- **Sharing economy**
  The original concept of sharing economy comes very close to the standard definition of sharing. It involves sharing or lending an unused asset for free, for example letting the neighbor borrow a tool. In this strict form, it is obviously not ideally suited for a business model. Instead, it is rather an idea to provide an alternative form of economy, especially as a contrast to a society based on consumption. However, it is the basis for most of the other terms described here, which amend it, sometimes more and sometimes less, to create a business model. The resulting concepts usually do not involve real sharing, in the actual sense of the word, but still represent ways to rethink consumption.

### 2.2.2 Shared mobility

With a clear definition of which concepts are considered for this thesis, and which are not, the next step is to study the market and analyze existing business models to see if they fit into the concepts stated above. If so, they are of interest for this project. First of all, a business model must involve sharing in the context of mobility. Depending on the definition, the idea of sharing mobility is not new. Well established concepts are public transportation, taxis, or car rental. However, these conventional models are not taken into account for different reasons. Public transportation is not in the scope of the task description. Taxis and car rental can be categorized as product-service systems, but for this thesis only digital business models shall be considered, which can be assumed to be dominant in the future. Also, usually all the functions of car rental can be fulfilled by carsharing as well. Apart from those conventional models, new concepts exist, which can be grouped into three categories; bike-sharing, ridesharing and carsharing. These are also imaginable to be applied to other mobility products, like flying drones. However, such products are not available yet, and therefore not considered in this section. In the following, the three models are introduced and categorized according to the different terms defined in section 2.2.1

#### Bike-sharing

Bike-sharing is a concept for urban mobility that provides bikes all around the city for a customer to rent. In contrast to conventional bike rental, this can usually happen around the clock, be done by the customer independently, and takes only a few moments, all achieved by using digital technology to unlock the bikes. Therefore, in order to use the service, a one-time online registration is required, and oftentimes a smartphone is used for the actual renting process. In regard to the availability of the bikes, two models exist. The first is station based, in which bikes can be picked up and dropped off only at certain points in the city. The second is called freefloating, allowing to drop bikes off anywhere. Consequently, they can only be picked up where other customers left them [9]. Both concepts can be categorized as product-service systems, as well as on-demand economy. Bike-sharing in general is growing, and hence can be expected to be more important in the future [10].

#### Ridesharing

This concept stands for at least two people sharing the ride in a car. Obviously, the idea itself is not new. But in this context, the people are strangers who connected via an online platform, and the drive usually costs money. All participants do not necessarily have to have the same destination, with some of them potentially being dropped off along the way. The ride can be provided by a private person or by a company. An example for the first option is the service blablacar [11]. A company providing ridesharing is MOIA, which employs professional drivers and uses vans to transport customers. It can be ordered through an app, and is effectively like sharing a taxi ride with other people, who have similar destinations and get on and off along the way [12]. Both concepts can be categorized as on-demand economy, and, except for being free, also fulfill the requirements for true sharing economy. In either case, the private ride or the taxi ride is something that was to happen anyway, and is just shared with others. Since MOIA is a company, it also qualifies for product-service system. Another service that is often labeled ridesharing is uber. Technically, driver and customer do share the same ride. However, in reality the driver usually just acts as a chauffeur. Therefore, the service is no different to regular taxis, except that the drivers are freelancers. Hence, it is mainly characterized by freelance economy and accordingly not considered for this thesis [13].

### Carsharing

Carsharing provides the user with access to multiple vehicles within a certain area, usually a city. Technically, it is possible to be crowd-sourced, meaning private persons make their cars available, but in reality that is not very feasible. Reasons for that are difficulties coordinating the schedules, taxation and legal issues. On top of that, the market is already dominated by carsharing companies, which provide a fleet of vehicles that are available around the clock to the user. Their services can be categorized as on-demand economy and as product-service systems. The renting process is very similar to that of bike-sharing, in that a one-time online registration is necessary and a vehicle can potentially be accessed by smartphone. Also similar is the distribution of the vehicles, with the two concepts of station-based and freefloating fleets available [8].

Carsharing is growing in Germany, and currently especially popular in cities and amongst young people, while old people still almost do not use at all [3] [14] [15]. Therefore, it can be expected to become increasingly important for future mobility. The market in Germany is already largely dominated by the car manufacturers themselves, who have founded companies that offer carsharing services, e.g. car2go or drivenow [16]. This shows the importance that the business model already has. It might also profit from other developments in society and politics. Increasing urbanization, along with higher rents and stricter pollution-limits in cities, combined with already increasing electro mobility and more awareness for ecology, can be promoting factors. All of that can make carsharing more attractive for customers, manufacturers, and politics. Experts expect it could even challenge private owned cars in the long-term [17].

## 2.3 Trends in society

Apart from sharing, two major trends in society can be identified to affect future mobility; demographic change and environmental protection. They can already be observed today, and can be expected to gain importance until the targeted timeframe of 2025-2035. Both trends are introduced in the following, along with an overview of how they can affect mobility.

### Demographic change

Demographic change is caused by three factors; immigration and emigration, birthrate, and mortality rate. In Germany, the birthrate is lower and people live longer than in the past, which leads to an increasing average age, and society containing a larger proportion of old people [2]. The demographic change is expected to have significant influence on the future and acknowledged to be a major challenge by the German federal government. Specific challenges, especially in regard to the

growing amount of elderly people, are senior-friendly conversion of real estate or barrier-free access to transportation [18].
Apart from the surrounding infrastructure being barrier-free and senior-friendly, future mobility products themselves should pay special attention to elderly people, since this customer segment will increase, and therefore become more important.

#### Environmental protection

Climate change is a major problem with dangerous consequences for humanity. Humans are responsible for climate change, and one of the main reasons for that are the carbon dioxide emissions caused by burning fossil fuels [19]. Most countries acknowledge this and have pledged themselves to stop climate change, for example by reducing emissions [20].
Since transportation is responsible for roughly 20 percent of greenhouse gas emissions in Germany, and both the European Union (EU) and the German federal government have decided to lower the emission of greenhouse gases significantly, new regulations for cars have been issued [1] [21] [22]. If the overall goals set by the governments are to be reached, those regulations can be expected to be further aggravated. Therefore, car manufacturers are forced to develop new technology, like electric vehicles, and it can be assumed that emission regulations will be a decisive factor for future products. Apart from the car industry, governments are also forced to develop new strategies for mobility. This can range from supporting and subsidizing public transportation or electric vehicles, to further restricting or banning combustion engines. In-between, new business models like carsharing or bikesharing emerge.
With climate change becoming an increasingly severe problem, it can be assumed that future mobility will be decisively shaped by environmental protection [23].

### 2.4 Technology

In this section, important technological aspects affecting mobility are presented. For each aspect, an overview of the state of the art is given, along with an outlook on future developments in the field. The thesis' scope is covering the gap between private cars and public transportation, so developments regarding trains and so forth are not considered. Instead, the technology presented here concerns products providing individual mobility. These can be grouped into three categories; products still requiring muscle strength, like bikes or carts, automotive products, like cars, vans, and small buses, and finally new concepts, like flying drones. Figure 3 depicts the product range that is of interest for this thesis.

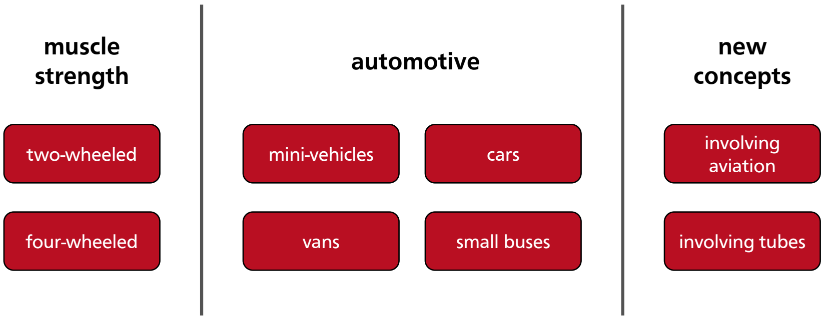



Figure 3: product range of interest for this thesis

Since cars are the largest segment of these products, and a lot of current developments are originally made for them, much of this section is related to cars. However, most of the technology is relevant for the other products as well. For example, autonomous driving developed for cars is equally applicable to vans and small buses, and much of it can probably be used for autonomous drones. Also, advancements in battery technology for electric cars can be applied to e-bikes as well.

### 2.4.1 New concepts for mobility

This section provides an overview of new concepts for mobility that fall into the range of products that is principally of interest for this thesis. However, as is explained in the following, not all new ideas are equally likely to play a major role in future mobility. The concepts presented here are categorized into the three groups introduced above. It is important to note that this selection of concepts has only exemplary character, and is by no means a complete list. However, the chosen products provide a good picture of the different trends and developments in this field.

#### New concepts for vehicles requiring muscle strength

Other than a bicycle, there are not many products in this category to begin with. The e-bike should be well known by now, and can hardly be considered a new product. However, there are some cart-like concept vehicles that fit in the category. One is developed by Schaeffler and was presented at the CES 2019 [24]. In the basic version, it has four wheels and one seat for the driver. It requires the driver to pedal, but supports him through an electric motor like an e-bike [25]. A similar concept is developed by the company e.GO. It features four wheels, a single seat, and pedal support through an electric motor as well. However, unlike the concept by Scheaffler, it designed to be used for leisure time and not necessarily daily life [26].

### New automotive vehicle types

Apart from the developments in electric vehicles, which are still mostly conventional cars, there are some new concepts for automotive mobility. A brief overview of these is given here. The first product is the twizy by Renault, a small electric vehicle covering the gap between a motorcycle and a proper car. Other concept vehicles of similar size exist, but the twizy is actually available to the customer. Then there are new concepts for buses like the e.GO mover, a small four-wheeled, electric bus, with room for 15 passengers that is intended to drive highly automated [27]. A similar product by the start-up EasyMile is tested by the Deutsche Bahn [28]. Another concept to transport multiple people is the MOIA developed by VW. It is smaller than the previously stated products, with room for six people, and is specifically designed for ridesharing [12].

### New concepts for mobility

The improvement of cars and the developments presented in this chapter are not the only ideas for the future of mobility and transportation. Another ground-based concept is called Hyperloop, which is worked on by different companies and research institutions. The basic idea is a system of tubes that are nearly evacuated, allowing for special capsules to, at least in theory, travel close to the speed of sound, due to the lack of air resistance. Recent tests have reached a top speed of more than 450 km/h [29]. A different tube-based concept is developed by the boring company. It consists of underground tunnels, in which regular cars can travel at high speeds. The goal is to reduce traffic in large cities [30]. One problem that these concepts have in common is that they are very expensive to realize, because of the high investments needed for the infrastructure [31].

Apart from these ground-based concepts, there are also new ideas for personal mobility involving air travel. Examples for this are the Volocopter or the Scorpion 3 hoverbike. Both are small vehicles that operate much like a helicopter, in that they can take off vertically and hover in the air, but are a lot smaller and powered by electric energy. They have a very limited range, but the ability to go the direct way, combined with urban environments, in which locations are not far apart in terms of the beeline distance between them, can enable viable usage [32] [33].

When regarding the reluctance of politics to invest even in electric mobility, it is unlikely that the concepts involving large investments for infrastructure are going to play a key role in Germany. As for the concepts involving aviation, they might be interesting for certain niches, but probably not for providing mass-mobility. This will most likely still be achieved by a mix of cars and public transportation.

### 2.4.2 Digitalization, connectivity and Big Data

Digitalization is a topic that affects all areas of society. Concerning the industry, it is usually concluded under the term industry 4.0. It stands for increasing connectivity between production and development, as well as between the different machines in a factory or companies as a whole [34]. This affects the manufacturers of mobility products, and can lead to faster product development and possibly more efficient production.

Apart from the companies, the mobility products themselves are also becoming increasingly digitalized and connected. This started with advanced driver assistance systems, in the case of cars, and infotainment modules like an internet access onboard the vehicle, which can be found in cars and public transportation alike. Furthermore, modern cars provide the ability to connect a smartphone to the entertainment system. For carsharing, connectivity is also very important, since the services rely on apps, some of which even manage the access to the vehicles.

In regards to the automotive industry, the next step is to further increase the digitalization of the car and use Big Data to improve products and services, by turning the car into a self-optimizing system [35, p. 11]. Real load data, collected from customers, can be used in product development, especially to reduce the weight of components. Currently, most components are designed for worst-case scenarios that are likely to never occur in real use. By collecting real load data, the components can be designed closer to actual requirements. Also, the data can be used to detect a high load in an individual vehicle, and either use predictive maintenance to exchange critical parts in time, or change driving behavior to reduce load and increase the component's lifespan [35].

Another way to use Big Data is to collect real driving data to adapt driving strategy and reduce emissions. Also, the driving data is needed for autonomous driving vehicles, where it is processed by machine learning algorithms to control and improve their driving strategy [35].

### 2.4.3 Automated driving

The increasing automation of driving, with the ultimate goal of an autonomous driving vehicle, is a big trend in the automotive industry. Autonomy is a goal in aviation products, like the volocopter, as well, but obviously not possible for vehicles requiring muscle power. Since it is most prominent in the automotive context, this section will focus on that. The information presented is concerning cars, but everything is equally valid for other automotive vehicles, like small buses.

In relation to driving, the automation process is divided into five levels. In level one, assistance systems support the human driver, who still has to pay attention for the whole time. In level five, the car drives entirely independent, and can do so with or without a human passenger.

Key for the automation of driving are driver assistance systems, of which a wide variety is available today, most of them related to safety. Some systems can intervene in the steering, such as lane departure warning or road departure protection. Others provide additional safety relevant information to the driver, such as traffic sign assistants or blind spot warning systems. Then there are systems that intervene in critical situations, like emergency brake assistants, electronic stability control or pre-safe systems. Furthermore, there are systems to prevent accidents in general, like adaptive cruise control, intelligent light control, tire pressure control, or drowsiness detection. Finally there are non-safety-related systems for parking [36] [37].

With the driver assistance systems described above, most current models of cars include level one technology. Level two stands for partly automated driving, with the human driver still in charge the whole time. However, the software can take control of and steer the vehicle, for example on the highway. This is achieved by combining several assistance systems to work together, for example adaptive cruise control and lane departure warning. The technology is available in some newer cars, but usually still restricted to upper class models like the Mercedes S-Class or the Tesla models. Highly automated driving allows the driver to turn away from traffic for a short period of time in certain situations, with the car taking care of the driving. A first version of such level three technology has been developed by Audi, but is not yet available to the customer. When the last legal issues are solved, this technology is expected to enter the market around 2020. The first systems are expected to be for highway-driving, with systems for urban traffic following towards 2030 [38] [39] [40].

Concerning the final steps towards autonomous driving, namely level four and five, predictions are more difficult. Some studies expect the first autonomous vehicles not to enter the market before 2040, while other studies expect them as early as 2025 [40] [41]. Independently of when this technology will be available in private cars, it is already tested in public transportation [42]. In this context, the first autonomous vehicles could appear during the next years, even if only in very restricted application.

To conclude, it is safe to assume that level three technology will be available during the timeframe that is relevant for this thesis. Also, it is possible, however uncertain, that level four or five technology will be available towards 2035. Maybe not in private cars, but possibly in public transportation, ride sharing or robo-taxis.

### 2.4.4 Emission reduction

As described in section 2.3 , environmental protection is a topic that leads to new requirements for mobility products. In regard to the product range of interest for this thesis, it mainly concerns automotive products, with muscle powered vehicles already being largely emission free. Because of pressure from politics, car manufacturers develop new technologies to reduce, and in the best case eliminate exhaust emission. This concerns the emission of pollutants, like nitrogen oxides or particulate matter, as well as the emission of greenhouse gases, mainly carbon dioxide. Several concepts exist to meet the increasing requirements from legislative regulations.

#### Electrification

The first concept is the electrification of the powertrain, along with the use of batteries, using electric energy instead of fossil fuels to power the vehicle. In theory, this allows for completely environmental friendly mobility, as long as the electric energy used in the car stems from renewable energy sources. However, in reality this is not necessarily the case. There are also other negative influences on the environment, which originate mainly from the batteries and the extraction of the raw materials needed for their production. Nonetheless, electric mobility is a proven way to eliminate local emission. So even though it might not be able to avoid greenhouse gases entirely, the absence of pollutant emission is very interesting, especially against the background of recent discussions about driving bans in cities [43].

Another disadvantage of battery electric vehicles (BEV), apart from the resource demand for the batteries, is the need for a charging infrastructure. The charging process takes significantly longer than filling up the tank of a regular car. While the vehicles can be conveniently charged at home, this becomes a problem when recharging on the road. Special speed charging stations are necessary, which are very expensive. Investments in this infrastructure are a drawback of this concept.

Concerning electrification, there are currently multiple options available for the customer. First are hybrid vehicles, which represent an intermediate step towards complete electrification, by combining combustion engines and electric motors. They are well established by now and available in most vehicle classes. Plug-in hybrid vehicles incorporate a small battery that can be charged directly, and therefore allows to drive a limited range purely electric. This makes them usually more expensive than regular hybrid vehicles, but they are still available from the compact class upwards [44]. The second main option available today are BEVs, which rely solely on the energy stored in a battery. Currently more than a dozen models are available, with a lot more entering the market in the next couple of years. These vehicles have a range between 100 km and more than 300 km and are a lot more expensive than comparable vehicles with combustion engines [45].

For the other products of interest for this thesis, electrification and using batteries plays an important role as well. However in regard to muscle-powered vehicles, like bikes, this is not done for environmental reasons, but for customer convenience. If anything, it would make the product environmentally more harmful. Concerning concepts involving personal aviation, the trend is to power them through batteries instead of fossil fuels.

Apart from ecological benefits, BEVs, combined with advancements in autonomous driving technology, open up new possibilities in the design of cars, especially the interior. Because the powertrain unit is much smaller, there is more space for passengers and luggage. Also, the batteries have to be accommodated, usually below the passengers, which leads to the vehicles tending to be taller. However, exploring these possibilities requires the vehicle to be designed on a platform designated for electric mobility. Currently, most electric vehicles are still based on platforms that were originally designed for cars with combustion engines. This will change in the future, with many manufacturers developing new platforms for electric mobility. When developing these, new aspects and requirements of mobility, like autonomous driving, can be taken into account, leading to a shift in vehicle design [46] [47].

#### Fuel cell technology

The second concept to reduce emissions is fuel cell technology. Like electric vehicles, cars using this technology are powered by electric energy. Unlike in a BEV, the energy is produced on-board by fuel cells, in which hydrogen reacts with oxygen to produce water. This reaction sets free energy that is then used to power the vehicle. If the hydrogen is produced using renewable energy sources, the net emission of greenhouse gases would be zero. In reality, fossil energy sources are often used to synthesize hydrogen. Nonetheless, this technology can still reduce greenhouse gas emissions. A major drawback is the lack of infrastructure to supply customers with hydrogen and the large investments that would be necessary to establish such an infrastructure [48].

#### Synthetic fuels

The third approach to reduce net emissions is the use of synthetic fuels. Exactly like fossil fuels, synthetic fuels emit carbon dioxide when burnt in a combustion engine. However, there are two major differences that stem from the fact that they are synthetically produced. First, they can be designed in a way that they burn significantly cleaner than fossil fuels with almost no pollutants being emitted. Second, they allow a closed carbon cycle. This means that cars would still emit carbon dioxide into the air, but the same amount of carbon dioxide could be retracted from the environment to produce the fuel. Therefore, the theoretical net pollution would be zero, as long as renewable energy sources are used for fuel production. A downside of this concept is the high production cost of synthetic fuel [49].

# 3 Development process

In this chapter the development process that leads to three different concepts for features in mobility products is presented. First, the methodical approach used in this thesis is described in section 3.1 . Following are the different stages of development, namely defining the stakeholders, determining requirements, a functional analysis and generating principal solutions. Finally, the three concepts emerging from this process are presented in detail. The chapter closes with a critical reflection of the obtained results and the overall process.

All of the developed features need to address challenges of mobility between 2025 and 2035 in the context of sharing economies, as is demanded in the task description. Chapter 2 shows that these challenges cover a wide range of topics and can be very complex. Regarding this, the results of the research phase could not point out a particular topic to focus on. But since this thesis is limited in its resources and time, and to avoid aimlessly looking for ideas, a goal of the development process is to work out a suitable topic for the product features. To achieve this, each step in the development process should narrow down the scope, leading to a clearly defined focus by the time the concept ideas are generated.

## 3.1 Methodical approach

The task description provides a first idea for the methodical approach in this thesis. It divides the whole project into four phases. Those are the research phase, the definition phase, the concept phase and the specification phase.

Several fundamental models for product development exist. Two basic ones are the VDI guideline 2221 and the V-model as described in VDI guideline 2206. Both could be applied to this thesis, as they describe the product development process in general. Therefore they can be used for any project of this kind. The downside to this generalistic approach is that they do not provide detailed information on the individual stages of the development process, but rather focus on the bigger picture. Since this thesis' scope is the generation of different concepts, but not with the whole development from start to a finished product, both models are not ideally suited.

An approach that fits well with the outline given in the task description can be found in the VDI guideline 2221 sheet 2, where a procedure model for a student project is presented. It also consists of several phases, four of which can be directly linked to the phases given in the task description. Those are called research phase, profile phase, idea phase and concept phase. Additionally, the model has a fifth phase for prototype testing that is not relevant for this project.

Apart from structuring the project into phases, the model also gives a list of specific work steps for the development process, alongside with a proposition in which phase each step should fall.
Based on that approach, the necessary steps for this thesis are identified. Figure 4 shows those work steps in relation to the corresponding phases of the project.

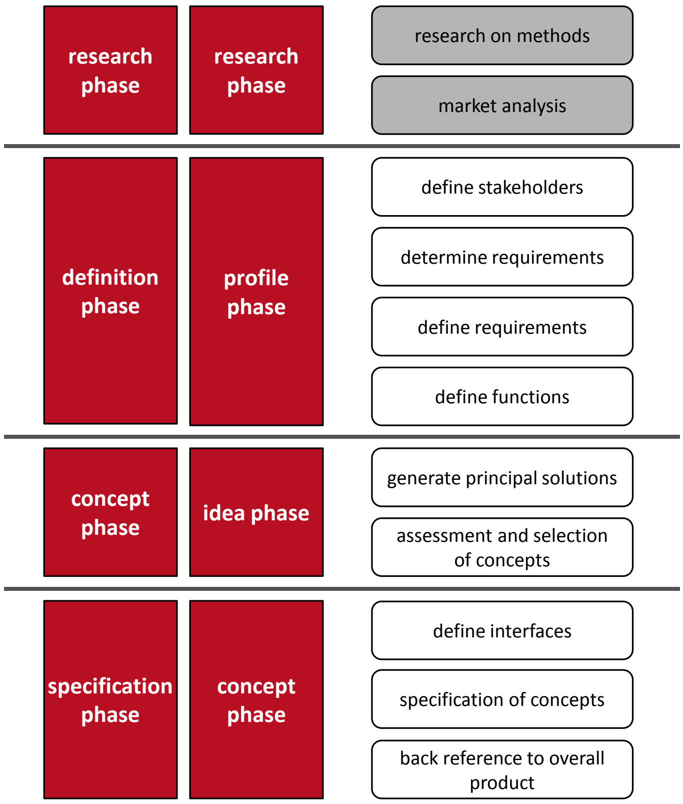



Figure 4: project phases with corresponding work steps of the development process

On the left side are the project phases as given in the task description. Next to them are the project phases as named in the model from VDI guideline 2221 sheet 2. On the right side are the work steps for the development process. The first two are marked, since they are necessary for the project, but not part of the actual development process. The result of these two steps is chapter 2.

## 3.2 Stakeholders

The first step in the development process is to identify potential stakeholders for mobility products and services in general. In economics, a stakeholder is defined as a person, a group of persons, or an institution that is affected by the activities of a particular company. Therefore, they usually have specific interests regarding these activities [50].

Since this thesis is concerned with mobility products, the acting companies are the manufacturers, who create the products that affect the other parties.

Unlike the classic stakeholder-approach suggests, not all of the company's activities are taken into account, e.g. sales or marketing are not relevant for this thesis. Instead, the only activity considered is the development process. And even here, only the result of that activity, namely the finished product with its specific properties, is relevant.

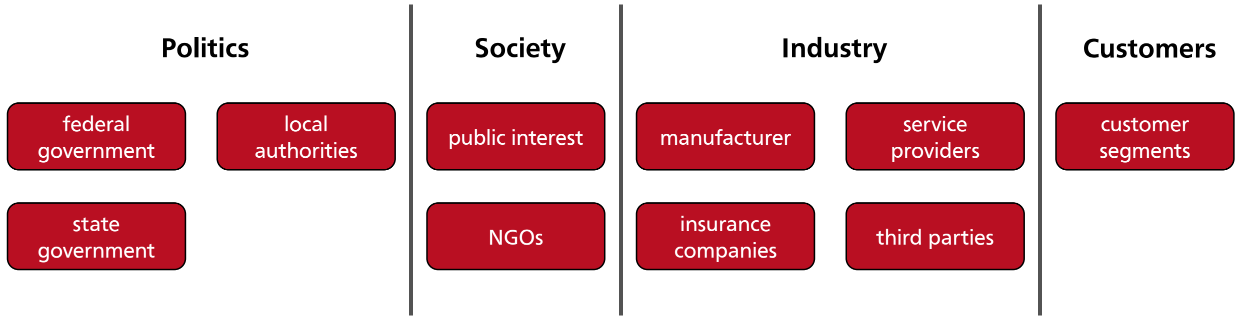



Figure 5: stakeholders for mobility products

Figure 5 gives an overview of stakeholders for mobility products as developed in this thesis. They can be grouped into four categories: politics, society, industry and customers. The category *politics* contains the different levels of government, each with their own interests and, unique for this category, the authority to issue legal restrictions. The federal government is in charge of policy on topics like climate change or economy, the state government is responsible for things like infrastructure, and local authorities can decide on issues like parking space.

*Society* can be further divided into two different groups; first of which is the overall public interest that includes demands like affordable and safe mobility. Second are different non-governmental organizations (NGOs) like the ADAC or the BUND.

The third category called *industry* contains different types of companies that have dealings in the mobility business. The main faction here are the manufacturers that develop and produce the products. Service providers are organizations like the Deutsche Bahn, Flixbus or taxi companies, which provide mobility services, but do not produce the products used for these services. For this group, insurance companies can be important partners. They play a big role in business models like carsharing, where insurance costs are up to four times higher than for private owned cars [51, p. 8]. The faction third parties covers all other companies that are involved in mobility services. A classic example are the oil industry and gas stations, and with the increase in electric cars this faction could also include electricity providers.

The last category are the *customers*, who dictate which products succeed in the market. They can be divided into different customer segments, for example grouped by age or by income.

Out of all four categories, the customers provide the most specific product requirements. The other three demand certain product properties like low costs, low emissions or safety standards, but these properties are only concerned with the overall product. How they are achieved is neither important nor specified. Low costs for example cannot be connected to a specific feature in the finished product. While a cheap product can be ensured by the development process, there are many other factors that come into play. Production costs, employee wages or contracts with suppliers can all influence the price of the final product. In contrast, a customer requirement like comfortable temperature can be directly linked to a specific feature in the finished product and is only affected by the development process.

Since this thesis has limited time and resources, and customers deliver the most relevant requirements, they are the only stakeholder group to be considered.

## 3.3 Requirements

After identifying the customers as the stakeholder group that will be primarily addressed in this thesis, the next step is to determine the customers' wants and needs. These consist of any expectations, demands or special needs that a customer might have regarding mobility products. Based on this, the requirements for such products are then defined.

### 3.3.1 Determining requirements

Two steps are taken to determine customer wants and needs. First, existing mobility products are analyzed. Second, a small survey is conducted to validate and quantify customer wants and needs.

#### Analyzing existing products

The basic functions and features of existing mobility products give a first impression of what a customer expects. To identify those functions, different products are analyzed. It is important that this happens in a methodical way, to ensure that none are missed. A simple but effective way is to go through the usage process for each mobility product. This points out any basic functions and features that a customer uses, as well as special aspects he might be looking for. Furthermore, any features that are not needed during the normal usage process should be taken into account. Based on the overall result, different features can be grouped together and customer wants and needs can be derived from that.

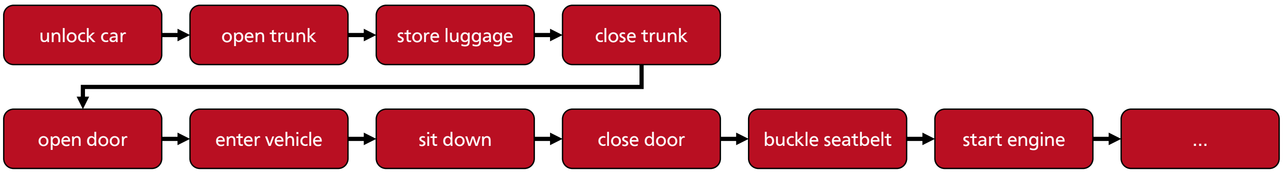



Figure 6: usage process of a car

Figure 6 shows the mentioned approach applied to a car. Examining the usage process identifies the use of features like seatbelts. Additional features not mentioned in the normal usage process could be airbags or hazard lights. All these go together and the corresponding customer requirement can be summarized as *safety*. Other functions require more abstract thinking, i.e. the function “sitting down”. Here, thinking of the car seat leads to the identification of *comfort* as a customer requirement.

After this approach is used to analyze the major mobility products, namely cars, bikes, buses and trains, an extensive list of customer requirements is generated. It can be found in appendix A1. Of course, this list is not complete, because the chosen approach offers little options to objectively check the results. This would require another person, or even better a team of people, to independently go through the process and then compare their results. But for the purpose of this thesis, the acquired list is sufficient, especially since another step follows in form of a customer survey.

### Customer survey

Conducting the survey serves two purposes. First, it helps to validate the results generated by analyzing existing products. Second, it allows for customer wants and needs to be quantified and connected to a particular group of customers.

In terms of validating the results from the previous step, the survey provides an objective check that is otherwise missing in the chosen approach. A survey, as it is conducted for this thesis, can of course not hold up to regular scientific standards, in that it cannot question a significant amount of people. But as far as checking the previous results, it would only need to consist of as many participants as a group-project would. Therefore, the absolute minimum number of participants is five people.

For its second purpose of connecting customer wants and needs to particular groups of customers, the survey needs to contain the opinion of people with different living situations. Possible criteria for grouping customers are age and gender. In order to associate certain requirements with a particular customer segment, the chosen segments should differ from each other as much as possible. Therefore, age is a good grouping-criteria, because usually other factors like job or family situation correlate with age. To further emphasize this, the selected age ranges are narrow and far apart from each other. This ensures that the people in the chosen segments have rather similar living situations, while they differ greatly from the other age groups. Table 1 gives an overview of the segmentation for this survey.

Table 1: segmentation of the customer survey

| customer segment | 18-25 years | 45-55 years | 75-90 years |
|---|---|---|---|
| number of participants | 5 | 5 | 4 |

The first segment of 18-25 years represents young people, especially students. Those obviously do not have a career yet and usually do not have children. The second segment of 45-55 years is chosen to represent adults that are likely to have a family and a regular job. The last segment of 75-90 years represents the age range in which people are not working anymore. Yet, the main point is not to represent pensioners, but more importantly, people with decreasing physical abilities.

In the survey, participants are asked to rate customer requirements based on how important they are to them. Therefore, twelve possible requirements are chosen, most of them taken from the results of the product analysis. The goal is to select basic requirements that are applicable to different mobility products and potentially relevant to all age groups. All requirements are rated on a scale of one to five, one being the lowest. This allows for a quantification of the customer requirements. The original questionnaire, as well as the data obtained by the survey can be found in appendix A2 and A3. Table 2 shows a summary of the average scores evaluated by age and by gender, as well as the overall average scores.

Table 2: survey results by age and gender

| Category | 18-25 years | 45-55 years | 75-90 years | male | female | **overall** |
|---|---|---|---|---|---|---|
| Design | 3,2 | 3,2 | 2,8 | 2,9 | 3,3 | **3,1** |
| Comfort | 4 | 4,2 | 3,5 | 3,4 | 4,4 | **3,9** |
| Spaciousness | 2,7 | 4,2 | 1,5 | 2,4 | 3,4 | **2,9** |
| Luggage capacity | 3,2 | 4,2 | 2,5 | 3,3 | 3,4 | **3,4** |
| Handling | 3,4 | 4,8 | 5,0 | 4,1 | 4,6 | **4,4** |
| Connectivity | 4,2 | 3,4 | 1,5 | 3,6 | 2,7 | **3,1** |
| Individuality | 2,4 | 3,2 | 3,3 | 2,3 | 3,6 | **2,9** |
| Safety | 3,8 | 4,8 | 5,0 | 4,3 | 4,7 | **4,5** |
| Privacy | 3,2 | 4,4 | 3,8 | 4,0 | 3,6 | **3,8** |
| Environmental Protection | 3,6 | 4,2 | 4,5 | 4,1 | 4,0 | **4,1** |
| Progressive Nature | 3,6 | 3,8 | 2,5 | 3,3 | 3,4 | **3,4** |
| Data Security | 3,4 | 4,8 | 3,5 | 4,1 | 3,7 | **3,9** |

In this stage of the development process, the exact scores for each requirement are not relevant. However, it is important that no category was found to be irrelevant by the participants, with all of them having an overall average score very close to or above three. This shows that all suggested requirements are actual customer wants and needs, even though their characteristic varies amongst customer segments.

### 3.3.2 Defining requirements

With the list of customer requirements generated in section 3.3.1 and the data obtained through the survey, it is possible to define specific customer profiles. Each of these is assigned multiple characteristic customer requirements. Therefore, the profiles are corresponding to the customer segments chosen for the survey, in order to incorporate the obtained data. For each age segment, one profile is created. This is appropriate, since the age groups were intentionally chosen narrow in order to be more homogenous.

To create the profiles, the Persona-Method is used. This method is made for product development in general, and aims to provide a better understanding of the customer. It enables the developer to take up the perspective of the targeted customer group, by engaging him logically as well as creatively. This two-sided approach is an advantage this method has over solely looking at numbers and statistics, which only engage the developer logically [52].

Using this method, very specific customer profiles, called Personas, are created, which represent a certain customer segment. These Personas characterize an individual, fictional person, who is given a name, age, appearance, short biography and other attributes, to create a conclusive picture. Since they are fictional, their characteristics can be defined to the best of judgement. However, it is also possible to base them on real customer data [52].

In this thesis, the Personas are based on the data collected in the survey. This allows to quantify the characteristic customer requirements of the Personas, so they can be better compared to each other. Also, with quantitative data, the actual importance of a particular customer requirement is easier to determine. Since one Persona is associated with each age group of the survey, the average scores of each segment are directly used to define their customer requirements. Those can be found on the right side of the Personas description.
Another benefit of this quantitative approach is that it prevents misjudgment when creating the Personas, and makes the process more objective. It can be hard to accurately guess a customer profile for someone very different from oneself, so relying on actual data increases the significance of the results.
The other attributes of the Personas, apart from the customer requirements, still have to be defined to the best of judgement. However, the answers from the survey help to estimate them realistically. For instance, the age group of 45-55 years has exceptionally high scores in all categories of the survey in comparison to the two other groups. Therefore, they are defined to have very high expectations. The additional attributes include personal details, abilities, and personality, all found on the left side of the Personas description. In the middle there are a short biography, goals for the personal mobility, concerns or problems, and special needs.

All three Personas created for this thesis can be found in appendix A4.

### 3.4 Functional analysis

Subsequent to determining the customer requirements and defining expectations for the final features developed in this thesis, the next step is to identify functions or systems of a mobility product that can be improved. In order to do so, a functional analysis is conducted, following the approach presented in the VDI guideline 2803 [53]. According to it, the first step is to analyze the functions of an existing product. Therefore at least one existing product has to be selected.

This guideline provides a methodical approach to conduct a functional analysis for technical products that results in a structure of abstract functions. A function is defined as a single effect of a system and always described by a noun and an infinitive verb. By determining those, especially by further abstracting them, the area in which new solutions are searched is expanded. Furthermore, structuring the functions is a learning process that leads to a better understanding of the product and its potential for improvement. This is very important, since the approach focuses on this learning process, and is intended to provide the developer with a tool to facilitate the generation of innovative solutions. The documented results of the various steps only play a secondary role [53].

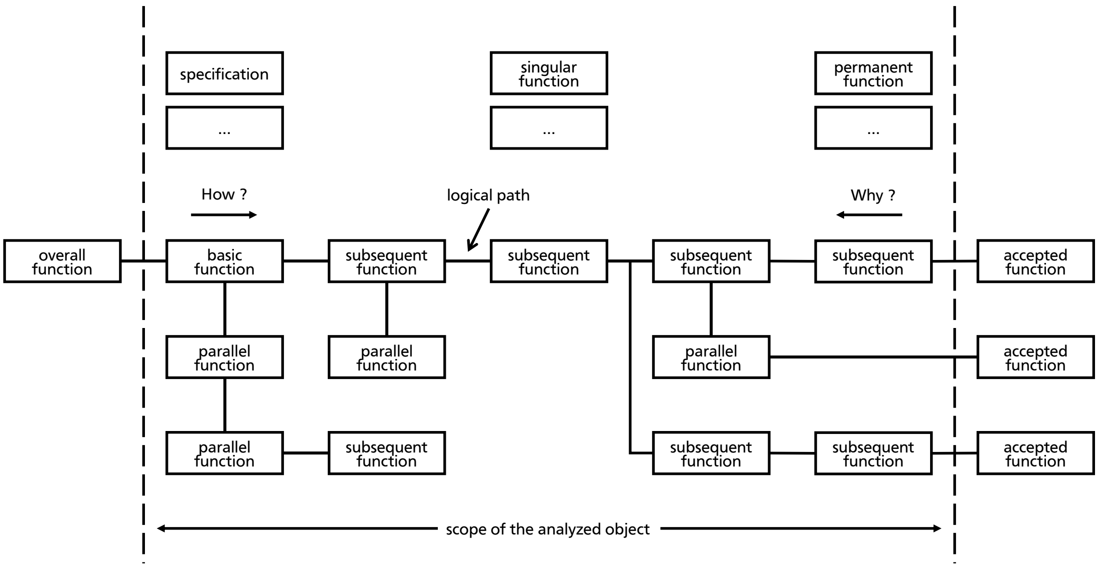



Figure 7: basic structure of a FAST-diagram (based on [53, p. 7])

A method presented in this guideline is the FAST-diagram, with its basic structure depicted in Figure 7. It logically structures the various functions of a product and can be used to analyze the current-state, as well as the target-state. In the FAST-diagram, the functions are aligned along a logical path. Following it from left to right, the question "How?" is answered, while from right to left, the question "Why?" is answered. On each level of the path, parallel functions are possible. Apart from the ones aligned on the logical path, there are three more categories of functions. First are specifications that a product must fulfil, such as safety standards. Second are singular functions that only occur once in the products lifecycle, like providing crash safety. Last are permanent functions that are fulfilled the entire time, e.g. protecting from corrosion. On both sides, the FAST-diagram is limited by the scope of the analyzed product. The function left of that scope is the overall function, while all functions to the right are accepted functions, meaning they can be taken for granted [53].

### Selecting a product

Concerning requirements, the scope was narrowed down to customers and then to three specific customer segments. In terms of the overall product that the features are a part of, there is no focus yet. Of course, every feature could be part of a different product. But firstly, this would extend the development process greatly, with the functional analysis having to be conducted for each of these products. Secondly, it provides the danger of aimlessly going through every possible product. Just like with the requirements, a clear focus seems more efficient and promising.

First of all, the chosen product must provide individual mobility, since the thesis is aimed to develop mobility solutions between a private owned car and public transportation. Therefore, the developed features should address some form of shared mobility, which still allows individual use but does not requiring ownership. As described in chapter 2.2.2 , the three main options for that are bike-sharing, ride-sharing and carsharing. Bikes are not ideally suited for all three of the selected customer segments, since old people might have issues with balance, stamina and more severe consequences in case of falling [54]. The two other concepts both include some form of a car. Although ranging from compact class to van, these vehicles have properties that are similar enough in terms of functionality. Therefore, the product that is most suitable to place the focus on is a car. Also important is the fact that a car is an already existing product, with rather predictable change at least until 2025. This is essential for the chosen approach, since an analysis of the current-state of a product is required. That is why other concepts for individual mobility, like flying drones, are not considered, because only concept ideas or prototypes exist so far. It is unclear if they will be widely available by 2025, and what exact properties they would have.

### Current-state analysis

After choosing a product to focus on, the functional analysis begins by examining the current-state of the product with a FAST-diagram. The analyzed part of the car is restricted to any function the passenger compartment in a wider sense is involved in. This makes sense, because the main functions concerning customer experience are located here. Other aspects of the car, like chassis and powertrain, are also important, but not experienced as directly by the customer as anything in the passenger compartment. Also, these aspects are a lot more complex, and developing innovative features for them seems unlikely within the scope of this thesis.

Showing the complete FAST-diagram here is not possible due to its size, but it can be found in the appendix A5. Therefore, Figure 8 only shows the logical path for one of the basic functions to give an impression of the obtained results. The basic function is bold, and the link to the rest of the diagram is grey.

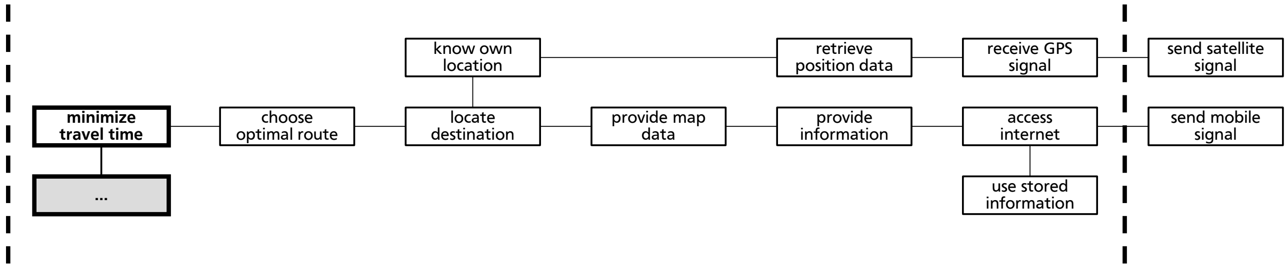



Figure 8: section of the created FAST-diagram showing the logical path for one basic function

It is important to note that the resulting FAST-diagram does not represent a definitive functional structure of a car. This is intended by the method, since the goal is not to clearly define all interrelations of the functions, but instead to provide a tool for the developer to find structure and spark new ideas. Therefore, the results are highly individual and other people would generate a different outcome [53].

After the current-state analysis, the VDI guideline 2803 continues with creating a FAST-diagram for the target-state. However, this is not done for this thesis, because the goal is not to develop a complete new version of a car, but rather single features that can be added. Also, creating a FAST-diagram for the target state requires a clear vision of where the product should be headed. In this thesis, such a clear goal is not defined. Instead, as described in the beginning of this section, the functional analysis is used to identify potential for improvement. Identifying such potential and then generating concept ideas for it is the next step in the development process.

## 3.5 Concept ideas

Following the functional analysis, the next step in the development process is to use the results produced so far to generate concept ideas for product features. This happens methodically and is described in the first section of this chapter. The second section covers the selection process to identify the best concept ideas, which are then chosen to be developed into product features.

### 3.5.1 Developing concept ideas

The first step in developing the concepts is to design a systematic approach that provides an efficient and transparent way to generate ideas. Based on the chosen approach, focusing on a single customer segment is necessary. Finally, the concept ideas are generated and presented at the end of this section.

## Systematic approach

During the creation of the FAST-diagram the first ideas and associations already came to mind, as is intended by the method. To develop more ideas, the systematic approach depicted in Figure 9 is implemented.

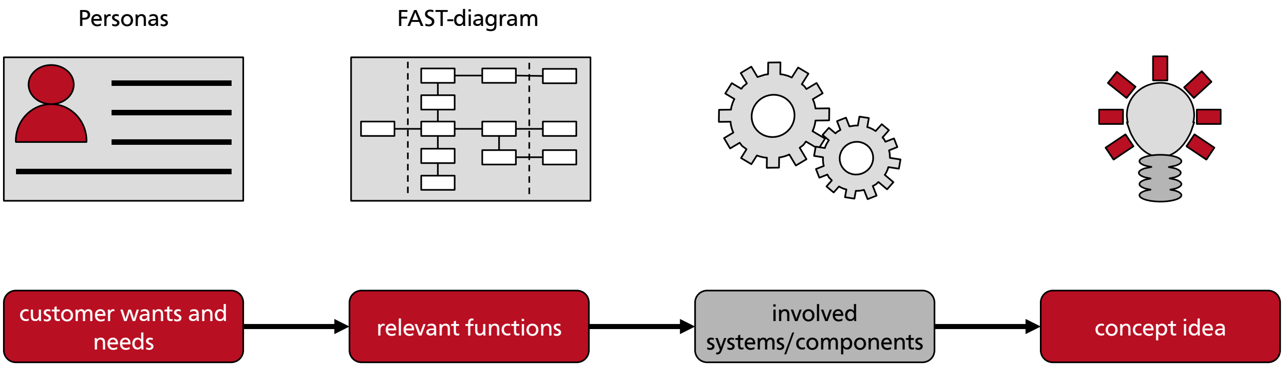



Figure 9: approach to generate concept ideas

Now, the Personas that were created to represent certain customer groups are used to view the FAST-diagram from their perspective. Based on the specific customer wants and needs, the FAST-diagram is analyzed, and any relevant functions are noted. In the best case, this already generates ideas on how to improve those functions or the customer experience connected to them.
If this is not the case, an optional intermediate step is made by determining systems or components of a car that are associated with the particular function. Through considering and analyzing those, new ideas to improve the original customer requirement can be generated.

Since this process depends highly on creativity, a concept idea cannot be guaranteed for every customer requirement. Therefore, the process, as depicted in Figure 9, can in some cases not be followed through completely, but will rather end at the involved systems or components. So even though this approach helps to stimulate creativity, new ideas cannot be forced. A possible way to further increase the amount of ideas generated would be to work in a team, but this is not intended within this thesis.

## Selecting a customer segment

At this point in the process, a further focusing makes sense. Of course, the approach introduced above could be applied for all the Personas created in section 3.3.2 . However, this would take too much time, which is not possible within this thesis. Also, going through the process for all customer segments could result in several ideas that are very similar to each other, which would be ineffective. To avoid this and stay within the possibilities of this thesis, the scope is restricted to only one of the prepared customer segments.

The customer segment that is best suited is the age group of 75-90 years, because current products do not focus on this group a lot. Choosing this segment therefore provides the highest potential for innovative solutions.
Concerning carsharing, none of the available services are specialized or adapted for elderly people. Instead, carsharing is usually aimed at younger people. Hence it is no surprise that old people are by far the smallest customer segment of carsharing in Germany [3].
As far as the actual cars themselves go, old people profit from some aspects like parking aid and driver assistance systems in general. Vehicles with a high boarding height are beneficial as well. However, most aspects of a car, like the controls, do not pay special attention to old people. Also, there are no vehicles specifically designed for old people. This would probably not be economically viable, and cannot be the goal of this thesis. Nonetheless, developing features to enhance the user experience of old people, especially in carsharing vehicles, is absolutely possible.
Finally, regarding mobility in general, there are not many concepts aimed at senior-friendly mobility. Public transportation is made barrier-free, but other than that the means of transportations mostly follow a one-size-fits-all approach. In public transportation, this might be necessary. But carsharing has great potential to individualize the customer's experience, and could be a good option to provide senior-friendly mobility.

To conclude, choosing old people as the customer segment to focus on is the most promising, because as explained above, dedicated senior-friendly mobility does not yet exist. Against the background of demographic change, as described in 2.3 , this topic will definitely be relevant in the targeted timeframe of 2025-2035. Other aspects of society have already been adapted, senior-friendly living being a great example. This can be a guidance and provide some ideas and inspiration on how mobility can be designed to better fulfill the needs of old people.

#### Generating ideas

After the customer segment of 75-90 years was chosen to focus on, the FAST-diagram is analyzed according to the approach presented in Figure 9. In order to do so, the first step is to make a list of specific customer wants and needs, or special problems a person of that age could have when using a car. This is accomplished by using the Persona created for that age group in section 3.3.2 .

At first glance, it might seem a bit redundant to go from determining customer requirements in form of a list, to creating a customer profile in form of a Persona, back to defining a list of customer wants and needs. But it is important to note that the list created in section 3.3.1 consists of general customer requirements, which were relatively easy to identify. However, that is not what is needed at this point. Instead, the unique requirements of the chosen age group are necessary, and those are not as easy to identify for someone in his youth. Therefore, going through the intermediate step of creating Personas is necessary, because they are a tool to put oneself in the position of a certain customer group. The latter is essential to successfully identify their specific customer wants and needs.

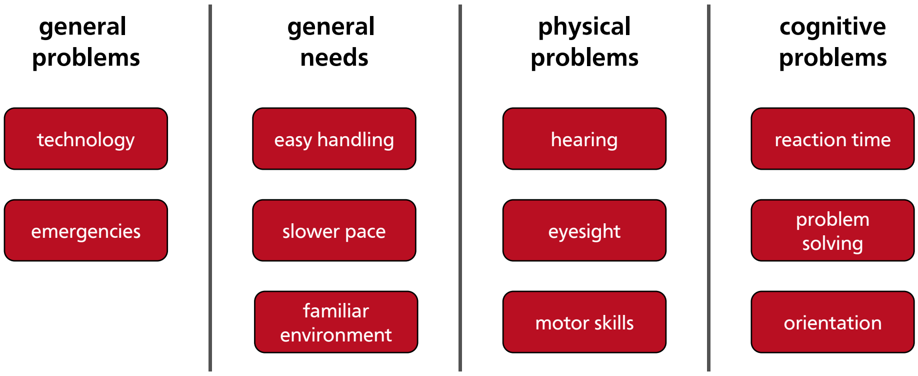



Figure 10: customer requirements of old people

Following this procedure, unique customer requirements of old people are identified. They can be grouped into four categories, as shown in Figure 10. General problems include difficulties with handling technology in general, but especially digital technology, and a susceptibility to emergencies like falling, sudden dizziness and more severe incidents like a stroke. General needs are easy handling of machines and devices, an overall slower pace to operate, and a familiar environment. Physical problems contain weakened hearing and eyesight, as well as decreasing motor skills, which are showing in less stamina, agility and strength. Cognitive problems are a greater reaction time, worse problem solving skills, and worse orientation. In severe instances, a complete loss of orientation can be the result.

Now, the FAST-diagram is analyzed based on these customer requirements. The whole process relies heavily on creativity and leads to several dead ends, as described above. Therefore, it shall not be documented in this thesis, since listing every function of the FAST-diagram that is analyzed poses no benefit for the reader. Instead, the results of the process are presented. Table 3 gives an overview of the generated concept ideas, along with the customer requirements they address. Also included is a short description of their functions, since elaborately describing every concept is not intended at this point in the development process, nor possible within the scope of this thesis.

Table 3: list of concept ideas with addressed customer requirements and short description of the functions

<table>
<tr><td>emergency button</td><td>emergencies, problem solving, orientation</td></tr>
<tr><td colspan="2">A button that can be pressed in an emergency and automatically calls a designated number, e.g. a relative or a care service. Not intended for severe medical emergencies, but for problems with the carsharing vehicle or with the app, problems with orientation, etc.</td></tr>
<tr><td>teleoperated driving</td><td>emergencies, orientation</td></tr>
<tr><td colspan="2">Allowing an operator to take control of the vehicle in case the driver is unable to continue driving. Not intended for severe medical emergencies, but for things like loss of orientation, dizziness attack, exhaustion, etc.</td></tr>
<tr><td>OLED-elements</td><td>eyesight</td></tr>
<tr><td colspan="2">Equipping the interior of the car with OLED-elements to provide better lighting. They can also be used to improve handling and safety, i.e. pointing out controls, giving a signal or visual feedback.</td></tr>
<tr><td>glare protection</td><td>eyesight</td></tr>
<tr><td colspan="2">Oftentimes, old people have very light-sensitive eyes. Features to protect them could be improving glare protection over the driver or adjustments to the windshield.</td></tr>
<tr><td>night vision</td><td>eyesight, reaction time</td></tr>
<tr><td colspan="2">Many old people have problems driving at night. A night vision system can aid them. This could use infrared or night vision cameras, along with a display or a HUD.</td></tr>
<tr><td>hearing aid</td><td>hearing</td></tr>
<tr><td colspan="2">To counter bad hearing, the acoustic feedback in the car could be increased in volume or replaced by other signals. Also possible is the incorporation of a person’s hearing aid.</td></tr>
<tr><td>rotating seats</td><td>motor skills</td></tr>
<tr><td colspan="2">Old people often have difficulties accessing a car. Rotatable seats ease access to a vehicle, by allowing a person to sit down backwards, while staying on both feet.</td></tr>
<tr><td>height adjustability</td><td>motor skills</td></tr>
<tr><td colspan="2">By adjusting the height of the vehicle, the boarding height can be adjusted to ease access. This could happen through an active chassis or adjustable seats.</td></tr>
<tr><td>specialized doors</td><td>motor skills</td></tr>
<tr><td colspan="2">Specialized doors can ease access to a vehicle by providing a large opening. Options are wing doors or sliding doors.</td></tr>
<tr><td>handholds</td><td>motor skills</td></tr>
<tr><td colspan="2">Installing extra handholds can provide extra stability when entering a vehicle.</td></tr>
<tr><td>loading aid</td><td>easy handling, motor skills</td></tr>
<tr><td colspan="2">Due to decreased physical abilities, loading items into the trunk can be difficult. Features like a plain and retractable storage area can help.</td></tr>
<tr><td>profile</td><td>technology, easy handling, familiar environment, hearing, eyesight</td></tr>
<tr><td colspan="2">By using a digital profile to save user settings for a carsharing car, seats, mirrors, etc. can be adjusted in the vehicle. Also, the user interface of the car can be configured senior-friendly, for example with larger text and symbols.</td></tr>
</table>

### 3.5.2 Selection

Now that several ideas for product features have been generated, the next step is to select the two or three best of them to focus on. The chosen ideas will then be further specified. To make an objective decision, it is important to have a tool to rate the different ideas. The Pugh-Matrix is such a tool.

#### Pugh-Matrix

A Pugh-Matrix compares different solutions or concepts based on weighted criteria. The concepts are rated in each criterion, either individually or in comparison to others. That grade is then multiplied with the weight of the criterion, and the sum over all criteria is used to compare the concepts. Apart from this basic idea, the exact implementation differs and many amendments exist [55]. Table 4 shows the version used for this thesis, with exemplary weights and grades. The grades are set to range from -2 to 2 and the weights from 1 to 3. The score equals the assigned grade multiplied with the weight of the corresponding criterion.

Table 4: scheme of the implemented Pugh-Matrix

| | | **concept 1** | | **concept 2** | |
|---|---|---|---|---|---|
| | weight | grade | score | grade | score |
| **criterion 1** | 3 | 2 | 6 | 1 | 3 |
| **criterion 2** | 1 | -1 | -1 | 0 | 0 |
| **sum** | | 1 | **5** | 1 | **3** |

#### Determine criteria

To use the Pugh-Matrix, different criteria to evaluate the concepts must be defined. Those criteria must be relevant for both the goal of the thesis and the generated ideas. To find suitable criteria, brainstorming is used. Since brainstorming is a method that lacks an objective check of the results, the first draft is discussed with the supervisor. This second opinion allows to further refine the list, leading to the final version shown in Table 5.

In the left column the selected criteria are stated. In the right column the criteria are described through questions that they pose to the competing ideas. Those are the same questions that are used to evaluate the ideas in the Pugh-Matrix later in the process.

Table 5: criteria for Pugh-Matrix with description

| criterion | description |
|---|---|
| degree of innovation | Does it already exist as a concept? Are there already prototypes or usable products? |
| cost | What are the expected costs? |
| feasibility | How difficult is the realization? How much effort will it take? |
| integration in overall product | Are there positive interactions with other systems? Are there conflicts? Do other systems have to be changed? |
| benefit | How many wants and needs of the chosen customer segment are addressed? How important are the ones that are addressed? |
| multiple customer segments | Do other user groups profit form the feature? |
| safety | Is the feature a possible safety issue? |

### Determine weights

The next step in order to use the Pugh-Matrix is to determine the weight for each criterion. This happens through another matrix that is made up of the criteria on both sides, allowing for all of them to be compared to each other. If a criterion is more important than its counterpart, it receives an X in its own row. At the end of the row, the number of X's is added up. The sum indicates the importance of the criterion compared to the others, and is used to assign a weight to it in the Pugh-Matrix. Table 6 shows the matrix to compare the different criteria. The diagonal is left empty, since a comparison of a criteria with itself is pointless. It should be noted that the results only apply to this thesis and are by no means generally valid. Other context would result in a different outcome.

Table 6: matrix to compare the different criteria

| | degree of innovation | cost | feasibility | integration in overall product | benefit | multiple customer segments | **sum** |
|---|---|---|---|---|---|---|---|
| degree of innovation | | X | X | | X | X | **4** |
| cost | | | X | | | | **1** |
| feasibility | | | | | | | **0** |
| integration in overall product | X | X | X | | X | | **4** |
| benefit | | X | X | | | | **2** |
| multiple customer segments | | X | X | X | X | | **4** |

Three criteria, namely the degree of innovation, the integration in the overall product, and addressing multiple customer segments, are most important. The size of the benefit comes second, followed by the cost. Least important is feasibility.
The criteria safety was not compared to the others, because it should technically be more important than all of them. But only because a concept has potential issues concerning safety, does not mean that an actual finished design could not overcome them. However, this is hard to tell in the concept phase, which this thesis is restricted to. Therefore, safety will be weighted with 1 to consider it, but not have it as a determining factor in the selection process.

Based on the outcome of Table 6, the different criteria are assigned weights that represent their importance. The assigned weights are not identical with the score in Table 6, but instead a bit lower. While they still reflect the order of the criteria, they are closer together, so that the influence of certain criteria is not exaggerated too much.
This reflects the fact that the matrix in Table 6 allows to rank the criteria amongst each other, yet they are all important to consider. So even though feasibility scored 0 in Table 6, it is still assigned the neutral weight of one. The weights for all criteria can be seen in Table 7.

Table 7: criteria with the assigned weights

| criterion | weight | criterion | weight |
|---|---|---|---|
| degree of innovation | 3 | benefit | 2 |
| cost | 1,5 | multiple customer segments | 3 |
| feasibility | 1 | safety | 1 |
| integration in overall product | 3 | | |

#### Filling in the Pugh-Matrix

With all criteria having a weight assigned to them, the Pugh-Matrix can now be filled in, which happens to the best of judgement. All ideas are evaluated concerning the different criteria on a range from -2 to 2, with 2 being a positive attribute. For example: An idea expected to have very low costs would be rated 2, while an idea that is not innovative at all is rated -2 in that category.

At this point, the process is possibly the most subjective. First, all the judgement is based on assumptions on how the different ideas would perform. Possibly, many expected problems or weaknesses of a certain idea could be eliminated during development, while other ideas might perform weaker than expected. Second, different people would probably judge the same ideas a bit differently. Both is unavoidable under the circumstances of this thesis. Nonetheless, the outcome of the

Pugh-Matrix is not random. Having several different criteria to judge the ideas helps to make the result more objective, since a misjudgment in one category is of less consequence to the overall outcome.

#### Results

The completed Pugh-Matrix can be found in appendix A6. Table 8 shows the concept ideas with their final scores in descending order. The ideas height adjustability, specialized doors and handholds were summarized as various boarding aid in the Pugh-Matrix.

Table 8: results of Pugh-Matrix in descending order

| concept idea | score | concept idea | score |
|---|---|---|---|
| profile | 19 | loading aid | 6,5 |
| teleoperated driving | 13,5 | hearing aid | 6 |
| rotating seats | 10,5 | OLED elements | 5 |
| night vision | 8 | glare protection | 2 |
| emergency button | 8 | various boarding aid | 1,5 |

As can be seen in Table 8, the three best ideas are a personal profile, teleoperated driving and rotating seats for easier access. Also, the score of the two best concepts is much higher than the others, and rotating seats still score significantly better than the following ideas. Therefore, the selection process was successful in determining three clear winners. Those three concepts are chosen to be further specified.

## 3.6 Product features

After developing principal ideas and selecting the three best concepts, they are further specified and developed into product features in this chapter. Generally, the approach according to Figure 4 is to define the interfaces to the overall product, specify the functions and properties and then put it into perspective with the overall product. However, it proved most useful to amend this approach where needed, to best suit the individual concept ideas. Therefore, the presentation of the results in this chapter does not strictly follow those three steps, but is instead adjusted to the different product features. Nonetheless, those steps are all done for every feature. It is also important to note that the focus of the specification lies on the adaptation for carsharing and old people. Completely developing all technical aspects of the features is not the goal, and not possible within the scope of this thesis. Apart from that, the basic idea for each of the presented features is not new. Therefore, the integration into carsharing and enhancing the user experience of old people is paramount, since this is something innovative.

The problems of old people addressed here are largely based on the ones identified through the use of the Persona-method in sections 3.3.2 and 3.5.1 as well as everyday experience, observation and conversations with elderly people. A complete review of scientific studies on old people is not possible within the scope of this thesis. Nonetheless, using the Persona-method should allow to accurately identify the basic problems of elderly people.

### 3.6.1 Rotatable seats

Elderly people often have difficulties accessing a vehicle. Especially sitting down and getting back up can be difficult or uncomfortable due to decreasing physical abilities. There are several factors that influence the accessibility of a vehicle.
First is the opening of the door. A large opening eases entry into the vehicle, for example in a van with a sliding door, whereas a small opening makes it harder to access, for example in a sports car. The size of the door is highly dependent on the design of the vehicle, and can therefore not be defined or changed freely. Hence it is not an option to focus on when improving accessibility, but should still be considered.
The second factor is the boarding height, which depends on the seat height, as well as on the overall vehicle height. Ideally, the boarding height is high enough so that the person has to bend their knees less than 90 degrees, because anything towards 90 degrees is increasingly difficult to control. A good comparison is doing a squat. As anyone can experience, the exercise gets more difficult the further the knees are bent. Therefore, people with decreasing physical abilities profit from a higher boarding height. When sitting down, this means that the person does not drop down, which is especially important if they have issues with balance. When standing up, it takes a lot less strength to get up. The boarding height is easier to influence than the door size. Both height adjustable seats and a height adjustable chassis can be used.
The last factor determining accessibility is the direction of the seats. This is a problem in all cars, because all seats are facing forward, while the doors open to the sides. Therefore, the seats cannot be accessed directly. However, this would be the easiest for people with restricted agility or balance, allowing them to just sit down backwards while staying on both feet. Having the seats facing forward is obviously necessary, so a way to solve this problem is to make the seats rotatable.

#### Concept development

Based on the factors determining accessibility identified above, a concept for a product feature that addresses these issues is developed. While the main idea is to rely on rotatable seats, the other factors described above are still taken into account, to present possible additions that can create a consistent overall concept. To determine such a concept, a morphological box is used, with possible solutions for each factor. The goal here is not to develop a detailed technical solution, but to identify the best options to provide an overall concept that is easing access to the vehicle for old people, and at the same time viable for the use in carsharing. Figure 11 shows the resulting morphological box. The selected principal solutions are marked by a red box.

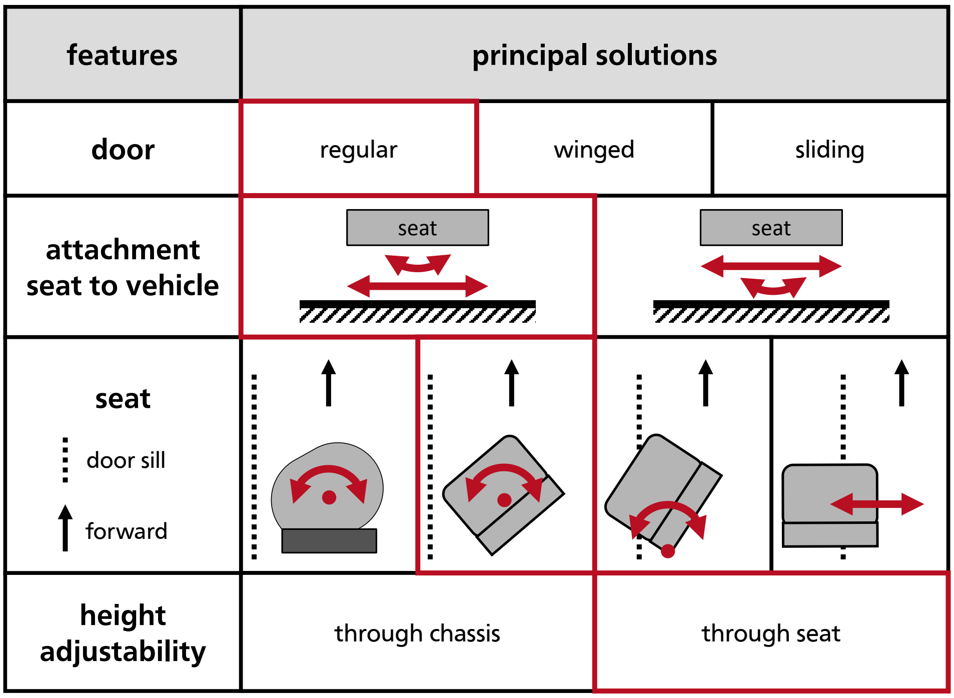



Figure 11: morphological box for principal solutions to ease access to a vehicle

For the door, the regular version is the only realistic option concerning carsharing vehicles, and can therefore by viewed as fixed. Winged doors would technically be possible, but they are more expensive and only used in upper class vehicles or sports cars, both not the type of car relevant for carsharing. Sliding doors are not an option for the driver's seat, hence of no use for carsharing either. When developing products for ridesharing, they could however be a reasonable option.

Concerning the attachment of the seat to the vehicle, longitudinal adjustability must remain possible. Having the rotational degree of freedom above the longitudinal seems to fit best into the vehicle. If it was the other way around, the seat could only be rotated freely when in position over the rotation axis. Otherwise, it would have a larger turning radius and the surrounding components could get in the way. Also, depending on the realization of the longitudinal adjustability, it could increase the turning radius even above the rotation axis, for example because of rails. While this is certainly avoidable, it is the technically more complex version, and therefore inferior.

Regarding the seats themselves, concepts three and four would provide straight access to the seat, as is demanded. But in combination with a regular door, they are not practicable, especially concept four. However, in a ridesharing vehicle, for example a van with sliding doors, they would technically be possible. Concept one has the advantage that it needs no extra package space. On the downside, it provides no back support when sitting down. That is achieved by concept two. Another advantage of this version is that in combination with highly automated or autonomous driving, it lets the customer turn around and face the passengers in the rear, allowing to better converse. Such a function would make the feature useful for all customers, not just old people.
Lastly, regulation of the boarding height is probably best achieved by height adjustable seats. Unlike an active chassis, they are standard issue in most cars, therefore creating no extra cost for the carsharing vehicle incorporating the proposed feature. If the vehicle has a low height, so the door-opening itself is not large, using the seat for height modulation is limited. In such a scenario, if the seat is brought up too high, the user would have to duck down to fit in the car. An extreme example would be a sports car. However, carsharing vehicles are usually high enough. Also, if future carsharing fleets consist of electric vehicles, this should be even less of a problem, since they are expected to be higher than current cars [46].

To conclude, the product feature is designed to make use of regular doors, by using rotatable seats as specified above. At least the driver seat, but better the passenger seat as well, has to be rotatable. In a compact vehicle that can be sufficient. In a larger vehicle, especially in connection to ridesharing or autonomous driving, it can be useful to have all seats rotatable. Height adjustability of the seats is optional, but since it is often standard issue, it can be assumed to be available anyways.

**Evaluation**

As described in this section, the developed feature can principally be incorporated into a carsharing vehicle. Since seats are a safety-relevant component of the car, it would have to be guaranteed that they meet all safety and crash requirements. Because the shape of the seats is not necessarily affected, this should not be a problem. Also all the current interfaces of a car seat, for example to the onboard power system or to the control unit, are not touched by the proposed product feature. Furthermore, the seats will still be able to fulfill their current extra functions, like heating or massage. The only thing that needs to be touched, is the package space, which the rotatable seats presumably require more of, depending on the final technical realization. In terms of the package space, the system that is in the way is the center console that would probably have to be eliminated. However, in an electric vehicle this should not be a problem.

Having worked out that the product feature is technically feasible, its usefulness in the context of carsharing must be evaluated to determine its overall viability. It can be assumed that the feature will add to the cost of a vehicle, and should therefore also add to its value to the customer. Providing senior-friendly mobility obviously does so for that age group. Also, anyone with restricted agility, for example due to injury or back pain, profits from this feature as well. Furthermore, rotatable seats make it easier for parents to fasten the seatbelt of a child. Lastly, in connection with autonomous driving, the feature allows passengers to face each other during the drive. This would be of value to all customers. Therefore, the feature definitely has potential to enhance user experience in a carsharing vehicle.

### 3.6.2 Teleoperated driving

There are several possible scenarios in which an elderly person cannot continue to drive. This can be because of personal health issues, for example causing sudden dizziness or exhaustion. Also possible is the sudden loss of orientation. While problems like dizziness attacks are obviously not exclusive to elderly people, they are a lot more common among them [54]. All of this is not necessarily a problem that has to be dealt with by car manufacturers. Nowadays, people with these issues usually just give up driving. In other countries, mandatory physical tests for old people exist, which if failed, can lead to a withdrawal of the driver's license [56]. However, both options restrict elderly people in their personal mobility.

This is especially affecting people who are already physically restricted. For them, using a car is usually the most comfortable, if not the only way to get around end run errands. Going by foot or riding a bike is not an option. Using public transportation is oftentimes stressful, more exhausting and, especially in rural areas, not very convenient. This leads to them either being greatly restricted in their personal life, or relying on others like relatives or care services. Against the background of demographic change in Germany, it is desirable to maintain the personal mobility of elderly people for as long as possible. That is not only important for their happiness and wellbeing, but independent old people also induce less stress on society.

In order to do so, the car needs some sort of safety function or assistance system to handle the situations described above, when a person cannot continue to drive. Autonomous driving is obviously a way to provide this, but until that technology is available, other options are required. A possibility is using teleoperated driving, also called piloted driving, meaning a human operator can remotely control the vehicle. This can use the technology developed on the way to autonomous driving, but does not require all of the software aspects. Therefore, it is available earlier. Having such a system on board would allow a person with potential problems to still use the car regularly, knowing that in case of an incident an operator can safely take over.

#### Fundamental functionality

Three factors are required to work together for teleoperated driving. The first is the vehicle itself. It needs to be able to receive and send information, and has to be equipped with sensors and actuators. The second factor is communication technology. It is required to exchange information between the vehicle and the operator. To transmit the signals with no restrictions to the car's movements, wireless technology is needed. The third component of teleoperated driving is the operator in his workplace, which must allow him to process the information from the vehicle's sensors and provide a way to control the actuators on the vehicle [57, pp. 31-32].
Figure 12 shows the fundamental functionality of teleoperated driving with its three main components and the exchange of information between them.

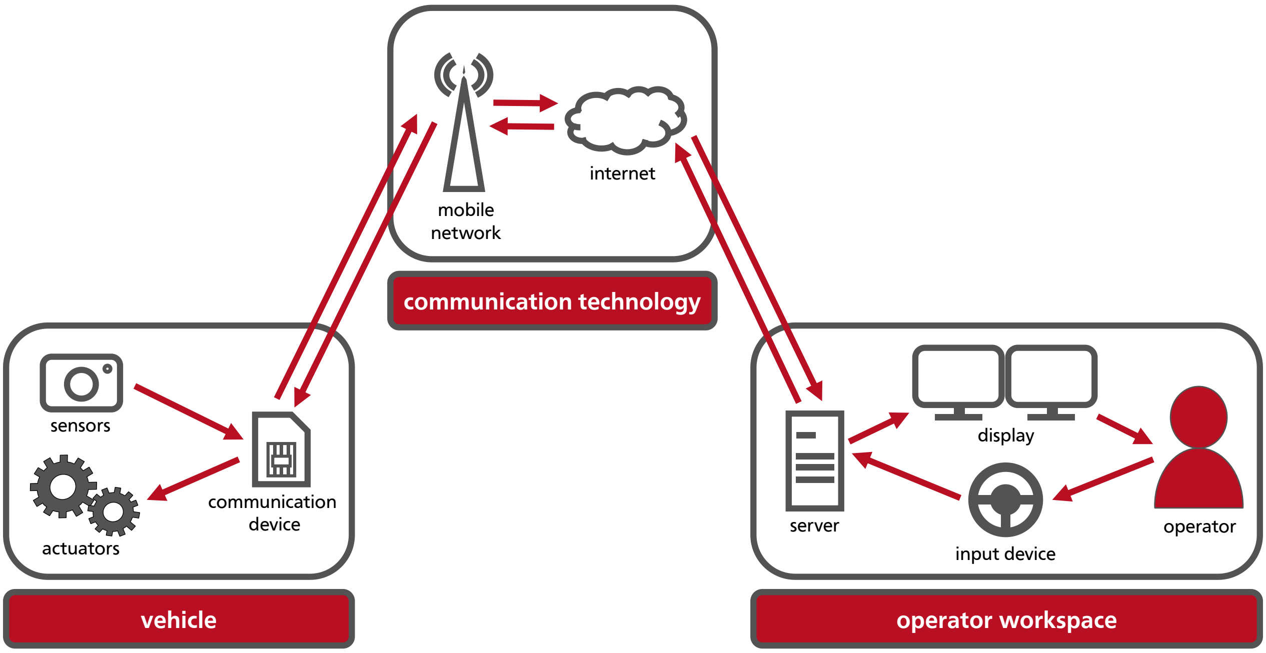



Figure 12: fundamental functionality of teleoperated driving with flow of information (based on [57])

#### Hardware requirements and interfaces

Teleoperated driving is not a new concept. There are already functioning prototypes, for example from the TU Munich. Hence, it is not the goal of this thesis to detail the technology itself. Instead, the focus shall be on how it can be incorporated into carsharing vehicles and successfully adapted for older people. Against that background, only a short overview of the hardware requirements and interfaces in the vehicle is given. For more details and information on the two other components, namely the communication system and the operator workspace, the article in the ATZ by Tang et al. is recommended [57].

Concerning special hardware, the vehicle needs to have at least cameras as sensors, to provide an image of its environment. Additional sensors, like ultrasonic, are possible but not necessary. To be able to control the actuators in the vehicle, a rapid prototyping control unit is used. This control unit has interfaces to the systems responsible for the following functions: Steering, accelerating, braking, lights, indicators, windscreen wipers and in case of vehicles with a gear also shifting. It can access and control all the standard systems responsible for these functions directly, with the exception of steering. Therefore, the vehicle must have electronic power steering. To process data and communicate with the operator, a CarPC is used [57, pp. 31-32].

### Adaptation as a service for old people

Several aspects have to be considered to successfully adapt this technology to be of use in the scenarios described above.

First, the teleoperated driving must be easy to initiate, while at the same time preventing accidental initiation. A possible solution is the activation through the user interface (UI) on the main display. This would allow to build in a two-step process, with a second screen asking for confirmation, and thereby preventing accidental activation. However, going through the menu might be too elaborate, especially in a stressful situation. A way to get around this, would be to have a specially designed UI for old customers. If that is not possible, perhaps a better option is to have a designated button that is easy to reach, like for the hazard lights.
Also possible is the activation by voice command. This is perhaps the most intuitive option, and since it allows the driver to keep his eyes on traffic, it might also be the safest. If a special code word is used to initiate the teleoperated driving, accidental activation can be avoided. However, the person would have to really internalize that code word, or else this version would lose its advantage in intuitiveness. In contrast, if several different commands lead to initiation, the intuitiveness is kept, but the risk of accidental activation is higher. The only way to solve that conflict would be a software that is intelligent enough to correctly identify a wanted activation. That is not yet possible. A negative aspect to all versions of voice command is the need to constantly record the passenger. This might not be welcomed due to privacy and data protection issues.

After initiating the teleoperation, the operator must be able to take control over the vehicle as quickly as possible, ideally in less than one minute. This means that a free operator must be available at all times. Also, the systems in the car must respond fast enough, and cannot require a long ramp-up. Of course, the takeover cannot be designed for emergency situations like a person having a stroke. However, if a person is feeling exhausted or dizzy, it should be possible to continue driving for up to a minute or two.

Another potential problem is the takeover itself. The operator must take control during the drive, which probably requires special training. Nonetheless, it is definitely possible, as can be seen by the example of driving instructors, who can intervene during the drive. But unlike driving instructors, the operator was not on board the whole time, and therefore has no feeling for the car's surroundings or the traffic situation. This might be a big problem, since the takeover is supposed to be as quick as possible, leaving the operator with almost no time to adapt to the situation. Possibly, special training can solve that problem, otherwise the takeover time would have to be increased.

Apart from taking control over the vehicle, the operator needs to be able to communicate with the driver. This is necessary to find out the destination, but also to check in with the driver and see if he needs further assistance. If that is the case, the operator must be able to order help. Ideally, operators receive a special training to deal with people in distress.

Considering these aspects, it seems the operator is the biggest issue when adapting teleoperated driving to provide a safety feature. Usually, teleoperated driving is discussed in relation to topics like valet parking. This would only require regular driving skills from the operator. As described above, the application as a service for older drivers requires highly trained professionals. That could lead to a high cost of the service.
In contrast, the hardware in the car and the communication technology should not be a problem, and with continuous advances in automated driving, the necessary components might even be standard in the timeframe of 2025-2035. The only adaption necessary here is the easy activation of the service. But as described above, this can be achieved rather easily and with little extra cost. Providing a specialized UI only requires software changes, voice command might be onboard anyway and a designated button should not cost too much.

#### Integration into the overall product

After having specified the feature and shown that it is feasible with little extra effort, the integration into a carsharing vehicle needs to be analyzed. At the same time the feature is evaluated to determine if it is viable for the use in carsharing.

Most of the required technology are sensors or control units, which might even be standard issue in the future. If that is not the case, they will make the vehicle more expensive, but other than that pose no restrictions on its usability for carsharing, since they do not influence the design and do not take up much extra space. The only hardware component that a user would notice is a designated button to activate the teleoperated driving, but as described above, even that could be solved differently.

Providing the communications technology, the operators and their workspace would probably be very costly. However, this does not have to make carsharing more expensive for all users. A possibility would be to have different rates, for example a standard rate and a premium rate with the option to the teleoperation service. Another possibility would be to charge per use of the service. Apart from that, the teleoperation could be used to provide other services to all users in exchange for extra payment. These services could include ordering a vehicle to pick up the customer, parking or chauffeuring the customer so he can do other things during the ride. Having such extra options available, would make carsharing more attractive to customers, and could generate extra income for providers. Besides direct services for the customer, teleoperated driving can also be used for fleet management, allowing to relocate vehicles. This could be interesting for free-floating carsharing fleets or for electric vehicles that need to recharge.

To conclude, this feature does not have to pose any major disadvantages to the overall product or the other user groups. Instead, it provides several potential benefits for all customers, as well as for the carsharing provider. The only critical aspect of this feature is the cyber-security. To prevent intrusion into the system and unauthorized takeover, the system has to be secure. Apart from software solutions for cyber-security, a manual off-switch could be built into the car. If the cyber-security can be ensured, the feature should be a viable option for more senior-friendly mobility.

### 3.6.3 Personal profile

The idea for this feature stems from problems that old people often have with technology. Many of them have difficulties adapting to new things in general. This shows in lower problem solving skills. Concerning technology, this means they usually do not learn intuitively and do not rely on try and error much, unlike younger people. Because they do not adapt well, many old people are reluctant towards change. Instead, they prefer their familiar environment. All of this leads to them often having difficulties with the handling of technology and seek to avoid it where possible. A good example demonstrating this are mobile phones. Because they are not familiar with the concept of a UI, operating a smartphone is difficult for many old people. And unlike younger people, they usually do not intuitively learn to do so. Instead, they need help from someone else to set everything up and explain it to them. Then they can use it. However, if something is changed and not the way it was when they were instructed, they often either avoid using it or need help again to set everything up again. In contrast to that, operating an older cell phone with buttons is usually easier for them, because it is similar to a landline-phone, a concept they are used to [58] [59].

Applying this to carsharing, two main issues can be identified that potentially prevent old people from using it. After all, old people are currently by far the smallest customer segment in carsharing in Germany [3].

First is the heavy involvement of digital technology. From registering online, over using an app on a smartphone to handling a UI in the car. Here, the targeted timeframe of 2025-2035 needs to be considered. At that point, the generation of old people might be more familiar with the use of the internet or a smartphone, especially towards 2035. Nonetheless, there will still be enough old people who never really got in touch with digital technology. Also, the interior of a car can be expected to further change, with a digital UI playing a significant role in controlling the vehicle and the functions provided through increased connectivity. In a private car, old people can currently avoid all this, for example by using an older model, which still has analog controls.
The second issue is inherent to the concept of carsharing. By using the same cars as other people, possibly even different models in the carsharing fleet, one cannot be in his familiar environment in such a car. Every time it will be configured differently, and the user would need to adjust it before every use if he wants the same experience every time. Some people, especially younger ones, might be flexible enough so it does not bother them, or they do not mind the recurring adjustment. But as described above, many old people prefer a familiar environment. This again is something that they can avoid by using private cars instead.

Developing a product feature that addresses these issues, and thereby lowers the mental entrance barrier for old people, can encourage the use of carsharing among them. Also, it would help to make the use more convenient and comfortable. Opening up carsharing as a valid alternative would be very beneficial for that age group, because often times owning a private car is not necessary for their mobility needs. However, a car is usually a lot more convenient for them, especially if they have decreased physical abilities, than other forms of mobility, like using a bike or public transportation. Therefore, carsharing would be a more reasonable option that still provides individual mobility.
In the best case, such a product feature would not only benefit old people, but make carsharing more attractive and more convenient for all customers.

While digital technology and increasing connectivity can be deterrent for old people, they can also be used to provide a product feature that reduces the issues stated above and eases the access to carsharing. This can be achieved by creating a digital profile for the customer that has access to many relevant systems and functions in the vehicle, allowing it to adjust them automatically to the individual customer’s needs. The profile would require the use of cloud technology to connect to the car and store all the necessary information. In the following, the functionality of such a feature is explained.

**Basic functionality and interfaces**

The main purpose of this product feature is to address the two issues of complex handling, mainly because of a digital UI, and adjusting the environment in the car. Therefore, it provides two main functions; a senior friendly UI and a memory function for the settings of relevant components.
To enable these functions, the feature needs to have interfaces to the UI of the car and to the relevant systems that are individually adjusted by every customer. In the basic version of this feature, these systems include the seats, the mirrors and the climate control. By accessing the UI, it will also be able to control the entertainment system. Lastly, an interface to the customer himself is required.

All of this is achieved by creating a digital profile for the customer, which is stored in a cloud. On the one hand, the cloud is connected to the vehicle via mobile internet, and the profile can access the necessary systems through the interfaces stated above. On the other hand, the customer can always access his profile through the internet, for example with his smartphone. Carsharing already requires to create a personal account online, so this account could be expanded to include the functions stated here. Figure 13 shows the principal functionality of the product feature, with its main functions and the necessary interfaces. The functions of current customer accounts are marked in grey.

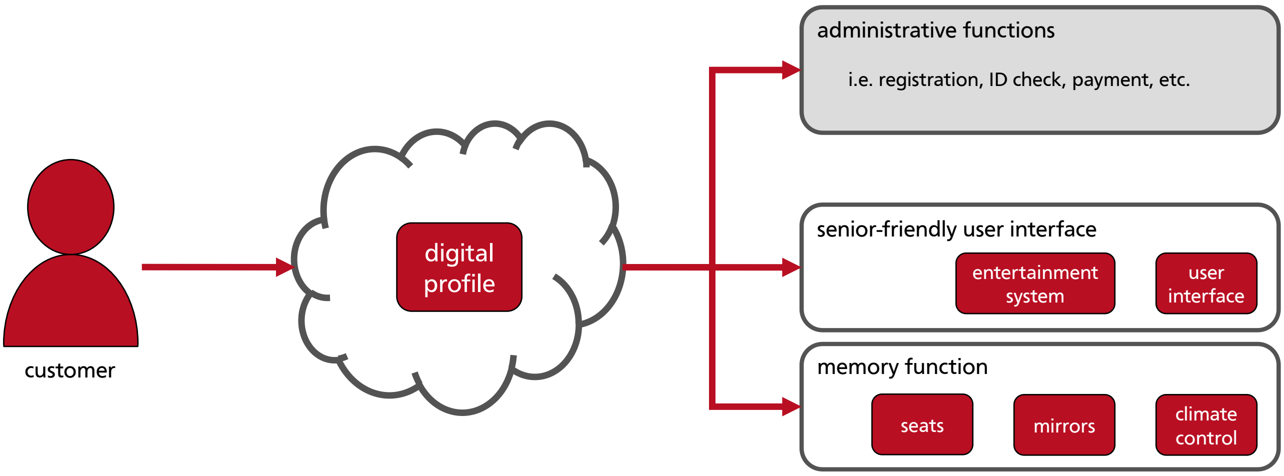



Figure 13: principal functionality of the digital profile

In the following, the two main functions enabled by the personal profile, namely a senior friendly UI and a memory function to adjust the drivers environment, are presented.

### Senior-friendly user interface

For the UI on the main display, a special version for old people has to be created. To make it effective in easing the handling, it has to be intuitive. Here it is important to consider that something young people regard as intuitive, is not necessarily viewed the same way by old people. Operating a touch screen is usually not a problem, but the digital concept behind it is. For them, the UI should resemble analog controls. This means several levels that need to be navigated through are to be avoided, and the controls should rely on buttons that can be pressed, rather than on motions.

Besides a more analog approach, it is important to address other issues that are common among old people, mainly weaker hearing abilities and eyesight. Therefore, in this version of the UI, audio feedback should have the option to be louder. Every user could adjust this once, and then the setting is saved in the profile. Also, a direct incorporation of a person's hearing aid is imaginable. Furthermore, the controls and text should generally be larger, so that they are easier to read. It might also be an option to heavily rely on symbols for the controls.

At this point, it is important that not all old people have the same needs. Of course, providing just one specialized version, following a one size fits all approach, would already be a step in the right direction. But better than that would be to make the UI adjustable. Assuming the car has one main display for the controls, a customer could configure his personal layout through his profile. Since the profile uses a cloud, it can be accessed and configured via the internet. This can be done from home, for example with the help of a relative. Then, every customer can decide how complex it should be, and how many features he needs. Configuring it once, especially with help, should be no problem, and after that the settings are saved in the digital profile. Every time the customer uses a car of the carsharing service, the UI will be in his personal configuration.

### Adjusting the drivers environment

Concerning the individual adjustment of the driver's environment, the four main factors are the position of the seats, the position of the mirrors, the settings of the climate control and the settings for the entertainment system, like radio channels and volume.
If the digital profile has access to the UI in the car as described above, controlling the entertainment system is no problem. Favorite radio channels, preferred volume and so forth can easily be saved. Current cars already have such options, but only for a limited amount of people. By using a digital profile in connection with a cloud, this option would be available to all customers of the carsharing service.

Like the entertainment system, the climate control could be accessed through the UI as well, so this should not be a problem either and require no special hardware. The other two systems, mirrors and seats, are already available to be electrically adjustable, but usually with separate controls. This means that the carsharing vehicle would definitely require these systems to be electrically adjustable, and an interface to the digital profile needs to be created. Then, the settings for the seat and the mirrors can be saved in the profile, and automatically restored every time the user wants to use a carsharing vehicle.

Some vehicles already have such memory functions, but they are not as greatly connected, restricted to a small number of settings per vehicle, and usually do not use cloud technology. By storing the data in the cloud, the number of settings per vehicle is unlimited, and the customer can access his profile from anywhere. Also, a digital profile of some form is necessary for carsharing anyway, to sign up for the service, provide proof of a valid driver's license, handle payment and so forth. Therefore, such an existing digital profile would only have to be expanded to incorporate the functions described above.

**Possible expansion**

Apart from the two main properties, namely providing a senior friendly UI and a memory function, the personal profile could be expanded to access more systems in the car and enable more functions. This could be used to further address other customer segments.

A possibility would be to set a maximum velocity for older people. The personal profile would know the customer's age, and if it is above a certain limit, the maximum velocity that the customer can go in the car could be limited to prevent accidents. To do this, the profile would need an interface to the control unit in the vehicle, but no special hardware would be required. However, a function like this must be based on a legal foundation or restriction. Otherwise, such a tutelage of older customers would not be acceptable.

Another idea would be to adapt the vehicle dynamics to the customer's wants, similar to what automatic transmissions offer. A customer could then configure his profile to have higher driving dynamics or a more comfortable ride. This would require an adaptive chassis. Such a feature can make the car feel more personalized and perhaps more familiar to the own car, and would be interesting for all user, not only for old people.

If future vehicles incorporate more OLED or other light elements into their interior design, those can be addressed by the profile as well. Then, a personalization using the profile is possible, creating the feeling of a very individual driving experience.

Other than adding new functions, the same profile could also be expanded to save the customers settings for when he is not the driver but the passenger.

#### Evaluation

Subsequent to specifying the properties and functionality of the feature, it is necessary to evaluate it by analyzing how well it fits into the overall product carsharing.

As worked out above, apart from electrically adjustable seats and mirrors, no special hardware is required for the basic functions that the user profile addresses. Everything else is accomplished by software solutions. This poses little demands on the carsharing vehicle, which is economically desirable. Another beneficial circumstance is the fact that carsharing already requires a personal online account. This could be used for this product feature, meaning that the carsharing companies do not have to make investments into technology they otherwise do not need.

Also useful is the fact that the product feature is not restricted to address old people. Even its basic functions can profit all users. Configuring the UI to fit the customer's taste and needs can make the vehicle feel more personal. The same goes for adjusting the seats and so forth. This also saves the user time, since he does not have to do it manually at the start of the drive. By increasing efficiency and personalization, carsharing becomes more attractive to all customers. Especially the individualization enabled by this feature is important, since that is something carsharing usually inherently lacks in comparison to a private car.

By adding more functions to the feature, like adapting the vehicles dynamics, the benefit for all customer segments can be further increased. All of this helps to improve the user's experience and should acquire new customers. Therefore, it can be assumed that the presented product feature would be economically viable.

In spite of all these benefits, there are also potential problems evoked by this feature. Saving customer data automatically raises the issue of data security. While carsharing firms already have to deal with this, since every customer has an online account, it is still something that should be noted. Also, by connecting the components of the vehicles to the profile and making them accessible through the internet, they become susceptible to cyber-attacks. Therefore, cyber-security needs to be ensured for a safe usage of the product.

# 4 Conclusion

In this last chapter, the previous development process is recapped and the results are evaluated. It is then discussed whether or not they fulfill the goal that was set for this thesis. Finally, an outlook is given on how the obtained results can be further expanded.

The methodical approach defined at the beginning of the thesis is fairly standard, and largely identical to a model presented in the supplement sheet 2 of the VDI guideline 2221. Yet, a characteristic of this thesis is narrowing down the scope of the task description with every step of the development process. This leads to a clear focus for the final product features and makes the development process leaner and more determined, which is necessary to stay within the possibilities of this bachelor thesis.

With this in mind, the first step of development is to identify stakeholders for mobility products. Here, a restriction to only consider the customer is made. Following is the definition of requirements for the product features. These, according to the previously made restriction, consist of the customer wants and needs. To determine them, existing products are analyzed and a small survey is conducted. This poses the next necessity to refine the scope. In order to generate data as significant as possible, three very narrow customer segments are selected, which differ greatly from each other. Age is chosen as the decisive factor for their categorization, resulting in the segments 18-25 years, 45-55 years and 75-90 years of age. Finally, customer profiles based on the obtained data are created using the Persona-method.

The next step of the development process is the functional analysis to identify potential for improvement through new features. Therefore, a suitable overall product to focus on must be chosen. In this case, matching with the previously made decisions and the scope of the task description, a car is identified to be the most fitting product. Since the thesis aims to develop solutions in the context of sharing economies, this also implicates a focus on carsharing. After the functional analysis is conducted, its results, in combination with the created Personas, are used to generate concept ideas. Again, a refinement to the scope is made, by choosing the customer segment of 75-90 years to focus on. This age group, in combination with the product car and the context of shared mobility, seems to provide the most potential for innovation, since currently carsharing is very unpopular amongst old people [3]. Also, demographic change was identified as a major factor to influence mobility in the future, so senior-friendly mobility would address this issue. Finally, a list of concept ideas is generated, of which the three best ideas are selected by using a Pugh-matrix to compare and rank them.

Those three chosen concepts are then further specified and finally the resulting product features are evaluated. The first feature aims to ease access to a vehicle by implementing rotatable seats. This addresses an issue that old people have with cars in general, but would nonetheless make carsharing vehicles more attractive to them. Other customers could benefit as well, for example people with restricted agility due to an injury or parents buckling the seat belt of their child. The second feature uses teleoperated driving as a service for old people who find themselves unable to continue the drive. This could be due to exhaustion, sudden dizziness or loss of orientation. In such an event, an operator would take control of the vehicle and steer them safely to their destination. People who otherwise have to avoid using cars could rely on this safety feature and stay mobile for longer. Teleoperation can also be used to provide services to other customer groups as well, e.g. ordering a vehicle to a certain location or taking care of parking. The last feature attempts to ease handling of carsharing vehicles and provide a more familiar environment in the car. This is achieved through two main functions. First, a senior-friendly UI in the car, and second a memory function allowing to adjust the users environment, for example seats and mirrors. Both is controlled by a digital profile. Having systems like the seats automatically adjusted when renting the vehicle is beneficial for all customer segments.

As worked out in section 3.6 , all features at least enhance the customer experience for old people, but have the potential to benefit other customer segments as well. Therefore, they fulfill that goal of this thesis. Since they make carsharing more convenient for old people, they encourage the use of it, and thereby tackle a problem it currently faces. By providing options for more senior-friendly mobility, all three features address demographic change, and hence fulfill the second goal of dealing with challenges of future mobility.

The three product features developed in this thesis provide first concepts on how to make mobility more senior-friendly. If this topic becomes more relevant in the future, these concepts can be further expanded. Some ideas to further develop the individual features are already given in section 3.6 . Especially the digital profile can be expanded and used to incorporate other features, for example a speed limit.

On a grander scale, the next step in consequently implementing senior-friendliness into services like carsharing, or cars in general, would be to combine the different features in one vehicle. Such a future car would be developed with the special needs of old people in mind, and include features to ease access and loading, as well as amended versions of the digital services, like a senior-friendly UI. In the context of carsharing, everything would be managed through a digital user profile.

Especially the increasing digitalization of a car should be considered in regards to senior-friendliness, since it makes handling more difficult for old people. However, if the digital aspects are implemented senior-friendly as well, they provide great potential to facilitate the use of the product. A first step can be to offer a senior-friendly version of the carsharing app.

# A Appendix

## A1 List of customer requirements

- Safety
  - prevent accidents
  - crash-safety
  - operational safety
  - not harmful to health
  - anti-theft safety
- reach destination quickly
- comfort
  - comfortable
  - pleasant temperature
  - quiet
  - odor neutrality
  - spaciousness
  - sufficient storage space
  - good handling
- visually pleasing
  - individualizable
  - high-quality materials and surfaces
  - good looking design
- entertainment
  - multimedia
  - internet access
  - connectivity
  - individualizable
- data-security
- privacy
- environmental protection

## A2 Original questionnaire for the customer survey

Note: Since this is the original version of the questionnaire it is in German.

### Nutzerbefragung zu Anforderungen an Mobilitätskonzepte

#### 0. Hinweise zur Bearbeitung

Vielen Dank, dass du mich durch deine Teilnahme unterstützt!

Abschnitt 1 musst du nicht lesen. Dieser ist optional und bietet dir bei Interesse Hintergrundinformationen zur Aufgabenstellung.

Alles Weitere solltest du für ein sinnvolles Ergebnis jedoch bitte **genau lesen**.

Die Ergebnisse werden selbstverständlich anonymisiert verwendet.

#### *1. Kontext der Umfrage* **(optional)**

*Viele gesellschaftliche und technische Trends der letzten Jahre führen dazu, dass für die Zukunft neue Mobilitätskonzepte entwickelt werden, die das bestehende Angebot aus privaten Pkw, Fahrrad und ÖPNV (Bus, Bahn) erweitern. Einige dieser Trends sind Carsharing, Autonomes Fahren, Elektromobilität, sharing economies oder die wachsende Bevölkerung der Städte.*

*Ziel meiner Bachelorarbeit ist es, technische Lösungen für solche zukünftigen Mobilitätskonzepte zu erarbeiten. Ein erster Schritt besteht darin, Kundenanforderungen zu ermitteln und zu bewerten. Diese Ergebnisse helfen mir dabei, nach Altersgruppen getrennte Kundenprofile zu erstellen. Insgesamt dient dies dazu, Verbesserungspotenzial der Produkte zu identifizieren und Lösungen zu entwickeln, die den Kundenwünschen entsprechen.*

#### 2. Aufgabenbeschreibung

Ziel dieser Umfrage ist es, verschiedene Kundenanforderungen an alltägliche „Mobilität“ zu quantifizieren. Mobilität ist dabei jede Art von Fortbewegung, für die man ein technisches Hilfsmittel (=Verkehrsmittel) benötigt. Also praktisch alles, außer zu Fuß zu gehen.

Es gibt eine Vielzahl von Verkehrsmitteln, die alle mehr oder weniger die folgenden Anforderungen erfüllen. Diese Anforderungen sollst du danach bewerten, wie wichtig sie dir sind. Da es darum geht neue Lösungen zu entwickeln, ist es wichtig, dass du versuchst die genannten Anforderungen so abstrakt wie möglich und voneinander getrennt zu betrachten.

Zu jeder Kategorie gibt es 5 Abstufungen, links und rechts stehen jeweils die Extrema. Bitte kreuze in diesem Spektrum jeweils das Feld an, das deiner Meinung entspricht.

| 3. Nutzererlebnis / Produkteigenschaften | | |
|---|---|---|
| **3.1 Design** | | |
| Mir ist optisch ansprechendes Design nicht wichtig | ☐ ☐ ☐ ☐ ☐ | Mir ist optisch ansprechendes Design sehr wichtig |
| **3.2 Komfort** | | |
| Besonderer Komfort spielt für mich keine Rolle | ☐ ☐ ☐ ☐ ☐ | Hoher Komfort ist mir sehr wichtig |
| **3.3 Platzangebot** | | |
| Ich brauche nicht viel Platz | ☐ ☐ ☐ ☐ ☐ | Ich brauche sehr viel Platz |
| **3.4 Gepäckmitnahme** (mehr als einen Rucksack/Handtasche) | | |
| Gepäckmitnahme ist mir nicht wichtig | ☐ ☐ ☐ ☐ ☐ | Gepäckmitnahme ist mir sehr wichtig |
| **3.5 Bedienung** | | |
| Die Bedienung darf kompliziert sein | ☐ ☐ ☐ ☐ ☐ | Die Bedienung muss leicht und intuitiv sein |
| **3.6 Vernetzung** | | |
| Die Vernetzung mit einem Smartphone ist mir nicht wichtig | ☐ ☐ ☐ ☐ ☐ | Die Vernetzung mit einem Smartphone ist mir sehr wichtig |
| **3.7 Individualität** | | |
| Ich bin mit einem Standardprodukt zufrieden | ☐ ☐ ☐ ☐ ☐ | Ich muss das Produkt meinen Vorstellungen anpassen können |
| 4. Nutzereinstellung | | |
| **4.1 Sicherheit** | | |
| Sicherheit ist für mich nicht entscheidend | ☐ ☐ ☐ ☐ ☐ | Sicherheit spielt für mich die entscheidende Rolle |
| **4.2 Privatsphäre** | | |
| Privatsphäre ist für mich nicht entscheidend | ☐ ☐ ☐ ☐ ☐ | Privatsphäre spielt für mich die entscheidende Rolle |
| **4.3 Umweltschutz** | | |
| Umweltschutz ist mir nicht wichtig | ☐ ☐ ☐ ☐ ☐ | Umweltschutz ist mir sehr wichtig |
| **4.4 Fortschrittsfreundlichkeit** | | |
| Ich bin nicht offen für neues, alles soll so bleiben wie es ist | ☐ ☐ ☐ ☐ ☐ | Ich bin für jede Neuerung zu begeistern |
| **4.5 Datenschutz** | | |
| Datenschutz ist mir nicht wichtig | ☐ ☐ ☐ ☐ ☐ | Datenschutz ist mir sehr wichtig |

## A3 Complete data obtained through the customer survey

| | 18-25 years | | | | | 45-55 years | | | | | 75-90 years | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **male/female** | f | f | m | m | m | f | m | f | f | m | f | m | f | m |
| | | | | | | | | | | | | | | |
| **Design** | 4 | 2 | 4 | 2 | 4 | 3 | 4 | 4 | 3 | 2 | 5 | 1 | 2 | 3 |
| **Comfort** | 5 | 4 | 3 | 4 | 4 | 4 | 5 | 5 | 3 | 4 | 5 | 1 | 5 | 3 |
| **Spaciousness** | 3,5 | 3 | 1 | 4 | 2 | 3 | 4 | 5 | 5 | 4 | 2 | 1 | 2 | 1 |
| **Luggage capacity** | 3 | 2 | 3 | 4 | 4 | 4 | 4 | 5 | 5 | 3 | 3 | 1 | 2 | 4 |
| **Handling** | 4 | 4 | 4 | 3 | 2 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Connectivity** | 2 | 5 | 5 | 4 | 5 | 4 | 4 | 4 | 2 | 3 | 1 | 1 | 1 | 3 |
| **Individuality** | 4 | 3 | 2 | 1 | 2 | 4 | 2 | 5 | 3 | 2 | 5 | 5 | 1 | 2 |
| | | | | | | | | | | | | | | |
| **Safety** | 5 | 4 | 2 | 4 | 4 | 5 | 5 | 4 | 5 | 5 | 5 | 5 | 5 | 5 |
| **Privacy** | 3 | 3 | 3 | 2 | 5 | 4 | 5 | 4 | 4 | 5 | 2 | 5 | 5 | 3 |
| **Environmental Protection** | 5 | 2 | 4 | 3 | 4 | 4 | 5 | 3 | 5 | 4 | 4 | 5 | 5 | 4 |
| **Progressive Nature** | 4 | 4 | 4 | 4 | 2 | 3 | 4 | 5 | 3 | 4 | 4 | 1 | 1 | 4 |
| **Data Security** | 3 | 3 | 3 | 5 | 3 | 5 | 5 | 4 | 5 | 5 | 1 | 5 | 5 | 3 |

## A4 Personas

**Student Stephany**

name Stephanie
age 21 years
job student

place of residence city
financial situation tight for cash
family situation single

**abilities**

creativity/intuition
technological Knowhow
education

**personality**

passive – active
conservative – progressive
rational – emotional

**biography**

Stephany studies medicine at the LMU in Munich. Since she lives in the city, she mainly uses public transportation and has no need for a car. However, sometimes it would be handy, i.e. for trips on the weekend. Apart from university, Stephany likes to spend time in the park and go hiking in the alps.

**goals for personal mobility**

- affordable and permanently available mobility
- mainly trips to university, friends or shopping
- mostly trips in the city, often spontaneous
- tours to the surrounding region on the weekend

**concerns/problems**

- worries if the mobility is available at night as well, for example after a party

**needs**

- readily available transportation
- mobility around the clock
- spontaneous trips must be possible
- cheap mobility

**product properties**

design
comfort
spaciousness
luggage capacity
handling
connectivity
individuality

**attitude**

safety
privacy
environmental protection
progressive nature
data protection

**expectations**

## Manager Matthew

| | |
|---|---|
| name | Matthew |
| age | 51 years |
| job | engineer |
| place of residence | suburb |
| financial situation | wealthy |
| family situation | married |

### abilities

creativity/intuition
technological knowhow
education

### personality

passive — active
conservative — progressive
rational — emotional

### biography

Matthew studied mechanical engineering at the TU Darmstadt. After his diploma he started at Siemens, where he is still employed. His career went well and he is now in a leading position. Therefore, he is used to perform, but also expects high quality. For his way to work he uses a car, since public transportation is to unreliable for his needs.

### goals for personal mobility

– comfortable and safe ride
– reach destination fast and punctual
– predictable mobility
– mainly rides to work, shopping, appointments

### concerns/problems

– afraid of delays
– does not want to miss appointments

### needs

– high quality
– punctuality and dependability
– productivity desirable
– quiet and privacy desirable

### product properties

design
comfort
spaciousness
luggage capacity
handling
connectivity
individuality

### attitude

safety
privacy
environmental protection
progressive nature
data protection

### expectations

## Conservative Karl

| | |
|---|---|
| name | Karl |
| age | 81 years |
| job | pensioner |
| place of residence | suburb |
| financial situation | wealthy |
| family situation | married |

### abilities

creativity/intuition
technological knowhow
education

### personality

passive — active
conservative — progressive
rational — emotional

### biography

Carl worked as a lawyer. In his 50s he began to be active in municipal politics and was deputy mayor for a couple of years. He is still a member in several clubs. Traditional values are important to him. Concerning technology, he prefers to only use things he is familiar with. Driving his car for longer periods exhausts him, but taking the bus to town is more stressful and inconvenient.

### goals for personal mobility

– comfortable and safe ride
– no long distances
– mainly trips to appointments, doctors, shopping
– rarely new routes, rarely spontaneous trips

### concerns/problems

– no interest in technology
– doesn't own a smartphone
– skeptical towards modern technology
– has trouble getting in a car
– „In my age you cant learn these things."

### needs

– sufficient time / slow pace
– ergonomic products important
– easy handling
– (technical) assistance should be available

### product properties

design
comfort
spaciousness
luggage capacity
handling
connectivity
individuality

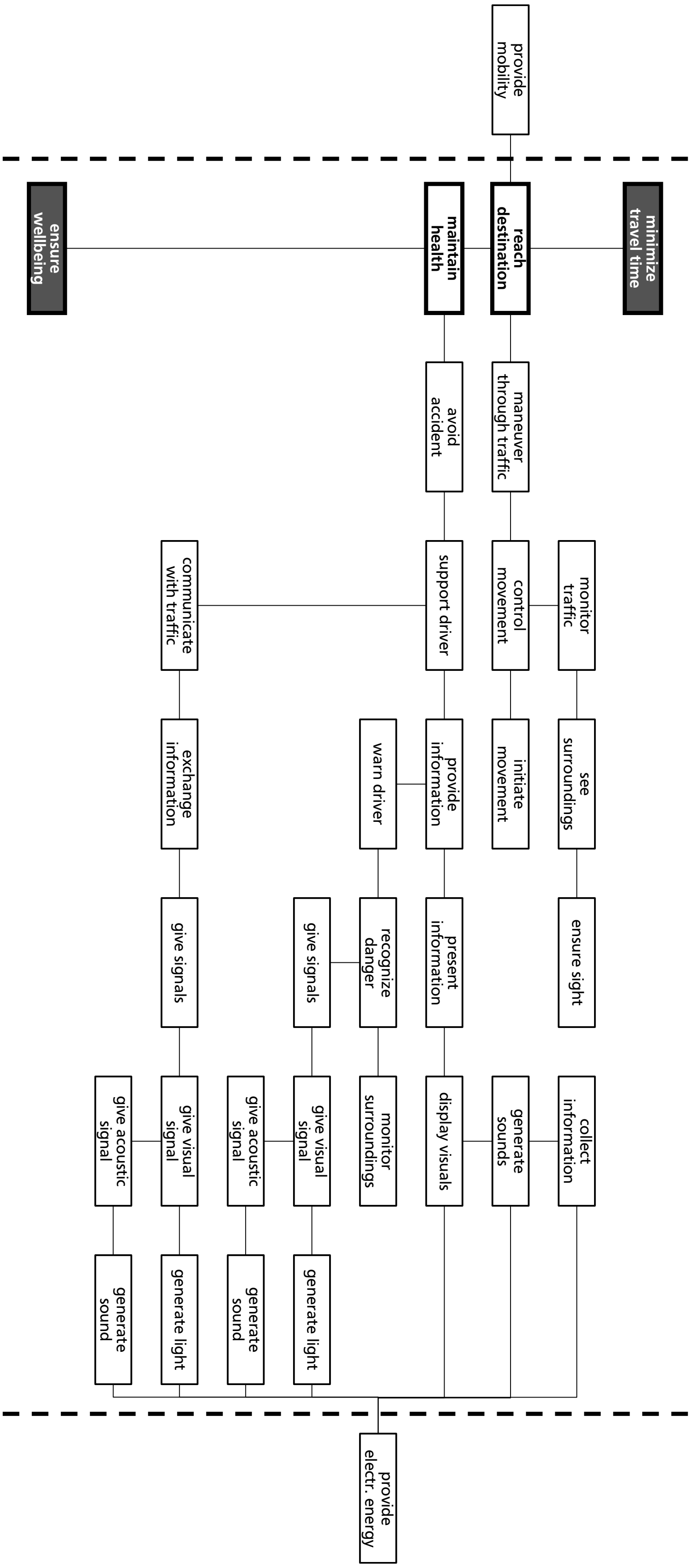
### attitude

safety
privacy
environmental protection
progressive nature
data protection

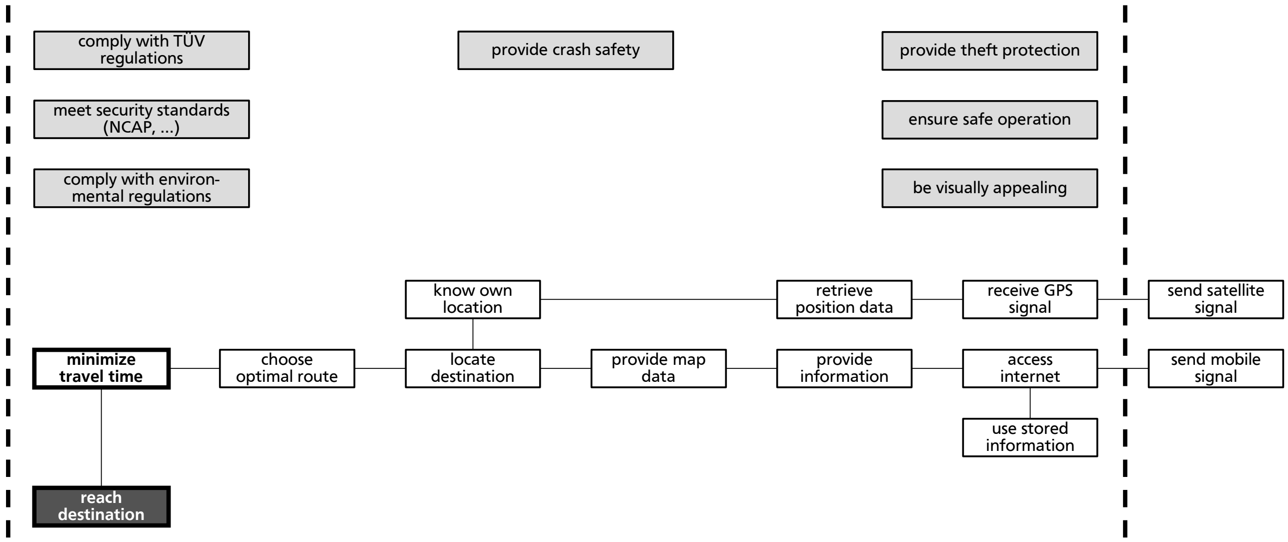
### expectations

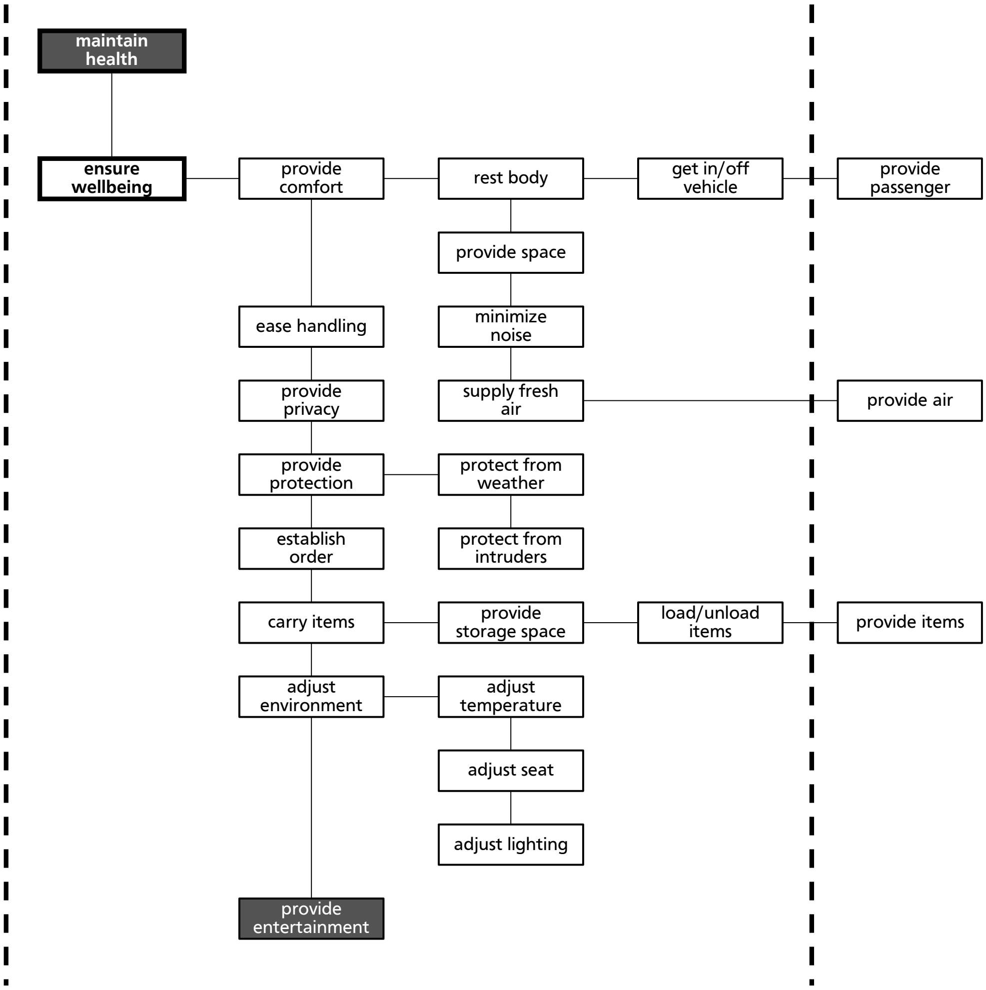
## A5 FAST-diagram for current-state analysis

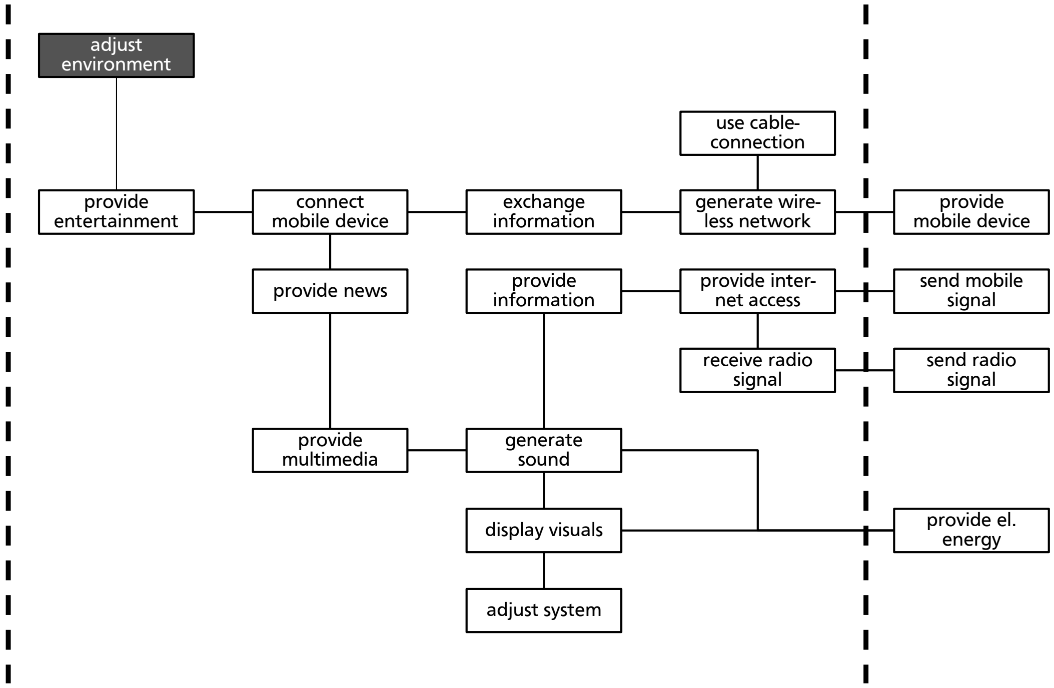
Note: The whole FAST-diagram does not fit the page, and is therefore divided into sections. In each shown section, the link to the adjacent sections is colored in dark grey. Basic functions are bold.



Note: Specifications, singular functions and permanent functions are colored light grey.






## A6 Pugh-Matrix

| criteria | weight | rotating seats | | various boarding aid | | loading aid | | glare protec-tion | | night vision | | emergency | | teleoperated driving | | OLED ele-ments | | profile | | hearing aid | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | g | s | g | s | g | s | g | s | g | s | g | s | g | s | g | s | g | s | g | s |
| degree of innovation | 3 | 0 | 0 | 0 | 0 | 0 | 0 | -2 | -6 | 0 | 0 | -1 | -3 | 0 | 0 | -1 | -3 | 1 | 3 | 1 | 3 |
| cost | 1,5 | -1 | -1,5 | -1 | -1,5 | 1 | 1,5 | 2 | 3 | -2 | -3 | 2 | 3 | -1 | -1,5 | -2 | -3 | 0 | 0 | 0 | 0 |
| feasibility | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | -1 | -1 | 2 | 2 | 0 | 0 | -1 | -1 | 1 | 1 | 2 | 2 |
| integration in overall product | 3 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 2 | 6 | 1 | 3 | 2 | 6 | 0 | 0 |
| benefit | 2 | 1 | 2 | 1 | 2 | 0 | 0 | 0 | 0 | 1 | 2 | 1 | 2 | 2 | 4 | 1 | 2 | 2 | 4 | 0 | 0 |
| multiple customer segments | 3 | 2 | 6 | 0 | 0 | 1 | 3 | 1 | 3 | 2 | 6 | 1 | 3 | 2 | 6 | 2 | 6 | 2 | 6 | 0 | 0 |
| safety | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | -1 | -1 | 1 | 1 | -1 | -1 | 1 | 1 |
| **sum (score)** | | **10,5** | | **1,5** | | **6,5** | | **2** | | **8** | | **8** | | **13,5** | | **5** | | **19** | | **6** | |

## List of figures

## List of tables

## List of abbreviations

| | |
|---|---|
| ADAC | Allgemeiner Deutscher Automobil-Club e.V. |
| ATZ | Automobiltechnische Zeitschrift |
| BEV | battery electric vehicle |
| BUND | Bund für Umwelt und Naturschutz Deutschland e.V. |
| EU | European Union |
| HUD | head-up display |
| NGO | non-governmental organization |
| OLED | organic light emitting diode |
| TU | Technische Universität (Technical University) |
| UI | user interface |
| VDI | Verein Deutscher Ingenieure e.V. |

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