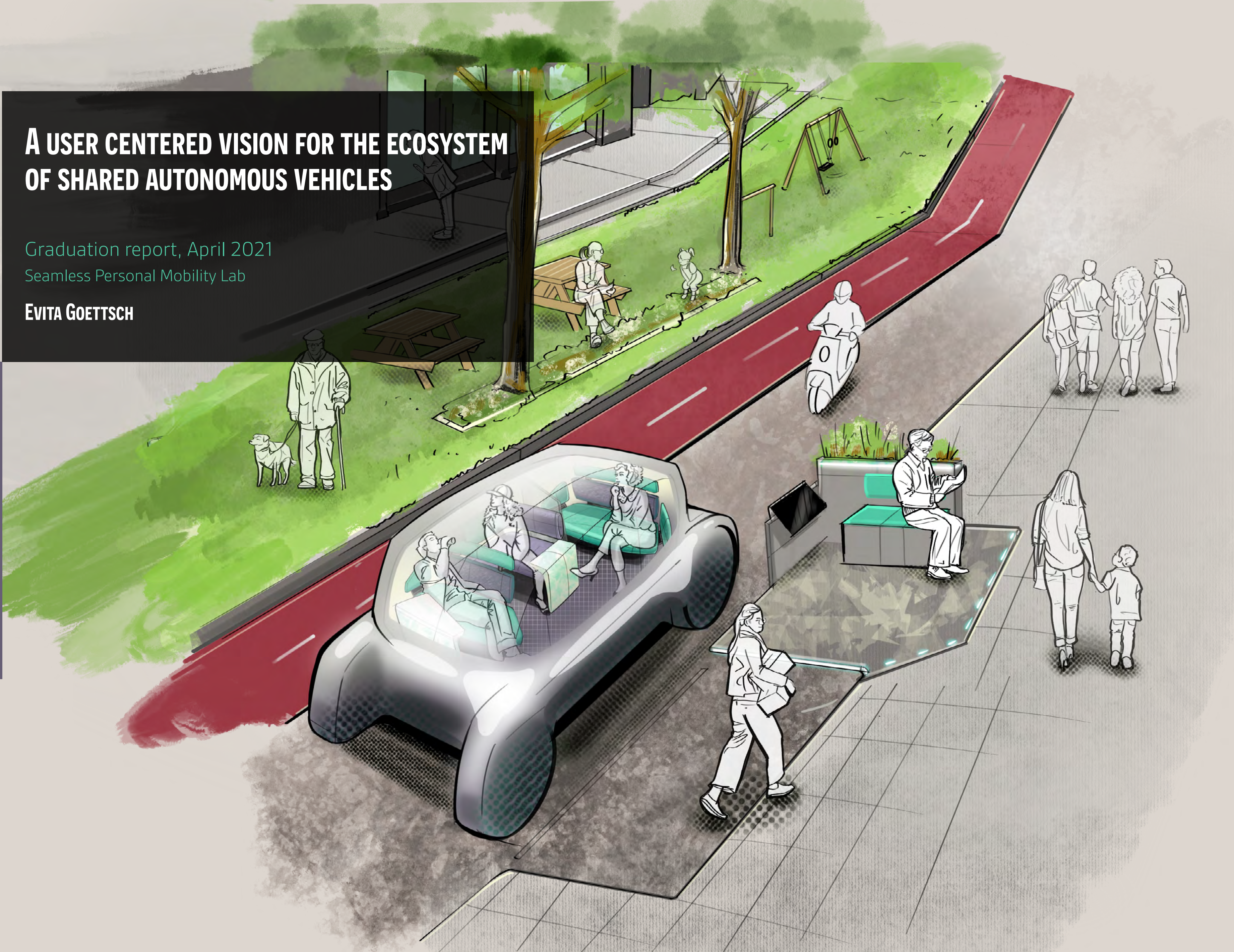
A User Centered Vision for the Ecosystem of Shared Autonomous Vehicles

Graduation report, April 2021

Seamless Personal Mobility Lab

Evita Goettsch



Faculty of
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TU Delft

Colophon

A user centered vision for the ecosystem of shared autonomous vehicles

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Author
Evita Goettsch

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Delft University of Technology
Faculty of Industrial Design Engineering
Design for Interaction

Chair
Suzanne Hiemstra- van Mastrigt, Dr, Ir.
Faculty of Industrial Design Engineering Department; Sustainable Design Engineering; section Materials and Manufacturing

Mentor
Jasper van Kuijk, Dr, Ir.
Faculty of Industrial Design Engineering; Department Human Centered Design; section Applied Ergonomics and Design.

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Reading guide

○	This symbol means “figure”
Insights for the design	In these areas, a summary is given of all the elements involved

Abbreviations and glossary

SAV	Shared autonomous vehicle
AV	Autonomous vehicle
Ecosystem	All active components regarding the product, such as interdependent products and users functioning within a certain ambiance and their interactions and business processes (Zhou, Xu, & Jiao, 2010, p. 47).
MRDH	Metropole Region Den Haag – Rotterdam
PT	Public transport
P + R	Park and Ride. It is a place where you can easily park your car for a reduced price and transit to PT.
OEM	Original equipment manufacturer (in automotive context: Volkswagen, Mercedes, Renault etc).
Geofence	A geofence is a virtual fence or perimeter around a physical location.
Reason d'être	Reason of existence, purpose or goal of a product or person.
ETA	Estimated Time of Arrival
V2V	Vehicle to vehicle communication
V2I	Vehicle to infrastructure communication
MVP	Minimal Viable product. A first version of a product, without much details.

Preface

I still get very excited when I come across the Renault EZ-Ultimo (figure 1) - one of Renault's autonomous concepts.
The EZ-Ultimo is the luxurious concept-vision of Renault's trio of autonomous vehicles. I had a chance to see the real model in 2017, a year before the release, at Renault's design office in Gyancourt (Paris). I remember the 1 to 1 scale-model being driven into the office for the first time. We were standing there, watching the model. It was very detailed in its styling, luxurious, and still totally a concept-car.
I remember thinking about how to get inside this vehicle. There were no doors, which slightly confused me. But I was still captivated by the design, and the promise of a better, more efficient future for our transportation systems.
One year later, it was released at Mondial de l'Automobile in Paris.
In Renault's imaginative scenario, a couple is waiting in front of the restaurant where they just ate, somewhere in Paris, about to be picked up by this luxurious autonomous limousine to that will take them home.

1. The EZ-Ultimo, the luxurious autonomous concept of Renault.

Once inside, they find two satin padded sofas with a table on the side for your whiskey and phone. It is styled in such a way that feels luxurious and takes you into this fantasy of fancy autonomous cars. It feels super romantic and classy, but how is this going to work? How does the EZ-Ultimo know where you want to go? Can you share it, or do you own it?
I always think about designing objects that just makes you feel happy.
With our design for the Renault Design Award in 2017, Ilse van Zeumeren and I designed a "romantic" concept for autonomous vehicles. The idea was about sharing a part of your ride together with someone you just met via an online profile. It connects you based on preferences and you can have a "date on the go". Everyone loved the idea but at the same time told us it would be too crazy to work. But what is so crazy about it? Why would we not design things that make us happy? Or even worse; design objects that makes us unhappy and destroy our immediate surroundings. I feel that there is a possibility to design for both happiness and feasibility. To both redefine the feeling of "racing in a sports car, getting excited about its power" and going from A to B in an efficient and sustainable way. I believe we should reconsider why we want something in a certain way. As these systems are not fully designed yet, we can still create it in a way that would benefit us. Both physically and emotionally.
Another figment of the imagination: When we talk about fully autonomous cars, we sometimes talk about "level 5". This is the highest autonomous level we can reach, fully taking over human control.
Many companies invest millions into making this a reality, striving for a highly complex transportation systems.
To accelerate this development, my proposal would be to get rid of most of the complexity. Hence, I share Elon Musk's vision, that in the most ideal world, we could split up people and mobility by for instance moving mobility underground. If we are redesigning the cities and building new cities, why not do it immediately? We would earn space and bring the car underground.
It is impossible to design a level 5 autonomous vehicle in the way cars drive around in the city now. There are too many variables for current technology to solve. Apart from the technology which enables the driving, the assuring nod of a car- driver when crossing the road as a pedestrian will still be essential.
These small human- to-human interactions should not be forgotten because this could be the difference between trusting an autonomous vehicle and being wary of it. Thereby, the technology would probably be solved at some point, but the ethical issues will not be.
This short piece of text might have put some ideas in your head or maybe it only raised questions. The main question that will guide you through this report is, "why?". This question should be asked much more often. Why are we designing this? Why do we want it in a certain way? The other "W" questions are as important as the latter. For Who? What? And Where?
Let's talk about the reason for shared autonomous cars to be here and what they should be.

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EXECUTIVE SUMMARY

Shared, autonomous, electrified vehicles (SAVs)– are expected to be the next most significant mobility disruption of this century. Not effectively steering this innovation could lead to undesirable effects on our society, lifestyle and behaviour. Therefore it is important to steer SAVs expansion in a desirable and sustainable way.
Existing SAVs-visions focus mainly on autonomous car technology and design. However, a more user-centered and holistic view is missing. The degree to which a SAV-system is aligned with users' needs, capabilities, and properties is essential for it to be accepted by users and society.

This graduation project aims to design a viable ecosystem for shared autonomous vehicles in 2040 from a user-entered and holistic perspective.
The project is executed within the Seamless Personal Mobility Lab and in cooperation with the Metropole Rotterdam- The Hague (MRDH).
The project explores the fundamental system elements needed to design a desirable SAV system to operate within the MRDH.

This research also shows relevant factors and criteria which could be used for further research in realising a desirable SAV-system.

Information about the user-centered vision for the ecosystem of SAVs, comes from expert interviews, user evaluations and desk research. Multiple visions were implemented in future user-scenarios. These scenarios were evaluated with users and then ultimately put into one main desirable system design.

In this proposed design system, there is an emphasis on **flexibility for users**, **fulfillment of different user needs**, and a **guarantee of privacy and control** within the vehicle.
User-needs for SAV systems vary per area. In cities, people mainly like to use SAVs for short distances and complex (chain) trips. Whereas in rural regions, people are more likely to use it for single commuting trips. In these rural regions, the coverage of PT is often inadequate. SAVs can play an important role here in increasing mobility. **A well functioning SAV system should be present in both the rural and urban regions.** This helps with creating scale and mass.

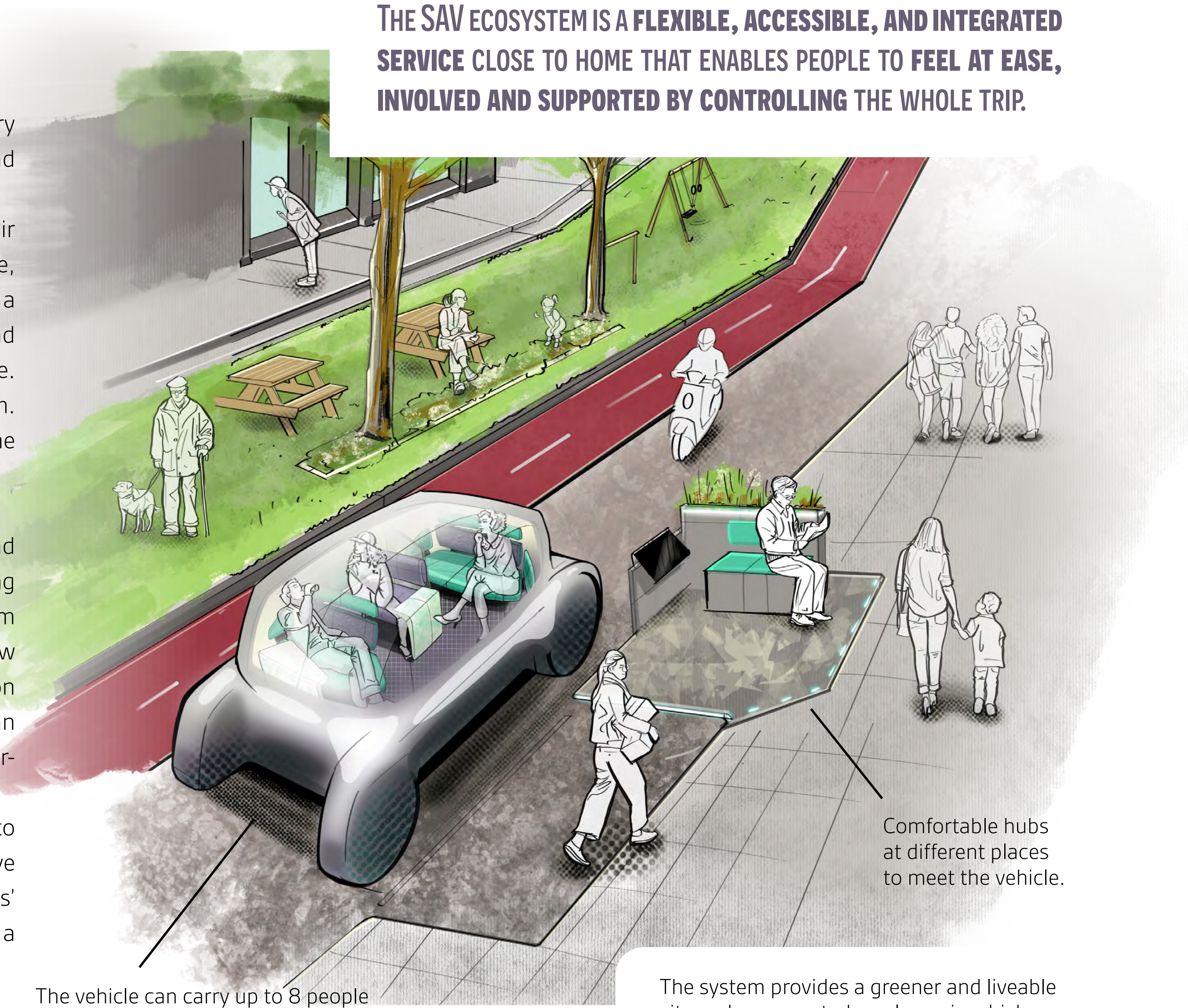
This future vision offers users a flexible, accessible, and highly integrated ride- and car-sharing service.
It promises people to feel at ease, involved, and supported by the service by giving them control over the trip and the interactions during the journey.
The goal is to motivate (private) car users to start using this system as a more sustainable alternative. As well as supporting public transport systems in areas where they are not or barely present.
The trips can be personalised, and many different needs are met in the interior of the SAVs. The user receives support and is involved with the trip, and has the ability to control their ride and request specific demands.
This system requires a continuous collaboration of government and industry.

From present innovations in the automotive sector and existing SAV-systems, we learned that standardisation and integration of services are crucial for user acceptance and can only be realised if the government regulates push and pull strategies for both industries and users.

To create a widely integrated system, industry stakeholders must share their knowledge and data.
Governments need to ensure there is a fair and accessible priced system. Furthermore, they should also provide the public with a continuous supply of vehicles, as more and more commuters become reliant on the service. Scale is essential in developing this system. Therefore European level roll-out could be the way to go.

As the system requires new infrastructure and services, governments need to keep using scenario-based methods. This will help them recognise changing developments and allow them to adapt their SAVs policies based on these insights. Additionally, future human needs should be monitored to maintain a user-centered perspective on the system.
A potential pitfall in the system would be to use an overly rational, and non-innovative approach. This would decrease the systems' appeal to the users, who are expecting a renewing and desirable way to travel.

THE SAV ECOSYSTEM IS A **FLEXIBLE, ACCESSIBLE, AND INTEGRATED SERVICE** CLOSE TO HOME THAT ENABLES PEOPLE TO **FEEL AT EASE, INVOLVED AND SUPPORTED BY CONTROLLING** THE WHOLE TRIP.



Comfortable hubs at different places to meet the vehicle.

The vehicle can carry up to 8 people and can create a private space or social space. This is critical for users to use the system.

The system provides a greener and liveable city and a connected rural area in which people have access to mobility

Motor Magazine, Annual Show and service number, November **1956**

1 Introduction

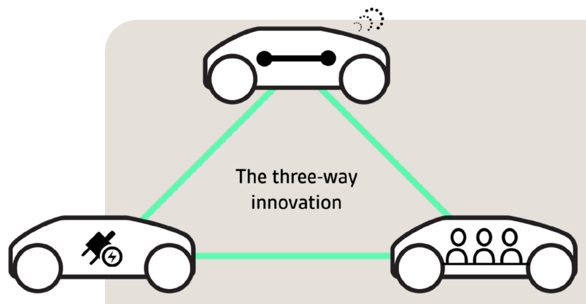
This chapter introduces this graduation project's topic – a shared autonomous vehicle ecosystem. It points out the project context, goal, scope, and approach. To provide the reader with all the necessary information to understand the project's starting point and desired endpoint.

1.1 Shared autonomous vehicles: a new transportation disruption

Our personal mobility systems will undergo a significant transformation with the emergence of electrified drivetrains, shared services, and autonomous technology (Sprei, 2018). We can already plan door-to-door transport, share various mobility modes, drive fully electric cars, and several vehicles can assist with some driving functions like automatic braking or parking.

Alone, sharing mobility, which can be both sharing a trip or a vehicle (Shaheen et al., 2015), will not disrupt our personal mobility system as much (Sprei, 2018). The **combination of shared mobility and autonomous technology** could make autonomous vehicles **financially feasible** (Narayanan, Chaniotakis, & Antoniou, 2020, p. 260). Therefore, this **three-way-innovation** – sharing, autonomous, electrified – is expected to be **the most significant disruption** (Sprei, 2018; Greenblatt and Shaheen, 2015; Walker and Johnson, 2016) (see figure 2).

Shared autonomous vehicles (SAV) could significantly impact our day-to-day lives and lead to more **equality** among people (Narayanan et al., 2020, p. 260) and provide **more convenience and reduce cars' usage and ownership** (Shaheen and Chan, 2015; Sprei, 2018) if appropriately designed. Governments and societies should be encouraged to **pro-actively engage and respond to these inevitable transportation disruptions**. If they do not, it could have **undesirable effects on cities and society** in the long term, such as changing infrastructure, lifestyles, and behavior. Therefore, it is necessary to **steer this disruption** in a **desirable way** (Sprei, 2018).



2. Electrification, autonomous and shared

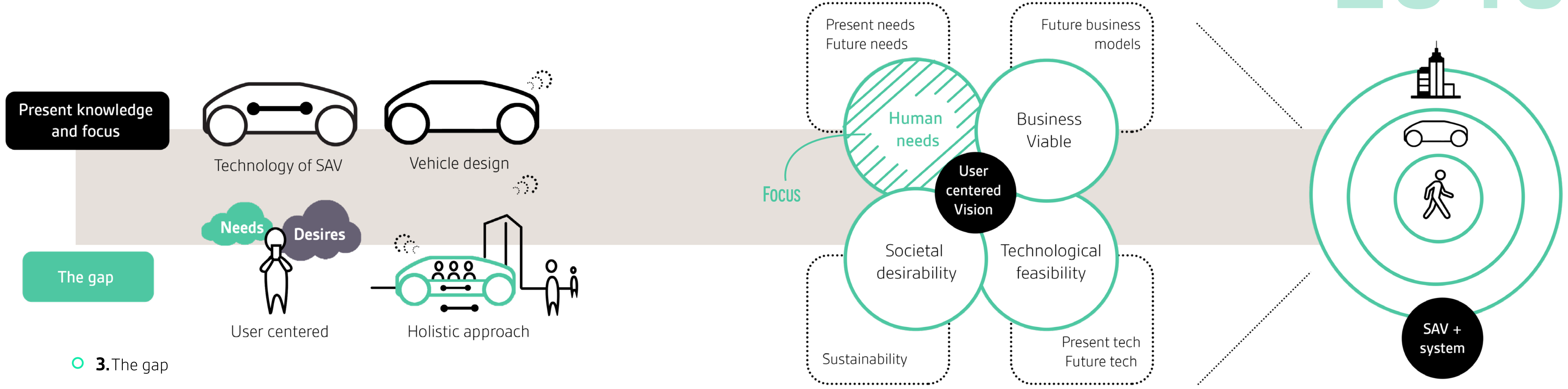
1.2 Design visions lacking holistic and user-centered approach

Concerning SAVs, the focus of automotive companies mainly lies in vehicle design and back-end technology. It makes sense to pay attention to vehicles' styling as this plays a significant role in societal acceptance, and no system can exist without the underlying technology. However, a user-centered and holistic approach is missing (see figure 3). This holistic view is needed to understand the complex stakeholder environment and all factors involved. The user-centered view is missing, such as thinking about interactions on board with the vehicle and other users.

For instance when looking at Mercedes-Benz' concept (figure 4), the F-015 luxury in motion, presented in 2015, the users are seated quite intimately. Users might not be comfortable with that, ultimately leading to discomfort and even people not using it anymore.

The degree to which such an SAV-system is aligned with users' needs, capabilities, and properties are essential for it to be accepted by users and society. Therefore, both a user-centered yet a holistic view is taken in this project.

4. Mercedes-Benz concept F-015, intimate set-up



3. The gap

1.3 Goal and Scope

This project aims to formulate **a user-centered vision for shared autonomous vehicles in the year 2040** and to design a connected **SAV-ecosystem** for the **Metropole region Rotterdam-The Hague** (MRDH).
The perspective of the users in combination with the advanced knowledge of stakeholders, will allow me to create **a user-centered solution that is feasible in terms of technology, societal desirability, and business feasibility**.

2040

1.4 Project partners

1.4.1 Seamless Personal Mobility Lab

The host of this graduation project is the **Seamless Personal Mobility Lab**, one of the Delft Design Labs (DDL), an initiative of the TU Delft Faculty of Industrial Design Engineering (IDE). The Seamless Personal Mobility Lab **explores the ideal user experience for future mobility services**. It works together with different stakeholders to develop solutions that match both traveler's and stakeholders' needs. Together they translates insights from various research studies into solutions that can contribute to solving some of the current mobility problems in The Netherlands.
Suzanne Hiemstra- van Mastrigt is currently the Lab Director and my graduation chair. **Jasper van Kuijk**, advisor in the Seamless Personal Mobility Lab, is my mentor for this graduation project.

1.4.2 Project stakeholders

The Seamless Personal Mobility Lab works with transport operators, mobility companies, government, and technology developers. As the problems differ per project, relevant partners are gathered for each project. The main partner in this project is the **Metropole Region, The Hague - Rotterdam**.

Seamless Personal Mobility

METROPOOLREGIO ROTTERDAM DEN HAAG

1.5 Project approach & report outline

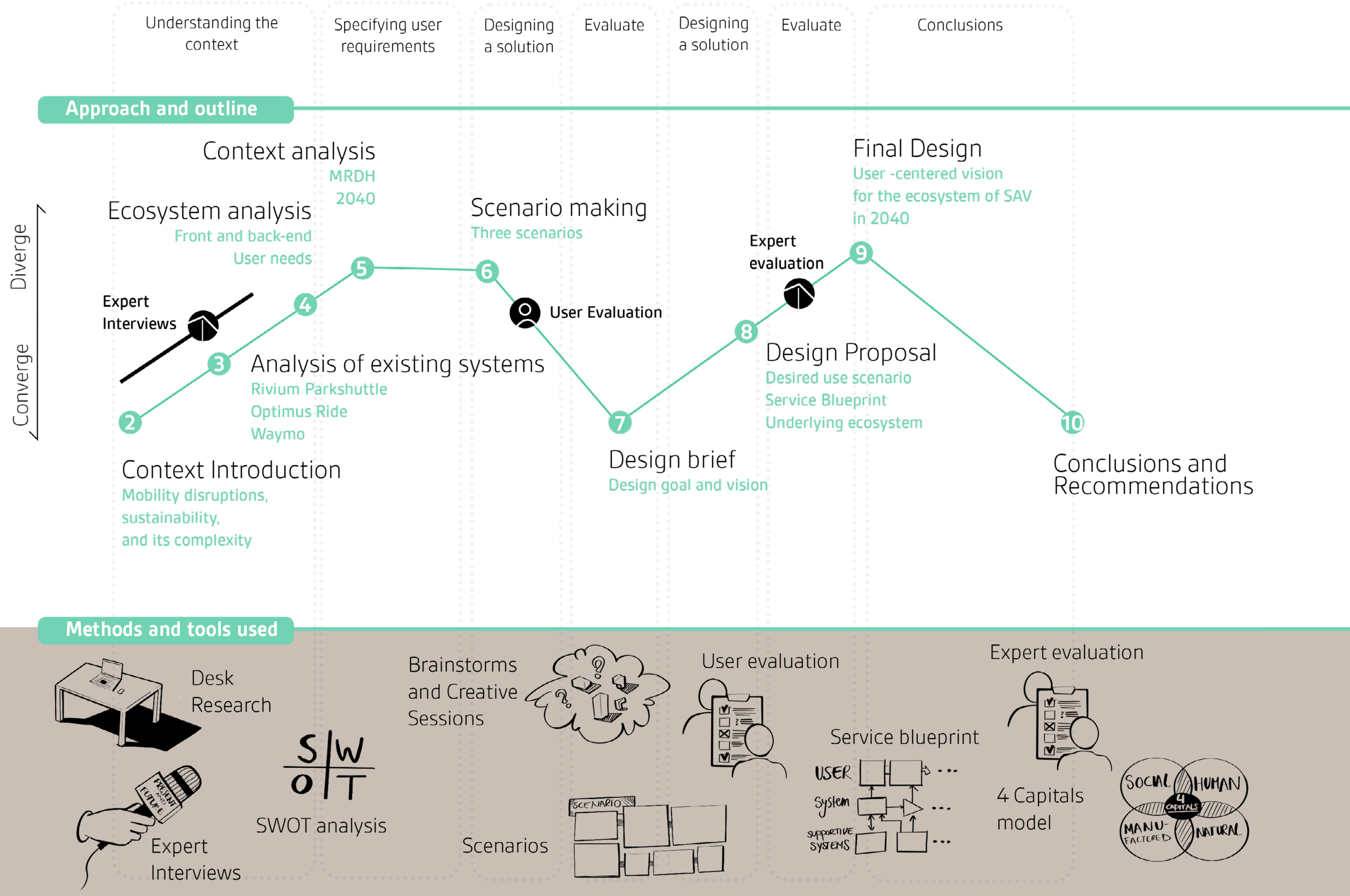
The **user-centered design approach** is mainly about analysing users and their needs. With this approach, there are four stages to approach; understanding the context, specifying the user requirements, designing a solution, and evaluating conditions (Interaction Design Foundation, n.d.). These four elements are shown in the top part of figure 5 is used iteratively, some steps are repeated.

In chapter 2, insights were gathered from similar **disruptive innovations** within the automotive context. In chapter 3, **existing SAVs** were analysed to gather insights. In chapter 4, **ecosystem elements** are explored to understand the complexity. The system's components are broken down into parts and analyzed using experts and desk research (see figure 5 for the methods and tools used). Comparisons are made with various existing mobility modes to identify possible gaps in needs using **SWOT analysis**. In chapter 5, **present** and **future context** elements are identified and created into a future framework used to build up **scenarios**. In chapter 6, present and future analysis and a **morphological map** are used to systematically build-up **three explorative scenarios**.

A scenario-based approach is chosen because it shows both the user needs and also shows the holistic view. Thereby scenarios are perfect for dealing with uncertain futures.
In chapter 6, also, **scenarios are evaluated** with users fitting these personas to narrow down to a system design fitting to the future needs. In chapter 7, all insights are concluded and the desirable **SAV- vision** is described.
In chapter 8 the design and system **proposal** is created, and gathered in a **service blueprint.** This is **evaluated with experts** to understand if it could be feasible, viable, and desirable.
With these insights, the final recommendations are made for all stakeholders involved.
Chapter 9 will **showcase the final design** and a **roadmap** for implementation. In chapter 10, all **recommendations for stakeholders and next steps** are concluding this project.

In figure 5, a general overview is given of the approach and the structure of this report. A more extensive explanation of the methods and tools used can be found in appendix A.

The user-centered approach is shown in the top part of figure 5. In the middle section, the chapters are shown in the green dots. The methods and tools below show the approach used in each phase of the project.



5. Overview of approach and report outline with used methods and tools

2 Context

Mobility disruptions, sustainability, and its complexity

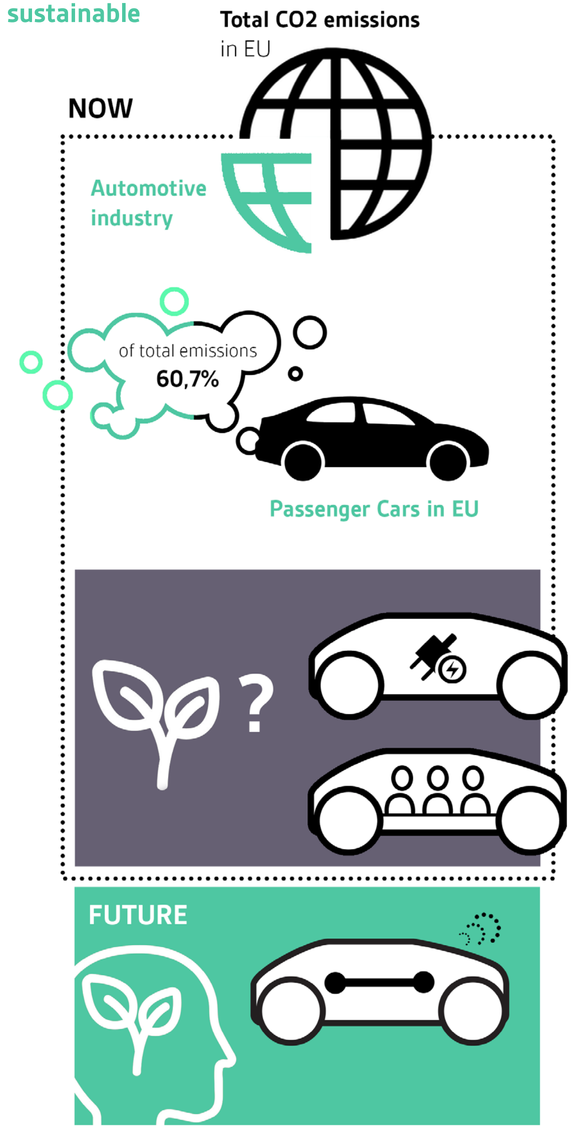
This chapter explores the current disruptions; electrification and sharing services. It explains how these innovations are stimulated and how we can learn from them to design an SAV-system that is desirable for a sustainable future context . It finishes by explaining how to approach this complexity with all stakeholders and how to define what is desirable for the future.

2.1 Current disruptions, electrification and sharing services

2.1.1 The urge for the mobility industry to be more sustainable

The automotive industry can be held responsible for a **quarter of the world's global CO2 emissions** in 2016 (Capgemini, 2020), see figure 6.

Passenger cars are a significant polluter, with **60.7%** of the total CO2 emissions from all road transport in Europe (European Parliament, 2019). The industry experiences pressure from governments and society urging them to change towards a more sustainable industry (Capgemini, 2020). Currently, there are two implementations of sustainability efforts noticeable by the general public, these are **electrification and sharing cars services** (Shaheen and Chan, 2015; Sprei, 2018). Both innovations can have a positive effect on CO_2 emissions. The **overall lifecycle** of **electric cars** is perceived as **more sustainable** than conventional engines (Rijksdienst van Ondernemend Nederland, n.d.), although other **resources doubt that** (Capgemini, 2020). **By integrating electric cars as batteries in our energy distribution system in cities, we could better cope with peak and non-peak hours** (appendix, Ton Venhoeven). Also, sharing cars could lead to less ownership and fewer cars might be required if people are willing to share vehicles and even rides.



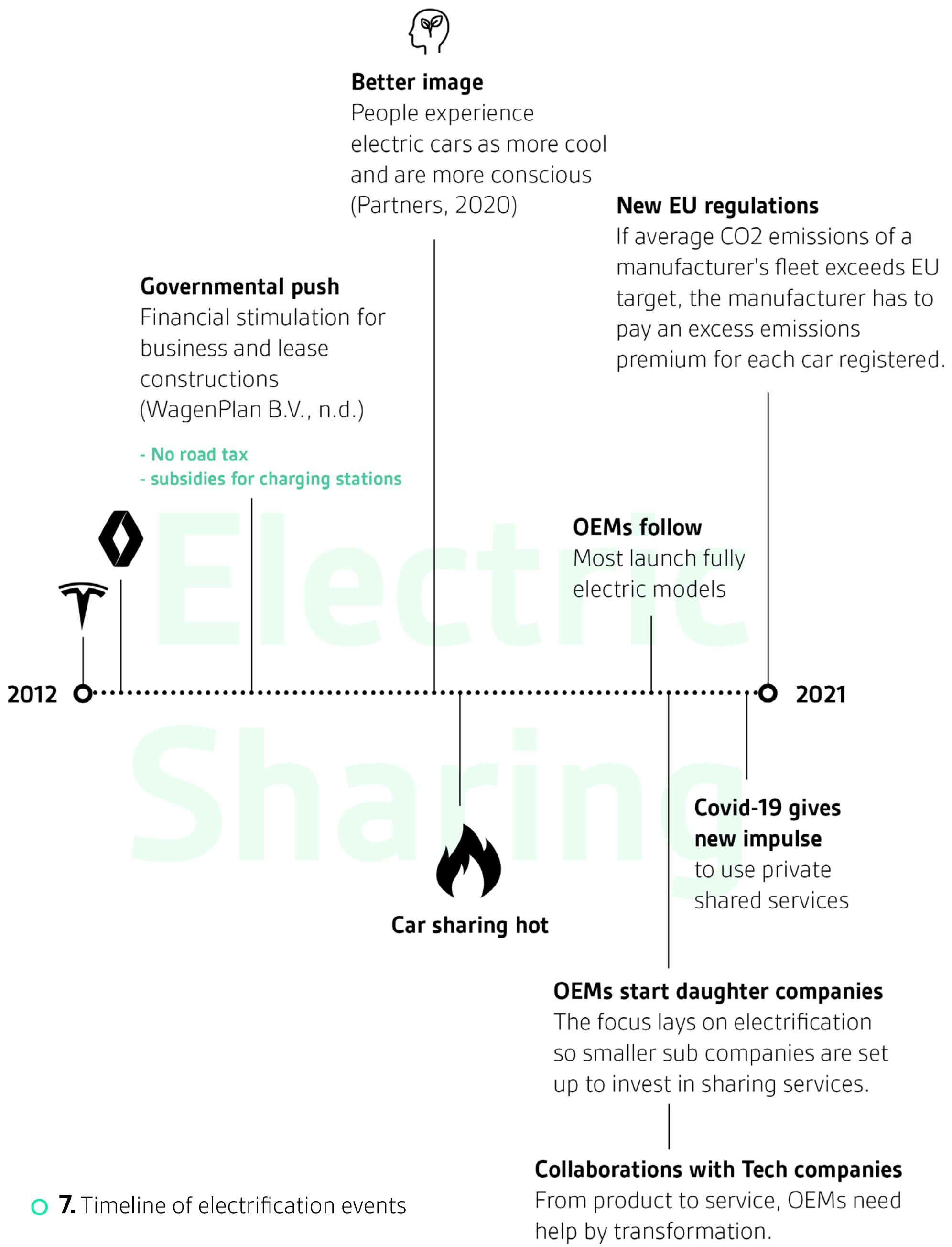
6. The need for a sustainable mobility system

2.1.2 Past events concerning electrification and sharing

In figure 7, a timeline of events shows an overview of the developments for electric cars and sharing services. At the top part the electrification events are shown and in the bottom the events of sharing services.

For years, fully electric cars from **original equipment manufacturers (OEMs)** did not exist. Tesla pushed the market with the model S and Renault was one of the first OEMs with the Renault Zoe. The European electric vehicle market has grown since. **In January 2021**, the **European union pushed OEMs to switch to electric drivetrains** by regulations (the European Union, 2017) which resulted in more electric models.

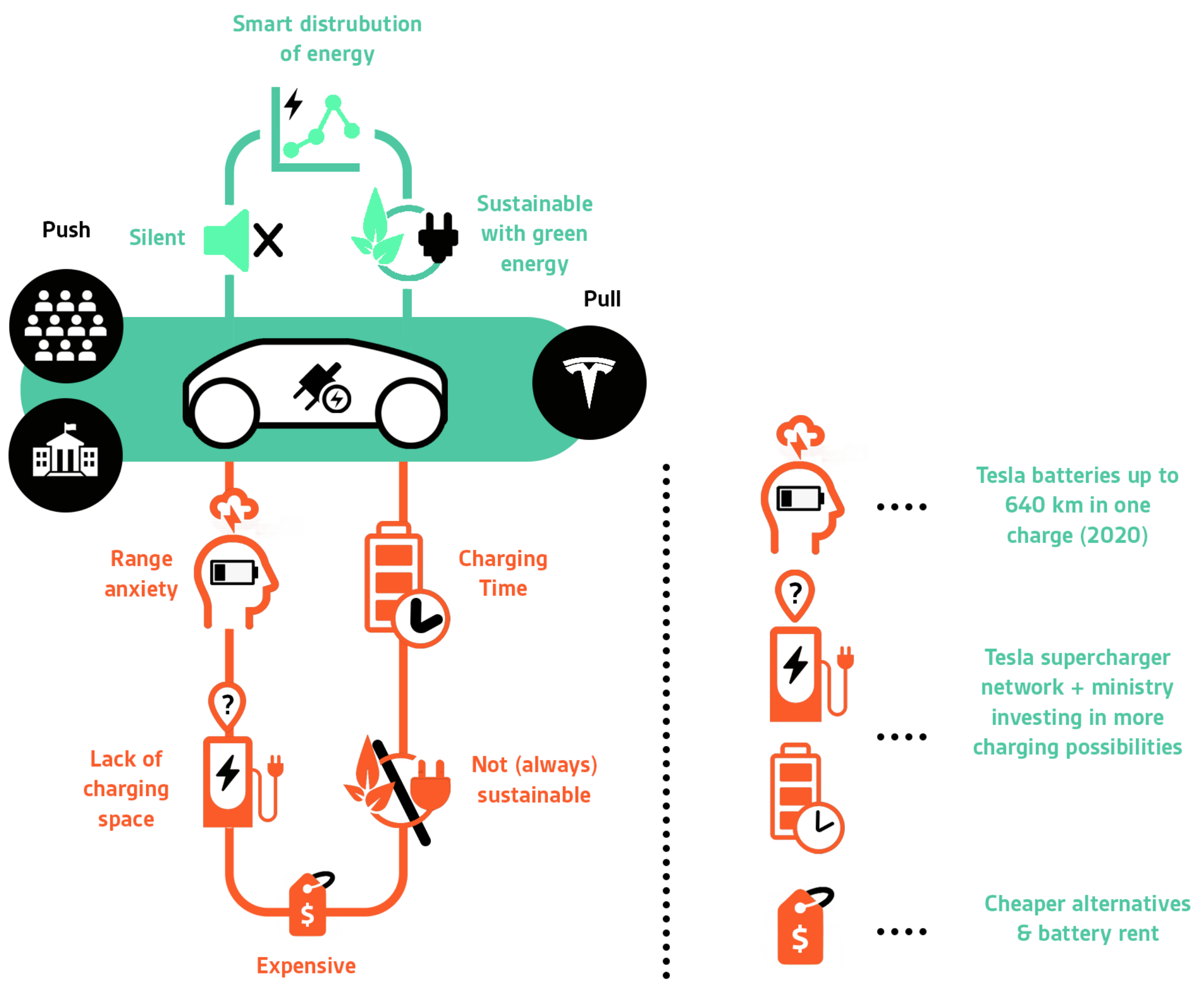
Carsharing was booming two years ago, resulting in more services being created. But when the hype stagnated, partnerships disappeared. However, during the Covid-19 crisis, carsharing services, such as Greenwheels, saw a resurge of users, as more people wanted to travel by car than by train (appendix, Bard). Also, stricter **parking regulations** in dense cities, created this need. It can **take years to obtain a parking permit** in the city of Amsterdam (appendix, Bard).



7. Timeline of electrification events

2.1.3 Lessons learned: Electrification of cars

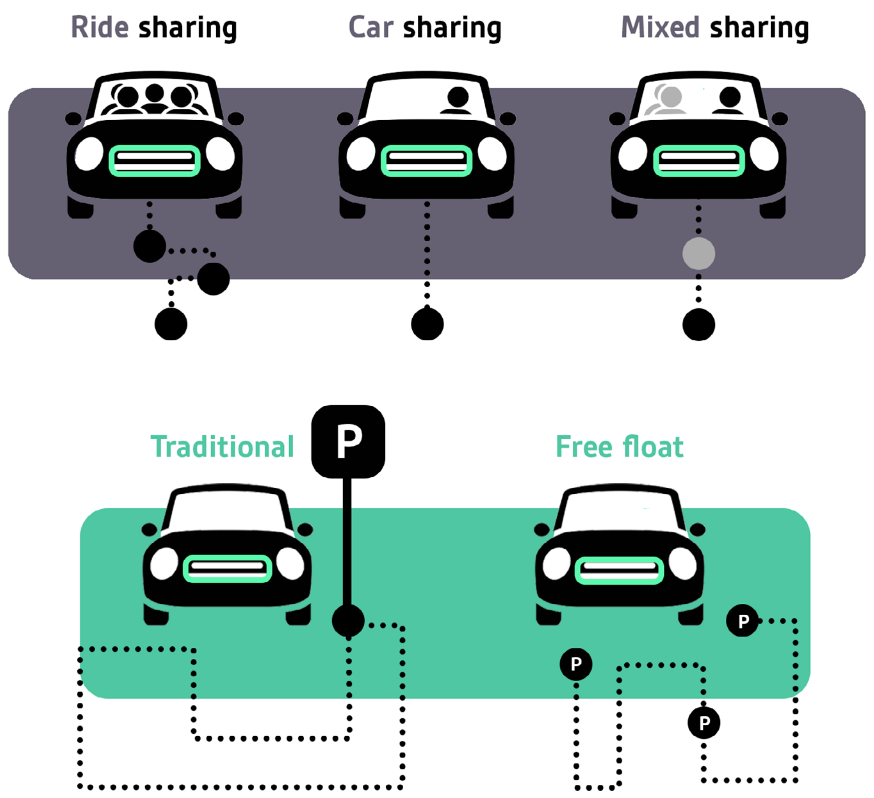
For general users, there are some inhibiting factors when it comes to using electric vehicles. The main **bottleneck** for most users is the **vehicle's range limit and charging duration**. Figure 8 shows these inhibiting factors, as well as the more positive benefits of electric driving. However, most of these **limiting factors are or will be solved** by faster and more charging opportunities. These are shown on the right side of the figure.
Tesla but also the Ministry of Infrastructure and Water Management are **speeding up charging stations'** capacity (Ministerie van Infrastructuur en Waterstaat, 2020). Although this is a positive change, there is still a **compatibility problem** in the EU regarding **charging plugs.** Car manufacturers should have had **consensus** about which charging system to use, to make electric cars more accessible. (Charging Cable and Plug Types | Knowledge Center, n.d.). Within Europe, **multiple plugins exist** which makes one system for charging not enough according to one expert from Renault (Appendix A5). In appendix A1, more information can be found that explains the elements in figure 8.



8. Benefits and limitations of electric cars

2.1.4 The different sharing types

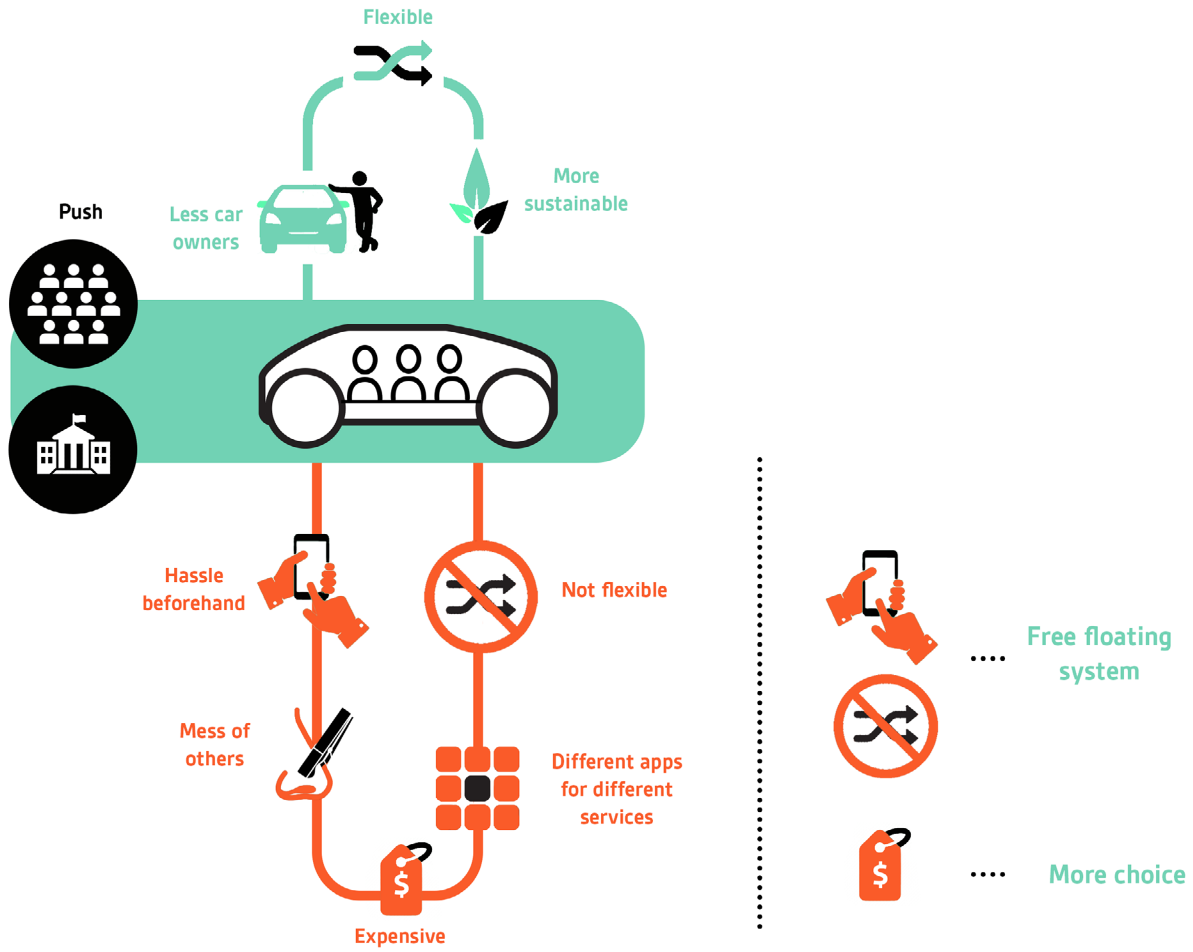
At the moment, different sharing services exist, see figure 9. Three main forms of sharing service systems can be identified: **ride-sharing, carsharing, and mixed systems** (Narayanan et al., 2020, p. 260). When someone is **sharing their ride** with someone in the same vehicle, it is called **ride-sharing**. When **only one person is using a vehicle** that can be shared, it is called **car sharing**. Here the distinction can be made whether the car is owned by a company or by a person. For a **mixed system**, **users can choose between using the car alone or share it with others**. When talking about sustainability, the more people ride in the same vehicle, the better. It would be better if people would share the ride or take the a bike for instance. At the moment, most cars are occupied by one person at the time. If only this number would be doubled, this would improve the carbon emissions significantluy. At the moment, two different system exist **traditional systems** and **free-floating systems**. With a traditional system, the car is parked at a certain spot and should be returned to this spot, with a **free-floating system**, the car can be **picked up and placed everywhere** (Dieten, 2015). Most existing systems in the Netherlands are **carsharing systems and both traditional and free-floating systems exist**.



9. Different car sharing system at the moment

2.1.5 Lessons learned: sharing car services

A bottleneck for users to use a shared service is the **flexibility related to reservations,** see figure 10.
Also the **idea that other people would use** it too and the **price** (Gemeente Leiden, 2017) are important factors. Sharing vehicles sometimes require some effort for the user. Most companies work with a **reservation-based platform**, and tell users to return the vehicle to a fixed spot (Kennisinstituut voor Mobiliteitsbeleid, 2015). As well, different services cannot be used with one app. You have to **install and use different apps**, according to an automotive expert from the Volkskrant (Appendix A8). **Maintenance and insurances** are included, you do **not have to worry about parking** either. However, these make the services **fairly expensive**. Also, shared vehicles are **vandalized more often** than private vehicles.
People use shared cars a replacement of a second or third car and use them for incidental use. Around 10% of the rides is between peak hours in the morning and 3% in the evening peak hours (Kennisinstituut voor Mobiliteitsbeleid, 2015). At the moment, the sharing services do not replace the commuting travels and only reduce the ownership of second and third cars. However, **the number of kilometers traveled by car will be reduced when more people use sharing services** (Kennisinstituut voor Mobiliteitsbeleid, 2015).



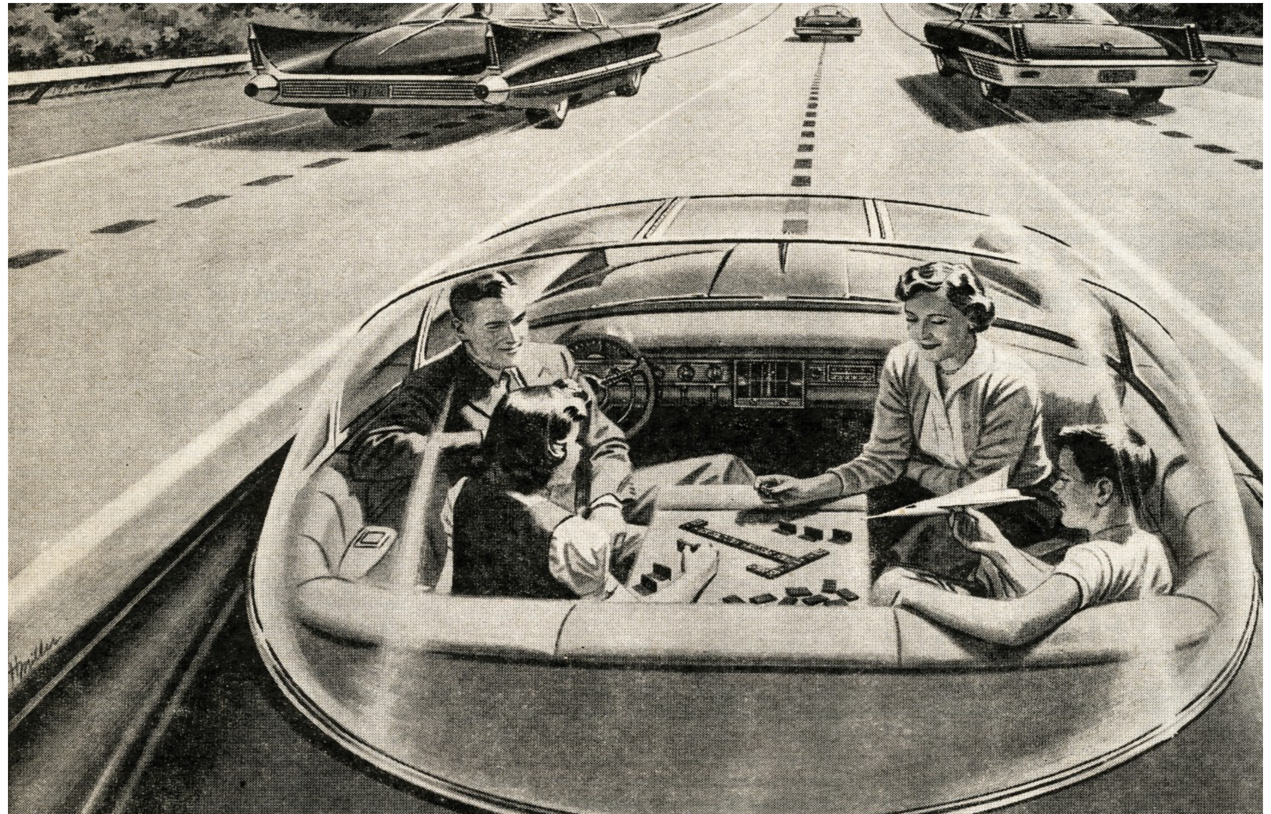
10. Benefits and limitations of sharing services

2.2 Expected disruption of shared autonomous vehicles

2.2.1 The idea of being driven

The idea of being driven by a car with an invisible driver is not new. In the **1920s, cars were already showcased that had no driver**, and in the '50s, an advertisement of General Motors was shown of a family in a self-driving car (see figure 11). It shows entirely what impact they expected for users: enjoying some family moments.

This innovation will not be far away as already, **many aspects of the self-driving future are implemented**, such as lane-keeping technology and self-parking modes (appendix, laurens). However, the **three-way-innovation of SAVs will be the most significant disruption** (Sprei, 2018; Greenblatt and Shaheen, 2015; Walker and Johnson, 2016) and will have a **substantial impact on city design, residential planning, employment, recreational locations, road parking, and bicycle and pedestrian infrastructure** (Duarte & Ratti, 2018, p. 7). In a world where autonomous cars have to **sense their surroundings and communicate with others**, new and different **technological and infrastructural elements** are needed (Duarte & Ratti, 2018, p. 7). It could **change our car-use-habits** and could lead, without regulation, to **undesirable effects**. It might stimulate to go by car, resulting in more traffic. It could also cause people to live further from work and therefore travel more. It could also reduce these effects and even lead to a more pedestrian-friendlier environment (Duarte & Ratti, 2018, p. 7). The impact it could have is still unknown.



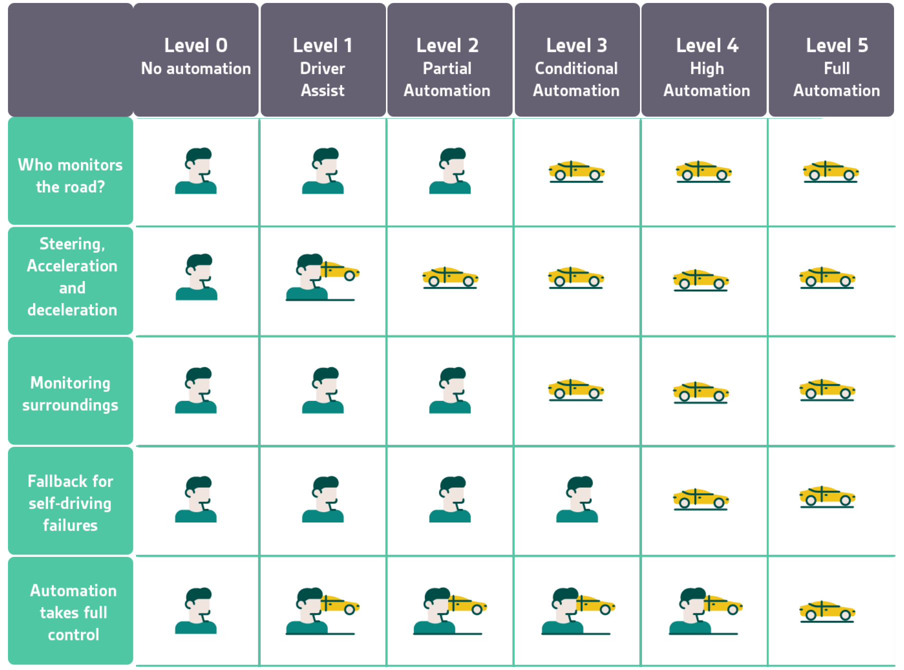
11. Image of a vision of a family playing a board game in their self-driving car in 1957

2.2.2 Stimulators of autonomous driving technology

AVs are **highly stimulated by the market** and, in particular, by OEMs, such as Volkswagen and Renault. Although the focus lays on electrification first, they are investing in autonomous technology and working together with different tech companies, the volkskrant expert noted (Appendix A8). The focus is to **increase the safety** and to become safer than humans, according to head of Design at Reanult (Appendix A5). Aside from technology, the **ethical aspects, insurances, legal issues** are being developed and evaluated. But as the technology is new, **institutional void**, which means there are no strict rules yet, **creates space to experiment and try new ways** , according to an infrastructure professor (Appendix A9). However, some experts stated that this void is actually inhibiting innovation. The Audi A8, that came out in 2020, could have had a level 3 system upon 60kp/h if there was a legal framework for level 3 automation. This **would have allowed drivers to do other activities before taking control back** (Autovista Group, 2020). Also, An expert from Systematica (R. Choubassi, personal communication, October 7, 2020) says that the technology is there in 2021 but only the legal framework is lacking. In appendix B3, a full analysis is given of the different collaborations and developments.

Levels of autonomy explained

There are 5 levels of autonomy and cars without autonomy. In figure 12 the levels are explained in how many autonomy features are involved and what is expected from the driver or passenger.



12. Levels of autonomy explained, picture from nhtsa https://www.nhtsa.gov/technology-innovation/automated-vehicles

2.2.3 Prejudices of autonomous cars wiped out

SAVs will be too expensive

The **costs are important** to consider for autonomous vehicles. **Uber is highly interested in AVs** because they want to get rid of the driver. The **driver is about 75% of the costs of running a taxi service**. So, although an autonomous vehicle could be expensive, the **return of costs can be reached in two years, according to the Renault expert** (Appendix A5). So, the price of autonomous vehicles is not the most important anymore. Moreover, sharing the vehicle makes its use **financially feasible for more people** (Narayanan, Chaniotakis, & Antoniou, 2020, p. 260). In chapter 4.7.2 more is written about prices.

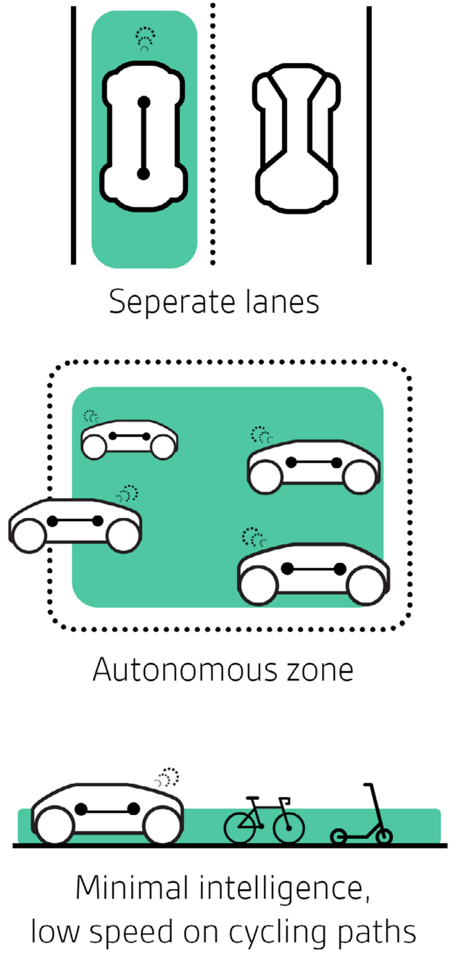
Will we ever reach full (level 5) autonomy?

Although many companies working on autonomous technology, most get stuck on **level 2** (B. van de Weijer, Appendix A8). The autopilot of Tesla models is able to drive partially automated (level 2). The problem though between level 2 and level 4 is the **transition for users to take over control**. This transition or interaction, could be **dangerous if not fully attuned** to each other. In case of SAVs, a fully autonomous vehicle is needed because multiple people will use the vehicle.

Aside from private cars, there are level 4 autonomous vehicles operating. The high level of autonomy is reached because they **minimized the factors involved such as intersecting other traffic, low speed and accessibility, and human interference**. Those vehicles will be explained in the next chapter and more about the technology of autonomous cars can be found in appendix B4.

A SAV cannot operate in the city

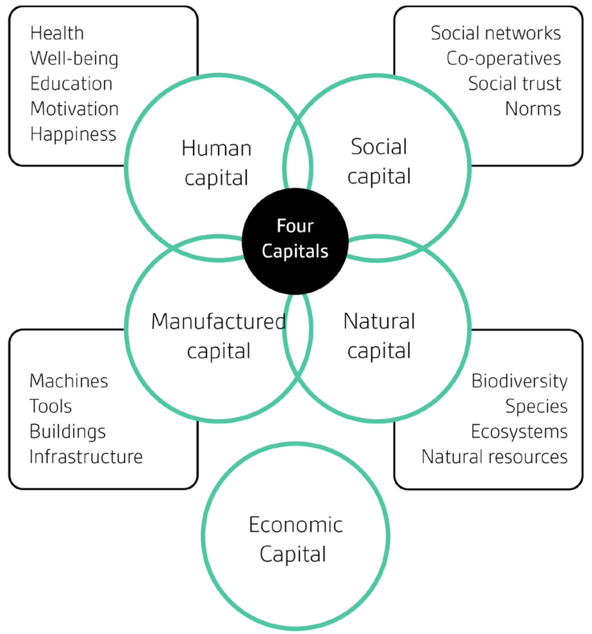
The development of **autonomous vehicles are a step by step process,** according to both the Renault and 2getthere experts (Appendix 5 and A7). We start by **driving autonomous on highways** and create **first and last mile solutions in restricted areas,** says the 2getthere expert (Appendix A7). In cities **lanes can be seperated** (see figure 13 in the top) and eventually **city AVs will be there,** according to the automotive expert (Appendix A5). Before 2040, autonomous zones can be created **for AVs** only (figure13). The **vehicle could return to another AV zone with minimal intelligence** when driving at **low speed** (figure 13). It might even be possible to let them **drive on the cycling pathways** if they are narrow. By decreasing the complexity it is possible.



13. Different spatial possibilities to decrease complexity for AVs

2.2.4 Measuring sustainability for SAVs

It is **not fully clear** how autonomous vehicles could **contribute to a more sustainable life** and how **society can benefit** from this new innovation. **Sustainability can be defined as a world wherein human, social, manufactured, and natural capitals are balanced**, these **4 capitals are called the Four Capitals model** (Ekins et al., 2008, p. 72). Economic capital **represents the value of natural, human, social and manufactured capital** and enables the other types of Capital to be owned and traded, therefore Economic capital is placed outside the four circles. The model can be seen in figure 14 and can be used as a tool to evaluate whether a design is "sustainable" on all capitals. The goal is to increase all or most capitals, than a product or service is "more sustainable". More about this model can be found in Appendix A13. The sustainability of SAVs depends on **how we use the systems**. **Three possible use mechanisms are identified that have impact** on the use of SAVs and therefore the sustainability of the system. Those are shown in figure 15 and are evaluated briefly, to give an example, based on the Four Capitals.



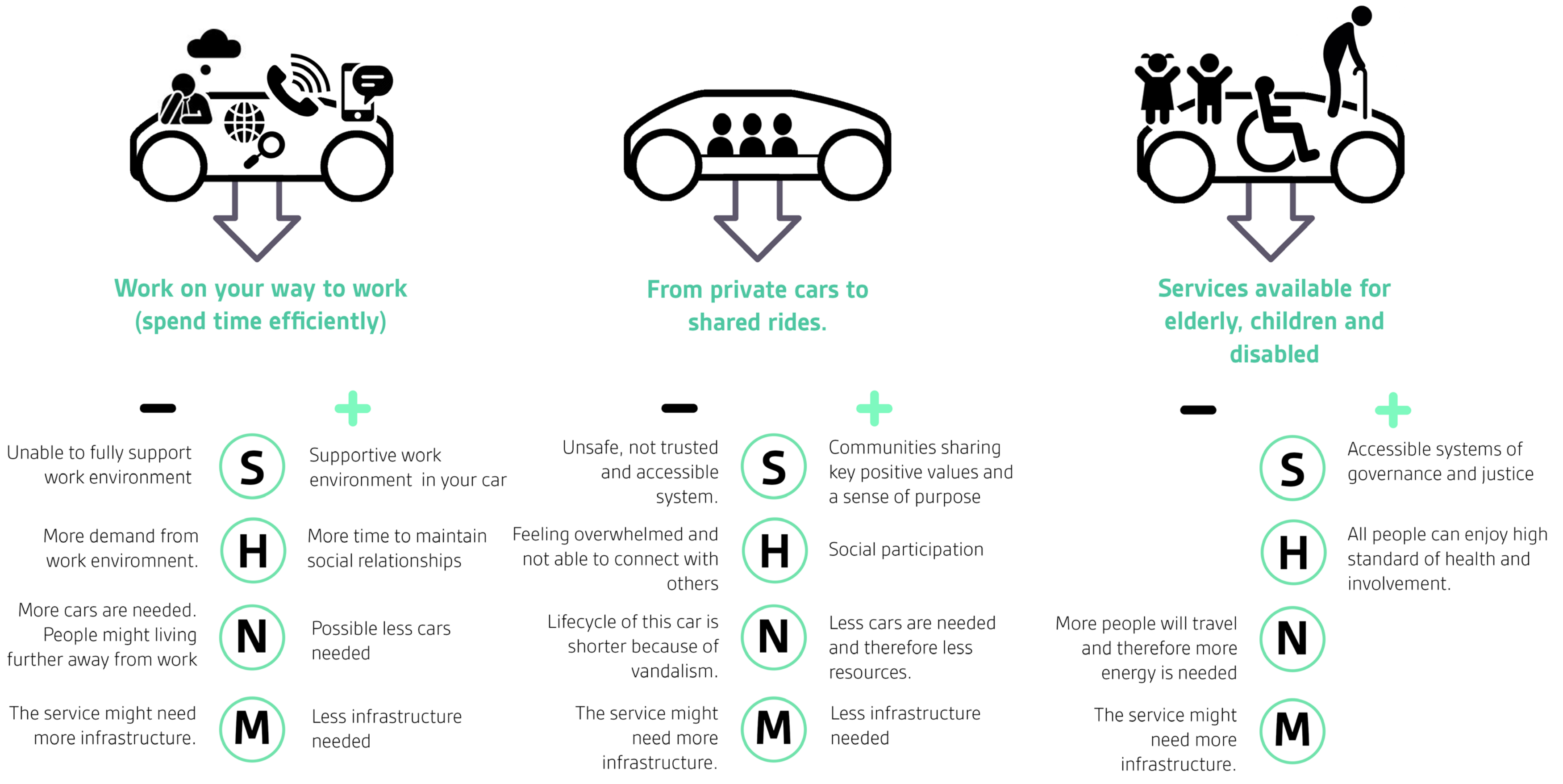
14. The four capitals model (Ekins et al., 2008, p. 72)

The first is that it enables people to **combine more activities during the ride** resulting in spending more time in their vehicle. Such as business calls and other working activities. It could lead to higher traveling distances **as people could live further from their work with more space around them and travel for the same time of more efficient**. Therefore, it could **lead to more recreational trips**, going back and forth from cities to rural areas (Williams, Das, & Fisher, 2020).

Second, the **willingness to share a vehicle**, which could **lower the price** and therefore **increases the accessibility** for people who could not afford it before.

The third, more people, such as **children, elderly and disabled**, can use such a system.

By evaluating these 3 developments with the Capital model, it becomes more clear whether a strategic investment should be made and if it could be sustainable. Many **different factors are involved and the direct and indirect impact** can only be estimated.



15. The four capitals model

2.3 Conclusion: designing for a complex, uncertain yet sustainable future

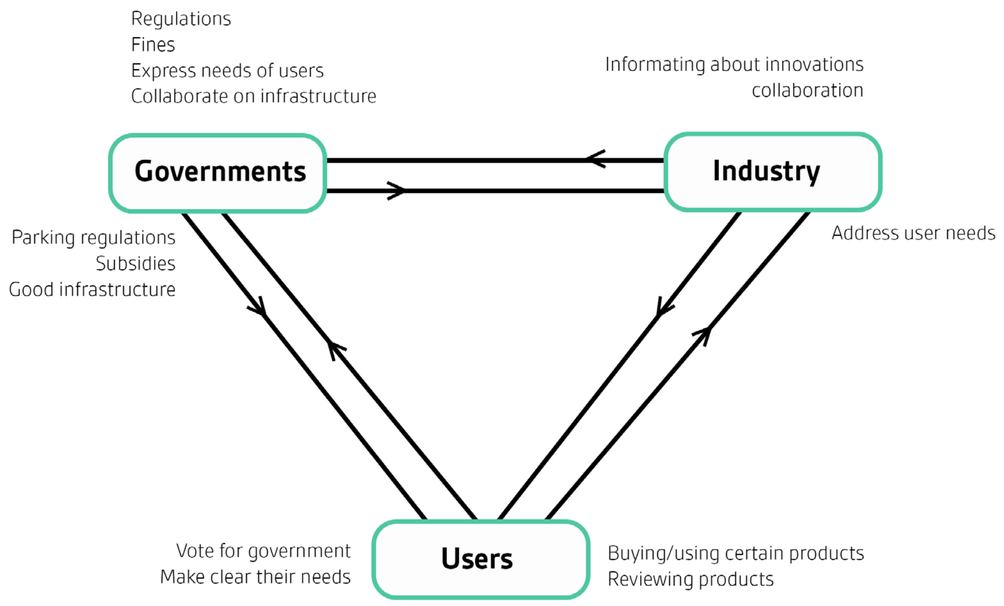
The main goal for our future mobility network is to **reduce carbon emissions yet maintain a sustainable and desirable** system for **users.** We learned from electrifying and sharing services that the **government plays an important role** in **pushing** (**financial regulations** for users and **fining** the industry) and **pulling** (**facilitating, paying for good infrastructure, regulations for new innovations)** towards these sustainable innovations. However, the **pulling strategy** is mostly lagging behind which makes the systems insufficient, looking at the user experience and usability. The pulling strategies are not widely used as they might need **high investments and involve higher risks regarding innovations in infrastructure** which could be recouped after years. To create a sufficient system, **governments, industries and users should collaborate,** see figure 16. This sounds easy, however, this is the most complex issue. **Users should be involved** by product and service development of the **industry. The industry** should further **collaborate with governments** to ensure **all infrastructure and regulations are in line** with the innovations happening. Also, different governments and companies should unify their systems to create a seamless travel, nationally and internationally.

To approach the complex problem holistically, **the whole ecosystem** and **its impact on the world** should be considered.

The **three main components in the ecosystem are the user, the vehicle and its context**.

The Four Capitals approach is used to assess whether the desired ecosystem really addresses a sustainable mobility network.

In the next chapter, existing SAV-systems and pilots are analysed to see how these work and what we can learn from it.



16. Collaborations mapped for governments, industries and users

Insights for the design

Ride or mixed sharing system
In order to make impact, a ride sharing system is wanted to increase the number of people in one vehicle in one ride.

A free float system is desirable
To guarantee feeling of flexibility.

One place to find all sharing services
To have a clear overview of all different services in one app

SAVs should be fully autonomous
As level 1 to 3 will not work in shared context

Autonomy can be reached in 2040 with
Separate lanes
Autonomous zones
Low speed

3 Existing SAV-systems

This chapter shows existing SAV solutions and explains how they work. The goal is to learn from these systems and get an understanding of the system elements involved. Existing fully autonomous shared systems in the MRDH and in the United States are discussed.

3.1 Why exploring existing systems

Three different systems are explored to **understand elements involved** in the systems. The **goal is to find design insights** relevant for a new SAV-system.

Rivium Parkshuttle is chosen as a Dutch example within the MRDH. This system exists since 2006 and some user research is done into the system trying to find out how users experience it. It rides on a track and serves as a connection from PT to certain areas.

Then the Optimus Ride is analysed. They are driving around in different areas in the US. The designers of Optimus Ride have a clear vision on how the interactions in the vehicle should be. Their vehicles are designed to bridge the first and last miles.

The last example is the Waymo robot taxi. It is now operating in the US testing with "real" passengers (within a certain group of people) in a certain geofenced area. Their service is quite standalone and used as a regular car.

3.2 Rivium Parkshuttle

Rivium ParkShuttle is an SAV operating between the metro station Kralingse Zoom and Rivium business park in Rotterdam, see figure 18. Technically, it is a **ride sharing, integrated and on-demand SAV-system**. The shuttle is unique because it is the only European SAV that is **intersecting other traffic**. The shuttle keeps lane by magnetic marks within a demarcated route. It is operational for over 10 years now and is run by Connexion. Future plans of the parkshuttle can be found in Appendix C1.

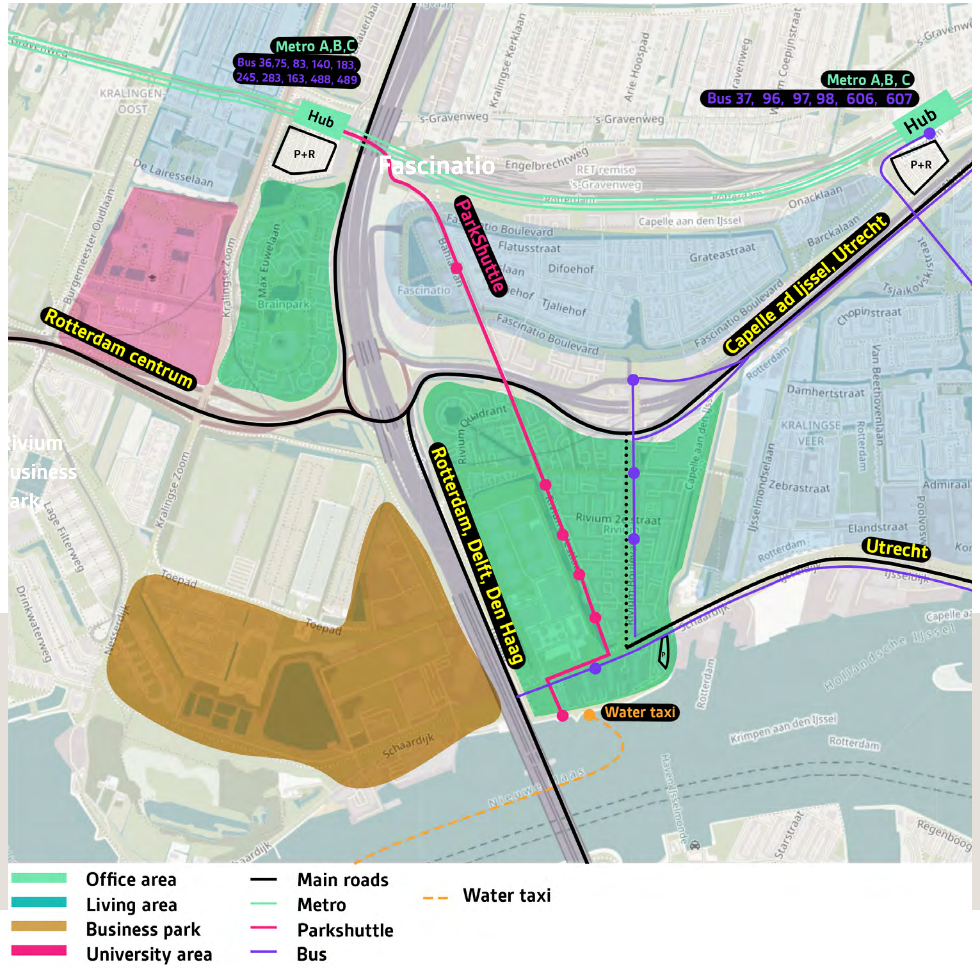
3.2.1 Reason d'être Parkshuttle

There was a clear problem the SAV could solve. The businesspark Rivium was an easy-to-reach location for cars, but now **deals with 30% vacancies** (Gemeente Capelle aan de IJssel, 2016). The bridge next to the area has become a bottleneck for traffic accumulating at that point and the area was hard to reach by PT. The bus going to the area makes a detour and between the Kralingse Zoom and Rivium (1km) an extra bus would not be feasible. The MRDH wanted to **stimulate the use of PT** and improve the **accessibility** in the area of Rivium, including the living area Fascinatio, shown in blue in figure 17.

3.2.2 Integration to other PT

The SAV-system is highly integrated with public transport at Kralingse Zoom. It is easy to transit from shuttle to metro, bus, car or bike there. Also at Rivium, a bus from Capelse Brug stops closeby and the water taxi can be reached. Thereby, the park shuttle can be used with a **regular OV-chipcard**. Integration is seen **as one of the successfactors of a sharing service** by Kennisinstituut voor Mobiliteitsbeleid (2015).

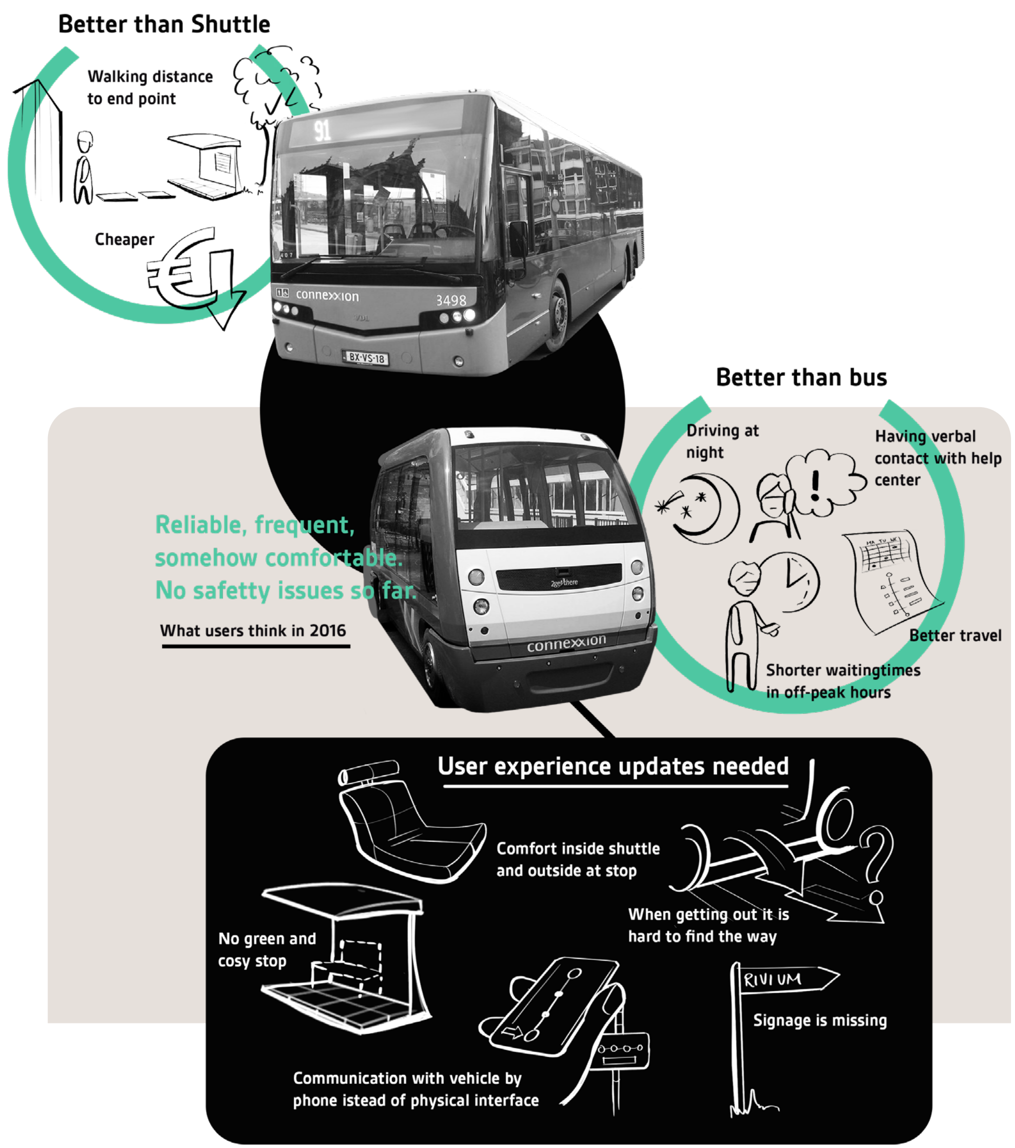
18. The New Transdev parkshuttle made by 2GetThere



17. Overview of area around the Parkshuttle indicating PT lines and highways

3.2.3 User experience of the Parkshuttle

In 2000 and 2016, users were asked to give their opinion about the shuttle. In figure 19, an overview can be found from the results of a study by Except for the municipality of Capelle ad Ijssel (2016).This research did not take into account the personal characteristics of the users. Overall, people were **quite satisfied about the shuttle**. **No safety issues** were mentioned and the **shuttle felt reliable**. From another research (van der Burg, J., 2018) it was found that gender did not play a role in the "ease of use" of the shuttle. **Reliability was an important factor** for the ease of use. The reliability of the shuttle was due to its **punctuality and high integration with the other PT**. In the bottom of figure 19, in the black box, design elements are shown that could be upgraded.



19. Overview of insights from research into Rivium Parkshuttle

3.3 Optimus Ride

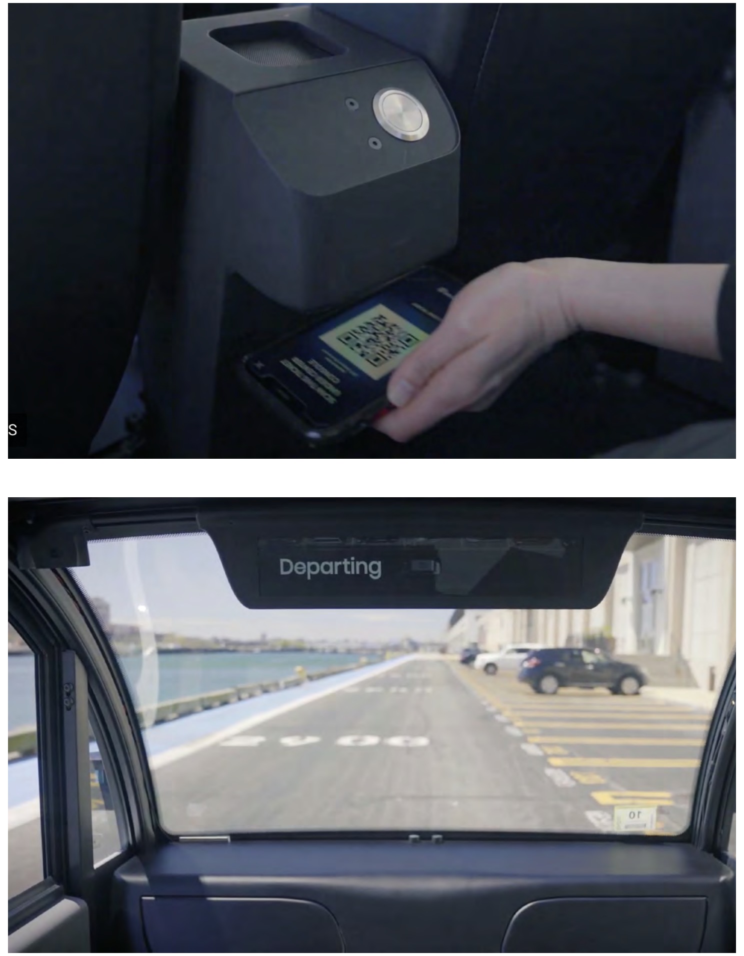
Optimus Ride is collaboration of the Massachusetts Institute of Technology and Microsoft and develops SAV-systems **focusing on first and last mile connectivity**. Their goal is to facilitate an **easier transit to public transport** to increase the usage of it. They use **geo-fenced** technology, three Velodyne LiDAR sensors and eight cameras. The vehicles can detect people and objects, as well as calculate the speed and trajectory of those objects (Crowe, 2020). The vehicle's on-board computer system determines how to drive to its destination. The technology enables a **smooth pick- and drop-off flow with low speeds.** Optimus uses modified **six-seat electric buggies manufactured by Polaris**, which two of the seats occupied by a safety driver and an engineer, see figure 20.

Optimus Ride has deployed self-driving systems in the following locations: Boston Innovation District, Brooklyn Navy Yard, Halley Rise (Reston, VA), and Paradise Valley Estates (Fairfield, CA). In Boston and Brooklyn New York, the Optimus Ride drives around a certain area. Halley Rise is a campus and Paradise Valley Estates is a 55+ independent living community (Optimus Ride, 2020).

20. The Optimus Ride driving around in Brooklynn and technicians sitting in front.

3.3.1 Interaction on board

The vision of Optimus Ride is to provide a **"Virtual Ride Assistant" (VRA)** that **enables interaction between riders, the vehicle and the remote assistance team**. The VRA provides audio-visual tools for riders to be informed of the system, request changes in destination or routing, and to contact Optimus Ride's remote assistance system. In figure 21, you see the person checking in the car to pay for their ride. In figure 21, you see the **VRA telling the passenger what is going on** (Taking the First Self-Driving Shuttles in New York, 2020, 03:15–05:21).



21. The Optimus Ride driving around in Brooklynn and technicians sitting in front.

3.4 Waymo robot taxi

Waymo started in 2009 as the Google Self-Driving Car Project. Now it is operating its **self-driving ride-hailing service in two cities: Phoenix and Silicon Valley**. Waymo's new self-driving taxi service "Waymo One" is **available for members** of the Early Rider program. The cars have trained drivers to check the ride. (Hawkins, 2019)

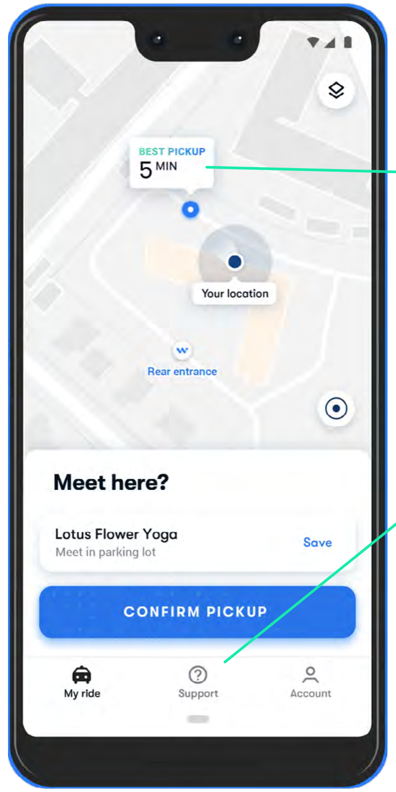
3.4.1 Interaction on board

The screen on the back of the driver's headrest features a large blue **"start"** button that I could press to initiate the ride. There's also a physical button in the headliner. See figure 22. After pressing the button, the One says, **"Here we go."** It shows the route and car and the buttons in the headliner also contain a help button, a lock and pull over button. "The riding feels normal". (Hawkins, 2018). However, some passengers complained about **weird drop-offs, circuitous routes, and shaky driving.** Even one employee said **"That ride was shit! Uncomfortable and downright alarming."**
Others praised the service for **navigating tricky traffic situations**.

22. Inside the Waymo One, normally a driver in the front seat who only intervenes in tricky situations, below the interfaces on headrest and headliner.

3.4.2 The Waymo app

Figures 23a, b, c are showing how the waymo app looks. All information is gathered from Hawkins (2018) and Waymo (n.d.).



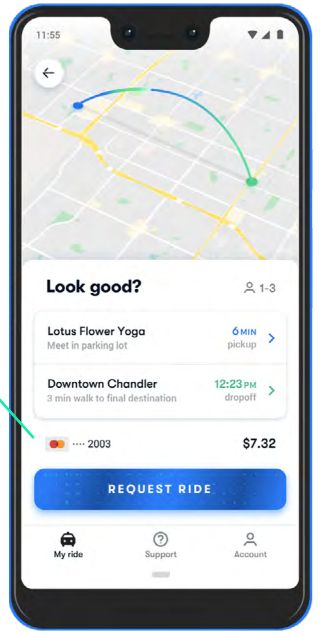
a.

The prices will be based on the **time and distance** of the trip. As with ride-share apps, **prices will vary based on demand**, which has become the industry standard for Uber Rides already. Waymo is thinking about how to **charge for in-ride entertainment and advertising** to drop base fares.

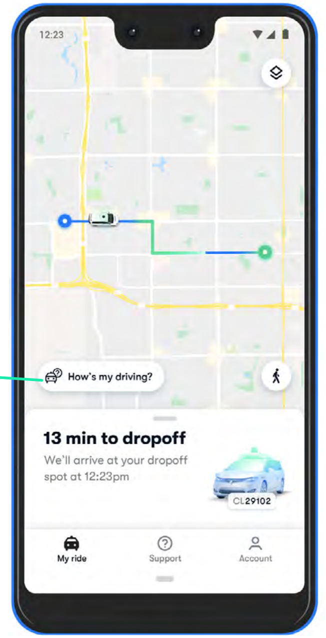
The app indicates an **accessible pickup or drop-off** location for the car. Users are prompted to walk a little bit so Waymo's vehicles have an easier access.

The support function allows users to get an **immediate phone call** with Waymo or chat with them.

Users can rate the quality of their trip on a scale of one to five stars. They can also elaborate on what made the ride great by selecting from a list of canned responses like **"route choice," "driving," and "car condition."**



b.

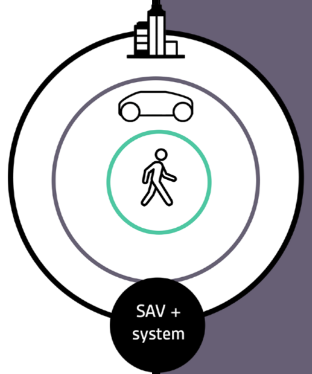


c.

23. a,b,c. Screenshots from the Waymo One app. a. (left) shows pick up location, b. (right top) shows an overview of the travel with the prize and c. shows (right bottom) the screen while on your way.

3.5 Conclusions from existing services

For the **first two cases**, the solutions mainly focus on **first and last mile**, operating in areas that currently have no last-mile public transport system, and are too distant to walk. The areas are re-developed into mixed areas that previously were business parks or port areas. Both cases are **highly integrated to existing PT**, with the Rivium Parkshuttle being also integrated with the payment system of the PT. The **Waymo system** is running in a neighborhood with no clear integration with PT. However, it is the **most advanced** service with a **working app** to book a ride.
The difference between the systems in the Netherlands and the US is the technology the shuttles use. They are all restricted to a certain area to control the environment reducing factors involved. The **Parkshuttle is relying on a track**, which will be extended to the public road. The **Optimus Ride and Waymo One are already driving on the public road**. A side note is the number of cyclists we have to deal with in the Netherlands. They make the design of the system more complicated than only dealing with pedestrians and cars in the US. What is **lacking in all cases is the typical user**. These systems are **created for young urban workers**, and is not yet for different target groups.



Insights for the design

No trust issues so far
With the Rivium Parkshuttle

High integration with PT needed
To increase feeling of reliability

Punctuality increases reliability
The service feels more reliable when punctual

Mobile application is wanted
Was lacking at Rivium Parkshuttle

People expect that the shuttle is comes close to destination
People expect the shuttle to come closer to destination

People want to know where to go when getting out of the SAV
If the SAV is not a door to door service

People with higher incomes are more satisfied
Than people with lower incomes

4 Ecosystem

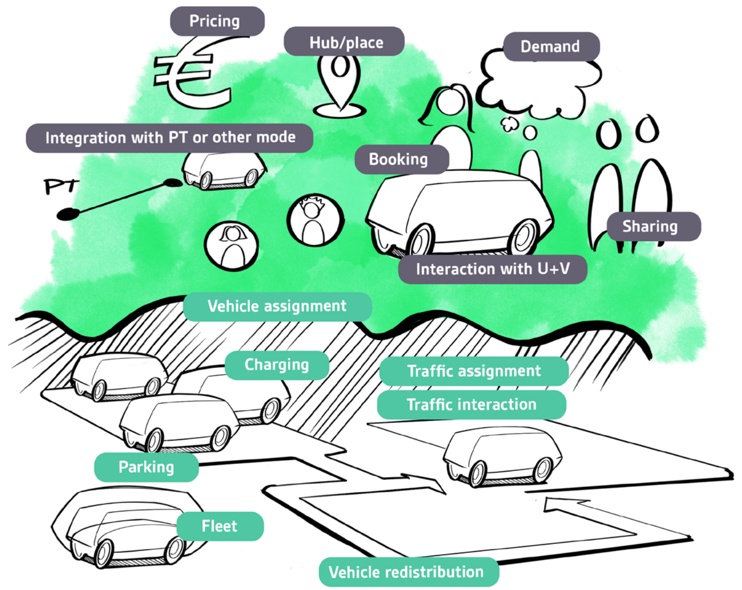
of shared autonomous vehicles

In this chapter the ecosystem of SAVs is explained. Both the frontstage (user touchpoints) elements and backstage elements of the ecosystem are clarified that have influence on the experience of users. Also, the unique qualities of an SAV-system are explained compared to other mobility modes. At the end of this chapter we have a clear overview of what the system should consist of and what user elements are important to consider when designing a new ecosystem for SAVs.

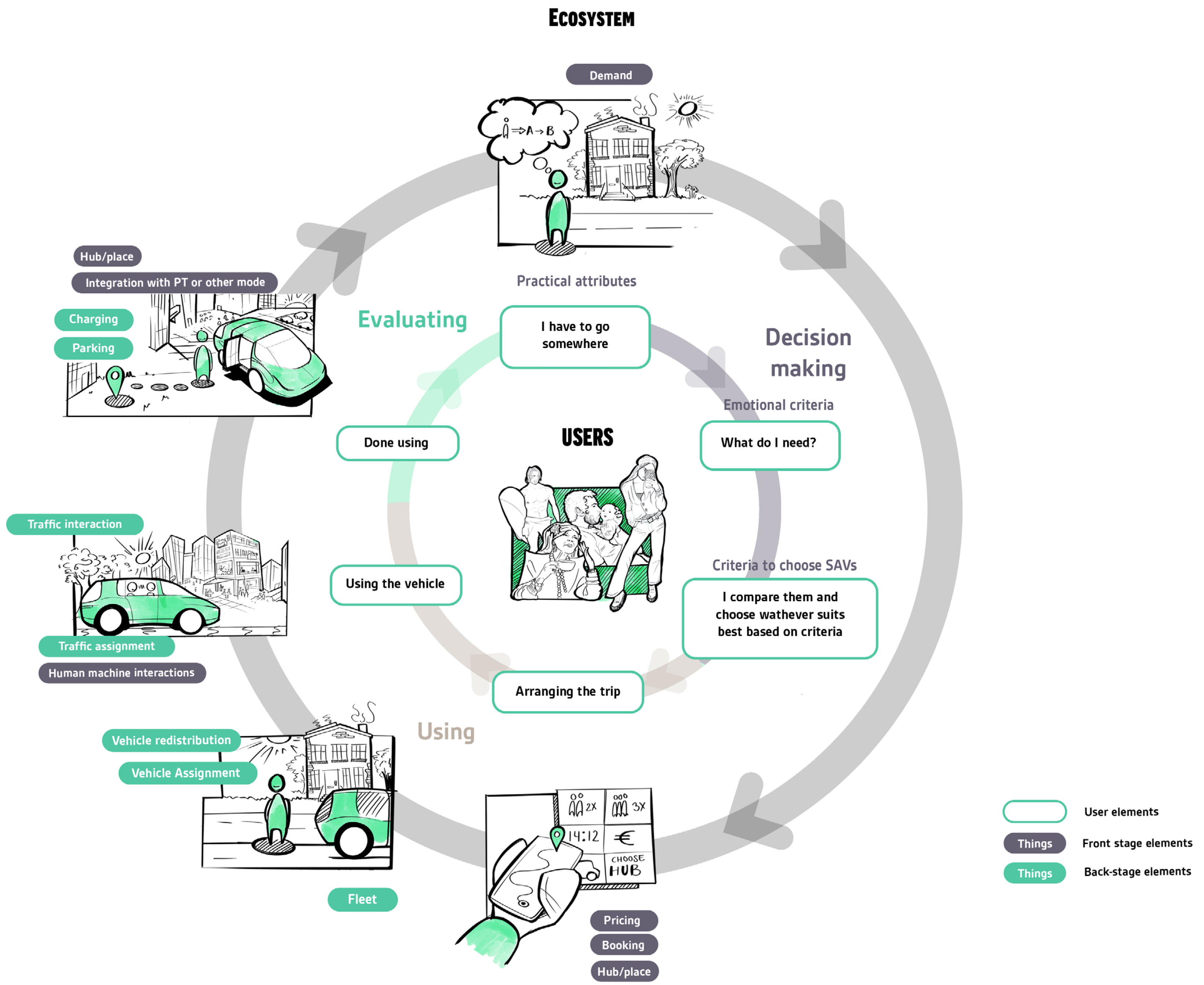
4.1 The cycle of the use of a SAV

The cycle on the right (figure 25) is an overview of the ecosystem. In the middle the user perspective is shown and in the outer circle the matching front- and back-end elements. It starts with the user having a particular need or goal to go somewhere. The green-white boxes in the cycle represent the user stages, the purple boxes present the related front stage elements and in green the system elements. Front stage elements directly influence users and can be actions or elements involved.

Back-stage elements support these actions to create a desired user experience (Kruitwagen, 2021). These steps can be placed in a service blueprint presenting how the user experience of the system is created. This chapter will discuss the system elements (back-stage) shortly and will discuss the user elements and front stage elements more thoroughly. In figure 24, the front- and back-end elements are shown as above and underwater elements.



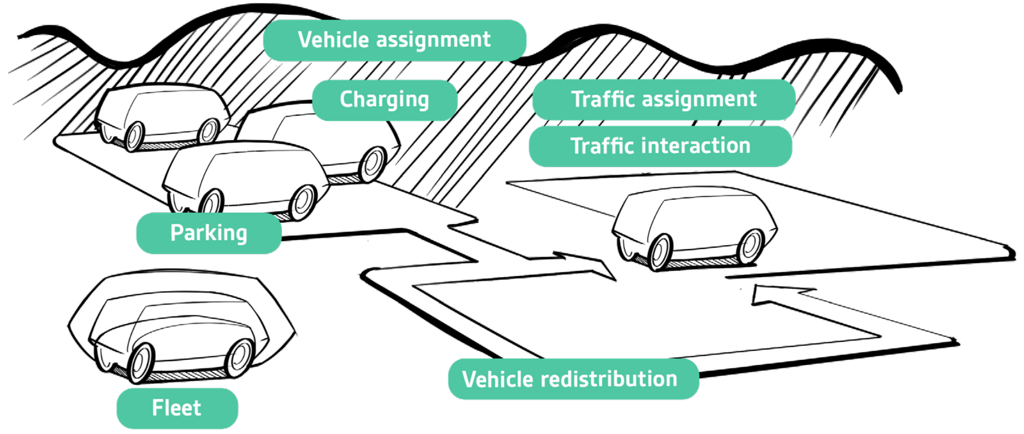
24. The elements of the ecosystem. Above, the elements visible and interacted with for users. Below, the back-end steps are shown.



25. basic cycle. The text in the green shapes are backstage elements, in black the fronstage elements.

4.2 A SYSTEM POINT OF PERSPECTIVE: THE BACKSTAGE ACTIONS

The backstage actions, shown in figure 26 are essential in making the service effective and are **invisible to users**. In this section those actions are explained.



26. The backstage elements of the SAV-ecosystem.

4.2.1 Fleet regulation

Fleet regulation is highly important to estimate the **required fleet size to serve a given demand and fixing the initial position of the vehicles**. The fleet can be **dynamic or fixed** (Narayanan et al., 2020, p. 260). In a dynamic situation the **fleet varies in size for instance and can be expanded in peak hours and diminished in low demand** hours, according to a 2getthere expert (Appendix A7). Optimisation of the fleet is important to understand the effect in terms of sustainability.

4.2.2 Vehicle redistribution

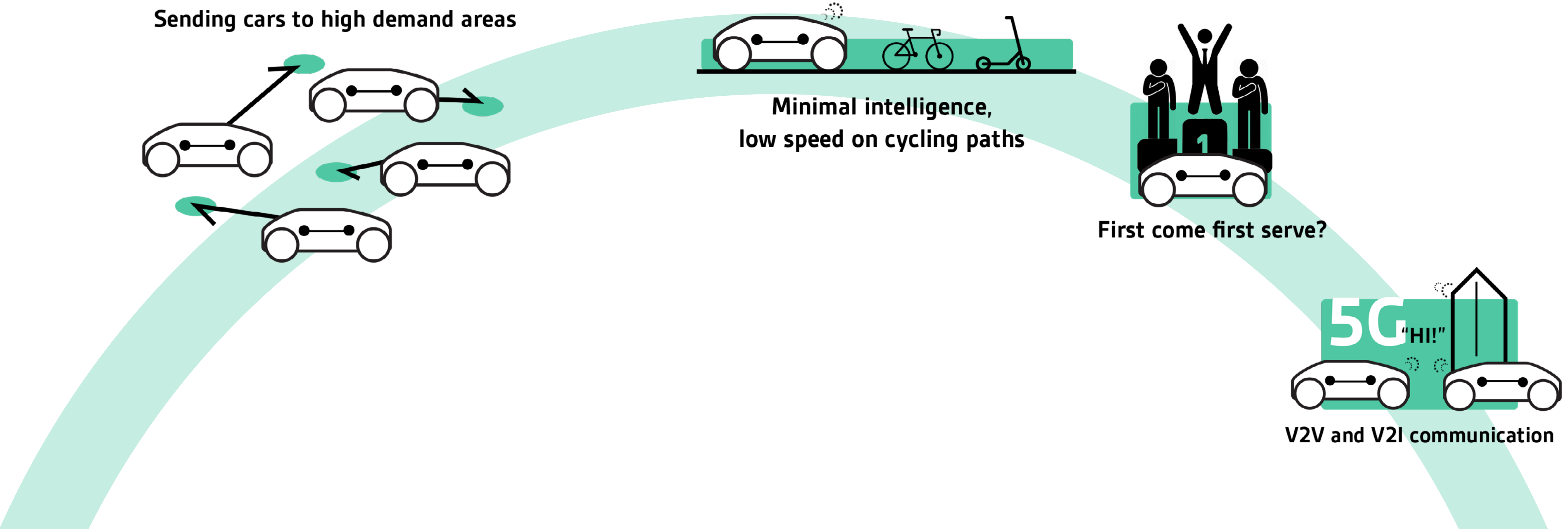
Vehicle redistribution is about the distribution of vehicles from **low demand areas to high demand areas**. Repositioning of vehicles could take place in a **slow manner** and therefore could also be feasible in the city centers. When **vehicles are narrow**, they can move themselves **on our cycle infrastructure and therefore only interact with cyclists**, according to the senior vice president design of Reanult Group (Appendix A5).

4.2.3 Vehicle assignment

Vehicle assignment is about assigning vehicles to customers. Depending on the type of system, you find the car, or the car finds you. In the first situation, **a rule-based vehicle assignment method is usually implemented** (Narayanan et al., 2020, p. 260). So, for **instance, first comes, first serves**. It could also be **based on spatial positions of the people using the system, where the vehicle closest to you, drives itself towards you.** It is still largely unclear which system would be most desirable.

4.2.4 Traffic interaction and assignment

The type of system determines which technology is needed to create an autonomous system. There are **four factors that are currently the hardest to solve in traffic**: **velocity, intersections, accessibility and human behavior**, according to the 2getthere specialist (Appendix A7). So, reducing one of these four factors increases the feasibility. The vehicle can **function with sensors and cameras sensing the environment** and by **communicating with other vehicles** (V2V) and **infrastructure** (V2I). These communication systems are called **Intelligent Transport Systems (ITS)** (Cybercom, n.d.) and would work with the **fifth-generation mobile network (5G) technology enabling short-range communication**.
5G is considered powerful enough to transfer data quickly between two vehicles (Loftus, 2020). Vehicles would exchange information about their **current place and where they want to go**. Not every car is ready for V2V (Vehicle-to-Vehicle Communication, 2019). **V2I communication is also expected to be essential** to create a smooth network of autonomous vehicles (3M, n.d.).



4.2.5 Parking

AV-systems allow us to design more efficient parking structures, reducing the amount of total parking space. Cars can be **parked closer to each other, within less space, in remote areas and vertically stacked**. There are some transformations that need to be considered in the transition times.

In the short term, both **autonomous and non-autonomous vehicles will be parked** and therefore some parking lots will be for autonomous and some for non-autonomous vehicles.

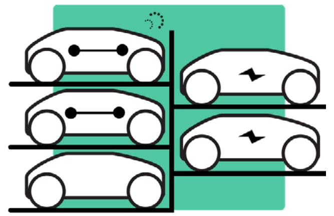
In the medium term, **more parking lots are destined for autonomous vehicles, with increasingly fewer traditional parking.**

In the long term, when fully autonomous**, parking structures can be retrofitted and also accommodate other functions such as playgrounds, more public space for recreation etc .** This change is predicted to fully take place by 2035 (Systematica Srl, 2020).

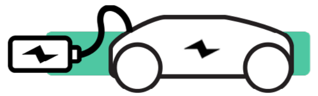
4.2.6 Charging

At the moment, **charging of electric vehicles is done mostly by a plug.** However, if the vehicles are not property of users, who is going to charge them? Companies are working hard to create **automatic charging stations** where only the car needs to be driven to (Easelink, n.d; Volterio, n.d.). Next to static charging, there is also a chance we could **charge while driving**.

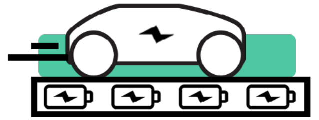
In Sweden, the world's first **electrified road recharges the batteries of cars and trucks driving on it has been opened this year**. About 2km of electric rail has been embedded in a public road. The Swedisch government also drafted a future expansion (Business Insider NL, 2020).



Various cars stacked



Automatic charging



Induction charging
(integrated in parking or while driving)

Insights for the system design

Fleet regulation is highly important for impact on sustainability
The right amount of vehicles should be available during low and high demand.

Redistribution possible at low speed
Even in cities, on existing infrastructure

It is unclear how cars should be assigned to users
This could be discovered in the user scenarios.

The velocity, Intersection with other traffic, the accessability for users and human behavior are obstructing elements
By eliminating those obstructing factors, autonomous systems work better.

V2V and V2I are crucial for AVs to drive safely
5G network is needed for fast and powerful messaging

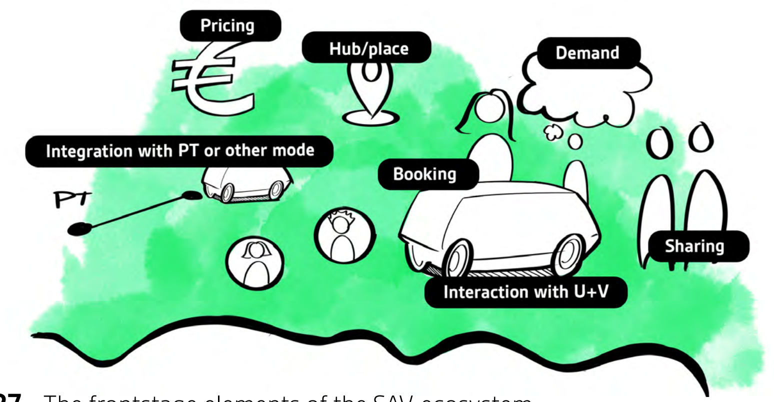
Induction charging
Different charging possibilities are feasible and therefore there is more design freedom.

Remote parking and stacked
Infrastructure could change as cars can park themselves outside of the city

4.3 Frontstage: The user decision and experience cycle

Below in figure 27, the frontstage elements are shown. These are the elements visible to users. Some elements are quite complex, such as the decision making process. Some are quite straightforward such as pricing. In figure 28, the **cycle of user decision making** and **experiencing** the ecosystem is shown. The user gets through many stages before and while using the service. Multiple elements have to be considered which we call **practical attributes, emotional criteria and practical criteria**. When the type of mode is chosen, the trip is arranged and the user experiences the trip. After use, there is a new experience which is gathered in the list of practical attributes.

In the following sections each step of the cycle is featured with corresponding design and user characteristics that influence the element.



27. The frontstage elements of the SAV-ecosystem.

User decision making

4.4 Practical Attributes

Time and Efficiency
Trip chaining and activities
Gender difference
Lifestyle

4.5 Emotional user criteria

User needs relevant for personal mobility
Must and Lust travel types
Benchmarking transport modalities against fundamental needs

4.6 Criteria for SAVs

Model for adoption of AVs
Clear message towards users about SAVs
Users should feel competent in SAVs
How to create a trustful SAV
The role of owning vehicles
Young and in the city more willing to share
Unique benefits of SAVs

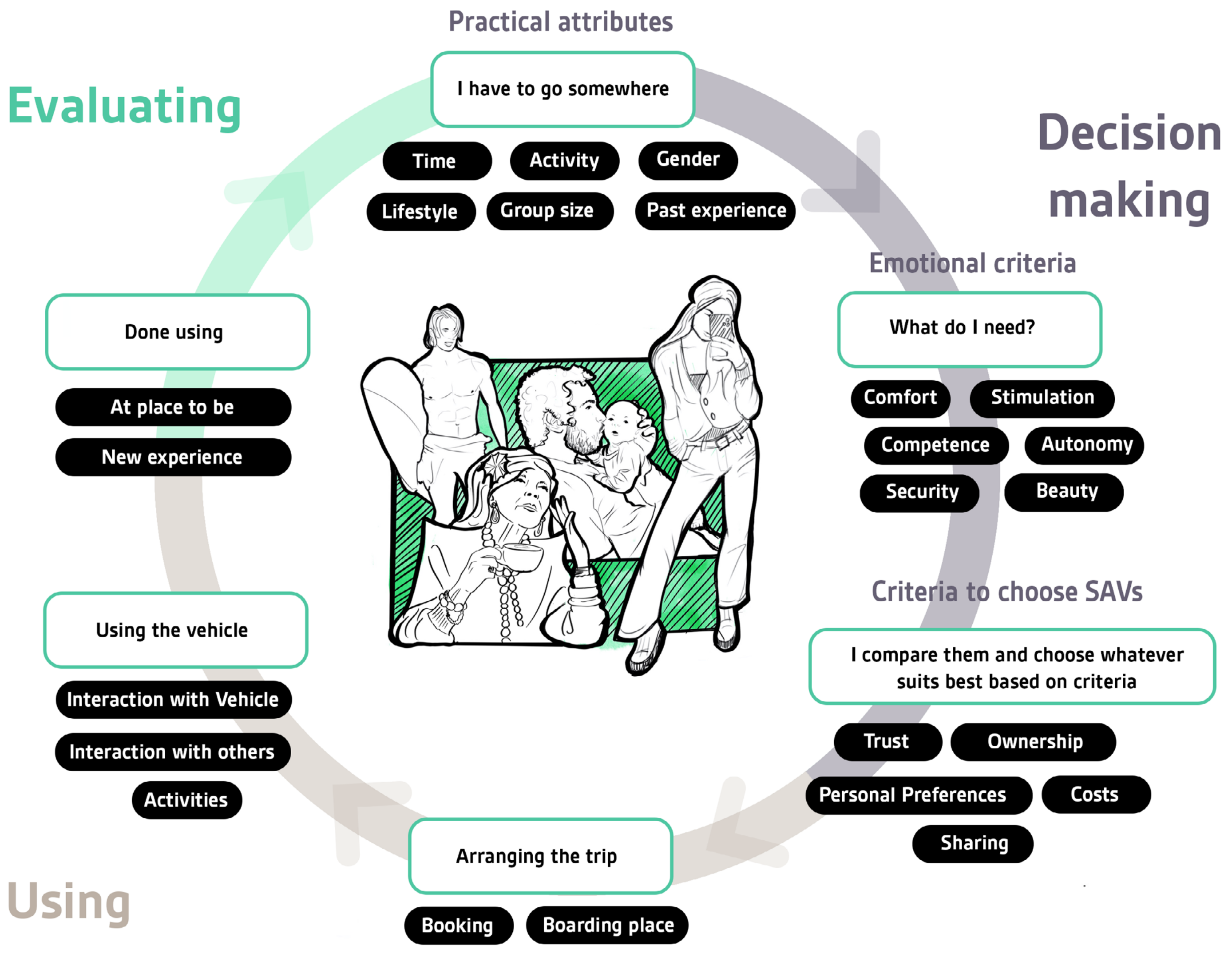
Using

4.7 Arranging the trip

Booking
Pricing
Boarding place

4.8 Interactions on board

Interaction with vehicle
Activities in SAV



28. The cycle of decision making and experiencing a mobility system by the user

4.4 Practical Attributes

4.4.1 Time and Efficiency

Travel Time Budget (TTB)

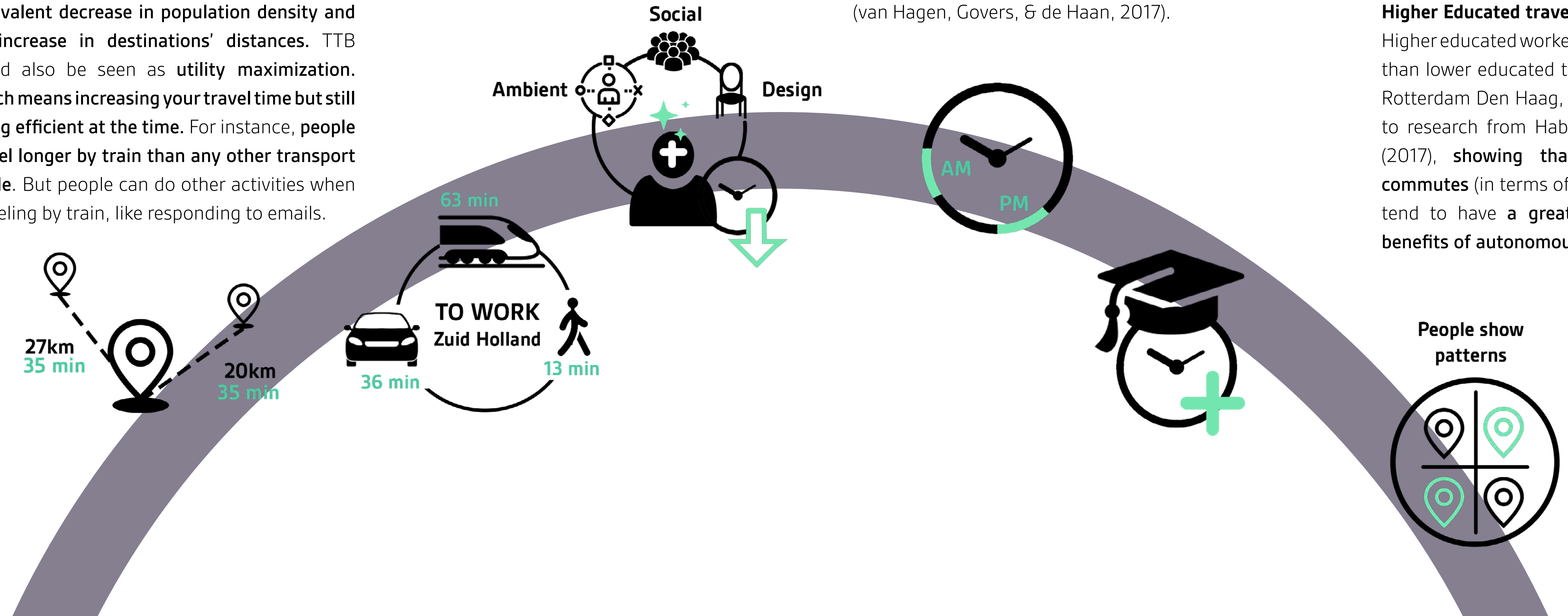
Worldwide, each person **spends around 70 minutes per day on the move** (Netwerk duurzame mobiliteit, 2020). This phenomenon, known as the "travel time budget" (TTB), is found to be applicable throughout time and to different cultures (SWECO, n.d.). **Increasing the average speed of the transport system**, leads to a **faster travel time**, leading to an **(almost) equivalent decrease in population density and an increase in destinations' distances.** TTB could also be seen as **utility maximization. which means increasing your travel time but still being efficient at the time.** For instance, **people travel longer by train than any other transport mode.** But people can do other activities when traveling by train, like responding to emails.

Average Time to work

In **Zuid Holland,** people travel on average, **32 minutes per trip when these are work-related**. For people who travel by car, that is on **average 36 min.** To work, people walk **around 13 minutes and travel by train for approximately 63 minutes** (Centraal Bureau voor de Statistiek, 2020b).

Experience of time

In general, people choose the fastest route. However, the time can be **experienced faster or slower (subjective time),** although the objective time is the same (van Hagen, Govers, & de Haan, 2017). The time appears to go faster when **being happy and relaxed** (Warffemius, de Bruyn, & van Hagen, 2016). **Ambient, social and, design elements** influence this experience (van Hagen, Govers, & de Haan, 2017).



Peak Hours

During the week, the **highest demand** for mobility is between **8:00-9:00 am and 4:00-6:00 pm** (Mobiliteitsalliantie, 2019; Primerano et al., 2007, p. 65). In two-worker households, children are dropped off at school between 8:00 and 9:00, mostly done by women. (McGuckin et al., 2005).

Higher Educated travel longer

Higher educated workers travel longer distances than lower educated travelers (Metropoolregio Rotterdam Den Haag, 2016). This finding adds to research from Haboucha, Ishaq, & Shiftan (2017), **showing that people with longer commutes** (in terms of both time and distance) tend to have **a greater appreciation of the benefits of autonomous vehicles.**

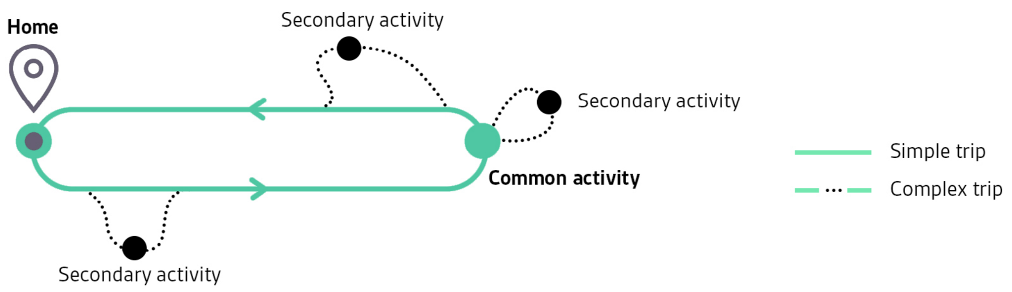
Routines

People show high regularity in their routes, mode of transport and destinations. People **travel similar distances at certain times and have a significant probability of returning to a few highly frequented locations** like their home and workplace (González, Hidalgo, & Barabási, 2008).

4.4.2 Trip chaining and activities

A trip

A trip is a tour that may **involve several activities, with a trip segment for travelling between a particular pair of activities**, see figure 29. Most **trip chains start and end at home** (Primerano et al., 2007, p. 59). **Simple trips are more common than complex ones** and only involve one main activity. **Complicated trips mainly revolve around one common activity** (mostly work or school). The **mode of transport can differ for each trip**. The **most complex trip chains are undertaken during weekdays** (Primerano et al., 2007, p. 59). **Workers who have trip chains live farther from their workplaces than workers who do not.** Since 1995, **people started to trip chain more** (McGuckin et al.l, 2005).



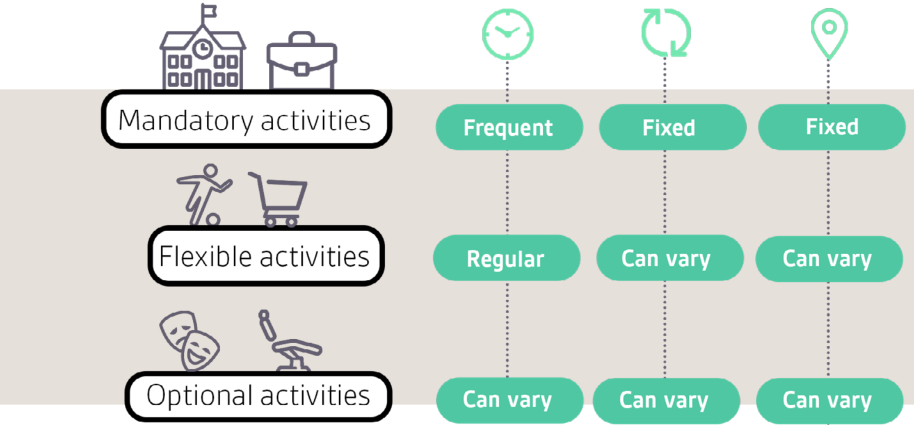
29. The basic rules of a trip.

Type of activities

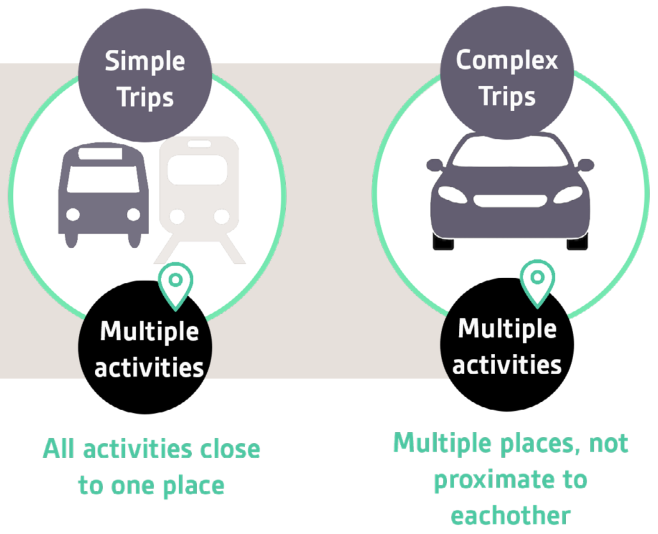
In figure 30, activities are divided into three categories, each with **other timings, frequency, and locations** (Primerano, Taylor, Pitaksringkarn & Tisato, 2007, p. 59). Activities that are pursued during **peak periods are mainly drop-off/pick-up activities**. Other activities tend to be followed throughout the day.

Type of transport varying for type activity

Specific modes of transport are more suitable for certain complexity; see figure 31. Trip chaining can be a **barrier to use public transport.** Public transportation is used more for simple trips. When more trip chaining is needed, the car is more likely to be used. For instance, if high flexibility is required when different activities are planned (Primerano et al., 2007, p. 65).



30. The three different types of activities.

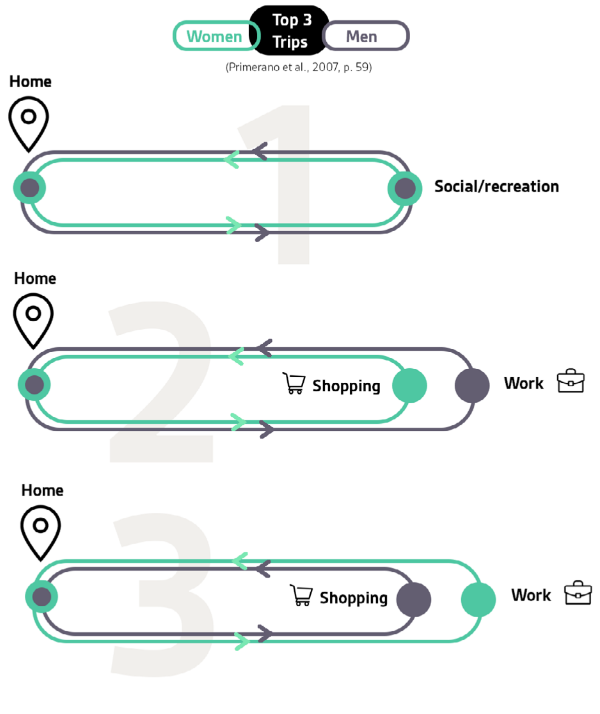


31. Difference in trip chaining and activities for PT and car

4.4.3 Gender difference

Trip differences

Gender (Shirgaokar & Lanyi-Bennett, 2019, p. 1367) (see figure 32) plays a rol in how people travel. **Activities and even infrastructure determine how women and men behave and travel**. Men's trips are mostly defined by **work or education,** and women's journeys are centered around shopping and **social/recreation**. **Women spend more time on home-serving tasks,** including shopping and taking care of children/ other adults (Shirgaokar & Lanyi-Bennett, 2019, p. 1367). **Women visit fewer unique locations than men** and **distribute their time less equally among such places** (Gauvin et al., 2020, p. 1). Trip chaining behavior is growing in the **direction of home to work for both groups.** However, **men often had more trip chains than women** (Primerano et al., 2007, p. 65).



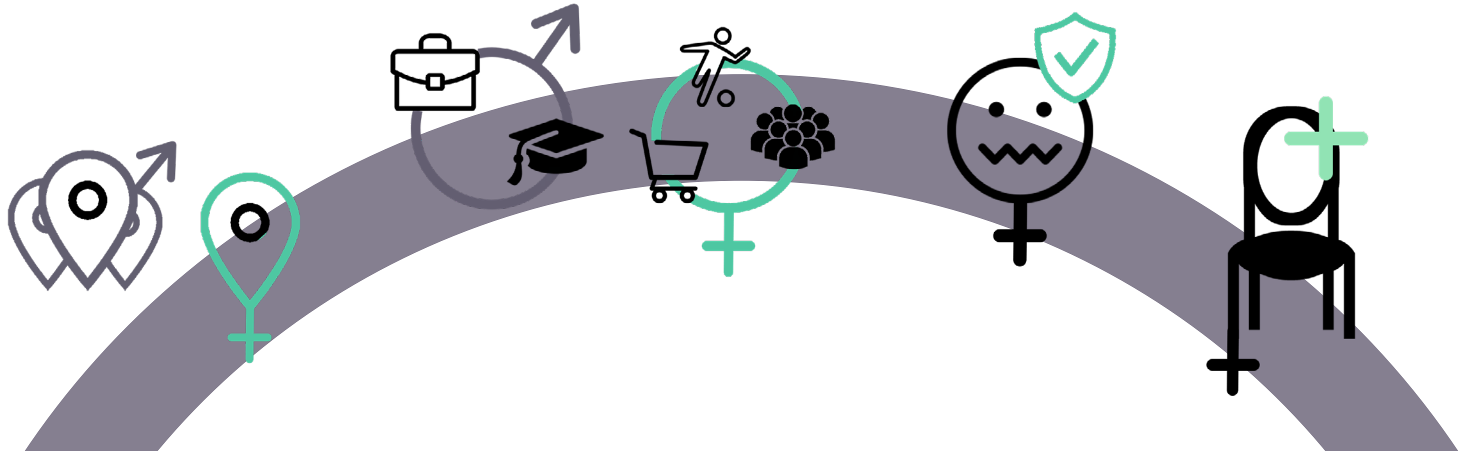
32. Top 3. trip chains of women and men.

Feeling safe

Women's behavior is **often limited by insecurity and fear of being physically or sexually approached**. This fear **exists in all age groups** (Loukaitou-Sideris, 2014, p. 253). Walking alone at night could evoke feelings of **vulnerability and uneasiness**. The ambient and design elements in a station impact how women move around, for instance.

Importance of interior design

For many women **design and functionality are important and therefore interior design is particularly interesting**. Compared to men, women are also **willing to spend more money for a more attractive ambience**. However, that does not mean that women attach less importance to other things like the driving experience (Daimler AG, 2020).



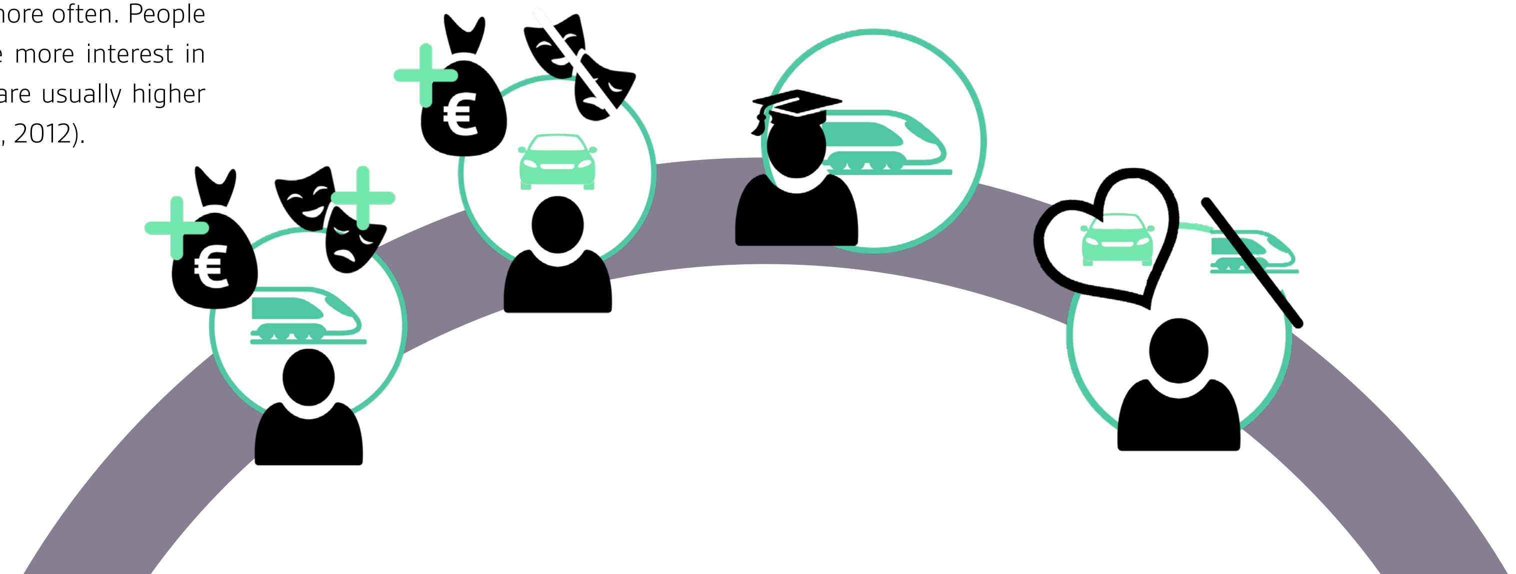
4.4.4 Lifestyle

Social position

Someone's social position influences their choice of mobility. This social position is determined by two factors: **cultural and economic lifestyles.** A cultural lifestyle is determined by someone's knowledge and abilities, the things they own, and educational attainment. Economic lifestyle is what someone can buy and how much value they attach to possessing things. The ratio between the two mostly determines what people do for a living. This ratio also defines the likelihood of choosing public transport or a car. People with an average score for both cultural and economic lifestyles would often choose public transport over going by car. People with a lower cultural score and a higher financial score would decide to drive a car more often. People traveling by train often have more interest in art, and cultural topics and are usually higher educated people (Spoorbeeld, 2012).

Ownership of a car

The barrier to public transport is strongly linked to the presence of household vehicles. The number of cars has a **smaller impact on complex non-work trip chains than on simple non-work trip chains**, which is 'counter to the hypothesis that complexity in trip chaining is a generic barrier to public transport use' (Primerano et al., 2007, p. 65). When someone has a **strong favour for cars, this person will usually also have a strong aversion towards public transport.**



INSIGHTS FOR THE DESIGN

Breaking user routine
People are routine seekers and therefore, their commute route will not change quickly. An external push is needed.

We might travel further
If we maximise our efficiency when traveling by working during the trip and being faster, we might live further from work.

The travel time can be perceived shorter
By increasing ambient and social factors. Can be created by the design

Trips from home to one activity most common
Most people do simple trips

We trip chain more
We integrate more activities in one trip and therefore need more flexibility

People living far from work trip chain more
They need a more flexible transport mode

SAVs could be used for trip chaining
Now, cars are used for trip chains.

Men and women have different needs regarding SAVs
Men could use SAVs more for trip chaining for work, women for trip chains in a social way and could use SAVs a safe and private way to travel.

Higher educated and cultural lifestyles possibly most interested in using SAVs

Ownership could be barrier to use SAVs

4.5 Emotional user criteria

Aside from the practicalities and habits shown in section 4.4 it is important to see which needs could be fulfilled by SAVs. These could overlap with other modalities but should not compete with one specific modality. Thereby it could have its unique qualities that could add value to the existing mobility system and add value to users.

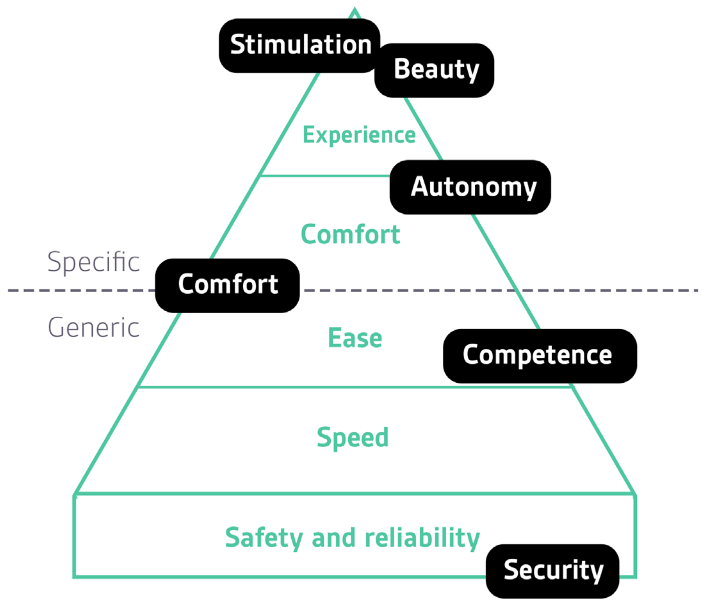
4.5.1 User needs relevant in personal mobility

Desmet and Fokkinga (2020) described **thirteen fundamental needs that are universal and contribute to our well-being**. All these fundamental needs contain sub-needs and can be found in Appendix D1. Designing for these fundamental needs strengthens a design by adding meaningful value to our lives (Desmet & Fokkinga, 2020).

NS created the Customer Need pyramid that **identifies general customers' needs on a trip** (van Hagen, 2014). This model is used to **select the relevant fundamental needs** by identifying the correlation of both models.

In figure 33, the ideas of Spoorbeeld (2012) and Desmet & Fokkinga (2020) about human needs have been merged.
The black dots show the **relevant fundamental needs** of Desmet & Fokkinga (2020) and, in green, the NS framework. The bottom part consists of **generic needs**, and the top part consists of **specific needs**.

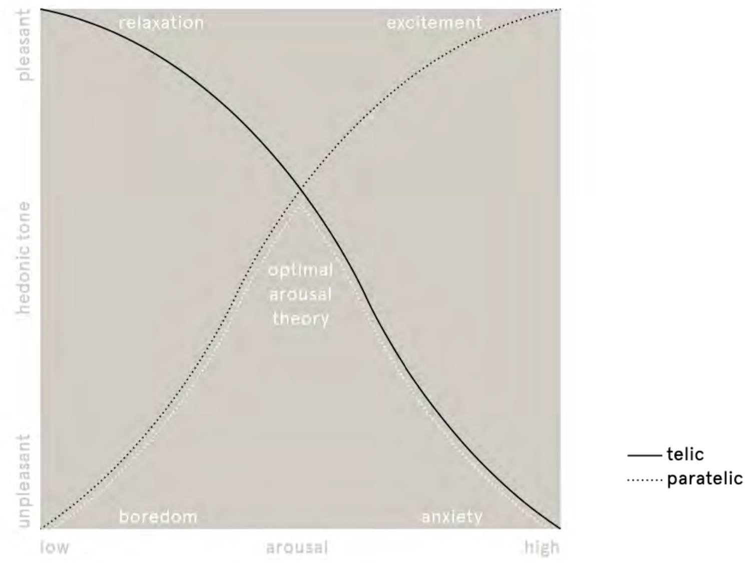
Spoorbeeld (2012) showed this by creating a visual hierarchy structure, similar to Maslow's pyramid; however, Desmet & Fokkinga (2020) pointed out that this hierarchy has been disproven. The hierarchy is not taken into account. The **needs are not static and differ per trip**.



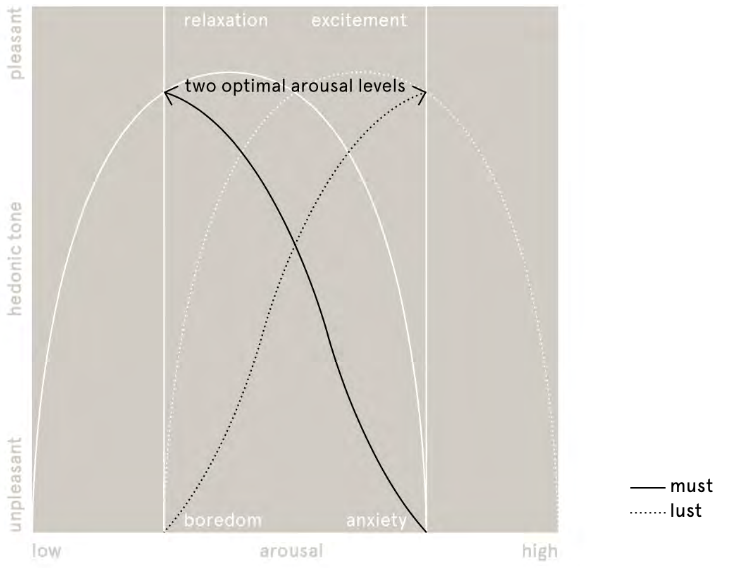
33. Fundamental and traveler needs identified

4.5.2 Must and Lust travel types

Spoorbeeld (2012) made a distinction between 6 different types of travelers, which have different sets of needs. They eventually **merged these 6 types into two psychological types**: must and lust travelers. There are two states; the telic (need for relaxation) and paratelic state (need for stimulation), shown in figure 34. In **telic state people are more goal focused**, in **paratelic state they are more loose and spontaneous**. People can **switch between states any moment.** When people are not experiencing the state they want, they avoid the situation. In figure 35, the two tops of the parabola are the optima. In between **must travelers are reaching for relaxation (from anxiety)** and **lust travelers are seeking for excitement (from boredom)**. Both can have too much or too less incentives, those are the most left and right area in figure 35.



34. Optimal arousal theory, telic and paratelic states (Spoorbeeld, 2012)



35. The must and lust traveler (Spoorbeeld, 2012)

4.5.3 Benchmarking transport modalities against fundamental needs

A SWOT comparison is made between different modes of transport. A distinction can be made between different types of transport: **Public, Private and Shared** (Veeneman, van Kuijk & Hiemstra- van Mastrigt (2020). Then there are also different types of sharing. Car-sharing is closely related to private modes, ownership plays an important role here and private cars fall under a separate category. Moreover, a distinction can be made between **autonomous and non-autonomous vehicles**. Figure 36 shows an overview of the options with examples. With these options, SW- diagrams are made, which are explained and can be found in appendix A10.

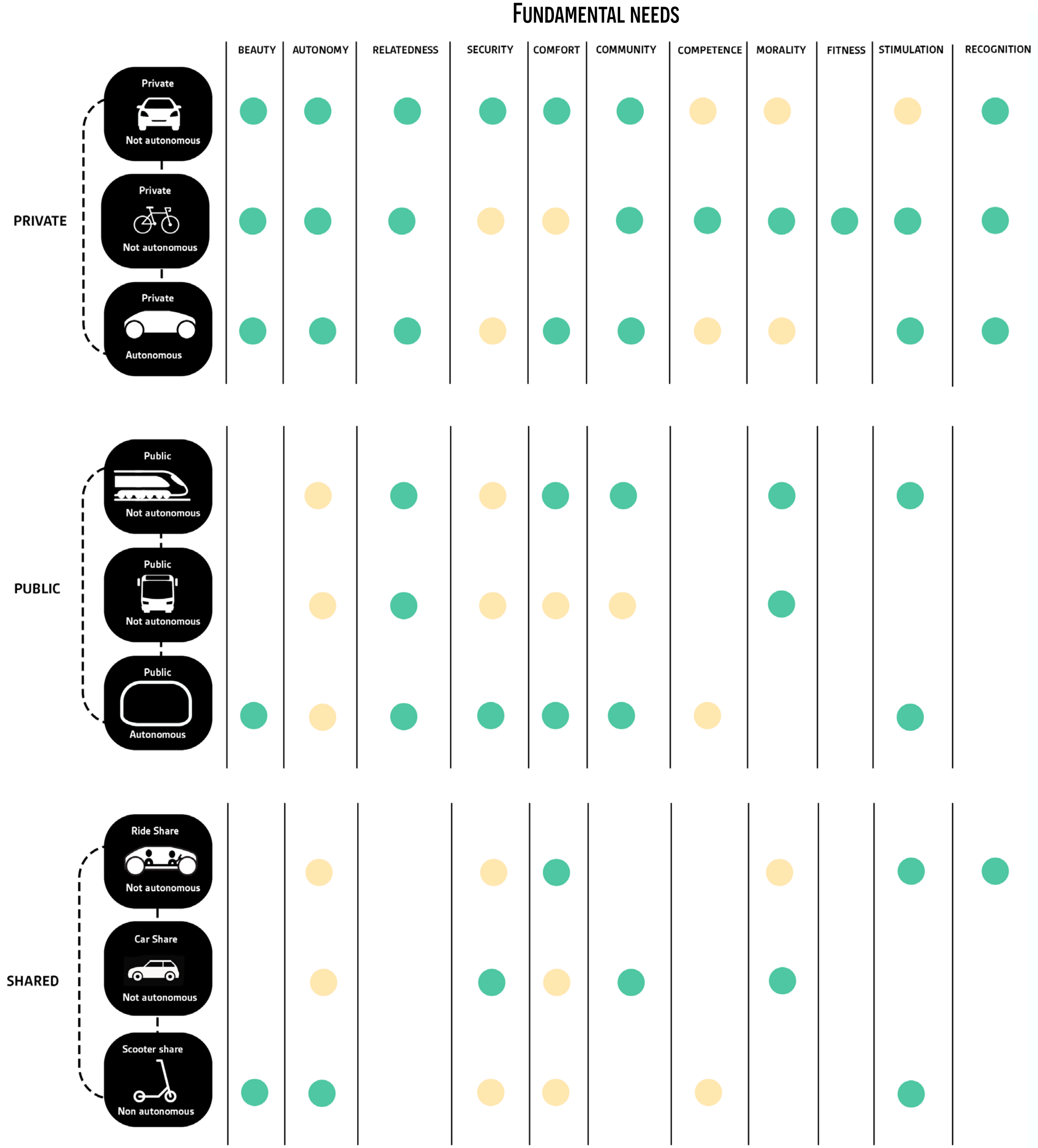
The conclusions for each need per modality are shown in figure 37. The need for **security, autonomy, competence, stimulation and comfort** seem interesting to design for in a SAV-system.

Security and safety are highly important for women, especially when they travel alone. this need is fulfilled mostly by private vehicles. **Autonomy** is **highly present for private modalities** as these modalities mostly offer the possibility to travel anytime. Autonomy can also be fulfilled if the **access is perceived as flexible**. Scooters for instance can be found anywhere on the streets, creating an all-time access.

The fulfillment of **competence** is the feeling of being competent and efficient. The opportunity that a **SAV can be used as workspace or sleeping spot can give users a sense of efficiency**. This could be a unique value for users. A SAV can also **enhance the need for stimulation**. These might not be activities that are efficient or acutely important, but activities that are overlooked in modern busy lives, such as mindfulness or reading a book. The **need for comfort is also important**. Of course, the SAV should be comfortable. SAVs could compete with PT and offer the same comfort levels, but in a more private setting. Comfort also is closely related to the need for security.

	Not autonomous	Autonomous
Public	OV (tram, bus, metro, train)	Rivium Parkshuttle
Private	car, bike, scooter, motor	Tesla autopilot
Ride Share	Car (carpool)	- (Optimus Ride)
Share vehicle	car, bike, scooter	-

36. Comparison table of different mobility to choose from



37. All modalities compared with plus (green dots) and less fulfilled (yellow). Open spots mean that those needs are not relevant enough.

INSIGHTS FOR THE DESIGN

Design for supplementing other systems
It must be an addition to PT and/or a substitute for private use of cars

Design for comfort
Create as much comfort as being perceived in cars.

Design for autonomy
Increase the flexibility and freedom to go anywhere.

Design for Security
Especially for women, creating a safe and secure trip is important.

Two main personas; relaxation and stimulation
The must and lust traveller. People could be want more relaxation or more stimulation.

Design for AVs unique properties
Unique elements such as being able to do activities and be efficient on your way (need for stimulation and competence) can be designed for. Also the need to be related and have social moments with people you care about are interesting to incorporate in the design.

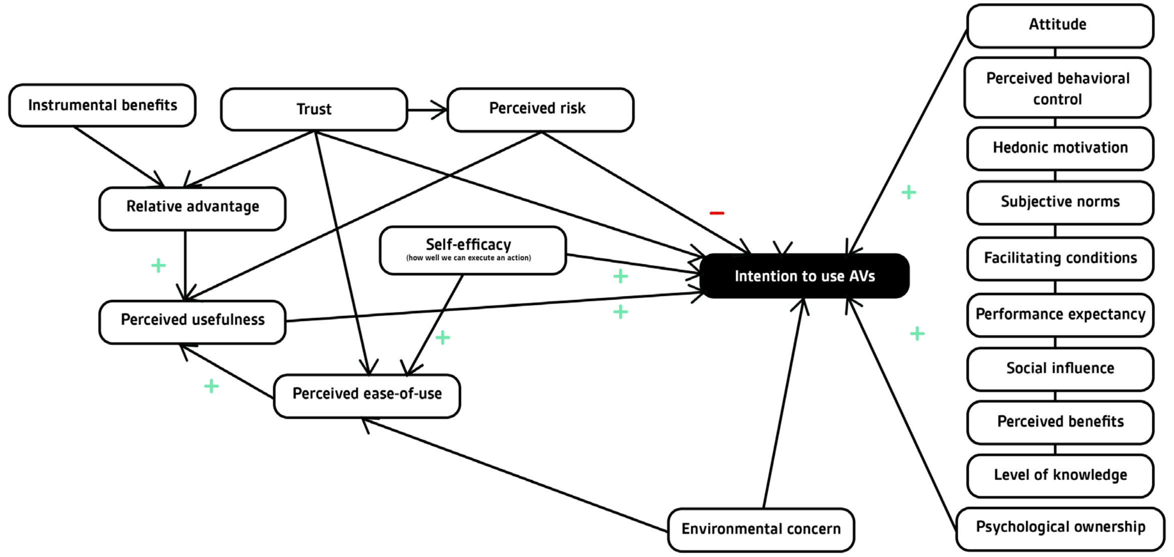
4.6 CRITERIA FOR CHOICE SAVs

SAV-systems are a relatively new concept - before they are fully implemented in real-life, it remains unclear how users would respond to them. Users are likely to base their choice for SAVs on certain attributes and phenomena, such as ownership and perceived ease of use towards the SAV system. These phenomena are especially worth considering when including car-owning user groups, who are not used to sharing vehicles.

4.6.1 Model for adoption of AVs

There are various papers which have researched factors that influence the potential use of AVs. In figure 38, an overview of the present knowledge about factors influencing the intention-to-use is shown. This is based on research by Lee, Lee, Park, Lee & Ha in 2019. These outcomes are researched with the **theory of planned behavior (TPB)** and the **theory of acceptance and use of technology (TAM)** to estimate the likeliness to use AV-systems (Lee et al., 2019).

As can be seen in figure 38, there are a lot of factors influencing the potential use of an AV. Some have direct positive or negative influence, some have an indirect influence.



38. Overview of influential factors on adoption of autonomous vehicles (Lee et al., 2019).

4.6.2 Clear message towards users about SAVs

As can be seen in the model in figure 38. The **intention to use** AVs is **mainly affected by the perceived usefulness** rather than by the **perceived ease of use**. The usefulness is therefore more important to users than the ease of use (Lee et al., 2019). In order to stimulate AV interest, it should clearly be communicated **what unique advantages** AVs have **over conventional vehicles**. Next to a clear explanation of the usefulness, the **trust in AV-systems should be build** and the **instrumental benefits** should be clear (Lee et al., 2019).

4.6.3 Users should feel competent in SAVs

Self-efficacy also has a direct impact on the intention to use and the perceived ease of use. On a **system level**, users may believe that **their ability to operate autonomous vehicles is not needed** as the car is selfdriving. However, at a **psychology level**, users still believe that some parts of **autonomous driving relate to their own abilities.** In this paradox, the strategy to enhance self-efficacy is **involving users** in **controlling the vehicle** (although it might not be really "involved") which will lead to a higher perceived usefulness.

4.6.4 How to create a trustful SAVs

Figure 38 shows the **negative impact of perceived risk** on intention to use of AVs. **Perceived ease-of-use and self-efficacy** are **not influenced** by this factor. Which could **imply that people only fear for the technological risks** of the system. This is in line with research that **people think that AVs will not be safe as they could have system failures** (The University of Michigan - Transportation Research Institute, 2014). However, other research showed that people **think that AVs can reduce the number of crashes caused by human errors**.

Trust also influences the perceived risk. People have a **fear of giving up control** (Howard & Dai, 2014).

Building trust might not be the most crucial in the Netherlands, as **Dutch people have high levels of trust in governmental organizations and other people.** Around 70% has trust in the legal system in the Netherlands (Centraal Bureau voor de Statistiek, 2019). Many studies studied features that enhances trust. From a design perspective, it could help to use **anthropomorphic features because they appear to be more trusted and therefore could decrease the level or perceived risk** (Lee et al., 2019). The **driving style of the vehicle should be human-like** and **actions and current states of the AVs should be transparent to the passengers** to increase the trust (Kraus, Althoff, Heissing, & Buss, 2009, p. 1).

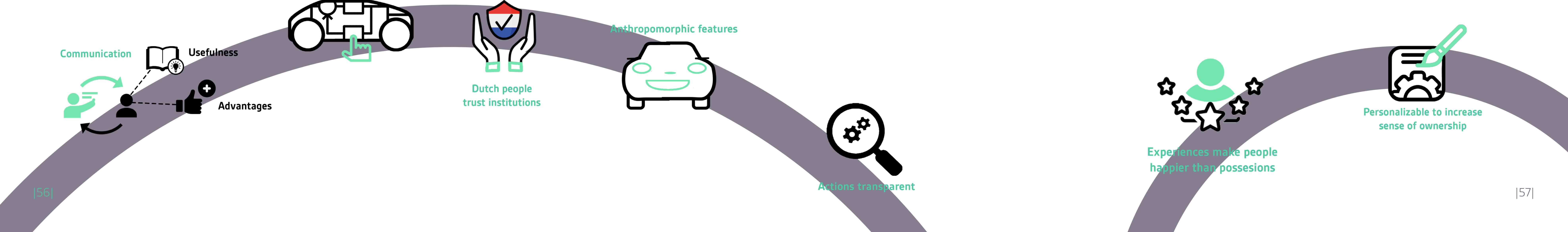
4.6.5 The role of owning vehicles

Psychological ownership positively affects usages of AVs. People are **interested in AVs (because of their usefulness), but are more inclined to try it than to actually buy one.**

In the Netherlands, we are **not used to sharing** and **car ownership is still increasing**. Mostly in the **group over-80s**. Which indicate the growing need for autonomy for the elderly, they might also be healthier. The car ownership of this group is more than twice as high as that of 18 to 25 years old (which is the smallest group) (Centraal Bureau voor de Statistiek, 2020a).

The biggest group of car owners are between 30-65-year-old and own 65%.

Personalising preferences in the AV can enhance the feeling of ownership (Lee et al., 2019). Personalisation might be even **more important for older groups** as they own significant more cars than younger groups. **Ownership** itself can **give more satisfaction than the use** (Kennisinstituut voor Mobiliteitsbeleid, 2015). However, this satisfaction from possession can be outdone by "experiences." **Experiences make people happier than possessions. Positive memories will be remembered longer than buying a new product** (Kennisinstituut voor Mobiliteitsbeleid, 2015).



4.6.6 Young city dwellers more willing to share

We do not like to share

The dimensions **Individualism/collectivism and Masculinity/Feminity** from Hofstede- insights (2020) correlate to the intention to share. Also, **Materialism** seems to influence the willingness to share (Perfili et al., 2018, p. 80). Countries with high individualism, high masculinity, and highly materialistic are less willing to share.

Dutch people are ranked as **high individualistic individuals and highly feminine.** As the individuality level is high, we also **prone to be materialistic** (Perfili et al., 2018, p. 80). This is underlined by Kennisinstituut Voor Mobiliteitsbeleid (2015), proving that Dutch people are more materialistic than other European countries. **64% of the respondents did not like to share their possessions comparing to 56% on average in Europe**.

Also, 75% of the Dutch respondents only share with close family and friends. Only 4 percent share with strangers. 82% of the shares is cost driven and people are **mostly concerned that things will be broken (57%) or not will be returned (51%). Also, the hassle (33%) and lack of trust (28%)** are factors inhibiting shared services. People who already have experience with sharing (10%), experience it as **an easy, cheap, and a relevant way** for products they only use once.

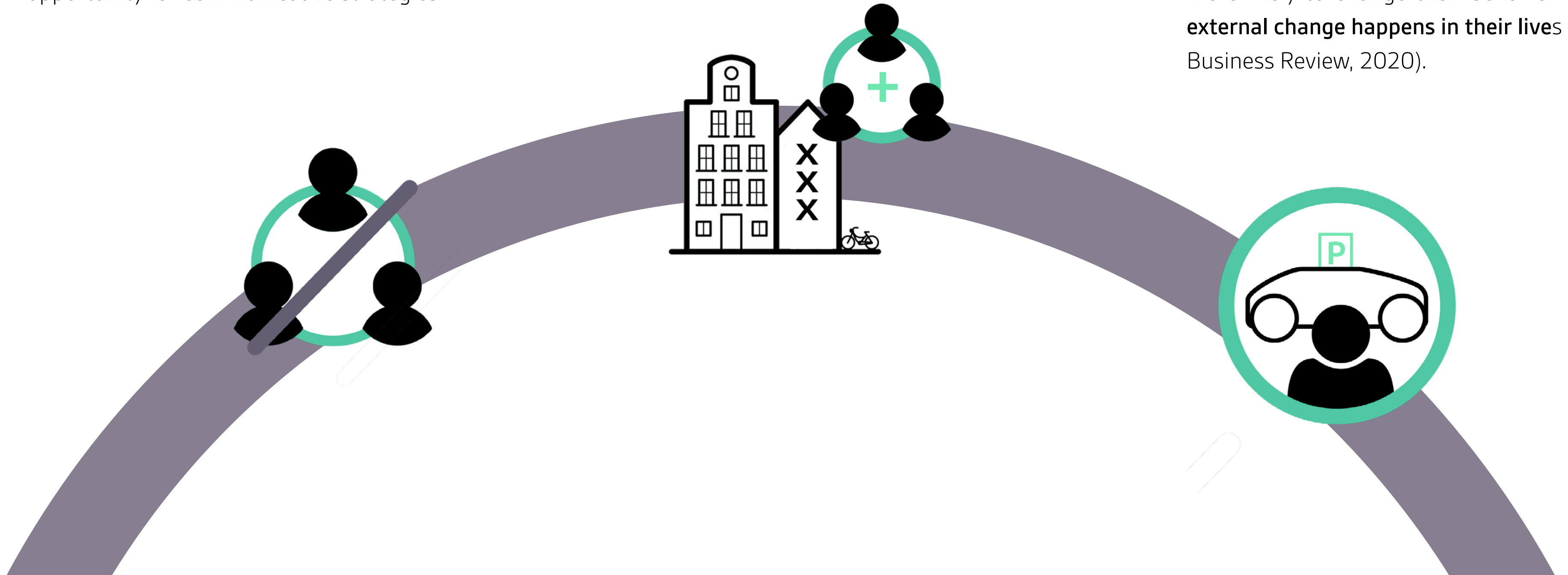
In research of Dieten (2015), Dutch people have a positive view on the sharing economy, but a slightly less optimistic view on sharing cars (Dieten, 2015). It is **rated as least favourite category for sharing** (Kennisinstituut voor Mobiliteitsbeleid, 2015). Informing positively affects this attitude. **Younger people were less informed about carsharing but are more likely to share cars** (Dieten, 2015). This seems an opportunity for communicative strategies.

Big cities

In bigger cities - like Amsterdam - people show a higher **interest in sharing**. As mentioned earlier, the **cultural and economic lifestyles influence the willingness to share**. People in bigger cities probably show a higher average score for both **cultural and economic** lifestyle and therefore are more willing to use PT and sharing options. Also, the **space available in the city creates a need for easy access to a sharing system**.

External push to do ride sharing

In the past, carpooling (ride-sharing) was used to stimulate people commuting together; however, most of them failed. Light-touch nudges, which might seem easy for companies to implement, do not provide strong enough stimili to make people travel together. The following factors increase people's willingness to shared rides: **paying for parking at work, making parking less convenient, give the possibility to work from home, and nudging at the right moment** (Kristal & Whillans, 2019, p. 174). Like when people switch jobs. People are more likely to change their behavior when an **external change happens in their live**s (Harvard Business Review, 2020).



4.6.7 Unique benefits of SAVs

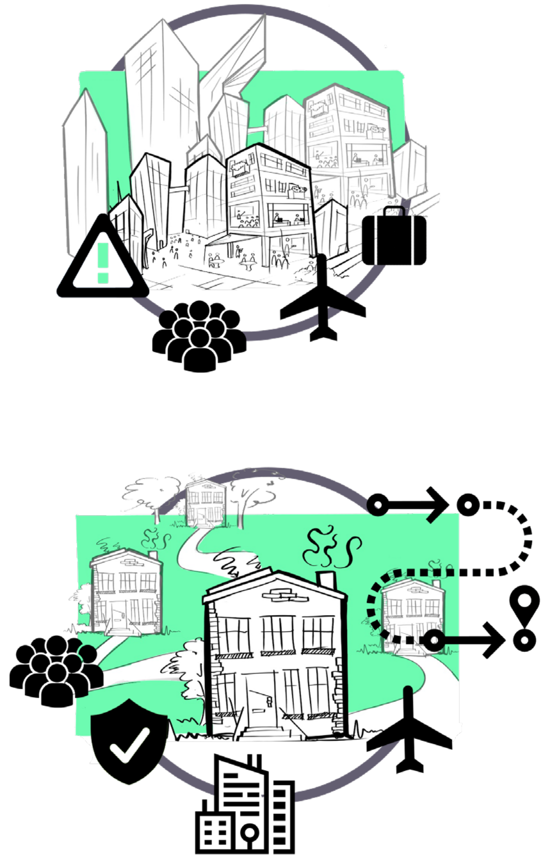
As mentioned earlier, the **unique benefits are important for users to use SAVs**. For a system to be useful, it needs to **fulfill multiple unique problems.** As we do want to create a sustainable system, it should **not compete but be an addition to existing mobility systems**.

Within a **high urban context** it could have the following unique properties, shown in figure 39:

- Incidental trips for extra luxury
- Rides with many people
- To the airport with lots of luggage and/or people
- Trip chaining where you cannot have a car parked and where people take taxi trips for.
- To go the rural areas

In **rural areas** the following unique properties are interesting to look at:

- There less transport means in the nights and weekends. Extra safe feel as less people live in rural areas
- To go to the city
- First and last mile
- People being isolated because they are not able to walk to PT.



39. Unique properties of SAVs in urban context (top) and rural context (bottom).

Insights for the design

Usefulness and advantages of SAV clear
By communication towards users

Informing young people
About the existence of SAVs.

Some control to users
Although users have no control over the ride, they should have the feeling they do.

Anthropomorphic features
Enhancing the feeing of safety and trust on product level.

Transparency in actions
The car should be informing the users what it's going to do.

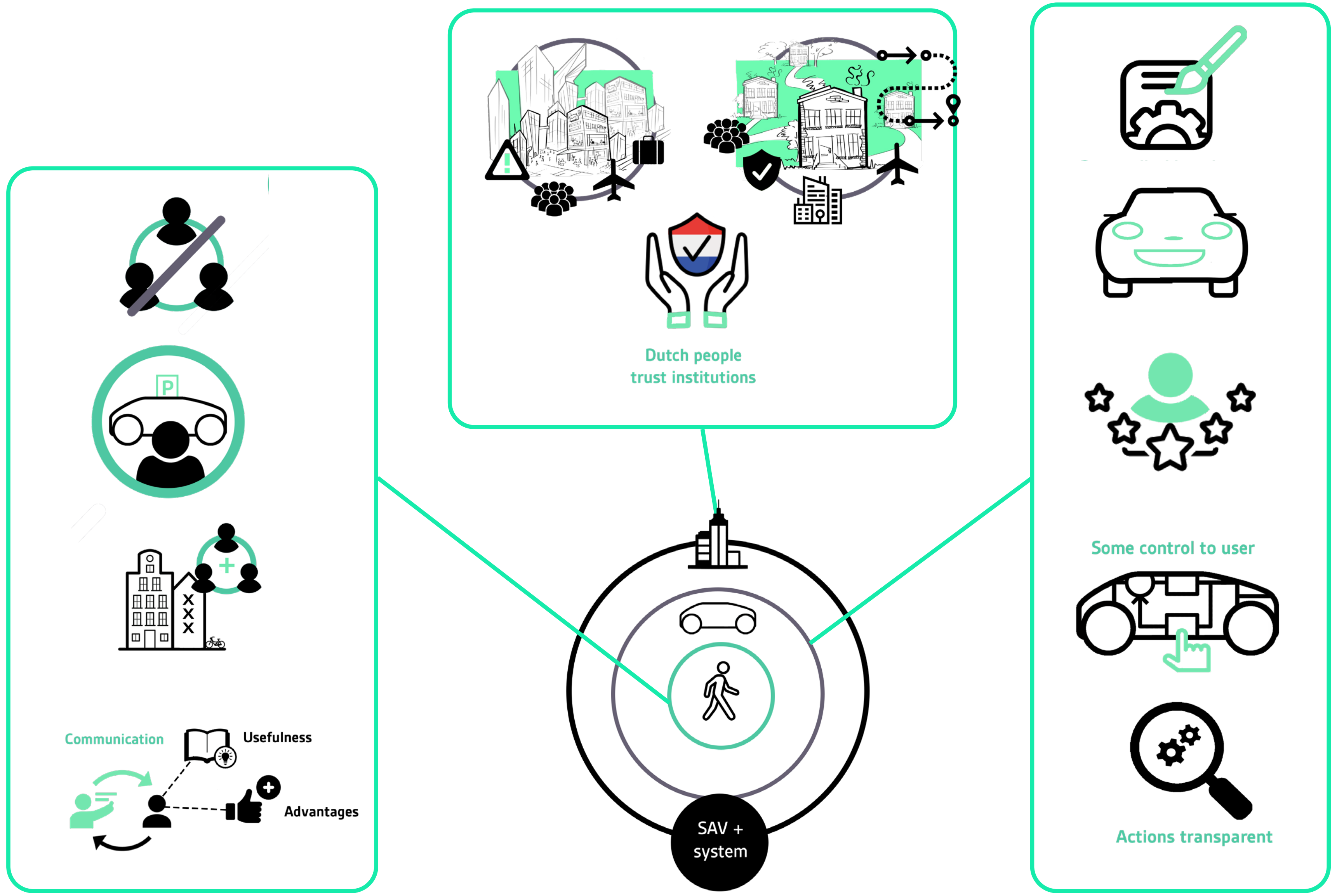
Creating personalized experience
Increasing feeling of ownership.

Sharing not immediately wanted
People rather not share. Soft nudging does not work.

Young people living in cities are more interested in sharing
However, the other population could be more interesting to look at.

Most likely to work in urban settings
However, the unique advantages also lay in rural areas.

Important to keep in mind the unique benefits of SAVs
It should not be a competitive service but be an addition to the existing systems.



40. The main conclusions and their impact on each main element of the system: the user, the vehicle and the context.

4.7 Arranging a trip with a SAV

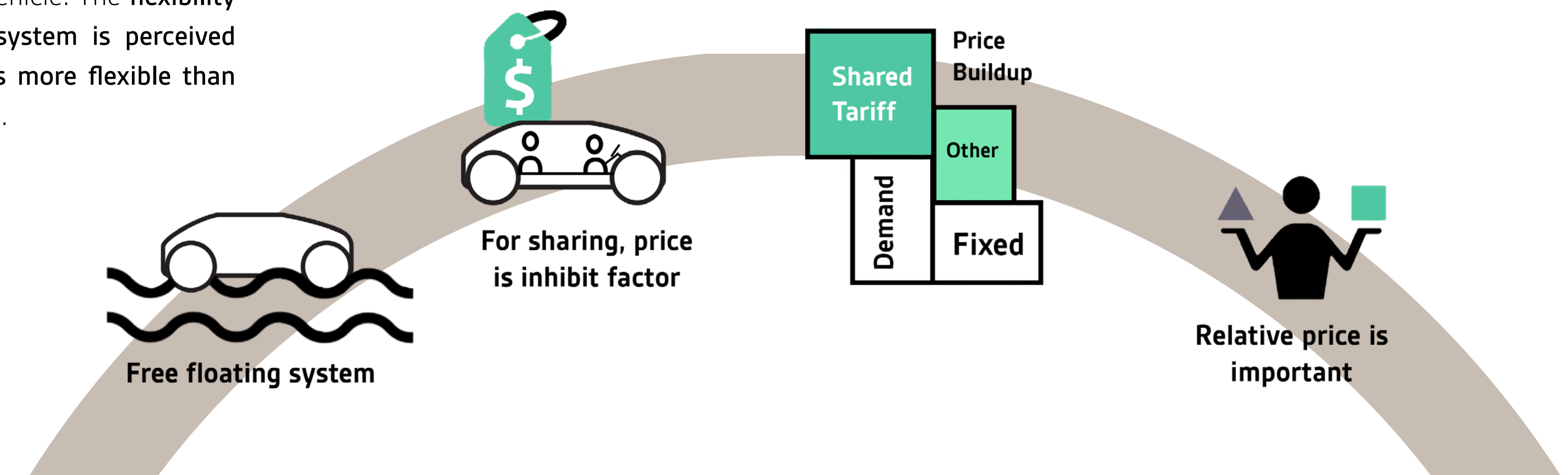
The SAV is chosen as travel mode. The user may need to book, pay and the right vehicle should be taken at a certain place.

4.7.1 Booking

The booking type could be **on-demand or reservation-based**. Most literature is written about on-demand booking and less about reservation-based booking (Narayanan et al., 2020, p. 260). From a system perspective, **reservation-based booking is potentially** interesting as it is **more efficient and needs fewer vehicles** (Narayanan et al., 2020, p. 260). From research of Dieten (2015), reservation seems not important as **peer-to-peer systems would offer many possibilities close to people's home**. Users find reservation only important when doing groceries shopping or activities in which they really need a vehicle. The **flexibility of a free-floating share system is perceived as a better option as it is more flexible than reservation based** systems.

4.7.2 Pricing

There are fixed and variable costs that determine what the price of a trip would be. The fee, cleaning, maintenance, and insurances should be included in the **fixed starting price** (Bösch, Becker, Becker & Axhausen, 2018). The costs for a trip can be estimated based on **spatial and temporal parameters**. Spatial fare is based on the customer's origin and destination. The temporal fare is calculated based **on demand levels and traffic**, with higher demands and a lot of traffic to be more expensive.
These **demand and congestion pricing strategies** and **splitting costs when multiple users involved are not much explored yet** (Hyland & Mahmassani, 2017). There are many different ideas about pricing.
For instance, Bai, Quan, Fu, Gan & Wang (2017) use the concept of **fairness in sharing ride services**. The first user of the vehicle can choose **whether they want someone to drive with them or not in exchange for reduction of the price for the trip**. They created a mathematic model to find a fair price. A conclusion from the research of Haboucha, et al. in 2017 is that the **price of an AV is not important for users when we talk about adoption**. The **relative price when comparing to regular vehicles** is more important. Some users **actively compared the costs of a shared system with their private vehicle** but most people do not know (Kennisinstituut voor Mobiliteitsbeleid, 2015). The **type of car** they own therefore **influences the comparison to a sharing system.**

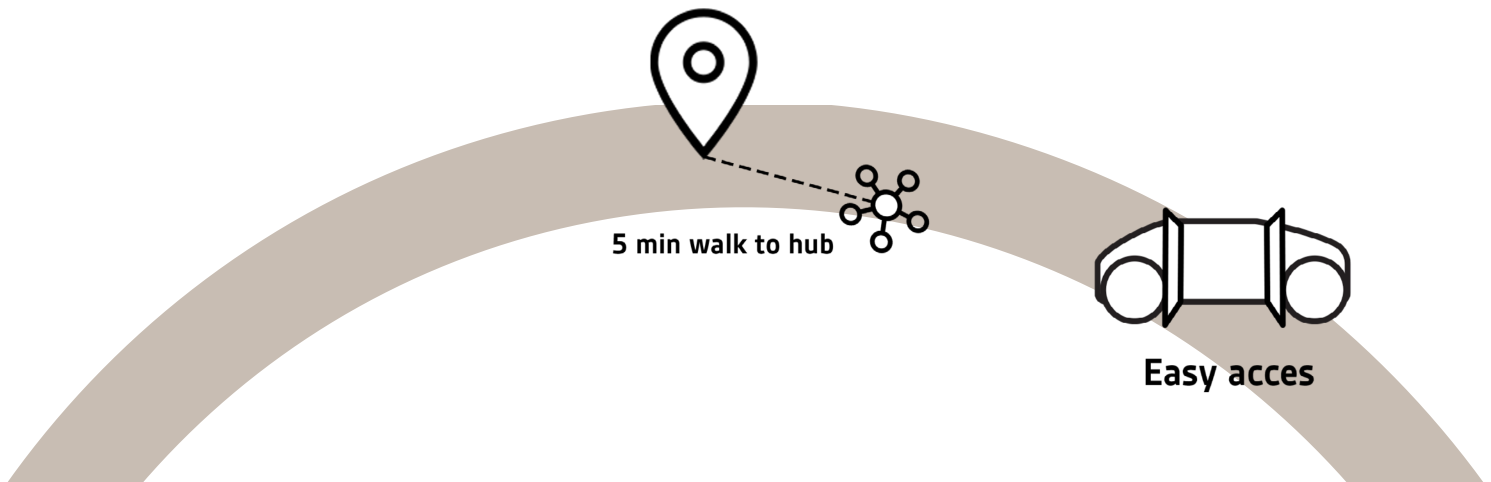


People do say that they see the **costs as the main inhibit factor for sharing cars**. They are willing to pay on average **0,3 euros per kilometer** (Dieten, 2015).
Some people think that the **technology** used in AVs **will be expensive** (Jardim, Quartulli & Casley, 2013) and others think that it could be **cheaper as other costs will be replaced by the technology** (The University of Michigan - Transportation Research Institute, 2014). However, the costs for the driver are replaced by the autonomous system which is **about 75% of the costs** , according to the head of design Renault Group (Appendix A5).

4.7.3 Boarding place

The place where someone gets in and out of the car is important to consider. From existing car sharing services we know that **people would not want to walk more than 5 minutes** to a vehicle (Dieten, 2015). People like to be brought from door to door. Areas where people transfer, if they need to, should be arranged in such a way that they **add value to the efficiency of the trip or be of value in another way**. Especially for transfers from one mode to another. **Park and Ride (P+R)** and **Park and Bike (P+(e)B)** areas are introduced to create a more efficient transfer from mode to mode.

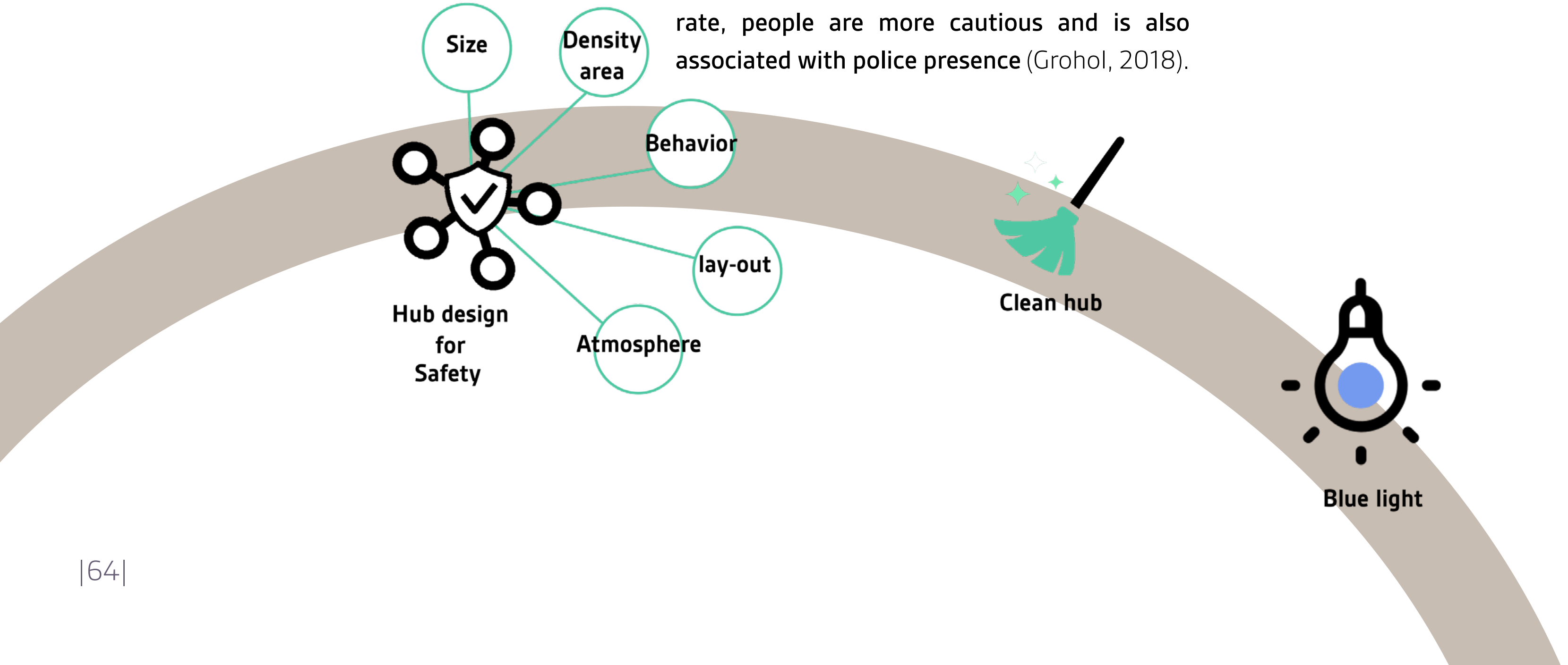
Especially the P+eB are relevant as the popularity of the e-bike is rising and **7,5 km is still a comfortable distance for a person with E-bike** (CROW fietsberaad, 2016). P+ bike is highly relevant in urban and interurban areas.



The Executive Vice President, Design Renault Group (Appendix A5) mentioned that getting in and out safely is highly important for SAVs. For the EZ-Go concept they did not design two doors on the side but created a **big door in the rear** of the car to create a wide opening for all people to get in and out. This way it would be safer and more inclusive. Also, a stop can be created for vehicles driving from stop to stop or certain pick-up and drop off places to regulate how people get in and out.

The **size of such place, density, behavioral factors, physical lay-out, tempo and pace** defines the atmosphere. For instance, **when walking speeds are high, people are impatiently waiting at a stop, this adds to your feeling of ease and even safety** (Milgram, 1970).

Also, visual components play a role, when there is a lot of trash around you, it attracts others to also trash it. This is called the **Broken window theory** which shows that a clean area is more safe. It also seems that **enlighten a public space with blue light decreases the crime and suicidal rate, people are more cautious and is also associated with police presence** (Grohol, 2018).



Insights for the design

Free float system
Offers the most flexibility, then reservation not needed.

Relative price plays role in adoption SAVs
Relative to other transport and when it is compared to PT or cars.

Price could vary based on how people share
To create a "fair" price.

Some people compare price to cars they own
So, for some it depends on which car they own now.

Efficient transfer if needed
As an integrated system is desirable, the transfer from one to another mode should be efficient.

We do not want to walk more than 5 min to hub
People would rather have door to door services.

Hub design is quite important for a safe experience
Getting in and out should feel safe.

Design elements important to consider for hubs
Choosing right size and lay out that fits certain area.

Tidy and clean feel of hub
It is important to keep clean the hub and vehicle to feel more safe. Thereby, blue light can be used to have a more safe feel.

4.8 INTERACTIONS ON BOARD

During use, interactions take place between people and the vehicle. Users might do different activities on-board of the SAV and talk to people they travel with or with strangers. These interactions and activities influence how the car should be designed and what the characteristics of the travel in a shared autonomous vehicle should be.

4.8.1 Activities in the car

Interaction with others

As people travel with others surrounding them, **interactions take place between people**. Interactions could be only eye contact, signifying that someone can pass you or keep the door open. It could also be a more intimate interaction in which you talk or touch someone. Interactions can be unwanted and wanted.

In bigger cities, people are **less polite and helpful because they are less relaxed than people who live in smaller towns** (Milgram, 1970). Because city dwellers experience information overload from their crowded surroundings, they develop **strategies to cope with interpersonal overload** by reducing their interpersonal contacts' number, duration, or intensity. This phenomenon only applies to strangers and not to friends or family.

Milgram (1970) hypothesized that social withdrawal in the city could be understood as a temporal adaptation to the threat of interpersonal overload. **Design elements can decrease interpersonal overload in high-density environments, such as architectural elements making it easy to withdraw socially**; for instance, the floor plan layout and furniture positioning (Evans & Wener, 2007, p. 93). These changes can increase the so-called architectural depth. **The paradox is that people interact more when the environment facilitates being alone** (Evans, Lepore & Schroeder, 1996).

Less eye contact between people in the city is a relatively reflexive and short-term adaptation to the crowded city environment. It does not have to do with the **habitual difference between people living in the suburbs and towns** (McCauley, Coleman & Fusco, 1978, p. 217).

Mainly people sitting in the passenger's **immediate area influences stress** (Evans & Wener, 2007, p. 93).

Also, **privacy and intimacy play a role in whether people want to interact or be close together.** Intimacy and privacy levels determine seat choice.

When **people are alone, they would like to sit in a less intimate, more private seat.** However, society's implicit norms also play a role in this decision as it is not polite to isolate yourself. When **people are fatigued, they also strive for more privacy** (Staats & Groot, 2019).

Design implications could be providing **less proximate seats in vehicles and territorial props** (armrests, small tables) in between seats to let users regulate the social interaction. More people could fit in the same room in larger spaces as the overall density of a vehicle is not essential (Evans & Wener, 2007, p. 93).

Desired other activities

Findings from the research of Pfleging, Rang, & Broy (2016) indicate that **besides traditional activities** (talking to passengers and listening to music), **people like to daydream, write text messages, eat and drink, browse the internet, and call during an automated drive**.

The research of Pudāne, Rataj, Molin, Mouter, Cranenburgh & Chorus (2019) identified two types of activities that people like to do in AVs. **High-priority activities and optional activities**. Within these two activities, people also thought of **new activities and the existing activities** people do currently. Some people feel that high-priority activities can be done during the ride and would also create more time for other activities on that day. Activity needs, wishes, and constraints determine travelers' daily activity schedules. Planning too much priority activities in the ride could lead to more stress (Pudāne et al., 2019, p. 230), so the combination working and relaxing should be balanced.

4.8.2 Interactions with vehicle

There are interactions between the vehicle itself - exterior and interior - and the people directly and indirectly involved. The indirectly involved interactions are not taken into consideration and are left out of the scope.
The interaction between the vehicle and the user, which can be called **Human-Machine Interaction (HMI)**, depends on the level of autonomy. At level 5, no attention is needed from the driver at any point or condition; at levels 4 and 3, the car can drive without intervention in some situations.

In these cases, an HMI system is not super crucial. In levels 2 and 3, the HMI is essential as the user should take over in certain situations. Therefore, a mutual understanding of senses and actions should be achieved. **For level 4 automation in public transport, humans should not have any other role than the passenger. Providing information about the vehicle's capabilities could even be confusing** (Carsten & Martens,2019). **In a fully autonomous system (level 4 and 5), no interruption of users is desirable.**

Insights for the design

In city contexts more privacy is wanted
As people are easily overloaded and cope with stress

A social interior could enhance spontaneity
The paradox of designing for sociability

Seats not close to each other
By just creating bigger distances between people, it feels more private

People want to sit alone mostly
When being alone and when tired

People like to do similar activities in an SAV that they would do in cars
Daydreaming, listening music etc.

People like to do new activities in SAVs
Such as texting, eating, working.

No human interception in SAV
Informing about what is happening is good, however, not too much as that would be confusing for users.

4.9 Conclusions

This chapter explained everything about the current knowledge of the elements involved in the ecosystem of an SAV. This present knowledge will be used, both as design principles and conditions, in designing the elements of the ecosystem. The next chapter will explain the context of the MRDH and the future build-up in which the future system will be designed.

5 Context

of 2040 and how SAVs fit in the future

This chapter is about understanding the possible paths for the future. First, the area of the MRDH is discussed as this area is used as example case for a SAV-vision. Then, three important topics are discussed that highly influences the way we would use and experience SAVs in the future context. A combination of these "worlds" can exist parallel and therefore should be all taken into account when creating scenarios for the SAV-ecosystem.

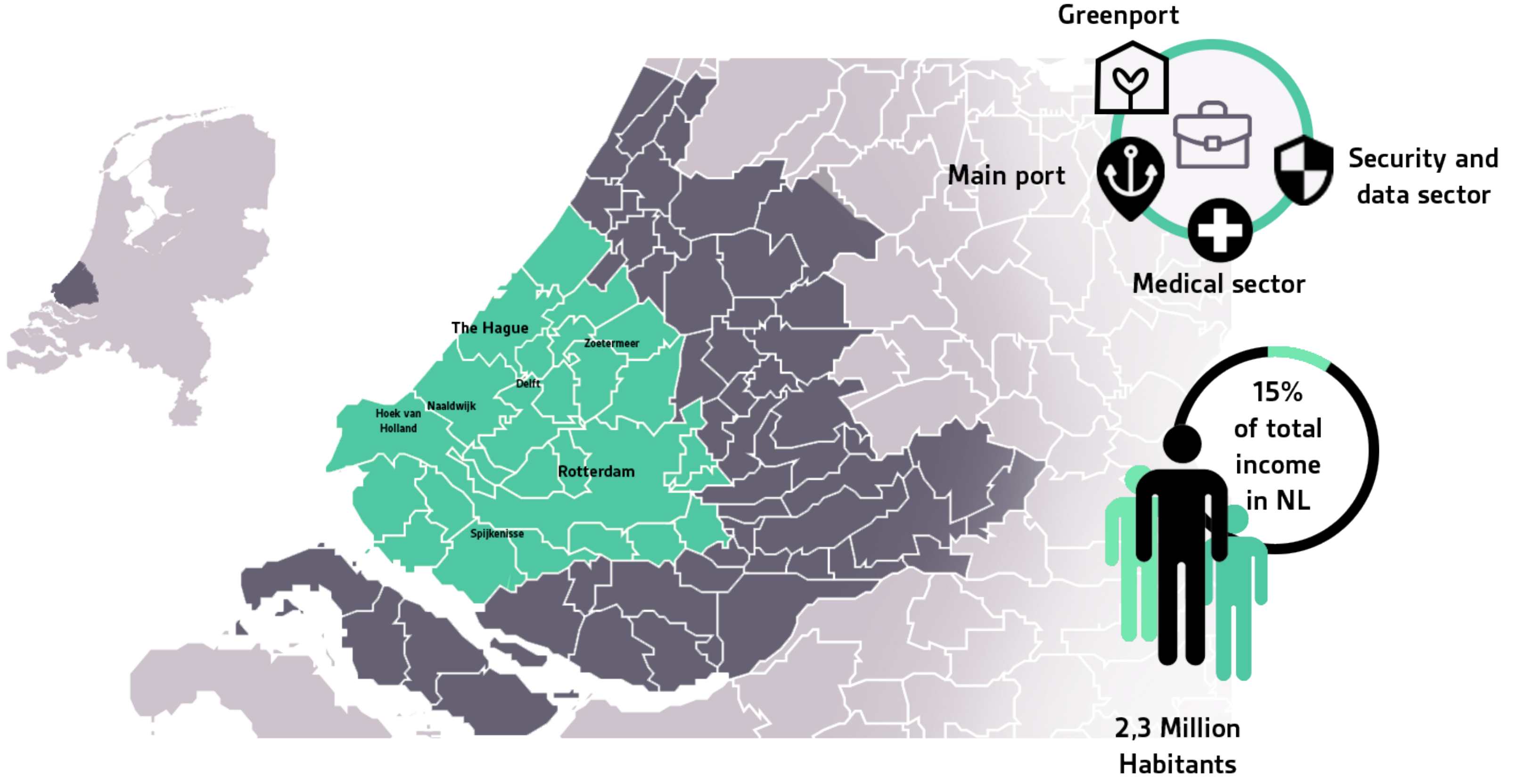
5.1 Metropole Rotterdam The Hague

The 23 municipalities in South-Holland form the administrative partnership Metropolitan Region Rotterdam The Hague (MRDH). The context in which the ecosystem of the SAV system will be envisioned. The urban build-up with the different areas are analyzed, the transport system and build-up, and the controlling and regulating role of the MRDH on transportation innovation. Also, the integration of an SAV-system within the MRDH is discussed.

5.1.1 Build-up of the MRDH

Metropole Rotterdam-The Hague is a dense urban area in the Netherlands. The area exists of two principal cities; Rotterdam – the port city – and The Hague – the royal city. Apart from Rotterdam and The Hague, the area also includes old cities like Leiden, Dordrecht, and Delft. Figure 41 shows the MRDH area in the Netherlands.

In total, **2.3 million people** live there, and it can be called the economic heart of the southern part of the Randstad. The region **represents 15 percent of the total income of the Netherlands**. The following sectors mainly represent the region; **Greenport (horticulture), mainport (port area), medical industry, security, and data.** However, the **economic performance is less than average compared** to the Netherlands and Amsterdam (Metropoolregio Rotterdam Den Haag, 2016).



41. In green, the MRDH area and position within the Netherlands. The purple area is the province South Holland.

5.1.2 Different areas within the MRDH

Six different areas can be identified for which the MRDH has certain ideas how personal mobility should look like. The areas are shown in figure 42 and also, the type of modalities are shown. In the figure, also leisure images are shown. These leisure centers could be experience areas which attracts people. In this way, the tourists could more be evenly spread.

Metropole
Dense urban area

In these areas, use of **public transport and bikes are stimulated**. Bike routes will be connected to public transport hubs. **Public space is really important** and focus lays on the attractiveness of it. Parking spaces for bikes are important. Parking for cars as well in the center as well on the edge of these cities with **P+R places**. In the city, **electric cars and emission free mobility is stimulated.**

Centers of The Hague and Rotterdam

Urban area

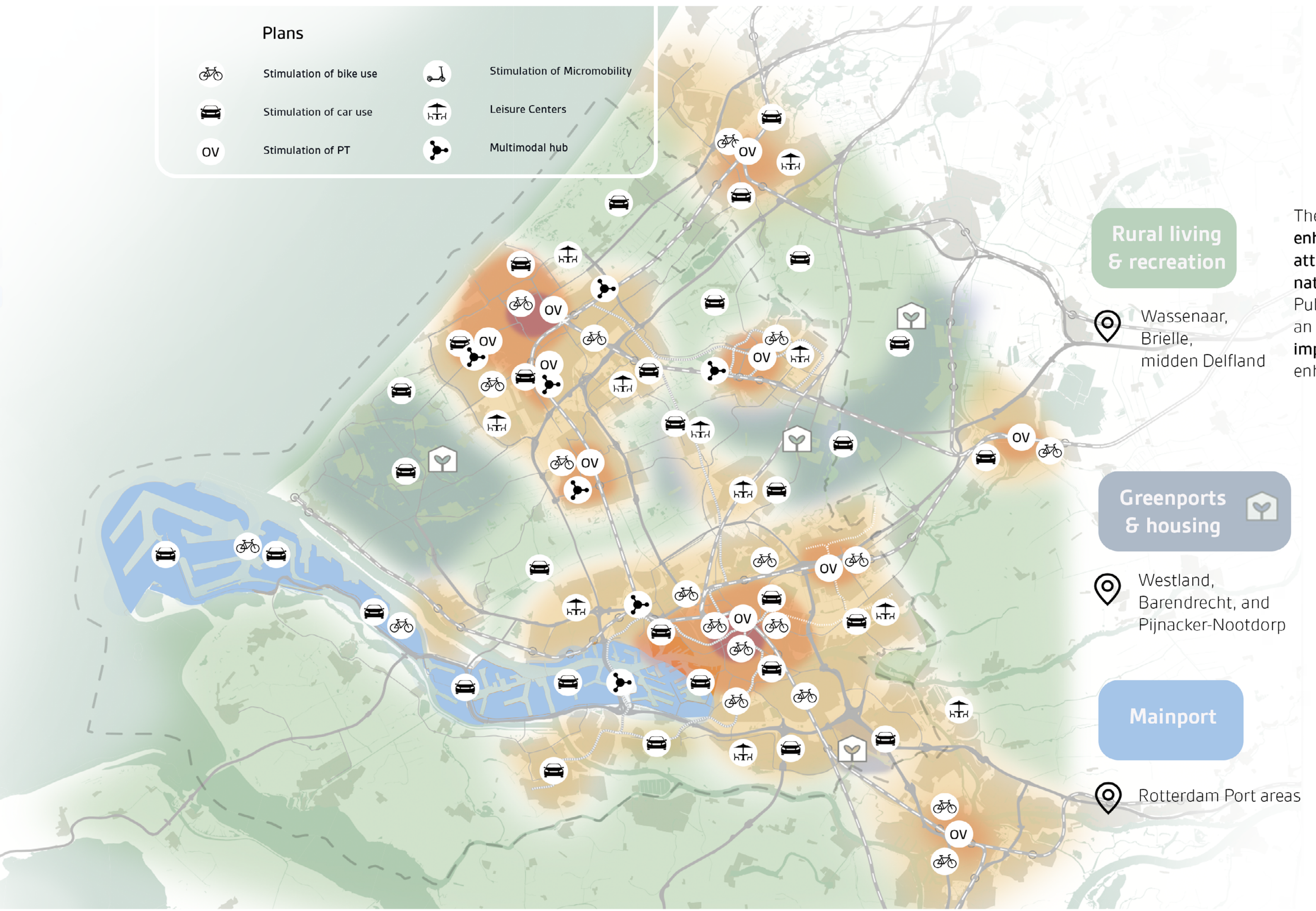
Use of **public transport and bik**e are the main goals. **Frequent and fast public transport** is needed. **Connecting existing PT and multi modal access** at certain points. The **existing networks will be re-structured**. The **bike is the main mobility but the access for cars is also important.**

Centers of Delft, Schiedam, Rotterdam Alexander.

Urban living and working areas

The focus is put on **restructuring leisure centers like shopping malls and expanding the attractiveness** of it. **Public transport is important as well as cars. Micromobility can be deployed for the accessibility of public transport hubs**.

Zoetermeer, Ypenburg, etc



Rural living & recreation

Wassenaar, Brielle, midden Delfland

These areas will be **kept special by enhancing the recreative and tourist attractions** and open living where **nature plays an important role**. Public transport and bikes do not play an important role here. The **car plays an important role**. The ideas exist to enhance PT-hubs with bike access.

Greenports & housing

Westland, Barendrecht, and Pijnacker-Nootdorp

The **car** is the dominant player. **Logistics is highly important**.

Mainport

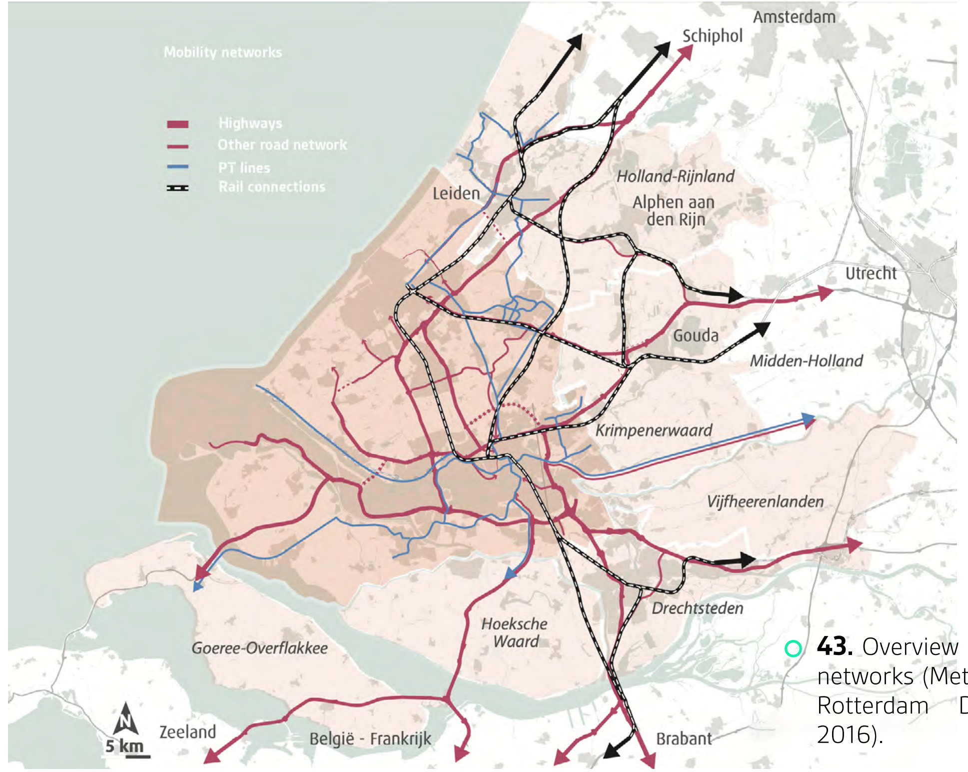
Rotterdam Port areas

In the mainport, it is important that goods and employees of these areas can go here easily. The **car stays the main mode of transportation**. However, safe bike routes are also exploitered.

42. The map of the different areas within the MRDH and the plans of the MRDH for mobility means in those areas.

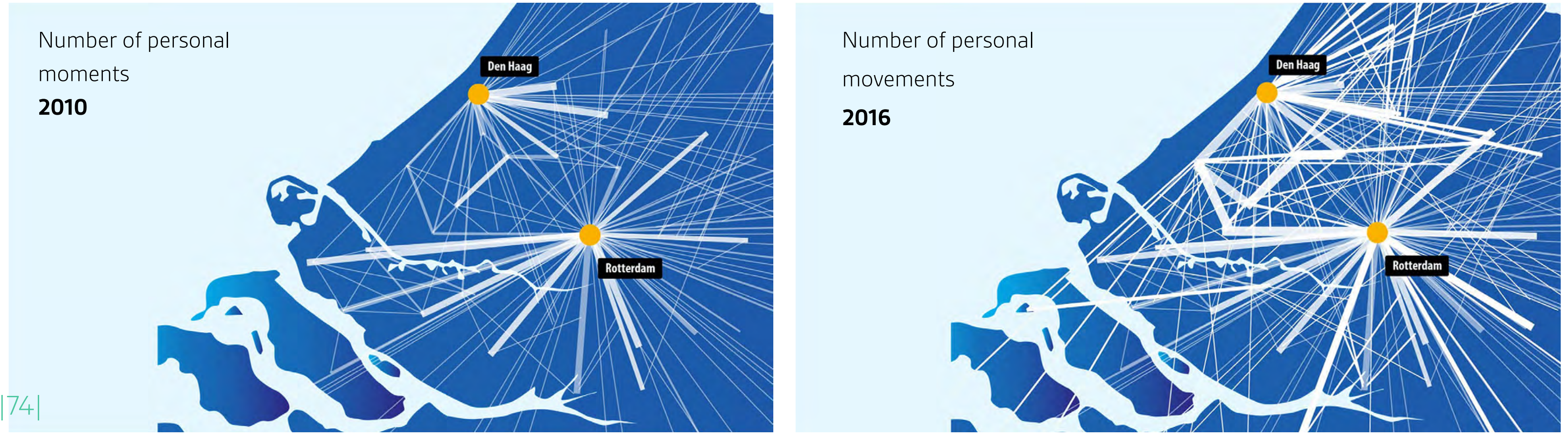
5.1.3 Overview of mobility networks MRDH

In figure 43, an overview can be found of the mobility networks in the MRDH. It shows bigger road networks as well as PT lines. Also, the most common directions outside of the MRDH are shown. In the **last decades, these displacements have grown**, see figure 44. Thereby, the average distance as well. Inhabitants are less focused on their city only. The number of **personal movements of people between cities has grown**, especially with public transport and highly educated people (Metropoolregio Rotterdam Den Haag, 2016).



43. Overview of mobility networks (Metropoolregio Rotterdam Den Haag, 2016).

44. Transport movements in 2010 and 2016. An increase of the amount and different movements. (Source: MRDH)



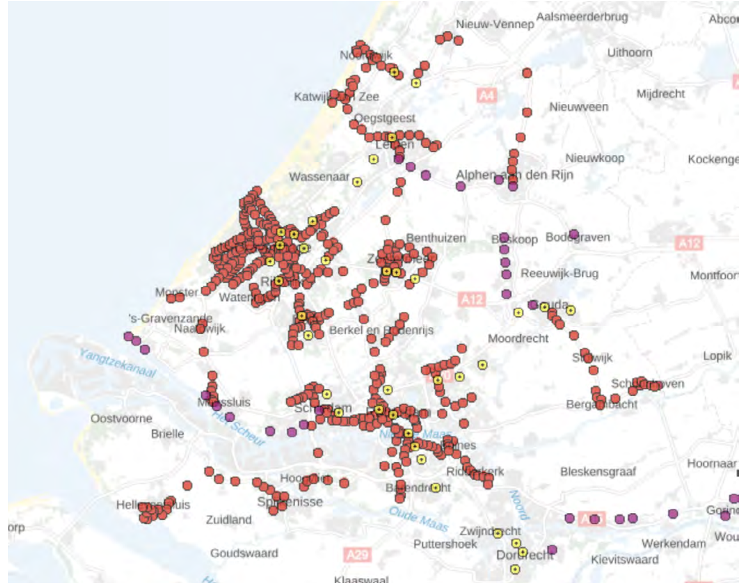
5.1.4 Accessibility and use of PT

The **commuters traveling between The Hague and Rotterdam mostly use the car (80%).** Compared to other cities in the Netherlands and within Europe, car use is much higher. The public transport in the region has only 20% market share. Only in part Haaglanden, the share lays around 30%. The public transport between Rotterdam-The Hague plays a critical role. The integration of the two cities is mainly guaranteed by public transport. The car plays a significant role in the towns around the bigger towns (Metropoolregio Rotterdam Den Haag, 2016). When looking at figure 45 and 46, it is noticeable that the southwestern part of the MRDH does not have as many PT as the northern parts. (Provincie Zuid Holland, n.d).

Station : National tracks

Station: Region tracks

Station: Other tracks



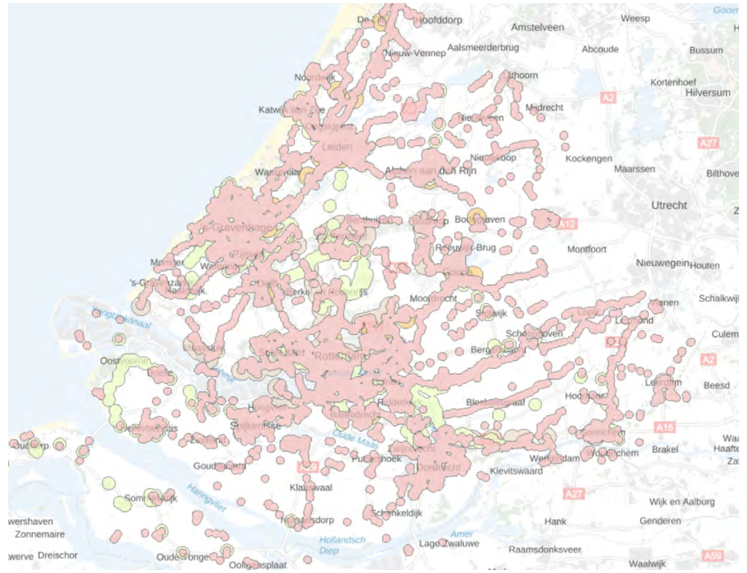
46. Stations within the MRDH. Clusters around The Hague and Rotterdam

Area of influence local transport within 500 m

Area of influence local transportwithin 800 m

Area of influence national tracks within 1km

Area of influence region track within 1,2 km



45. Areas facilitated by various public transport

5.1.5 MRDHs vision for future mobility

Although the Hague and Rotterdam cities are **located close** to each other, the areas are **not interconnected**. It cannot be called a metropole. People do work in one city and live in the other, but there is **no such thing as social cohesion** (Metropoolregio Rotterdam Den Haag, 2016). **The MRDH wants to strengthen this connection and create cohesion in the area.** Accessibility within the metropole is highly relevant; they invest a lot in mobility between the different places in the metropole. The **Randstadrail** is an example. This randstadrail is placed on existing networks of past train and tram networks. It is a hybrid system between The Hague and the city of Zoetermeer, and subway-like carriages between The Hague and Rotterdam; metro E see figure 46. The stations used by both lines have extended platforms with a high and a low part.

Moreover, the network includes two bus lines. The ambition of the MRDH is to become one functional, diverse and attractive metropole eventually. Within a polycentric structure with all different centers having their qualities.

A robust mobility network is crucial to achieving this vision (Metropoolregio Rotterdam Den Haag, 2016). In the short term, the goals are set on increasing an easy traffic flow. Also, creating "autoluwe" (somehow car-free) zones and strengthen the public transport system. In the long term, an accessible and sustainable design is the goal.

47. Metro map of Rotterdam and some areas in the Hague. Line E is part of the Randstadrail.

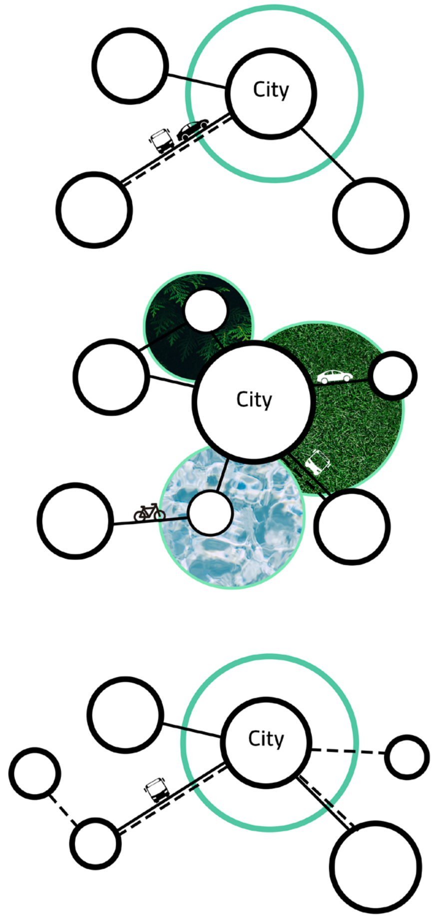
5.1.6 Sustainable city growth strategies

We will face an **increased population**, and therefore the infrastructure around us will and could change. There are different ways to grow cities which are shown in figure 48.

In the first scenario, existing city areas will be built and strengthened. This means there will be infringement, urban renewal or residential areas, densification, and transformation of the urban business park into residential places. In this scenario also, the existing infrastructure will be extended and enhanced. In the end, there will be a 'green belt' around cities with a fast-intercity transport system.

Another scenario could be to **urbanize the countryside.** This is called Residential Landscapes. The model is based on expansion and transformation, served by a regional network of car and public transport. This model contains most of the expansion locations.

The last scenario could be to **expand areas close to existing public transport junctions**. The existing infrastructure will be utilized to the maximum. Green places are being extended, and old investments in public transport are smartly used. In this way, residents could choose multiple modes of public transportation. (College van Rijksadviseurs, 2018).



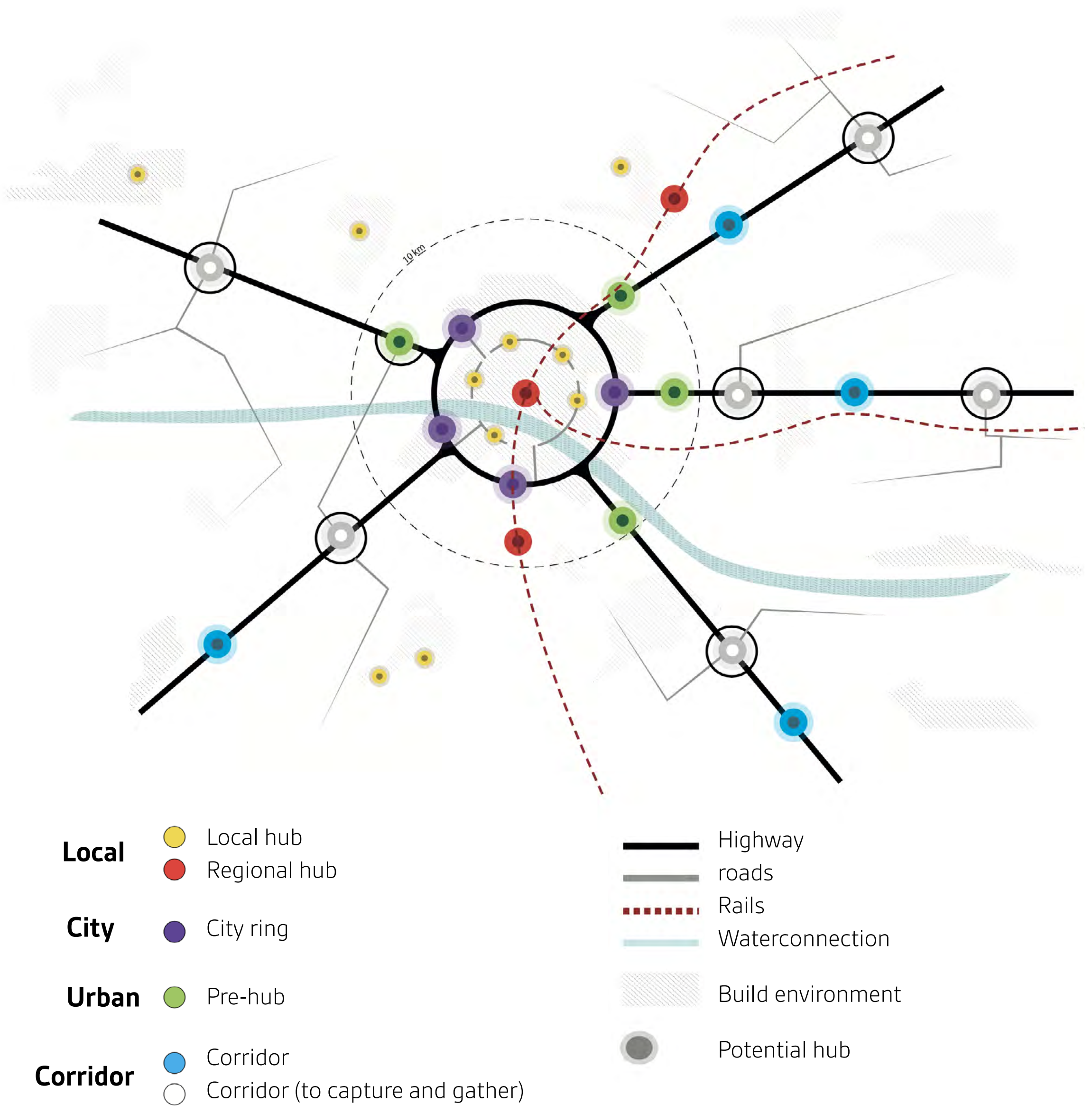
48. Three scenarios to expand. From top to bottom: Densification of cities, extending cities and junction growth.

According to College van Rijksadviseurs (2018), the **first scenario would be the best option** when looking at **costs, spatial planning, and making use of existing infrastructure**. Therefore, this model could be used in **2/3 of the cases**. The second scenario is too risky as it is a slow process and could lead to more cars and energy use. The **last scenario is also feasible and could be sustainable.** However, building next to PT is quite hard in terms of regulations. Eventually, the mobility system serving those areas should be sustainable. Area development and planning for mobility go hand in hand.

5.1.7 Multimodal hubs

Suppose we would take the last case, which is investing in housing next to PT-junctions. More people are incented to travel with PT. They also might **transfer from junction to junction.** These junctions, being called multimodal hubs, should be defined and be useful for SAVs.
The director and urbanist of VenhoevenCS (Appendix A6) mentioned four different hubs: Local hubs, city hubs, urban hubs, and corridors. (Rijkswaterstaat & VenhoevenCS, 2020)

In **local hubs**, people arrange their mobility, trash and parcels at one spot. Those are positioned at places where local trash bins are located around 500 meters from people's homes. Those local points already exist in certain parts in the north of the Netherlands. Those are called **Mobipoints** and are recognizable local points where PT and shared services can be found (Mobipunt, 2020). The difference between a local and regional hub is that there is also a **train connection in a regional hub.**



49. Overview of the different types of hubs (Rijkswaterstaat & VenhoevenCS, 2020)

City hubs are located around the ring of a city City hubs are ;and can be used for intercity travel. They can also be used for trucks being turned into **city-logistics.**

10 km further outside the city hubs, **urban hubs** can be found to travel from more rural areas to the city. Before people enter the highways, they are "caught," so they can use a rapid PT-system from here instead of the car. These urban hubs can also function as meeting points.

Corridors do not exist yet. They could serve as transfer points for cars, shared vehicles, and trains.

The idea of a multimodal hub is that it connects different forms of mobility. Trains, planes, busses, metros, everything comes together in a hub that makes it easier to use multiple mobility modes. Most of the time, cars are not considered in these hubs, and therefore, people travel from a to b in a car instead of doing a trip chain. Granstudio (2019) designed an urban hub that makes it easier to take the car, drive into a hub, and further drive into the city with public transport.

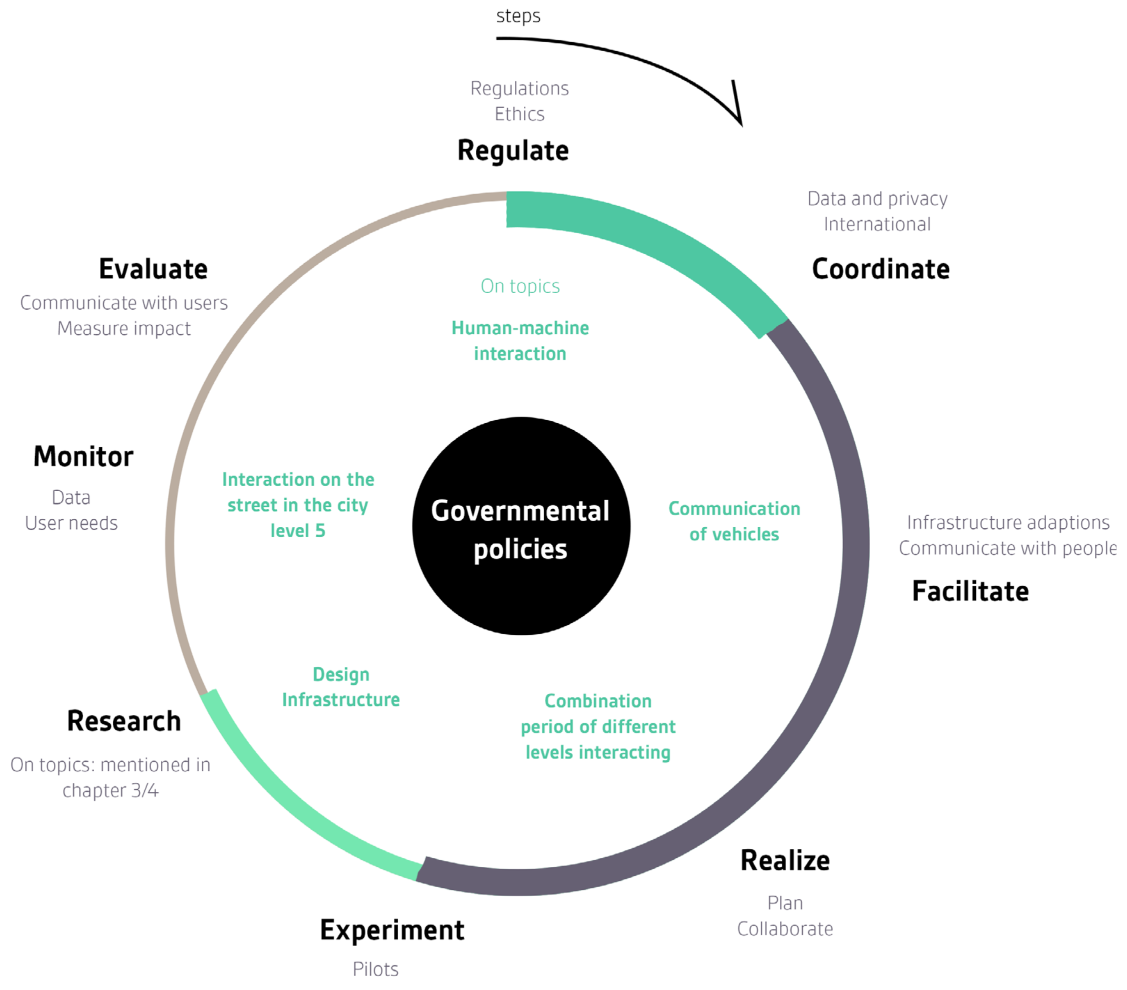
Multimodal hubs are significant to consider in SAV-systems as they can help integrate SAVs in the existing PT network.

5.1.8 Regulatory role of the MRDH

The MRDH has a lot of impact on how SAVs will and can be used in the future. From chapter 2, we learned that governmental organizations' regulatory role, such as the MRDH, has an enormous impact on innovations. **They focus on pushing strategies and lack pulling strategies**, which might be because these include large investments, and the technology and future are relatively unknown and insecure.

In figure 50, within the circle, relevant topics could be found that should be addressed by the MRDH to create a desirable SAV-system. These topics were selected by Mobiliteitsbeleid (2017) and are called "showstoppers," which are topics that could be in the way of the transition.

Around the circles, the different steps to make policies for autonomous vehicles are shown: regulate, coordinate, facilitate and realize, doing research and evaluate. The government should do these activities or actions.



50. Cycle of actions for regulatory parties

Within the metropole, some pilots are done such as the Rivium Park shuttle, which already exists for a more extended period. Also, at the ESA (European space agency) and Haga Hospital, autonomous shuttles drive around. However, the metropole has **strict regulations for facilitating these kinds of projects** (L. Zandstra, personal communication, September 23, 2020) and therefore there are only a few pilots of SAV-systems.

Insights for the design

Different areas need different mobility
But the connection and transfers between mobility are important in each area.

In high urban contexts focused on bike and PT
P+R areas are promising and public space is important. Multimodal access is important.

Urban living and working contexts
Focus on attractiveness of recreation areas and nature. PT and cars are important. Micromobility could enable first and last mile.

Rural and port areas focused on cars
Focus on attractiveness of recreation areas. PT and Cars are important. Micromobility could enable first and last mile.

Displacements have grown, towards other cities
Especially high educated people travel to more places with PT

80% uses a car for commuting
Which is higher than average in other parts in the Netherlands and Europe.

MRDH wants a strong mobility network
To achieve one metropolis. The network should be sustainable in the longterm.

Integration within metropole only exists in PT
Other mobility networks are not really metropolitan.

Two growth strategies relevant
Densification of the cities and building at junctions, strengthen infrastructure and renew.

Multimodal hubs are important
For designing the right transfer, which might be a SAV-vehicle.

Active role for the MRDH
For designing the right transfer, which might be a SAV-vehicle.

5.2 Dive into the future

The future can **partly be predicted**, be **random**, and **influenced by our actions** (Kosow, H., & Gaßner, R., 2008). Based on present knowledge and the knowledge about developments and trends, we can identify different future paths. In this section, three pillars are explained chosen as future context build-up. The pillars are built upon knowledge which can be found in Appendix E. Based on these different future paths, different future "worlds" are build to create scenarios for.

5.2.1 Where do we live?

Whether the idea of the MRDH to mainly live in dense metropolitan areas will be correct or not, Rotterdam and The Hague will have to deal with **15 percent growth**. There are two movements, that can be distinguished.

On the right side of figure 51 the metropolitans are shown. In these dense areas, people are living in **superblocks**, which contain multifuncional spots. People mainly walk and bike and for longer distances, use the PT lines. In these metropolitan areas, innovations are needed to guarantee seamless mobility and a healthy environment for people to live in.

On the other hand, there has been a **counter development of people moving away from the cities to rural areas**. People expect more space around them, live bigger with fewer costs, live in a less crowded place, and closer to nature. This spread of people could benefit the traffic flow. However, it puts pressure on our sparse nature.

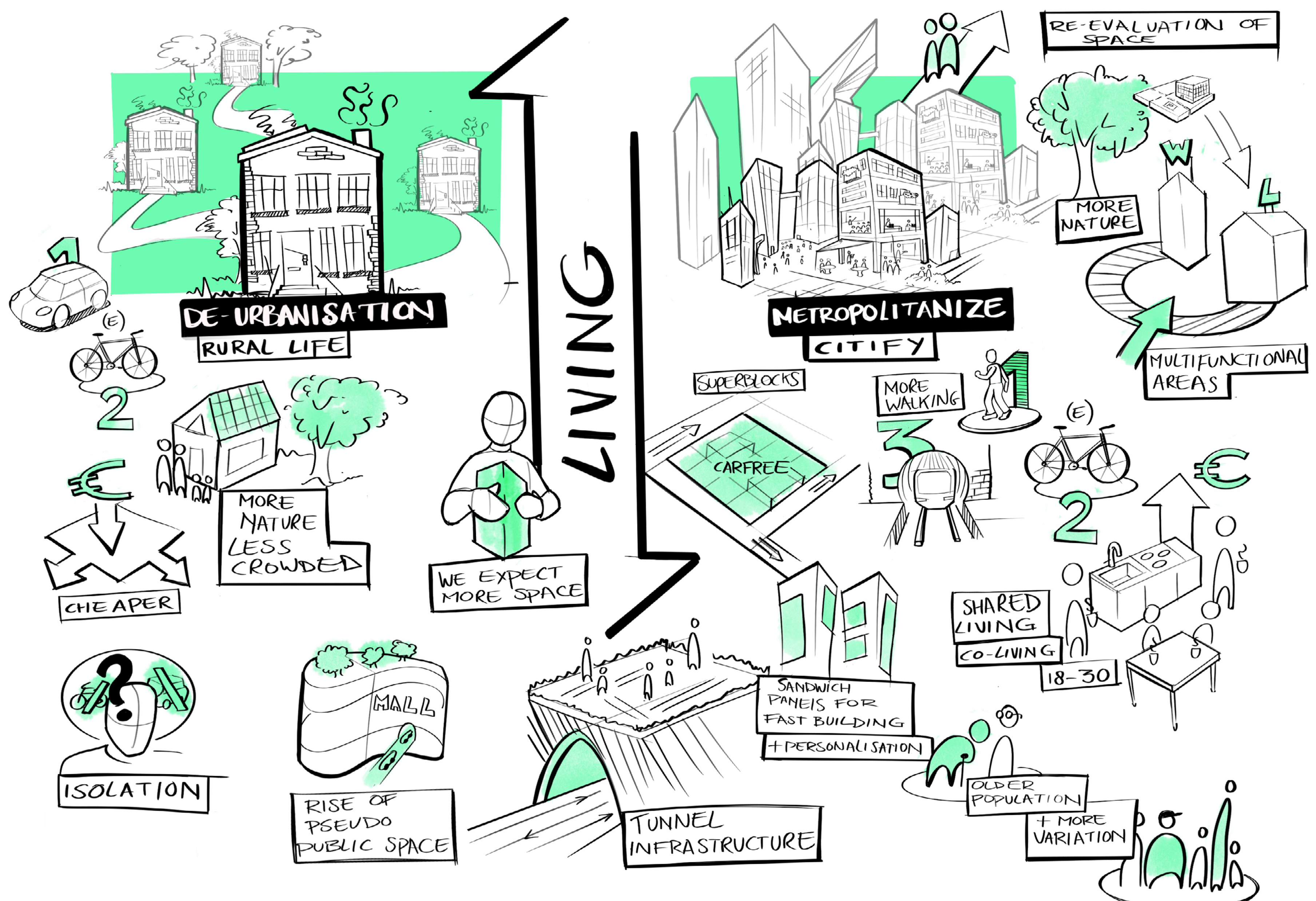
Trends and developments Appendix E

Rural life

Too expensive in cities
More nature wanted
We expect more space
Rise of pseudo public space
Rise of the mall
Ban the car from the city centre
Travel further within one-hour travel time
Hubs and Mobi points

Metropolitan

New composition of habitants
Tunnels
Urban ageing
Sandwich panels
Mixed use neighborhoods
Superblocks
Co-living
Growing pedestrian areas
The need for more housing in the city; Urbanisation
Number of residents grow in the city
Cities grow, non urban areas recede more
hubs and mobi points



51. The future of living

5.2.2 How do we live?

It has become easier to reach many more locations within the same time, see figure 52. More mobility options and faster trajects are enabling us to expand our life towards more places. We care more about quality and are **willing to travel** for festivals, experiences and **explore the world**. Also, user experience centers such as malls and entertainment areas are attracting visitors from many places. On the other side, you see how we would like to keep our **circle smaller, do more local activities** and find ourselves closer to home. Although the pandemic forces people to stay home and work from home, it is a development that could become more normal. People will work multiple days at home and will work more remotely.

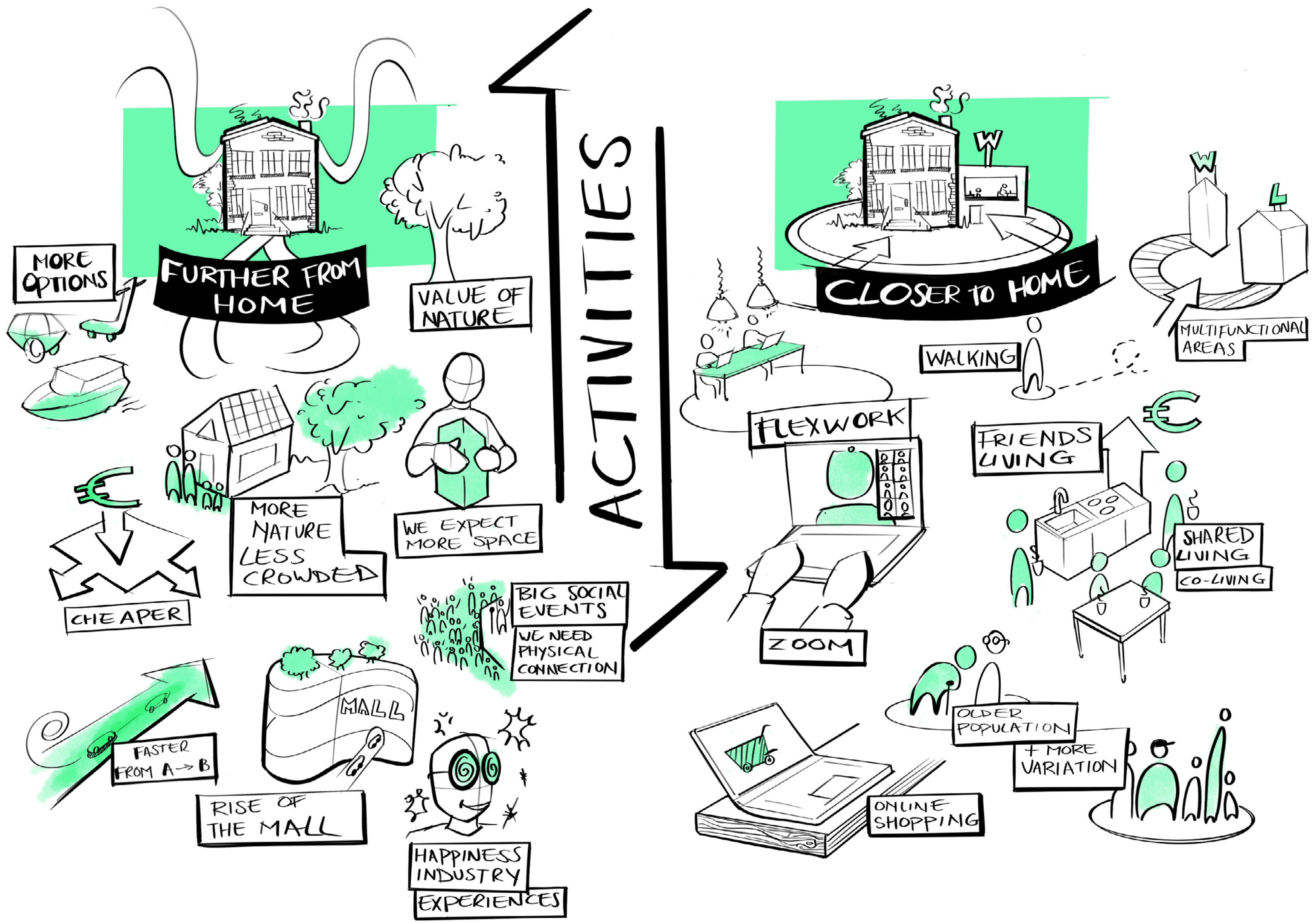
Trends and developments Appendix E

Further from home

More choice for mode of transport
Value of nature
Rise of the mall
More demand responsive transport
Hyperloop
Internationalization
Experience centers
Travel further within one-hour travel time

Closer from home

Co-living
Friends living
Flexworking
Pandemic life
Online shopping
Urban ageing
New composition of habitants
Ban the car from the city centre
Rise of micro mobility
Urban gardens



52. The future of activities

5.2.3 What is our attitude towards sharing?

In figure 53, our future attitudes are shown. We **share more and more personal informatio**n with companies like Google and Apple. It is easier to click OK and not think about how your data is used to make money. As data is used in bulk and can be processed by a blockchain system, it would be super anonymous. It is quite lovely to have a personalized advertisement that fits your lifestyle. Sharing and connecting data is the only way to live a seamless and connected life. There will also be a counter development of people being more conscious about their data sharing. Companies will ensure that data is not gathered and "offline" experiences and services will rise. People will choose services that can be used alone without sharing, and not all information is shared anymore. The question here is what the majority's attitude is.

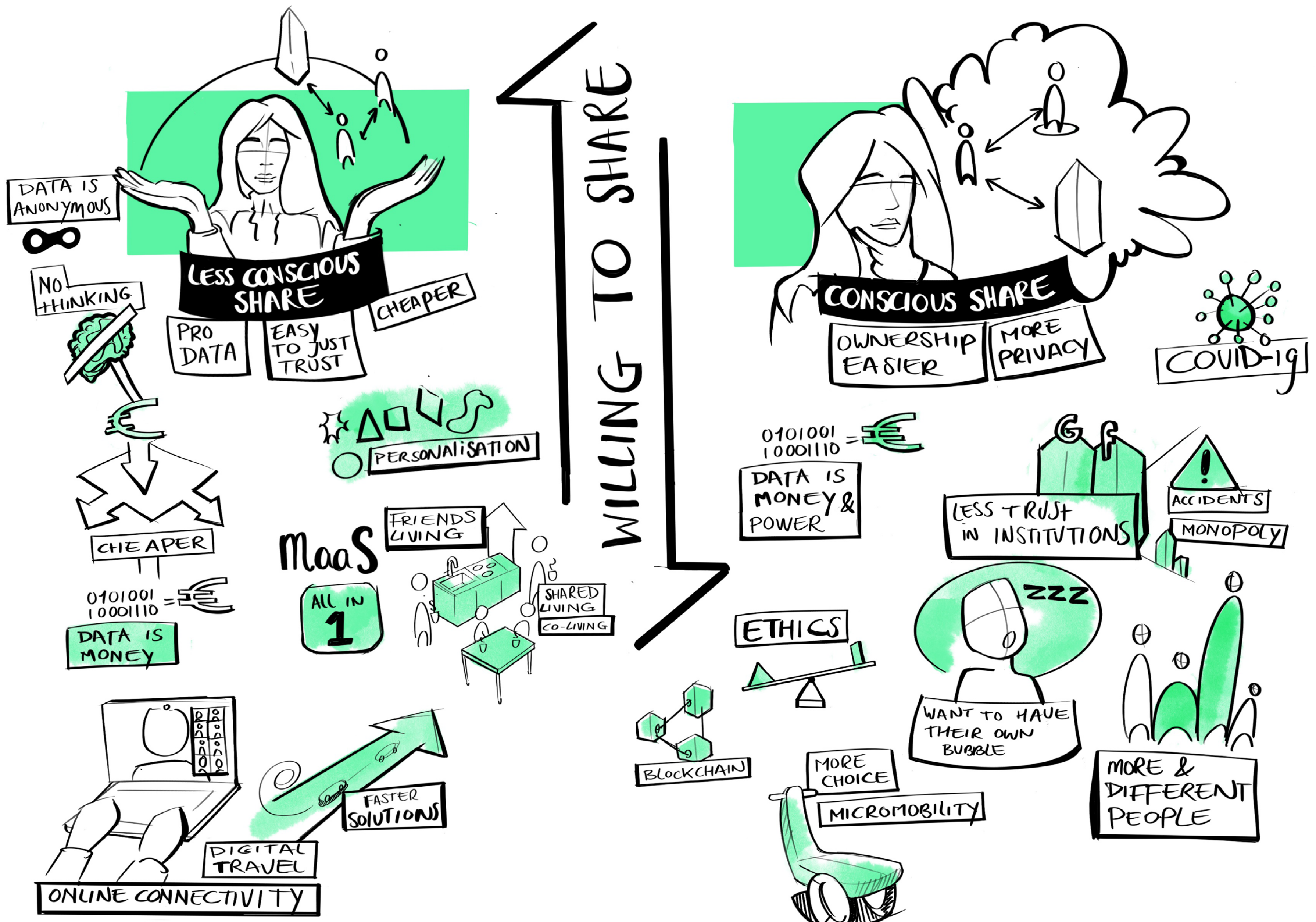
Trends and developments Appendix E

Willing to share

Blockchain
Data is anonymous
Easy to share data
Personalisation
MaaS
Data is money
Digital travel
Online connectivity
Shared living

Rather not share

Ethics
More choice to travel alone (micromobility)
Less trust in institutions
More variation in population
Wanting to have own bubble
Pandemic
Crowding in cities

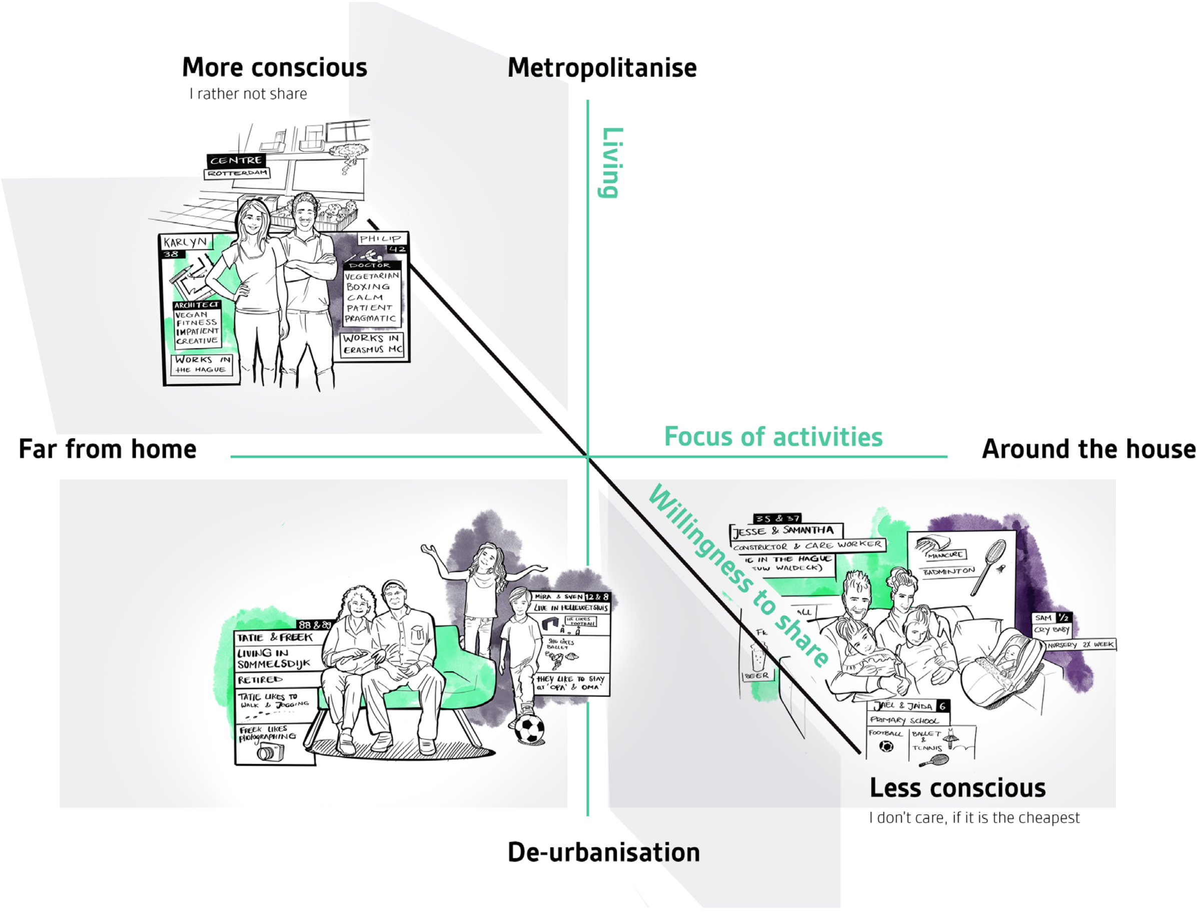


53. The future perception on sharing

5.3 Creating scenarios in future worlds

If we consider all future directions I discussed before, we could have eight different possible future worlds. However, some combinations are left out of the scope because they would work best with other mobility modes such as train systems or pedestrian lifestyles. For instance, only one metropolitan scenario is chosen as there is already a relatively good working PT network. However, it is still interesting as there are also reasons for city dwellers to use SAVs for longer distances or activities in which people would take the car.
Non-urban contexts are more interesting to explore as there are less or even no PT systems. Later, these explorations are merged into one system that could operate in most future contexts.

Three different future propositions are explored to find out how an SAV system might work. Those combinations are shown in figure 54. The next chapter will introduce the user stories and the evaluation of these scenarios.



54. The three worlds combined into three scenarios.

6 Scenarios

The possible role of SAVs in 2040

The design characteristics found in chapter 4, in combination with the possible paths of the future discussed in chapter 5, are used in three explorative scenarios. The three scenarios are based upon elements explained in the previous chapters. Those scenarios are evaluated with users. This chapter finishes with those insights.

6.1 Creating and evaluating scenarios

The goal of these scenarios is to make existing basic assumptions about future developments explicit. It focuses on possible paths of development, salient characteristics, and the interaction of critical factors. Scenarios cannot be viewed as "hard and fast" predictions. They indicate the spectrum of possibilities and reveals the limits of knowledge. In figure 55, a morphological map is shown that is used to systematically choose the storylines for the scenarios. The first three rows are the future scenarios described in chapter 5. The other rows are based on input from earlier chapters. In appendix A11, more is explained about this morphological chart and more information can be found about creating scenarios for explorative use.
After creating the scenarios, they are evaluated with users fitting the personas. The method and the set up for the evaluation can be found in Appendix G1.

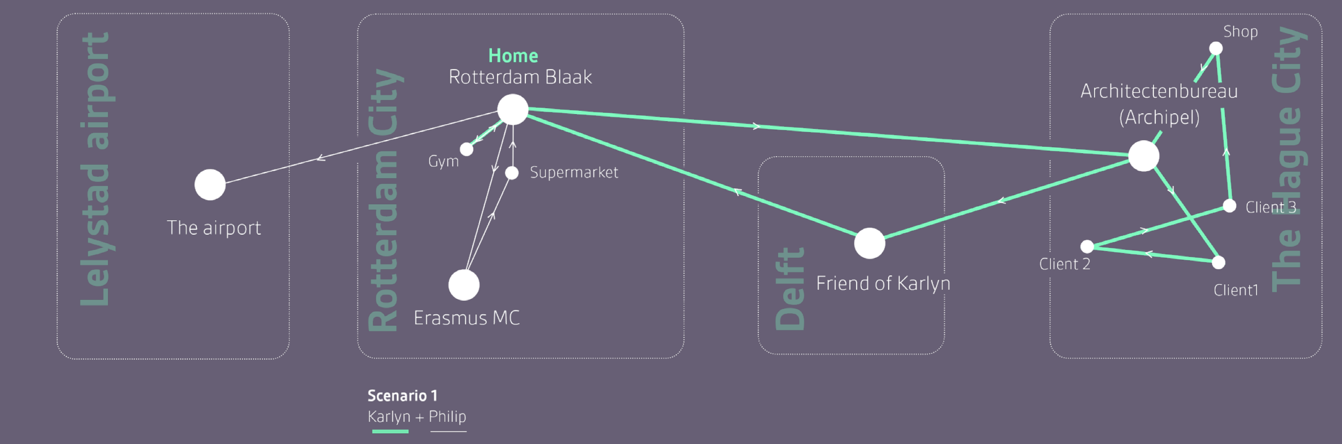
Components	Hypothesis 1	Hypothesis 2	Hypothesis 3
Living	Urbanization in bigger cities	Urban Sprawl	
Activities	Around home	Far from home	
Sharing	Not willing to share	Unconscious sharing	
Education	Low educated	Mid educated	High educated
Age	18 - 30	31 - 65	66 - 100
Family structure	Solo (1)	Double (2)	Family(2+)

Scenario 1 Scenario 2 Scenario 3

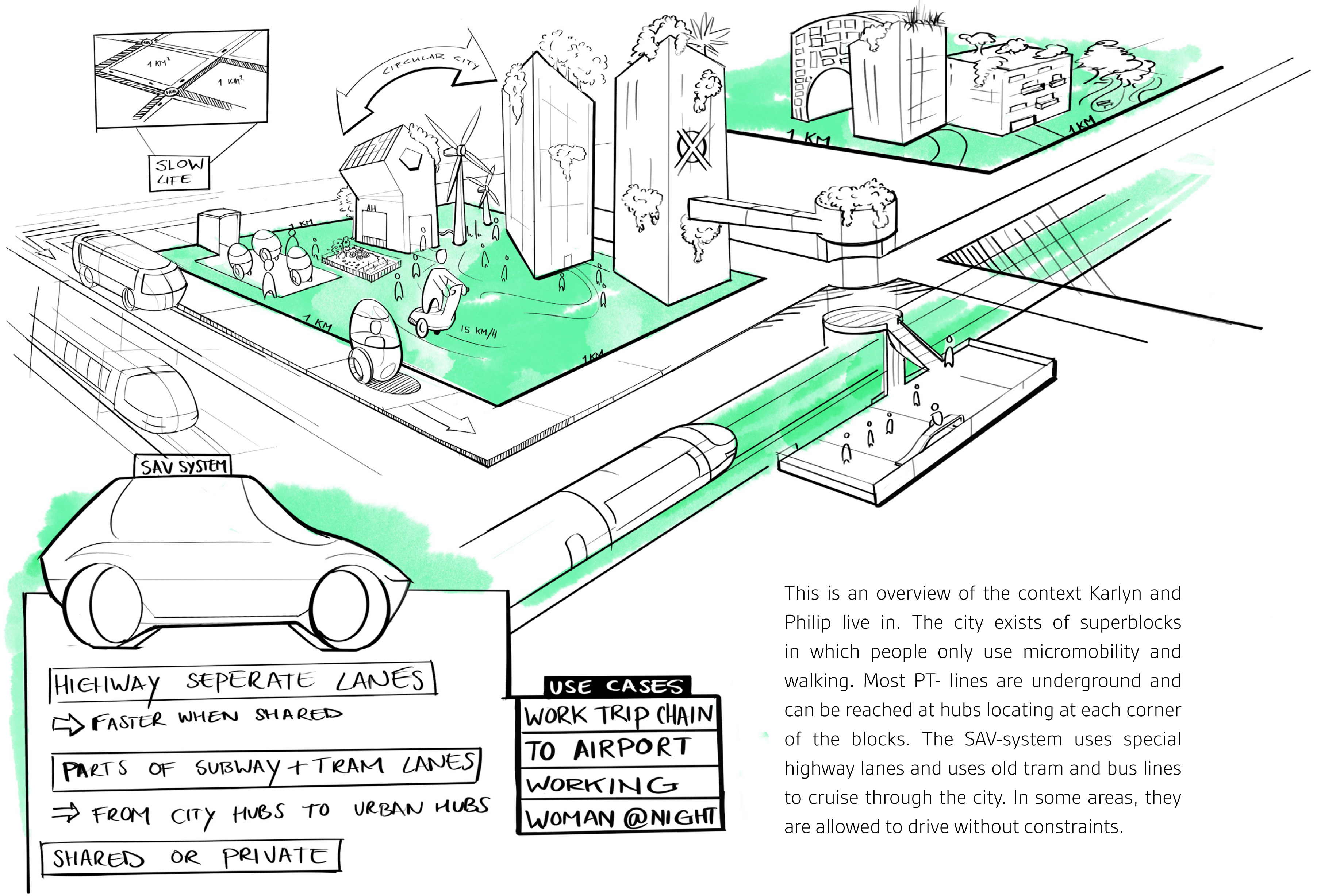
55. Cycle of actions for regulatory parties

6.2 Scenario 1: Young couple in the city

Figure 56 showcases Karlyn and Philip living in Rotterdam center in a co-living home in the center of Rotterdam. They live in a shared apartment. They are hesitant to share products with strangers. They value quality products, experiences and travel a lot. They live in the superblock Blaak but mainly search for other blocks to find the best things. They had a car but had to do it away because it was too expensive to park in the city.
Below, a regular working day is shown in a chart. The trips for which the SAV is used are furher explored and can be found in Appendix F1.



56. The life of Karlyn and Philip



This is an overview of the context Karlyn and Philip live in. The city exists of superblocks in which people only use micromobility and walking. Most PT- lines are underground and can be reached at hubs locating at each corner of the blocks. The SAV-system uses special highway lanes and uses old tram and bus lines to cruise through the city. In some areas, they are allowed to drive without constraints.

6.2.1 Insights scenario 1

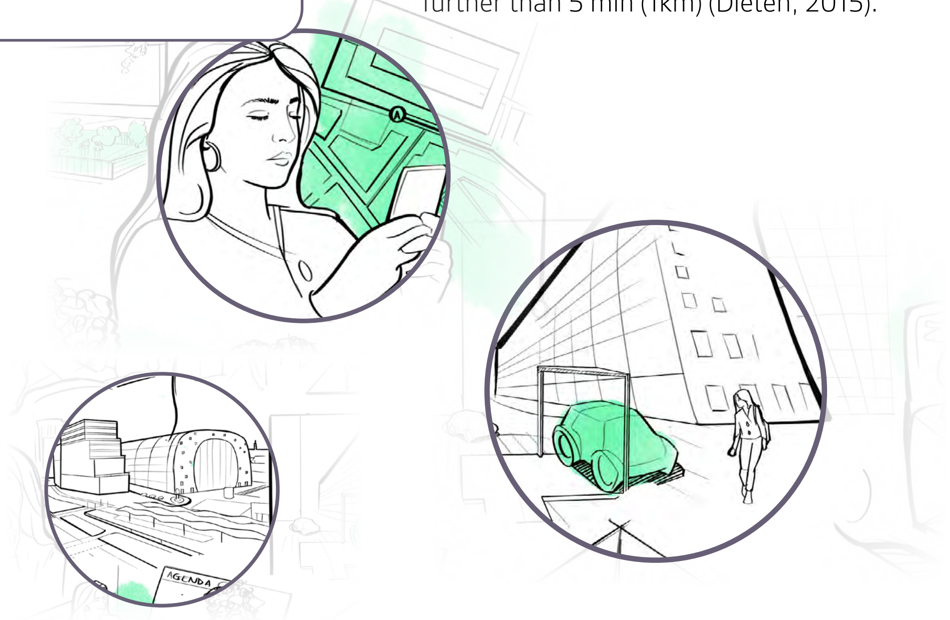
The first scenario is evaluated with 9 people that fitted the persona of Karlyn, shown in the table below 57 All participants are selected based on age, lifestyle and living area (in a city). The full interviews can be found in appendix G2.

NUMBER	F/M	AGE	LIVES	WORK
1	M	21	Delft	Student
2	M	21	Rotterdam	Student
3	M	23	Delft	Student
4	F	28	The Hague	HR
5	F	27	Delft	Design
6	F	36	Hoofddorp	Care
7	F	40	The Hague	Care
8	M	40	Haarlem	Architect
9	M	28	The Hague	Engineer

57. User evaluations' list

The following things were said about the different events in scenario 1.

IN THE PURPLE BALLOONS, THE STORY IS TOLD IN SHORT. FOR THE FULL STORIES, CHECK APPENDIX F1.



Walking to the shared service (to a hub)

Participants felt that it was quite logical to walk to the car. A participant mentioned that people would be used to walking to car-free zones. However, some noted that these hubs should not be far away, and 1 km was the furthest to walk to a mobility hub. This is in line with literature saying people do not want to walk further than 5 min (1km) (Dieten, 2015).

A random meeting with a colleague

In the scenario, Karlyn randomly got on a ride with her colleague in the morning to work.

Most participants mentioned that it is unwanted or abrupt to share a vehicle with a colleague in the morning if you do not know beforehand.

"I still want to be waking up, and if it is a stranger, you do not have to talk." However, it could also have been an open meeting with a colleague, which would be less informal than a "normal meeting at the office," one participant mentioned. It is also a very efficient way, someone else said. Informing the user beforehand with who you are joining the ride would be beneficial.

"

New ideas about interaction inside -
In conversation with a participant

Maybe you can choose what the layout will be. It is very personal if you are sitting next to each other, it might be nice that the interior changes towards the wanted interaction.

You can choose to make contact by creating some room to interact but mostly close it off as a default setting.

Maybe you first see the contours by the oblique glass, then during the trip, it will be more see-through. Slowly, you will see each other more, and yet you are prepared for this interaction. You know that you can do private things for the first time on the trip and then it will be more social when you arrive closer to your destination.

It could also be that when you get in and out, the glass is clear, and when driving, it will be oblique. Or when you talk, it recognizes that you want to be social and immediately gets more social. You can give people a choice to make contact with. Kind of an "In between social mode."

"

Getting picked up by a business SAV

All participants perceived the business service as a useful way and making fair use of the technology that an SAV can provide. Also, participants mentioned that the streets look more calm and green, which is an excellent future perspective. "I like the idea of many types of cars, which also works quite well with Uber." However, "you need many vehicles in the system to make it work," one participant mentioned.

In case people do not want to use their personal information to reserve such a car, companies could have the account, and workers just use it anonymously. You reserve the vehicle, similar to booking a room. Multiple companies could even share those vehicles. Also, the idea of having the company name projected on the car is cool, most participants commented.

She and a colleague reserve a business vehicle to go to a client and already prepare the meeting on the road.

"

Ideas about working in the SAV
In conversation with a participant

What will happen if you need more discussion time in the car? And you arrive there too early? Discussions and meetings always take longer than expected. Maybe, there are neutral places where you can wait and finish your appointment. An "afrondplek." Within a city, a trip is probably 15 minutes. If you want a more extended session in the car, just wait at a place. It could ask how much time you need.

"

Waving at the car

I suggested a physical interaction to get an SAV to stop, similar to grabbing a cap in NYC. "A cool interaction actually for holding the car," one participant said.

Karlyn was visiting a friend and together with another friend take an SAV at 2:00 PM.

Guarantee safety

A double verification is the most desirable way to identify someone. A warranty before people uses the service that the system and a rating system can check by other users. Thereby a picture is desirable. Some said that only a picture inclines to discrimination, and therefore the two-way verification is wanted. Someone said that a live photo would also be beneficial to see how someone is looking at the moment.

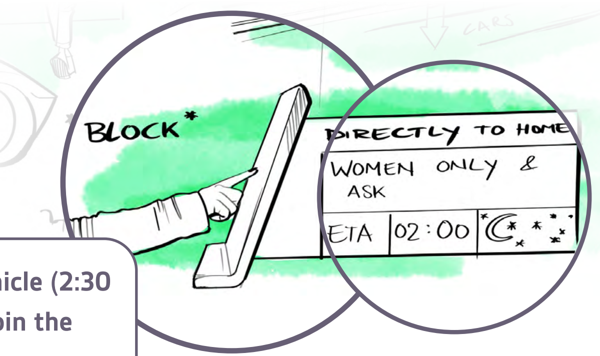
An emergency button can be placed in the car, and everyone would like that. Not everyone agreed on placing cameras.

"

Ideas to create non-discriminating system
In conversation with a participant

Maybe you can still have a private upgrade, but this person can actually enter the vehicle in a separate room. You do not get in touch. Perhaps she has to pay more, and he can pay the "shared" price because he wanted to share and only she doesn't want to. You could buy a premium account that can be private, but others can join but will not see you. When you get in, you know that it will be a shared service. On the train, you also know that someone can sit in front of you.

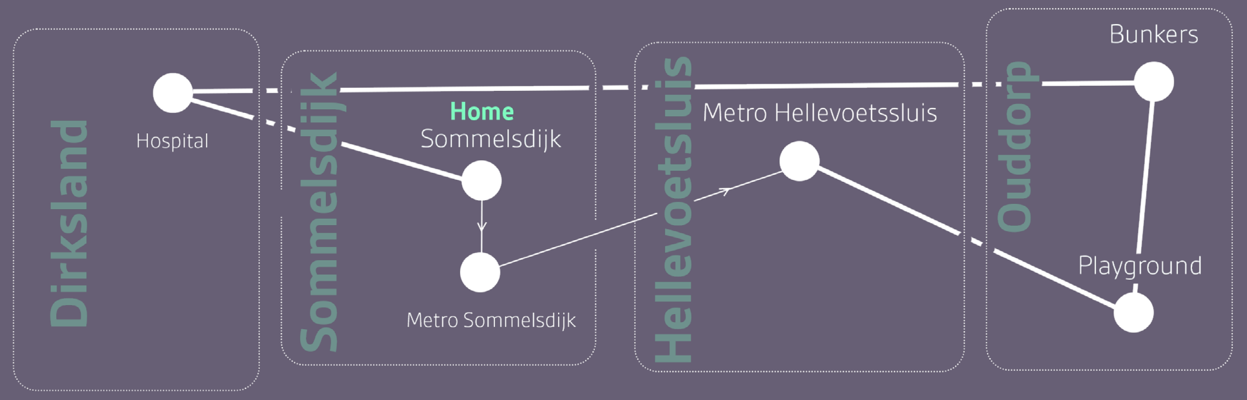
"



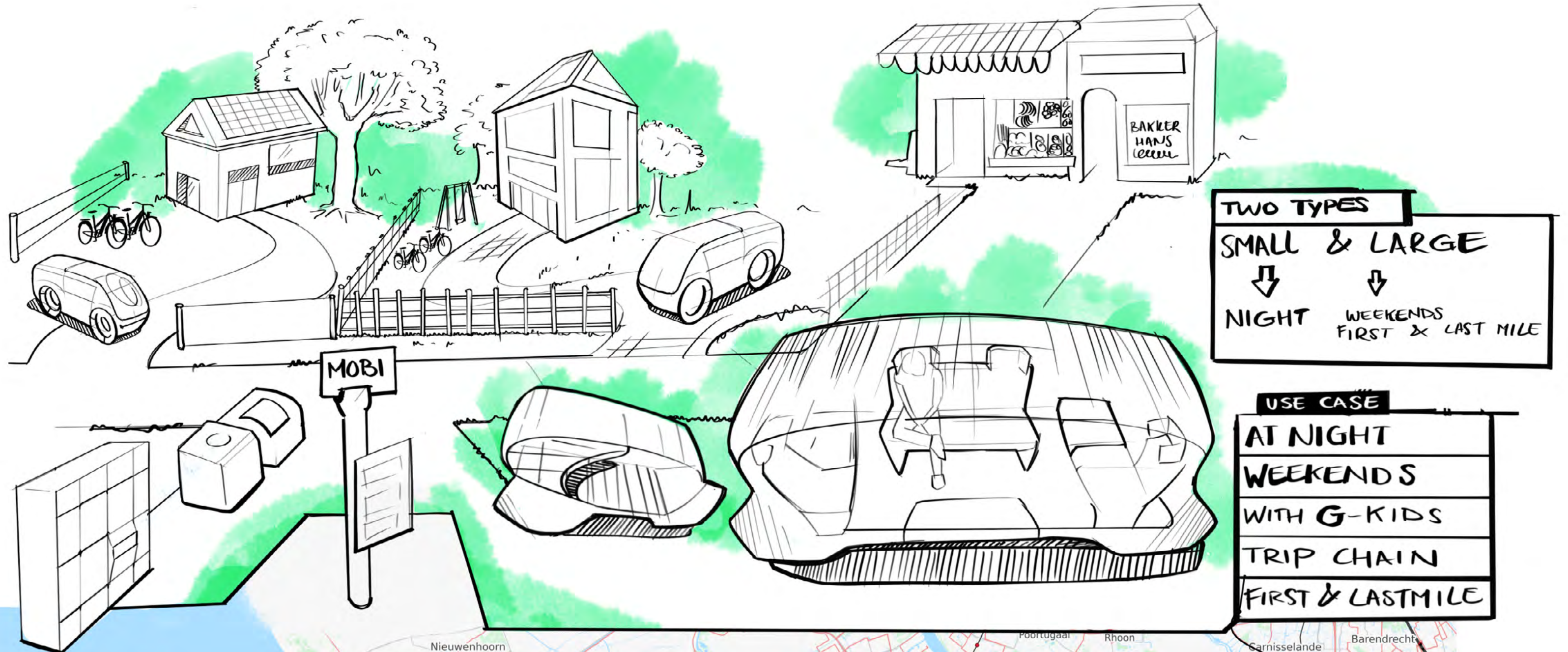
When alone in the vehicle (2:30 PM), a guy wants to join the vehicle. She blocks him.

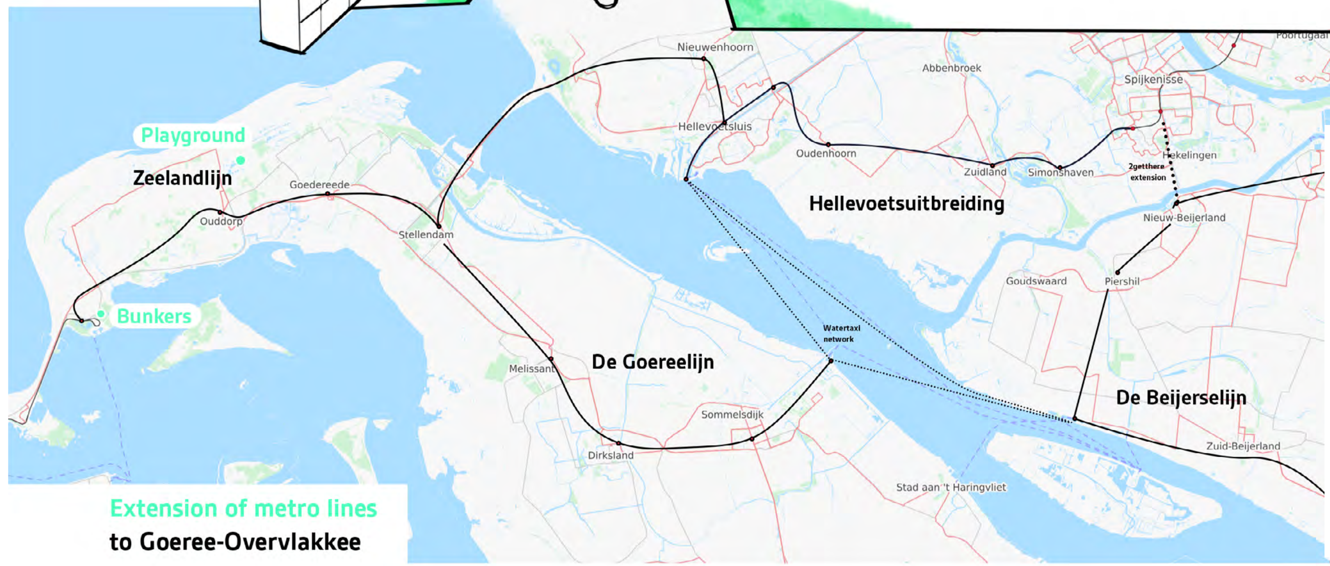
6.3 SCENARIO 2: ELDERLY COUPLE AND GRANDKIDS

Tatie and Freek live in Sommelsdijk as they always have been. They are retired and are unable to drive a car. They miss their freedom, and luckily they came into touch with the SAV system. Also, as more people moved to Goeree, the metro is extended. However, the walk is quite far from their home. The grandchildren typically stay at Tatie & Freeks place on the first weekend of the month.
A day in the weekend of Tatie and Freek and the grandkids is shown in the chart below. The full scenarios can be found in Appendix F2.



Scenario 2
Tatie & Freek + grandchilderen





Extension of metro lines
to Goeree-Overvlakkee

The metros from Rotterdam and the Hague will be extended towards Goeree. As more people are living in areas outside the cities, there is more demand. The SAV service can be used for first and last mile transport to PT and also from door to door. Because the PT lacks in the weekends, at night, and for complicated trips.

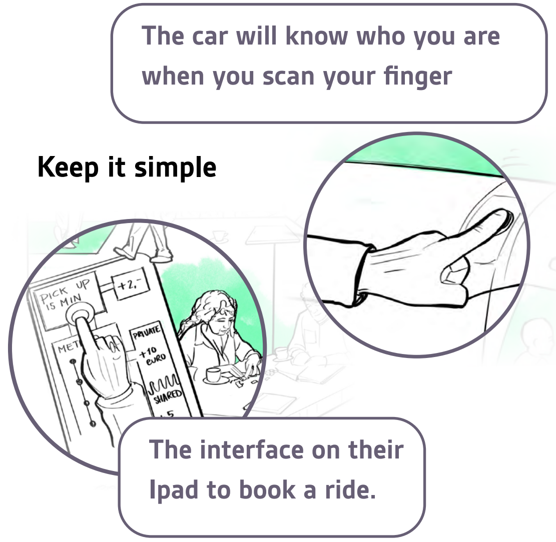
6.3.1 Evaluation scenario 2

This scenario is evaluated with 6 people that could fit in this future of 2040. The elderly were sought for this evaluation; however, it was hard to reach more participants because of the pandemic. Therefore also people around 60 were interviewed as they would be around 80 years old in 2040. Information about the participants can be found below in table 58. The full scenarios shown to these participants can be found in Appendix F2, and the full interviews can be found in Appendix G3.

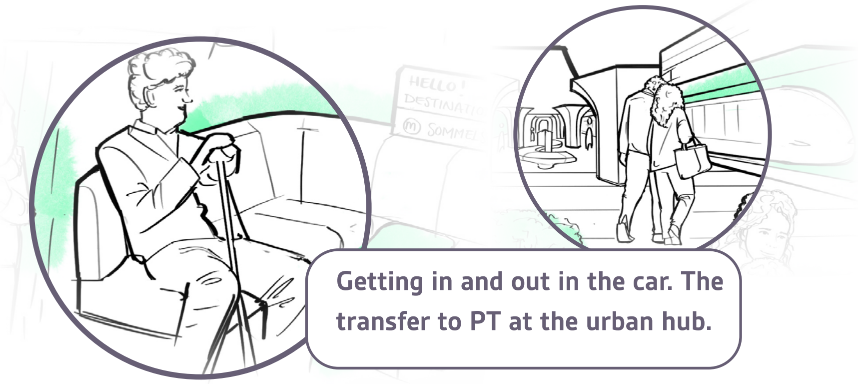
Number	F/M	Age	Lives	Work
1	F	71	Rhenen	Retired
2	M	69	Rhenen	Retired
3	M	59	Amsterdam	Government
4	F	58	Amsterdam	Care
5	F	89	Nijmegen	Retired
6	F	90	Petten	Retired
7	M	55	Montfoort	Construction
8	F	18	The Hague	student

58. User evaluations' list

Keep it simple



Accessibility



The elderly are not digital natives
The system should be easy to use for people who are insecure about technology and complex actions. The fingerprint scanner was a little too much for participants. However, the attitude towards technology innovations might change in 2040. Participants mentioned that the steps you have to take to use the system should be as small as possible. Most participants said that a help desk would be excellent. This physical interaction was perceived as helpful. One participant could only use such a system to ring (by phone) the SAV to come to pick her up.

Design for elderly
Two participants mentioned that getting in and out should not involve strange movements. Actually, you just want to walk in. When help is needed when getting in and out, someone could physically help at the hub. And there could be a personal assistant when using the system for the first time. "As elderly cannot process big steps, a possible transfer to PT, for instance, should be easy to follow, safe and comfortable," a participant said. The next modality should be easy to find and recognizable. A participant mentioned that when people panic or do not know what to do, they could push a help button.

Sharing the vehicle
Participants were quite okay with sharing the vehicle with others if people do not smell foul, for instance. Most participants mentioned that the car should have enough space, it should not be too intimate, and there should be enough room to look the other way.

Intervention possible
All participants want the possibility to **overrule the system and get out any time.**

Great experience with grandkids
"It is nice to share the vehicle with the grandkids and have a conversation with your grandkids. Normally, they would have been busy with their phones". It also enables spontaneity and flexibility, which fits the situation with kids as they always have spontaneous plans and ideas. The car's screen can be used to show videos to entertain the kids and give the grandparents some rest.

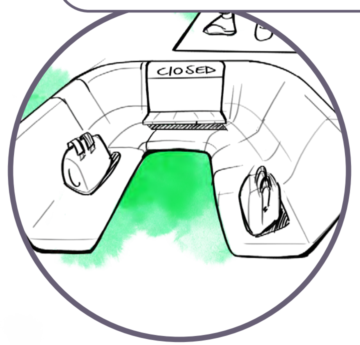
Great family experience, suits the different needs

Facilities in the car
Participants mentioned that there could be more facilities such as an umbrella, can dispenser in the car. Participants liked the lunch spot. Participants indicated that they liked the idea of a first-aid box. However, a solution should be found for users who are stealing or breaking things. Not having to park was also perceived as handy and easy.

A table in the SAV makes it possible for users to do things together such as playing a game.

The car as locker
Four participants mentioned that the car is kind of a mobile locker. Participants liked the idea of storing stuff you do not need and pause the vehicle. This is essential because it should feel safe in the car and that the car will get back to you.
This is similar to using an own vehicle as this can also be used as a mobile locker.

They went to a playground and paused the car. They can leave stuff they do not need and later get back in the car.



The car as locker

The metro being extended to the south
Mostly the participants living far away from PT liked the idea of extending the metro. However, one participant mentioned that there must be many people living next to the metro to afford it because it is costly to build (underground).

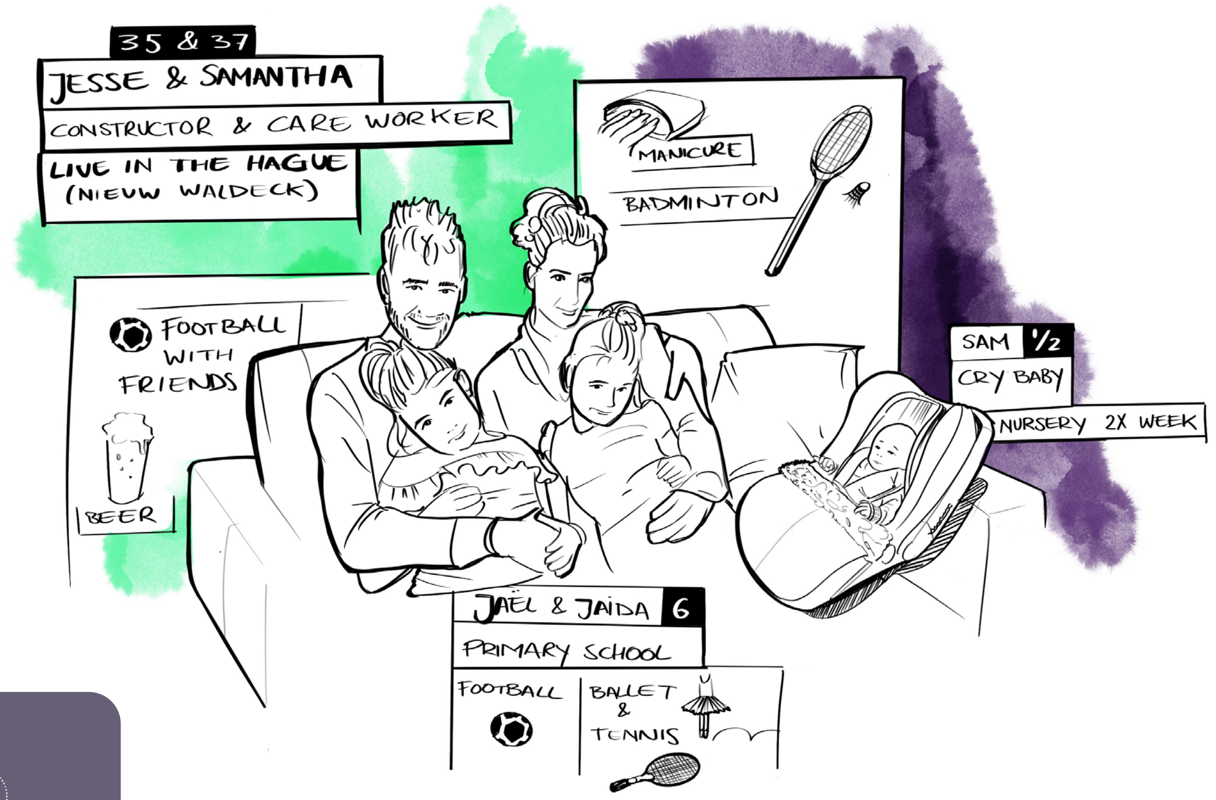
> "
> **An outside locker at street hubs**
> **An idea from a participant**
> The locker could also be outside the vehicle at the pick-up and drop-off locations and serve as a delivery locker. For instance, to get pizza delivered.
> "

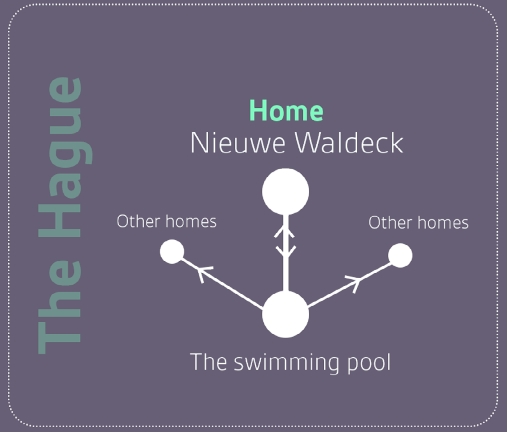
High value for elderly if community remains
Mobility is essential for the elderly. The Elderly can be highly dependent on others in their community. Especially the two older participants mentioned this. The system should maintain and respect the relationships people still have because of their dependence. Otherwise, it could lead to more loneliness. With an SAV-system, two participants mentioned, it becomes easier to reach places or to reach PT. One participant said that it enables freedom and mobility as there is nothing at the moment. Also, the car could allow getting to know more people, one participant mentioned.

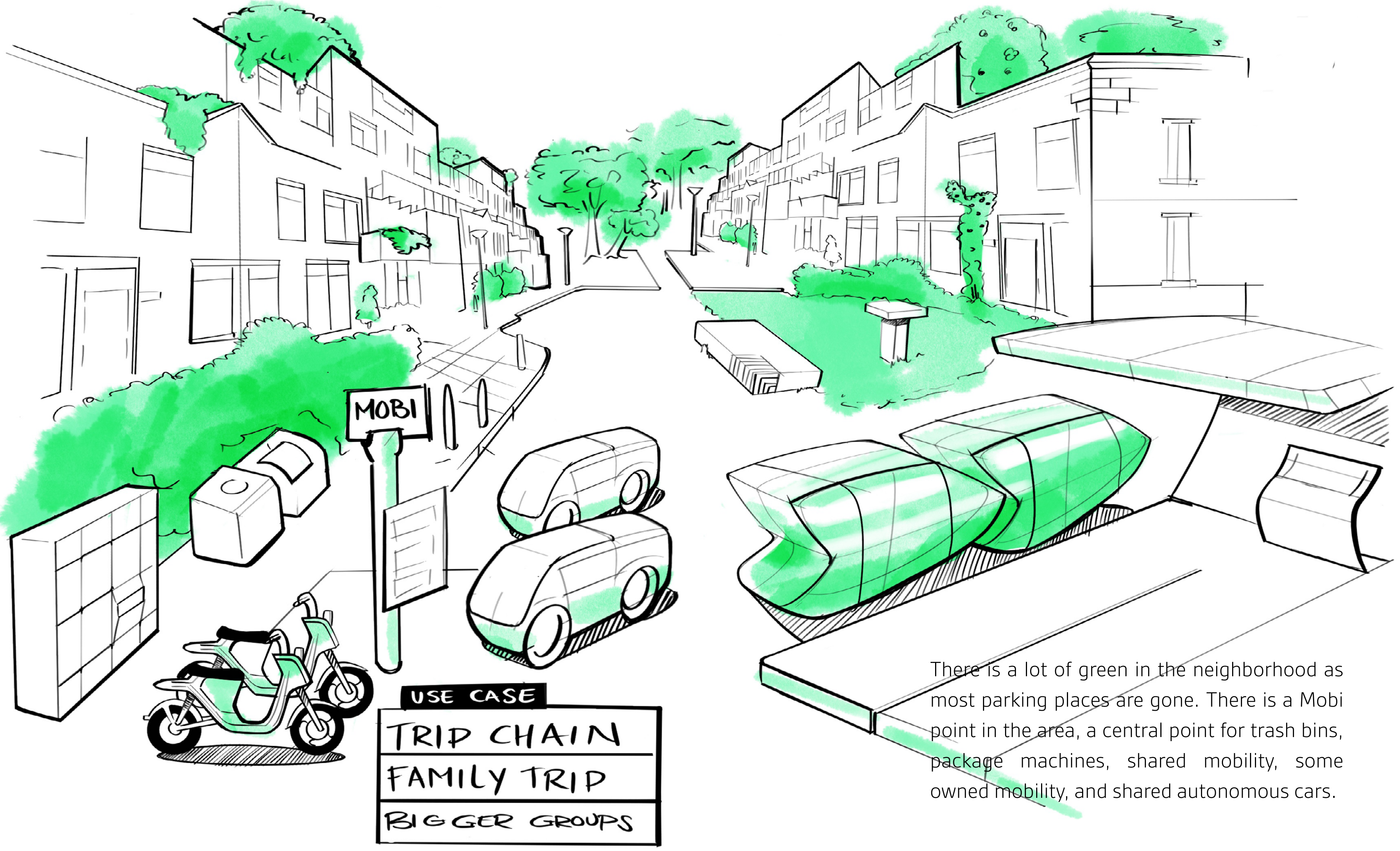
Keep the community in mind

6.4 SCENARIO 3: YOUNG FAMILY

Jesse and Samantha live in the Nieuwe Waldeck in the Hague and have three children. Sam, which is a cry baby and a twin of 6 years old. They do not have a private vehicle. She is a care worker (part-time) and always takes the bike to her work after dropping the kids at school and nursery. He is a constructor and has a business vehicle from work. They like to hang out with friends and go to the playground with their kids. The full scenarios can be found in Appendix F3.







There is a lot of green in the neighborhood as most parking places are gone. There is a Mobi point in the area, a central point for trash bins, package machines, shared mobility, some owned mobility, and shared autonomous cars.

6.4.1 Insights scenario 3

This scenario is evaluated with 4 people that have kids and envision this in the future 2040, see table 59.
The following insights were gathered. The scenario can be found in Appendix F3, and the full evaluation interviews can be found in Appendix G4.

Number	F/M	Age	Lives	Work
1	F	36	Hoofddorp	Care
2	F	36	Heilloo	Care
3	M	40	Haarlem	Architect
4	M	28	The Hague	Engineer

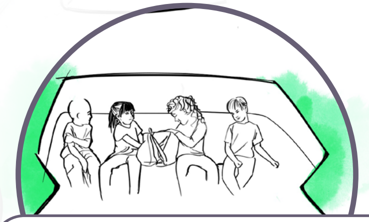
59. User evaluations' list

"
Ideal for women that just had a baby
An idea from a participant
When women just had a baby, a car is the only means to go somewhere. You are not going to take your newborn on the train. That is not comfortable and stressful even. My girlfriend does not have her driver's license and was very isolated that time our daugther was born. This could be a really good solution. You can even match young mothers in those SAV.
"

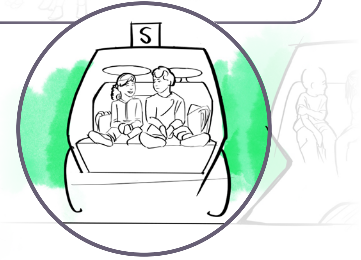
Interior
Two participants mentioned that the interior looks cool and even looks luxurious like a limousine. However, it should have got seats that face forward, one participant mentioned. Also, one participant said that there should be a universal system for child seats inside (Isofix) to fix every child seat.

No kids in the car without supervision
No participants liked the idea of 6 years olds being alone in the car with other kids. All participants thought that 10 to 12 years old could be a better idea because they also go to high school. Participants mentioned that sharing a vehicle with children is quite hard to design because it is a bit sensitive to mix random children and adolescents. Participants suggested that kids could use it but preferably not in a shared vehicle. Some participants saw opportunities there as kids could be monitored, and there could be an AI or VR assistant. If kids could do more on their own, it also creates more spare time for parents to do useful things. Also, a participant mentioned that it is less of a big deal when a kid is used to travel with the SAV.

Their twin is celebrating their birthday and they invite many friends to go the swimming pool. They take a huge SAV.



After the party, the kids go home in smaller groups in SAVs

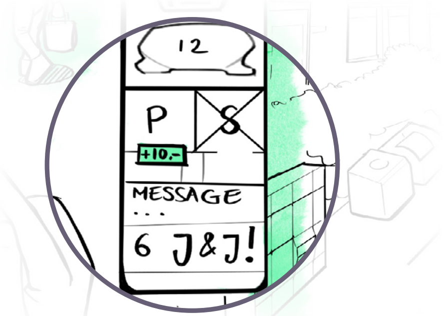


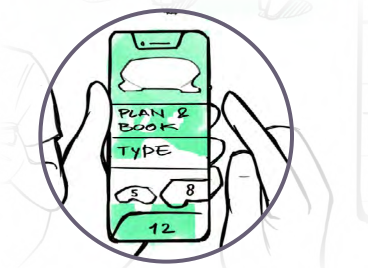
Having fun in the swimming pool

The SAV has the option to project a personal message on the side.

Booking a car
Participants found it quite handy to reserve a car for more significant events and with extra people. However, someone pointed out that you should also pay the "shared" rate when having a full car as no one can enter the vehicle anyway. Another participant mentioned that It would be nice to reserve for multiple people during the route, such as picking up the kids from home or first picking up grandma and then driving to you.

Message is nice
Most participants fancied the personalisation option of the personal message being projected on the car.





6.5 Conclusions from evaluation interviews

6.5.1 Personal benefits of SAVs

Practical benefits

It **takes less energy** to not be attentive and perform driving tasks. Therefore it leaves more time and energy for things users care about. It gives **opportunities for other activities and could enable more spare time**.

It enables mobility for groups that have **sparse access to mobility**. For the elderly, it leaves more energy to do activities they would like. It could give them the **freedom** to go places without parents having to drive them around.

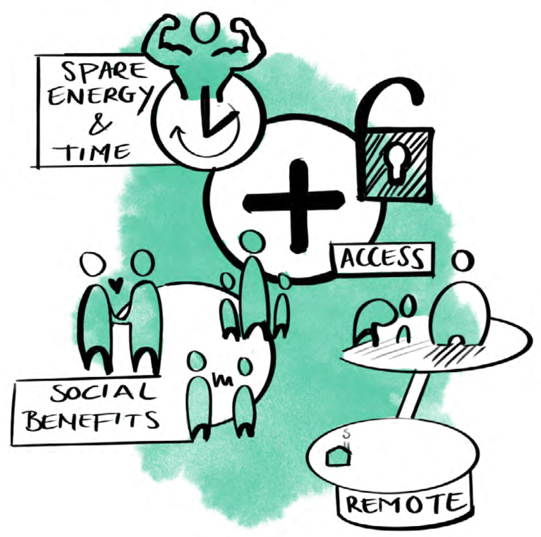
In remote areas, it is **more flexible and more accessible than taxis and dial-buses**. It could help to solve the big stream people from rural areas to big city centers by car. It takes away every downside of living in a remote location.

Social benefits

The SAV could be a space where you can have **family time, have a private moment, or get to know new people**.

6.5.2 Different needs

For each persona or target group, the needs are different. However, an SAV-system could be of **high value for different groups.** Also, within **different future contexts**, the SAV-system could work. This is shown in figure 60.



Young family

The young semi-urban dweller wants **privacy in situations with children**. Especially when children are small. As children can be **unpredictable, high flexibility** is needed. The most significant benefit for these people is that the **system can unburden** their life. They can **save time** if they do not have to put energy into driving and do not have to bring their children to every place.

Elderly

Access to **mobility, in general**, is of **high value** for the elderly. Also, the **social aspect** with being able to engage with people around them, get connected with grandkids. It is vital to **keep the community alive**, and they **might be interested in meeting new people**.

Young and working in city

The young city-minded individual wants to deal with their time effectively. They **like to work or do other activities in the car**. Safety is an important issue when people who might feel **vulnerable are traveling alone at night.**

60. Different needs per personas

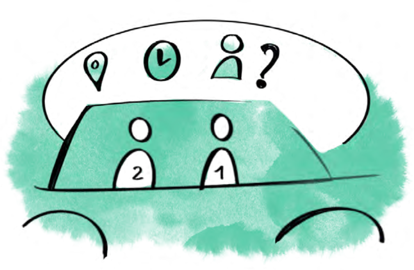
6.5.3 Desired activities

People would use a ride-sharing SAV for **short distances trips**, for which a car is the only efficient and available alternative. People would like to go **to work with the SAV because**, in the morning, they are sleepy, and after work, they are tired.

There is room to have breakfast and do your make up which saves time. People liked the idea of using it with **big groups** with kids and having a private trip. There different generations perceive the unique advantages of the SAVs differently.

6.5.4 Considerations about sharing

People want to **choose whether to share the ride with others.** People prefer getting out of the SAV despite the desired destination, especially if the situation is undesirable (for instance, when someone smells terrible). The attitude towards sharing depends on **activity, duration of the trip, and with who**. A colleague joining the ride could be okay but can also be unwanted as you have to have a conversation. With strangers, you do not have to force a conversation. Preferences differ per trip and moment. Some participants said that they preferred, would share the ride with strangers because they would not have to talk to an acquaintance.



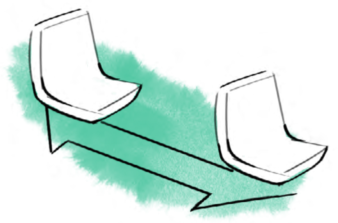
Privacy of others

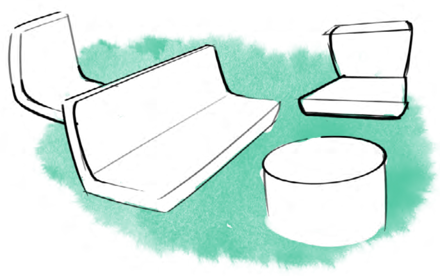
The combination of not having a driver and not having control who is joining the ride can cause discomfort of users. However, **not much** information can be **shared** about someone because of **ethical and privacy issues.** People could be verified by other accounts, reviews, and a photo. However, it should not give an incentive to discriminate.

However, people **would feel at ease knowing something about people,** such as a picture, a live photo. There is a tension field between **guaranteeing safety yet preserve privacy.**

6.5.5 Design of the interior

People like the idea of **distance** towards people they do not know. **A mix of seats** next to each other for smaller groups and stand-alone groups with some space is a probable setting. Thereby, there should be room to look outside from every spot (for motion sickness and unwanted interactions), and the interior should be filled with fresh air.



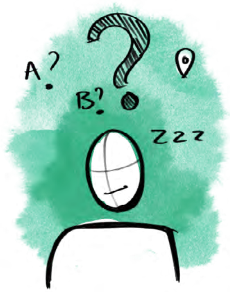


6.5.6 Trust in technology

The SAV should always work. Otherwise, there is no trust in the system, and it's hard to get back. The technology should be supportive, however, **not patronizing people.** Also, there should be a mass for systems like this to enable people to go anywhere when they want and **not have to wait for a long time**.

6.5.7 Unwanted impact

Participants mentioned that some people should be **involved in the routing and driving activities** because otherwise there will be no stimulation anymore. With these means, we could travel even more and make use of mobility differently. It **invites people to make different combinations** of activities. It could result in **fun driving, going to many more places** than we do now, and therefore, resulting in **more people on the road.**



6.6 CONCLUSIONS

All insights gathered from the evaluations with users will be used to create one system and service design. In the next chapter, the design brief can be found in which the challenges to design for various needs are explained. Also the goal and other challenges are noted. The design brief is the starting point of the final design proposal.

7 Design Brief

Design goal and interaction vision

The Design brief concludes the research and insights gathered from future scenarios. It repeats the the focus of the project, the main challenges and finally, the design statement that includes what the SAV-system should be.

7.1 Vision and mission

7.1.1 Vision

Fewer vehicles on the road

The main goal is to create a shared vehicle system in which people share rides and/or share cars instead of driving their own car alone. This will reduce the CO_2 impact and helps to achieve climate goals.

7.1.2 Mission

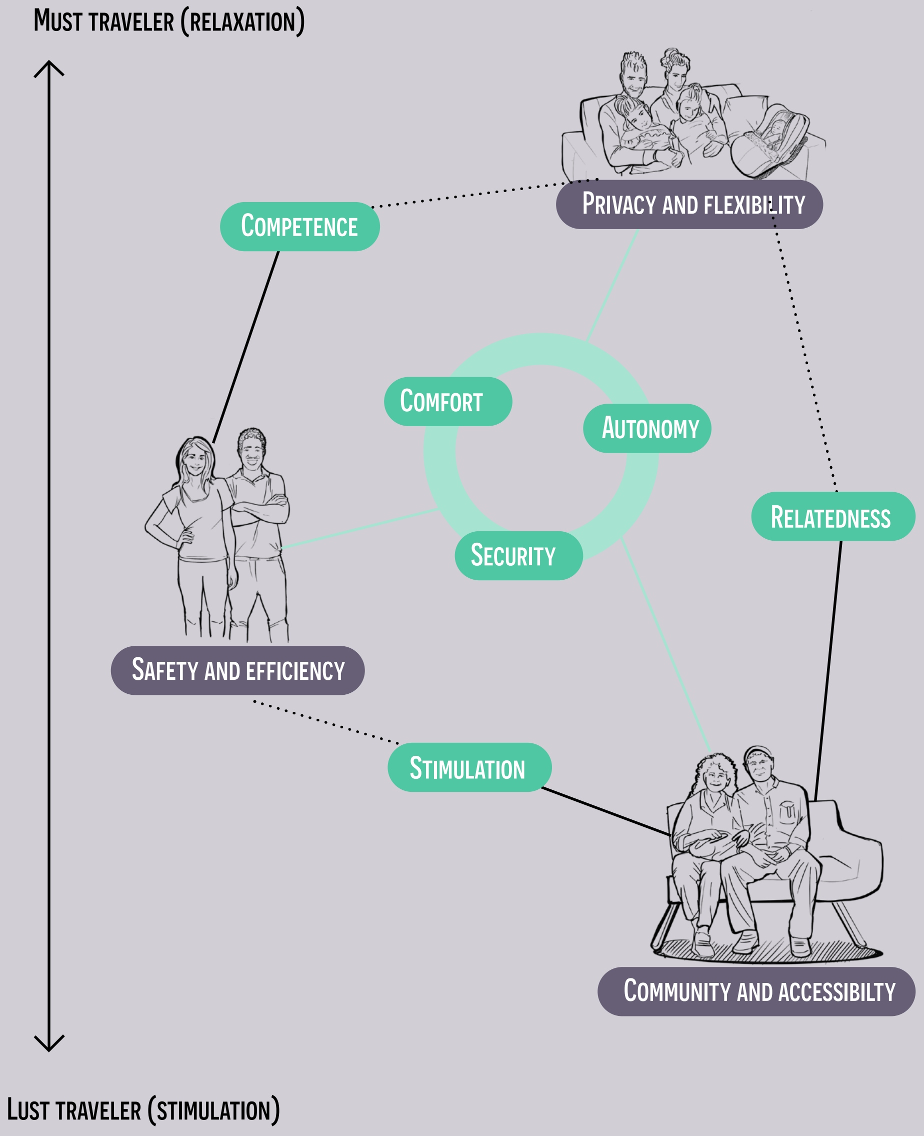
Offer human-centered and desired system

To change people's behavior from owning and driving solely, the system should fulfill individuals and society's future needs. The design should be competing privately owned car usage and be supporting PT use.

7.2 Main challenges

7.2.1 Design for different human needs and desires

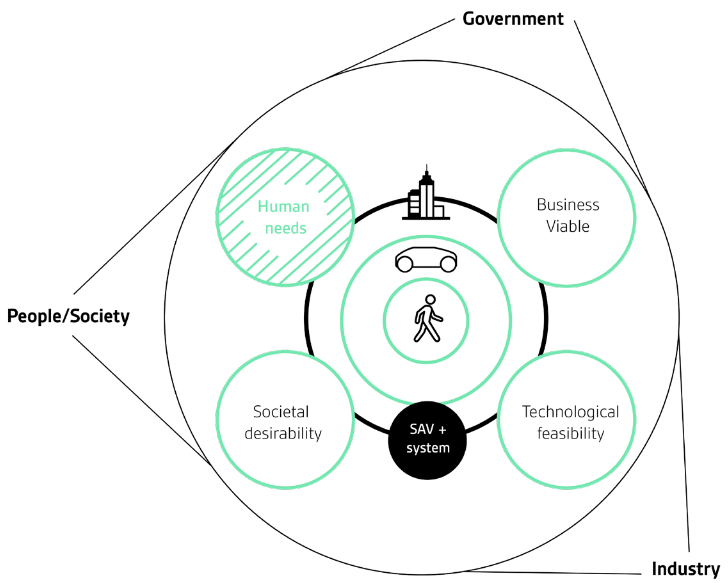
All users have different needs and wishes. **Creating a universal system that allows many people to use it, is a challenge.** In figure 61 on the right, the different needs are showcased, both from literature, showing relevant fundamental needs, in green, (Desmet & Fokkinga, 2020) and the must and lust travellers (Spoorbeeld, 2012) in black. Insights from the scenarios created, fit those needs, from both literature. These are shown in purple.



61. The different needs that should be facilitated by the system

7.2.2 Many stakeholders involved

The shared autonomous vehicle ecosystem is complex, and many stakeholders are involved, such as users, society, the government, and the industry (shown in figure 62 below). To design for this complex system, all stakeholders should collaborate and benefit from it. The design should be fitted to human needs, be business viable, feasible when it comes to technology, and desirable for society. Creating a system that touches all four elements and involves all parties is a challenge.



62. Complex stakeholder environment

7.2.3 Design for the uncertain future

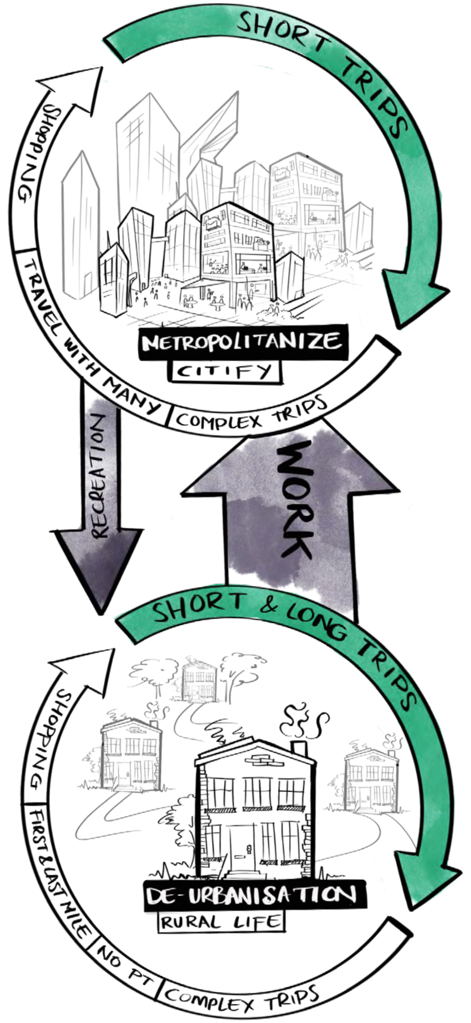
We have to deal with uncertainty while making choices about how the system will work. Many different futures are taken into account, and overlap is sought to design a system suitable for various future directions.

For different living areas

Within cities, the system will mainly be used for **short distances**. People want to use SAVs mainly for shopping, complex trips, and traveling with a bigger group of people. It will be a challenge to make it work on existing infrastructure as this is already quite developed and extensive.

In between metropolitan and rural areas, the SAV-system creates value as it can be used for recreational purposes for people in urban areas and for daily work purposes for people in rural areas.

Within rural areas, the SAV will be used for short and long distances because the PT systems could still not be sufficient in those areas.
The SAV-system could be more flexible as there is not much infrastructure, meaning that a flexible system can be easily created.



For different sharing preferences

People are willing to share the ride with strangers for shorter distances. It depends on the perception of privacy. The more privacy, the more willing people are willing to share with strangers. There can be moments in which the user wants to have a private vehicle, then it is possible to pay for a more personal trip without strangers. Also, there will be moments in which people like to chat, then the interior should also facilitate social interaction.

For longer distances, people would like to have a private vehicle. This should be supportive, however, not stimulated. These trips are more expensive and sharing the ride will be encouraged. It is essential to give incentives to people using multi modalities for distant trips. The first and last mile could easily be an SAV. It is crucial to create safe, comfortable, and seamless transfer solutions from one to another.

Our future attitude towards data

People have different attitudes towards sharing data and should all feel comfortable using the system.
Therefore, the system **should use as little personal information as possible.** The minimum is the necessary verification personal information to guarantee safety on board of the vehicle.
However, for people who like **a highly personalised service**, it should be adaptable to a bigger extent, guaranteeing a seamless and personal experience.

7.3 Design Goal and statement

I want to design a flexible and integrated future SAV service, that is aligned with the human needs' and fits the future, creating an easy, controlled and supported experience that makes people feel at ease, involved and in control.

THE SAV ECOSYSTEM SHOULD BE A **FLEXIBLE, ACCESSIBLE, PRIVATE AND INTEGRATED SERVICE** CLOSE TO HOME THAT ENABLES PEOPLE TO **FEEL AT EASE, INVOLVED AND SUPPORTED** BY CONTROLLING THE WHOLE TRIP.

8 SERVICE PROPOSAL

BLUEPRINT & EVALUATION

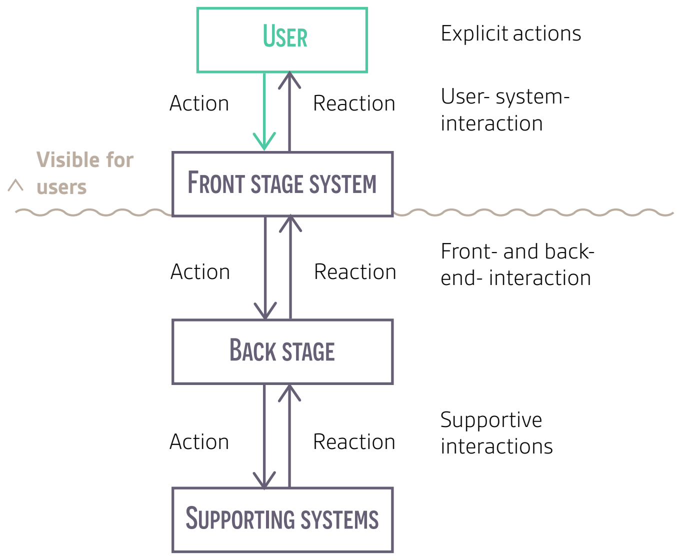
This chapter introduces a service proposal for one desired system being accessible for different types of users. It explains how the system is build up in a service blueprint and underlying ecosystem elements are explained. Experts are involved to evaluate the system design.

8.1 WORKING TOWARDS A SERVICE BLUEPRINT

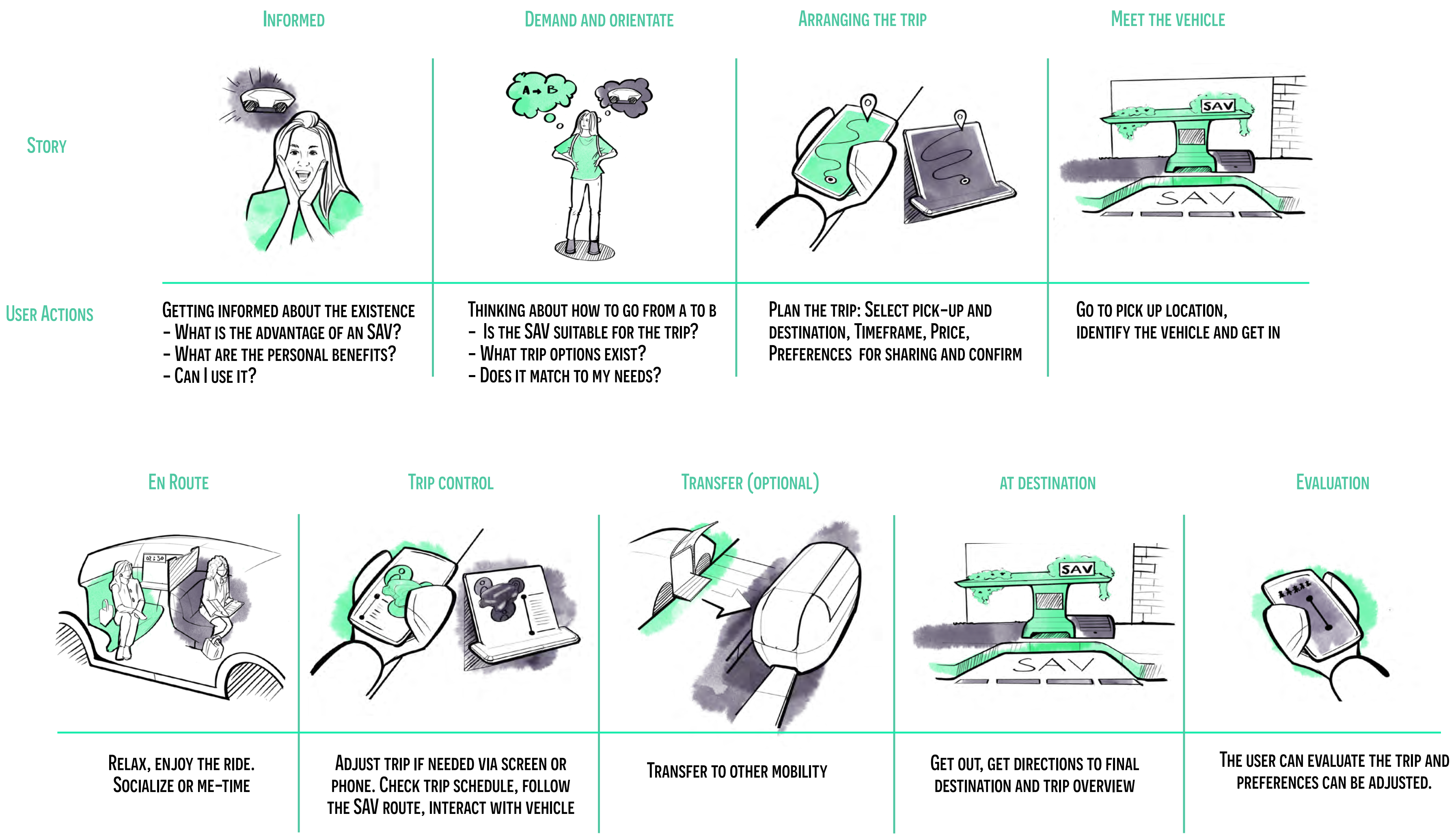
An ideal user journey, shown in figure 64, is created. The **first setup** of the user flow was **evaluated in a knowledge-sharing session with the Lab partners** and adjusted upon ideas from that session. These insights can be found in Appendix H2.

The user journey steps are shown in figure 64. These **actions describe what the user wants, does, and needs to know.** Some actions will **include interaction** with the service, which could be digital or physical interactions. In figure 63, the relations between system elements and the user journey shown in figure 64 are explained and show the system elements involved, such as front-stage actions and back-stage actions.

The user journey and user actions will be discussed one by one in the following sections and will be used as a **starting point to design the service blueprint**, which is the service's system design.



63. Overview of the system interactions, both visible and unvisible for users. This model is used to create a service blueprint.



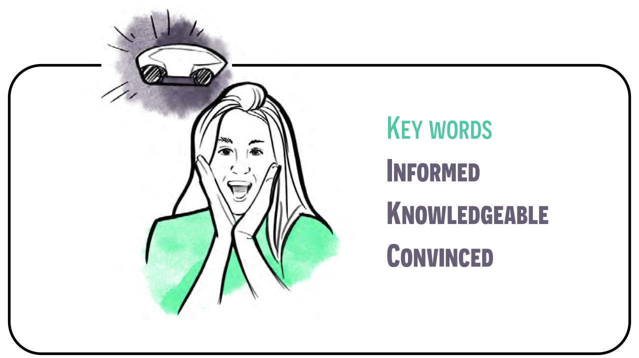
64. Overview of the user journey with corresponding user actions. The starting point for designing the system.

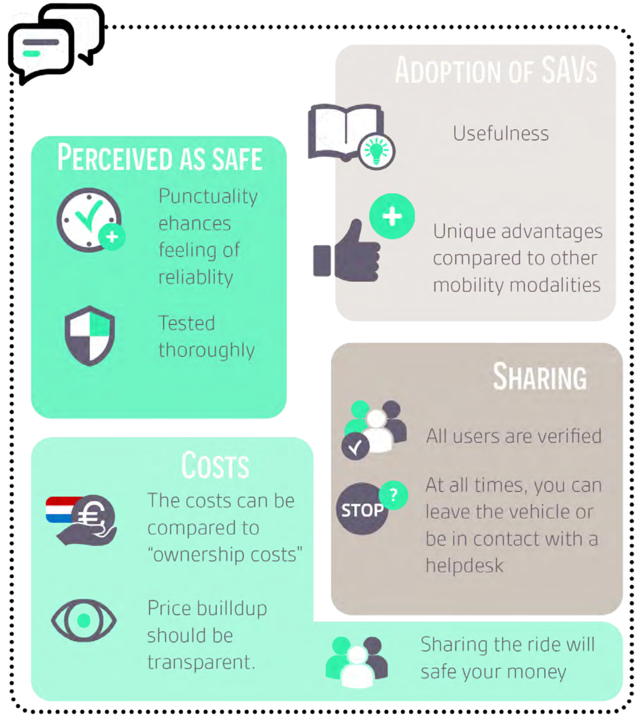
8.2 Desired user scenario

8.2.1 Informed

The user is **informed** about SAVs and is **aware of the advantages and usefulness** of the system. It is perceived as safe and a pleasant way going from A to B. Thereby, it should **be clear how the user can benefit from the system**.

Which topics are important to communicate?
The service is new, and people should be informed. We learned that young people in cities are not informed well about sharing services and are most willing to use them. Thereby, topics like **safety, costs, and sharing safety are essential to communicate** (see figure 65), to increase the adoption of the SAV-service. The adoption will also be positively influenced when people think the service is **useful and offers unique advantages**. Also, the overall costs need to be compared to for example private use, as some people compare only parts of these costs (gasoline) while actually ownership is much more expensive. .
Lastly, the user should know that the service is a ride-sharing service with option to carsharing. People should be aware of that.



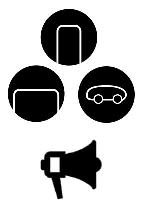


65. Topics important to consider informing possible users about

Main concern of the user in this stage
Being informed about the new SAV service and if it could fit to their different demands. Mainly, the sharing elements are important.

System actions
Should inform and show the user what is possible for the user. It should inform the most basic information about the service.

User system interaction topics

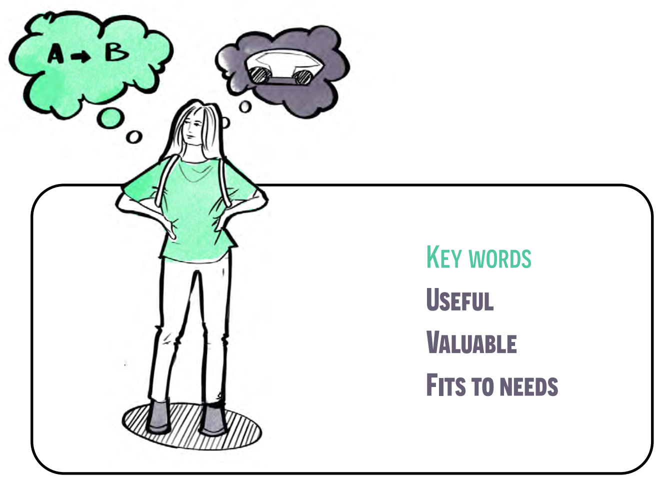


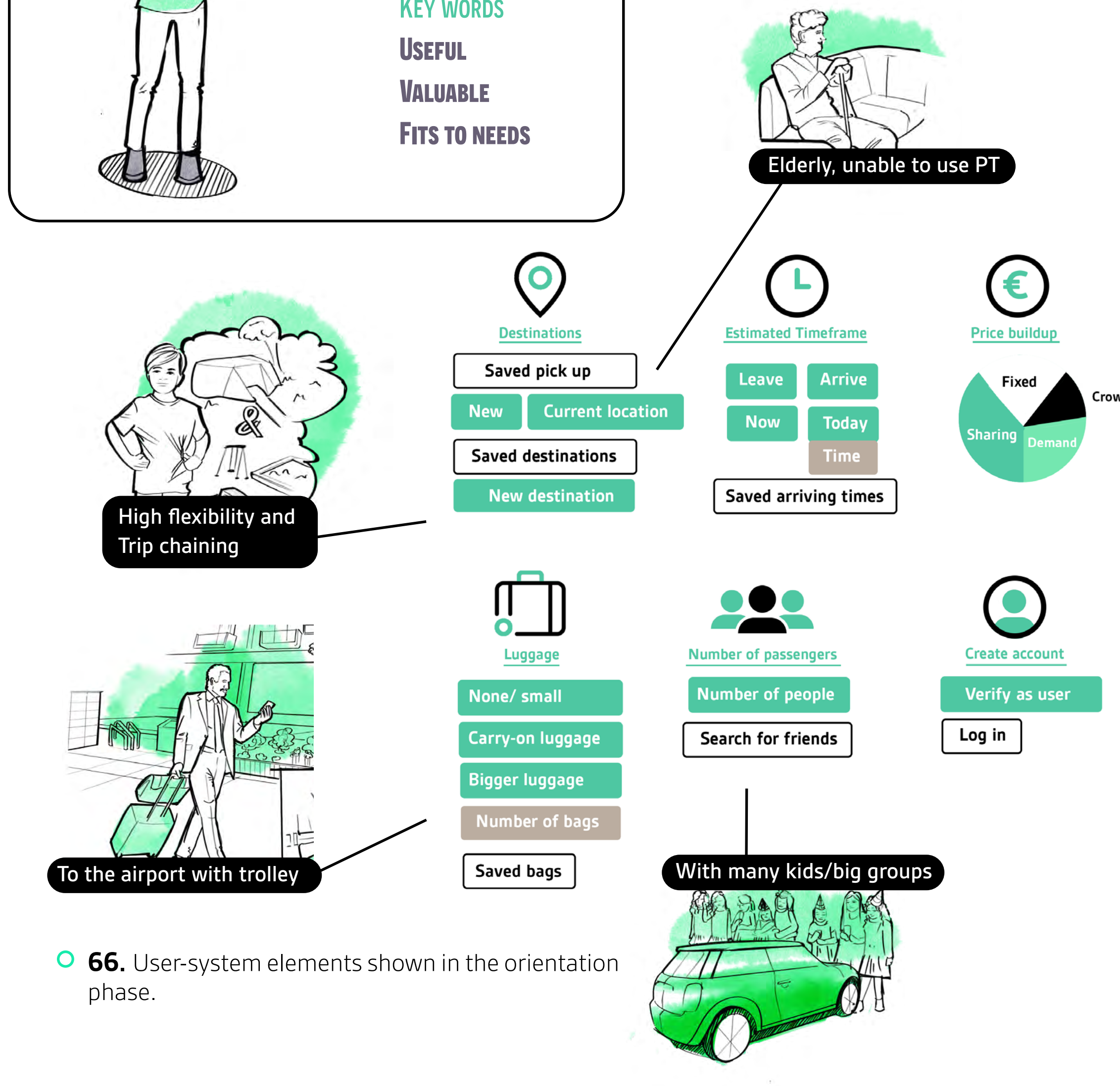
Awareness campaign
Basic information service

8.2.2 Orientate and Demand

The user wants to go somewhere and needs to find out if the SAV-service matches their needs. **Practical and specific elements** (Time, efficiency, price) and **personal needs** (need for privacy for instance) can be inserted. Some requirements (practical or emotional) are more critical than others, are different for users, different per activity, and can even change over time.

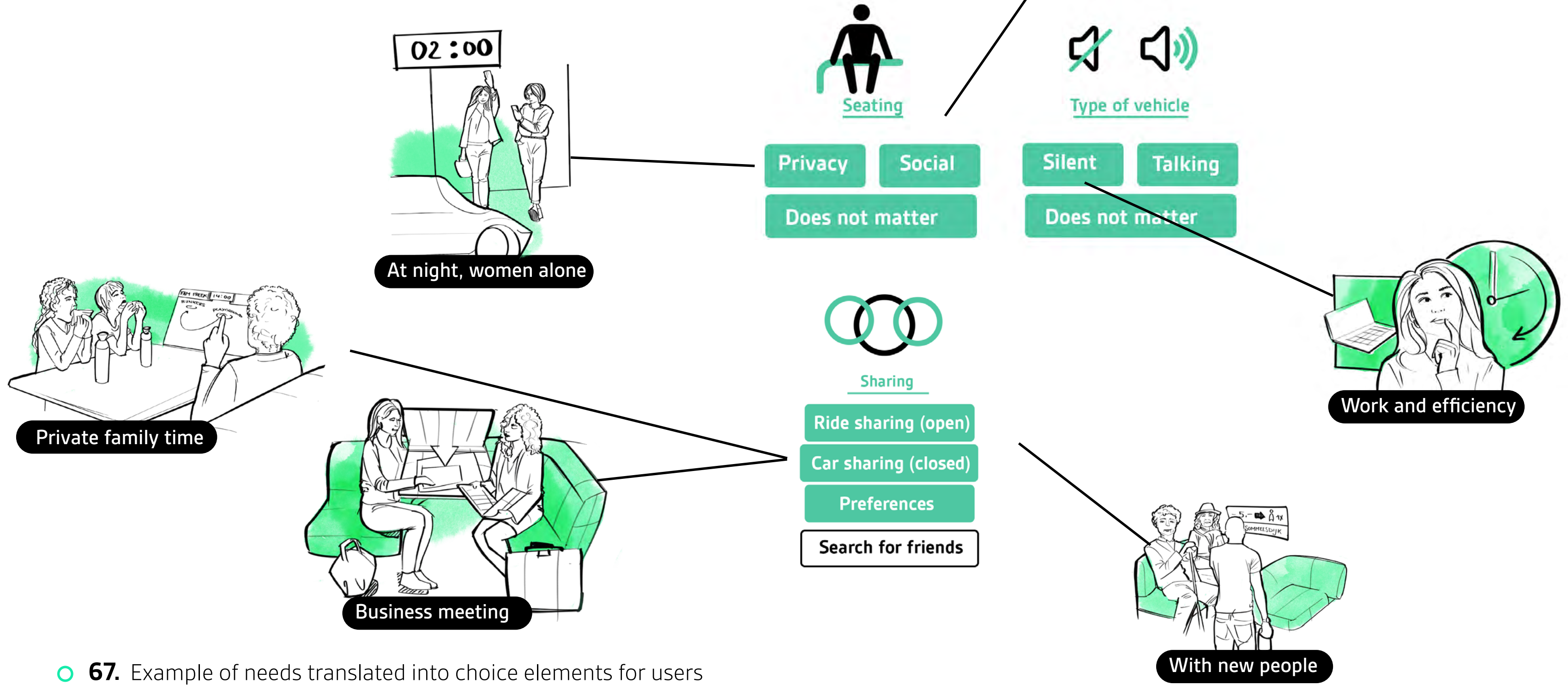
Practicalities and specific criteria
The user is going to a particular place in a specific time frame. Maybe, the user carries luggage that needs to fit and could travel with others too. Also, the user could have a particular budget. In figure 66, the six essential elements (with some examples from the scenarios) are shown and what the user can choose from. The white and black boxes show information for users that already use the service and have an account.





66. User-system elements shown in the orientation phase.

Personal needs
The SAV-service fit the different user's mood and emotional needs. These needs vary per person and even at the time. Below, in figure 67, examples of these various needs from the scenarios are shown. These different demands are clustered in specific criteria the user can choose from. These personal needs mainly express interior specifications. In the orientation phase it should be made clear that the car has the opportunity to be used as a **social and private space, suitable for work or relaxation** and for **private (carsharing) or open use (ride sharing).**
The ride sharing service is much cheaper than car sharing.



67. Example of needs translated into choice elements for users

Non-commital planning tool
The user should generally plan the trip (with both the practical and emotional requirements) to see if the user would like it and if it is possible. After this **non-commital planning, the user can register, verify themselves and schedule the actual trip.**

Ride sharing and car sharing
There are two options; car sharing and ride sharing. **Ride sharing is the default setting.** However, for **longer trips, people prefer car sharing** (to fully control who is in the vehicle). That means that other users are unable to use that car and therefore you pay more. User's can adjust sharing types during the trip.

Main concern of the user in this stage
The user wants to know if it is possible to take the SAV for their demand criteria and orientate for the different possibilities of the SAV-service.

System actions
Should inform and show the user what is possible for their demand. It needs information about the user's demand to show information.

User system interaction topics

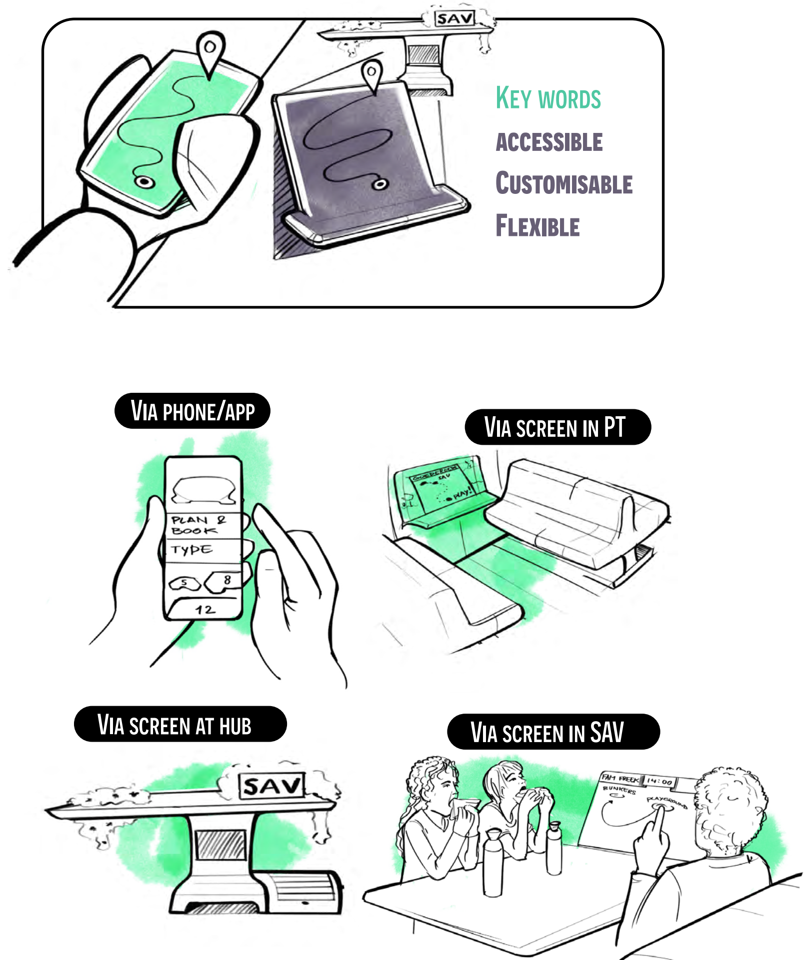
General information about the service
Make the demand concrete
Non-committal planning tool
Match demand to supply
User verification (preconditions for use)

8.2.3 Arranging the trip

The user can use a **phone, platform-screen, a SAV-screen and one in connected PT** to plan a trip, see figure 68. Local hubs have a **platform with a screen**. Minimal verification in the shape of a profile photo and a scan of the user's ID is needed to use the system. Also, a **deposit is required. Personal preferences can be adjusted** to the likings of the user. The system can also be **used without customization**. One of the selections could be who they want to share rides with.

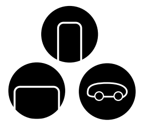
Variety of means to arrange

The service should be easy to arrange and can be arranged by phone, and screens at SAV hubs, in the SAVs and even in other publict transport when logging in.



68. Variety of means to arrange the trip.

User system interaction topics



USER VERIFICATION
TRIP PLANNING
TRAVEL TIME
PRICE ESTIMATION
TRANSFERS
SHARING PREFERENCES
RESERVE WITH OTHERS
ON BOARD OPTIONS
SEATINGS

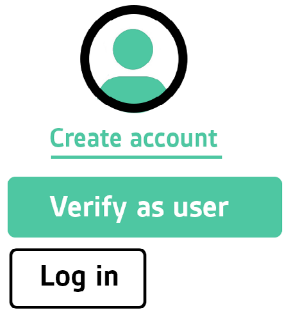
Main concern of the user

The user wants to book the trip, based on what they would like it to be.

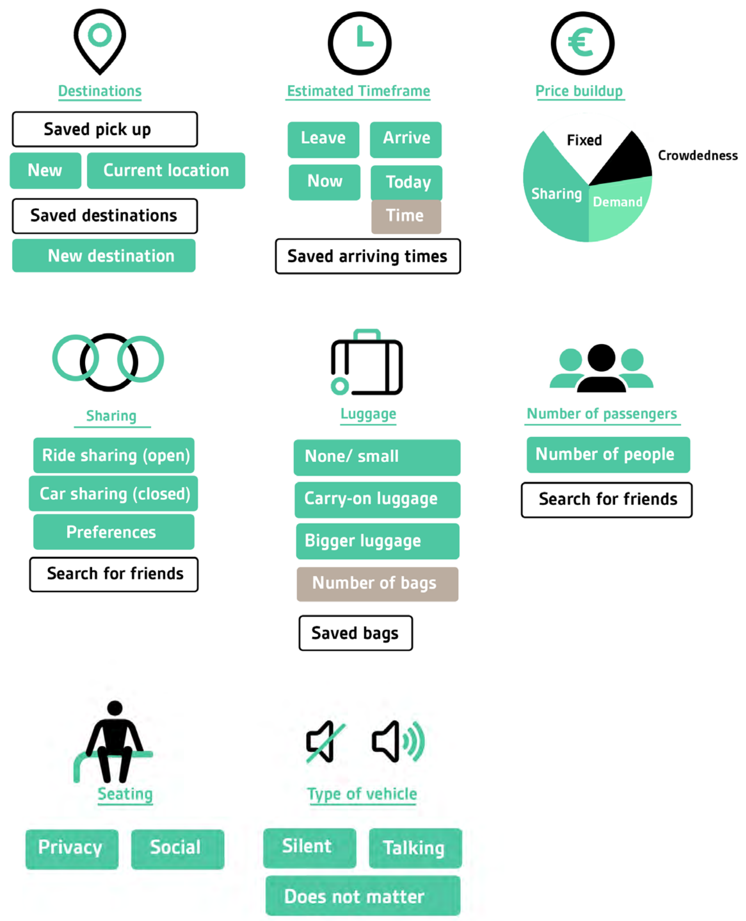
System actions

Provide all information to arrange the trip.

First the account needs to be set



A final combination is chosen



8.2.4 Meet vehicle

The user does not have to walk more than 1km to find a pickup location. There are **local hubs (in towns), city hubs, urban hubs for seamless transfers to PT**, and cases in which the SAV can reach more remote areas. For instance, for people living very distant. The hubs feel safe as there is enough light, an open structure, and enough shelter against rain and wind. Some hubs have **public lockers** to temporarily store luggage.

Variety of hubs

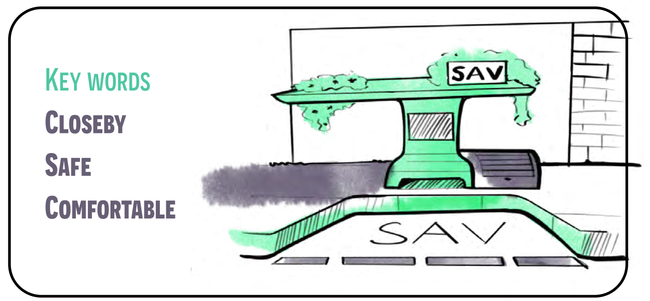
There are different hubs, from street spots to local, to urban hubs. Street spots does not have much infrastructure, local and city hubs have more facilities like a screen and shelter. The urban hub is a multimodal hub in which the user can transfer easily.

Main concerns of the user

Know where to go and which car belongs to them and if the car is good.

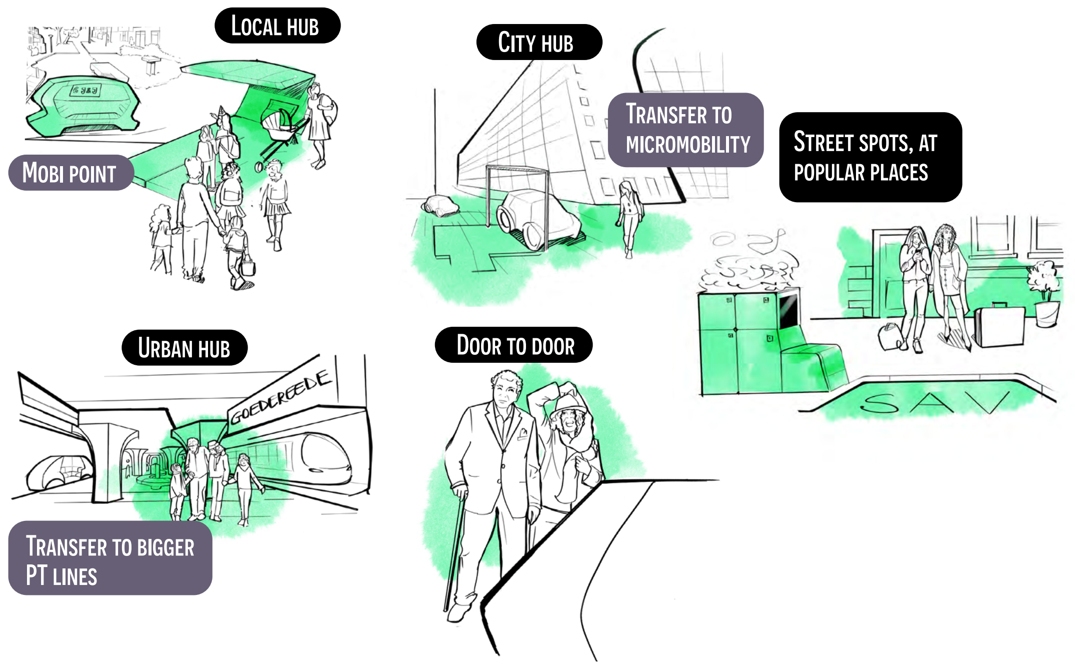
System actions

Make clear which vehicle belongs to who and where user needs to go.



User system interaction topics

- Find general information
- Find the right location
- Identify the vehicle
- Check if vehicle is okay
- Get in the vehicle

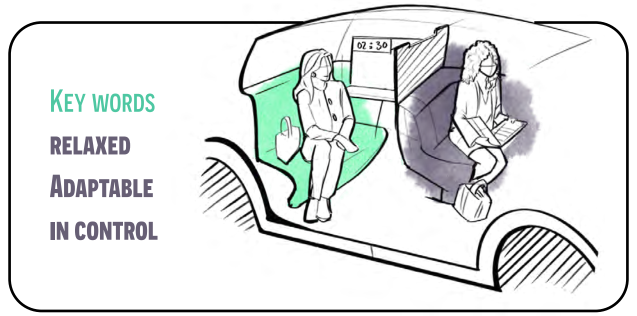


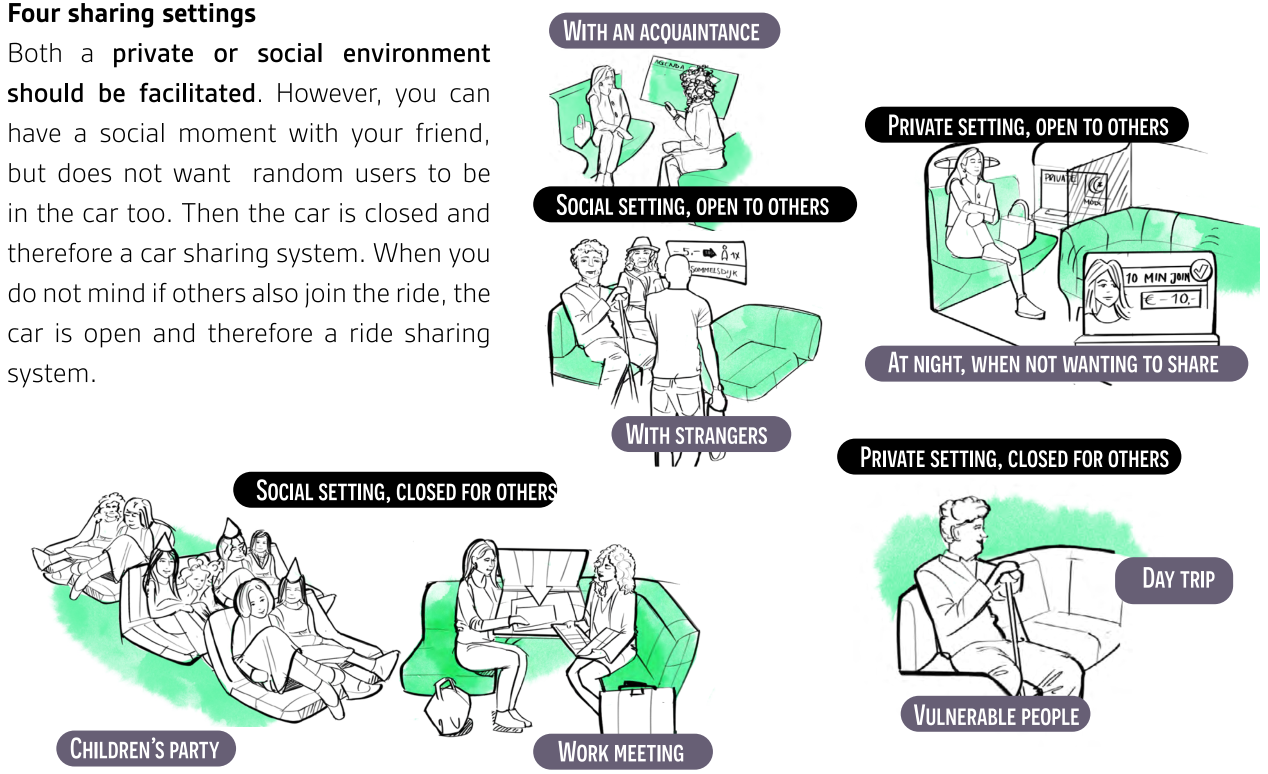
8.2.5 En Route

The **user feels in control** of the space. The user has the opportunity to create a private or social space. The interior is more **privately set up** to guarantee safe and convenient sharing experiences. The area also enables people to do activities they like such as working and eating.

Four sharing settings

Both a **private or social environment should be facilitated**. However, you can have a social moment with your friend, but does not want random users to be in the car too. Then the car is closed and therefore a car sharing system. When you do not mind if others also join the ride, the car is open and therefore a ride sharing system.





Main concerns of the user

Having control over the situation in the car. Being informed who enters the car, and the trip duration

System actions

Clearly showing who joins the ride and real time trip information.

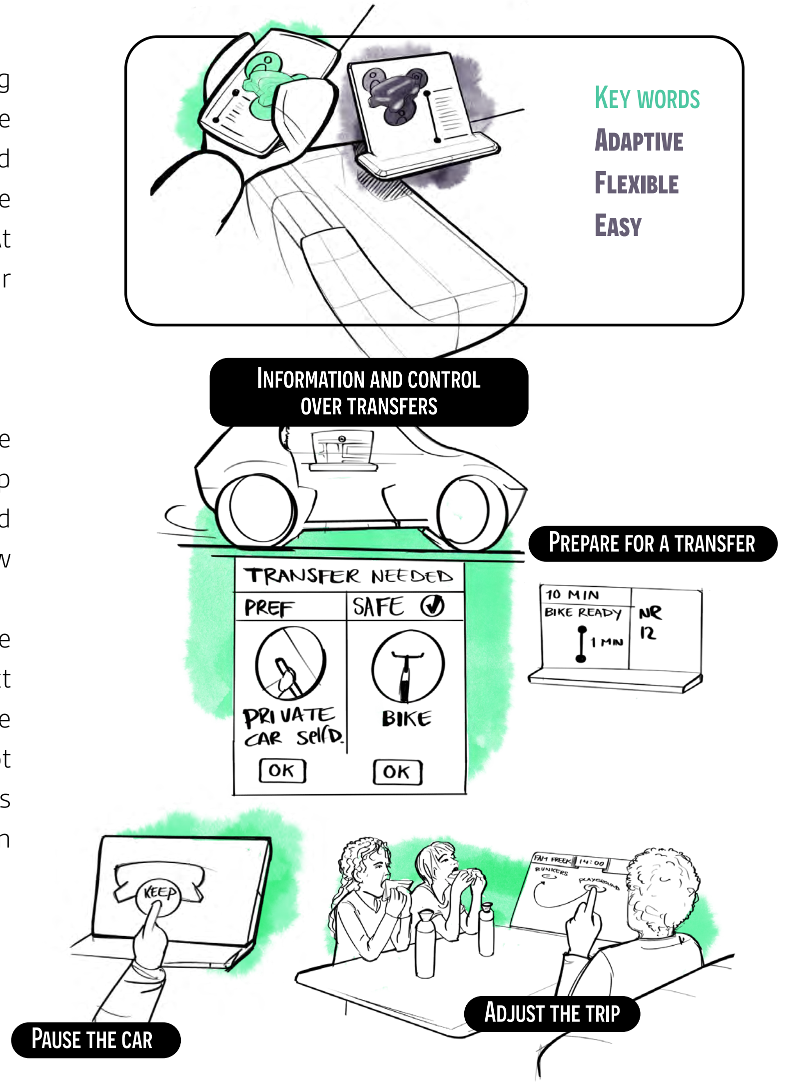
User system interaction topics

- Trip overview
- Travel time
- Price estimation
- Transfers
- Sharing preferences
- On board options
- Seatings
- Information other users

8.2.6 Trip control

The user can **easily change the trip** using a phone or screen in the SAV. Also, the actions of the vehicle are shown here, and preferences can be adjusted. The interface is **simple, concise, and intuitive to use**. At any moment, the trip can be changed or canceled.

How and what options are available?
At all times, the user can get out of the vehicle. Also, the user can decide to keep the car and pause the usage (if not shared with strangers). When getting out, a new ride needs to be sought.
Already, in the car, this trip change can be planned, so the system knows your next transfer or stop and creates a new route for you. Sometimes, the vehicle cannot go to specific locations, and a transfer is needed. This will be shown on the screen and on the users' phones.



Main concerns of the user
Knowing how and changing their trip to their likings. Information like ETA and price are important.

System actions
Clearly showing what options are possible and how the trip can be adjusted.

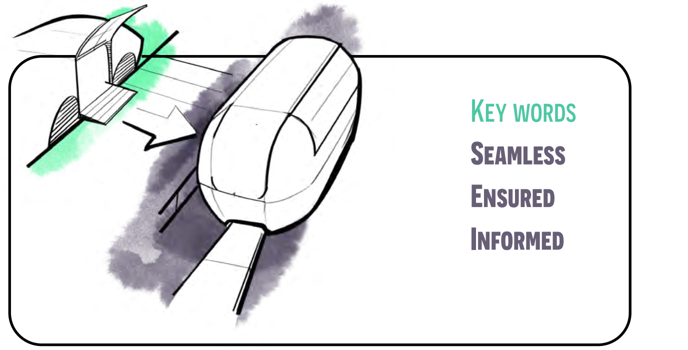
User system interaction topics

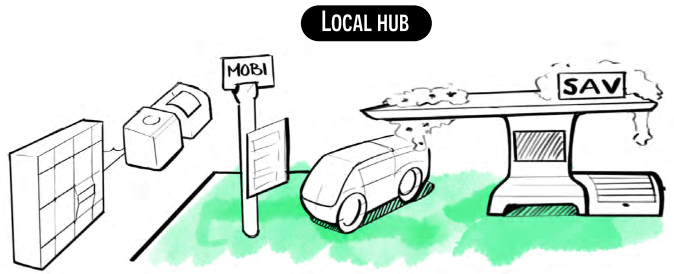
- OPTIONS TO PAUSE CAR (CARSHARING)
- ADJUST TRIP SCHEDULE
- SEE ETA
- SEE (ADJUSTED) PRICE BUILDUP
- TRANSFERS AND INFO ABOUT TRANSFERS
- SHARING PREFERENCES
- INFORMATION OTHER USERS

8.2.7 Transfer

The SAV is **mainly used for short distances**. Transfers to large PT lines can be done at urban hubs. Users feel **confident transferring to other mobility** as they are **kept up to date about relevant real-time information and get explained where they have to walk to**. Transfers should be comfortable especially in the case when someone has to wait some time. Also, transfers are possible at smaller hubs but are mainly to smaller mobility such as bikes and other micromobilty.

Variety of means
At urban hubs, transfers to bigger lines are facilitated in a comfortable and seamless way. At local or city hubs, multiple micromobility can be found at those spots. The local hubs should also comfortable and seamless. Therefore the user will be kept up to date about the variety of vehicles and PT vacant.





Main concerns of the user
Being sure about where to go to and which means is next.

System actions
The system should guide the user to the next mobility means and will help if the user has questions. Ensuring the user that they are in the right vehicle.

User system interaction topics

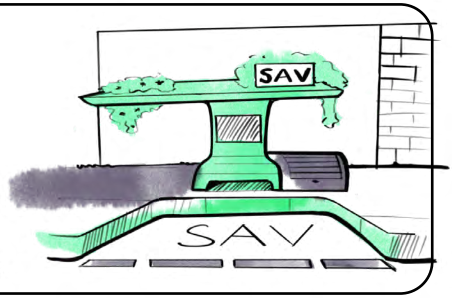
- INFORMATION ABOUT TRANSFER
- TRANSFER TIME
- IDENTIFICATION OF VEHICLE

8.2.8 At destination and review trip

The SAV can **come close to your final destination.** In rural areas, that will be closer than in urban areas. People can get out at pick-up locations and at several street spots with room for an SAV to temporarily park. At popular locations close to recreational parks or musea, also **lockers are placed to leave luggage**. Hereby, users will not pause vehicles and just book another later, when they want to go to a different place.

When the trip is finished, the **user can review the trip** and adjust personal settings. The user feels in control of the possible future trips and adjust to create a good future experience.

Key words
Closeby
Safe
Comfortable



Key words
Supportive
Easy

Main concerns of the user
Knowing where to go to and how to get there. Also, the total costs of the trip are good to know. The user want to comment on the trip to improve future trips.

System actions
Help the user to find the way. Show a clear overview of the trip. Thereby, it should be possible to review the trip and also inform what will happen with the review.

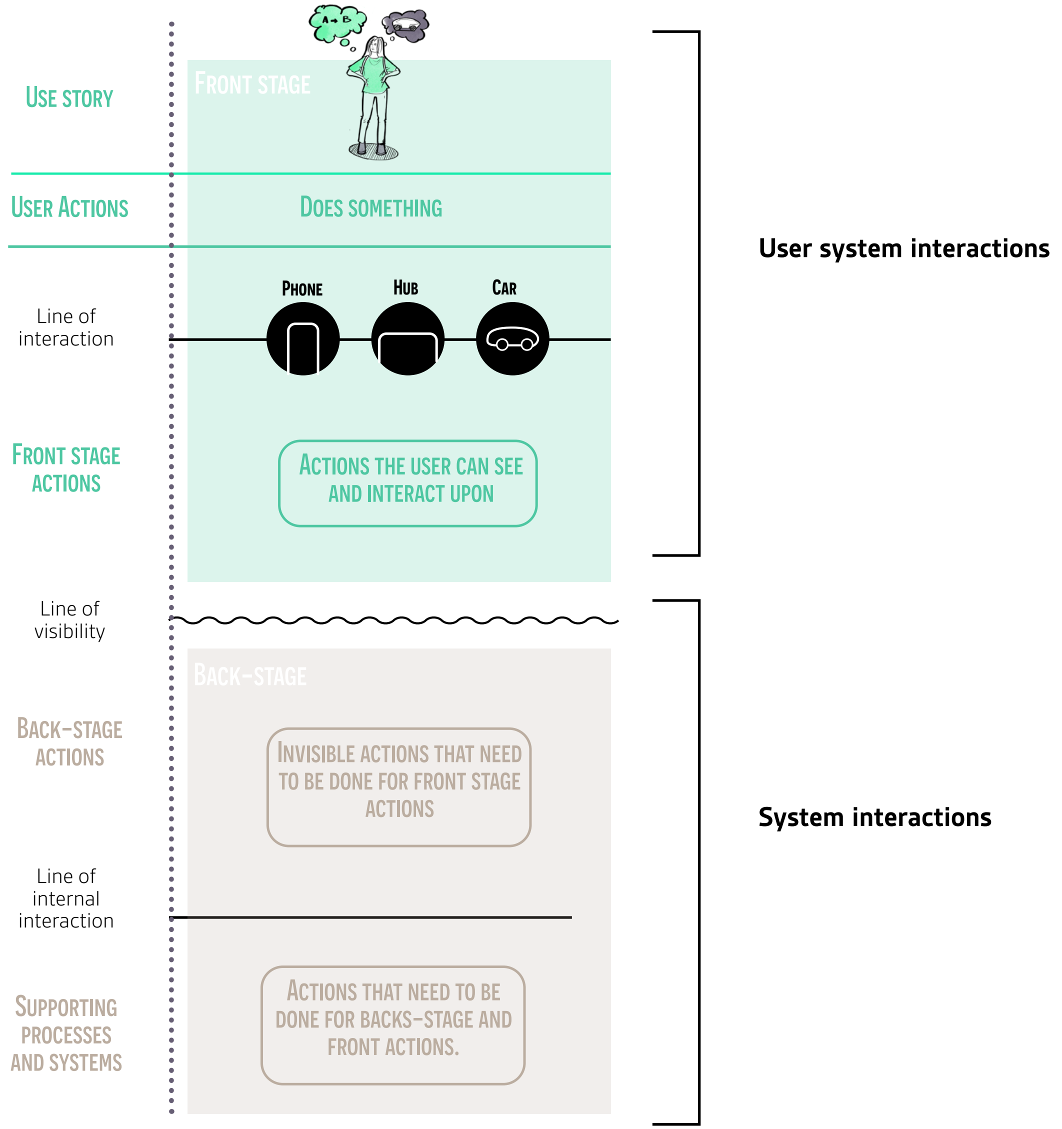
User system interaction topics

Show current location on map
Show walking route
Overview of the trip
Option to review the trip
Adjust personal preferences

8.3 Service blueprint

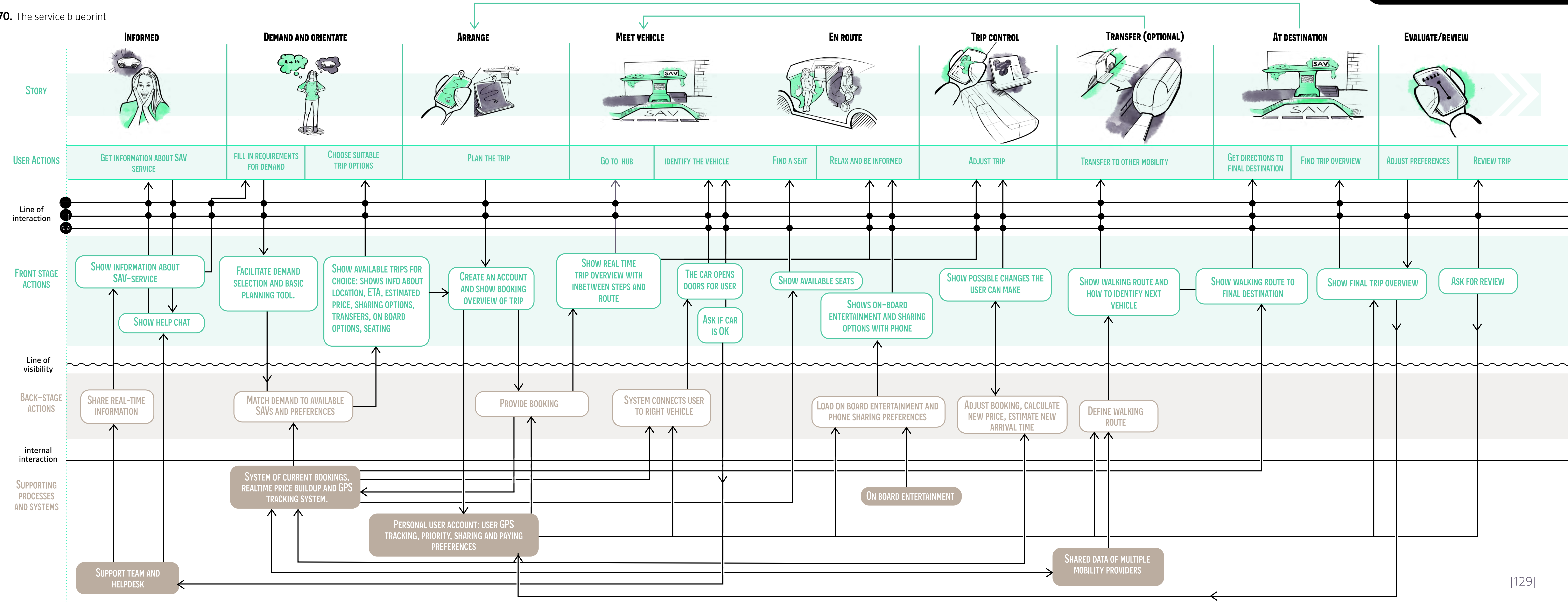
On the next two pages, in figure 70, the service blueprint is shown. The buildup of such a service blueprint is explained in figure 69.
It exists of four levels, **two in the front stage (visible for users)** and **two in the back-stage (unvisisble for users)**.
The first upper level is the user journey.
The user interacts with the front stage of the system. The facilitator of this interaction can be a phone, a screen or in-car interfaces. In order to make this possible, the back-stage should provide the right information. This underlying system is needed to create a successful SAV-system.

There are **five supportive systems needed** to create the desirable system; a **support team** that helps users, a **realtime booking system** that also tracks vehicles, a **personal account system** for users connected to account based ticketing, an **on-board entertainment system** and a **data sharing cloud** for integrating PT to the SAV services.



69. Build-up of the service blueprint

70. The service blueprint

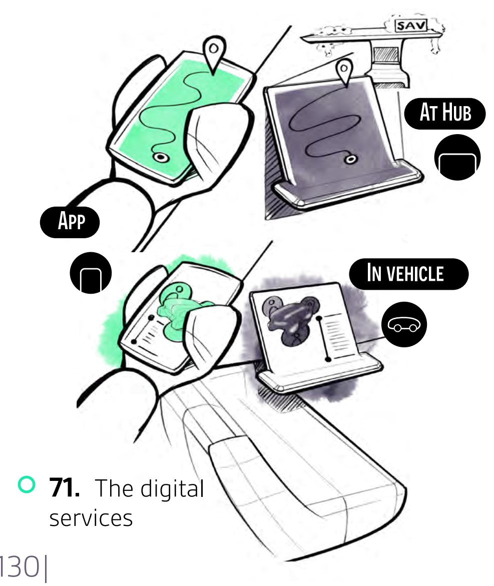


8.4 THE UNDERLYING ECOSYSTEM

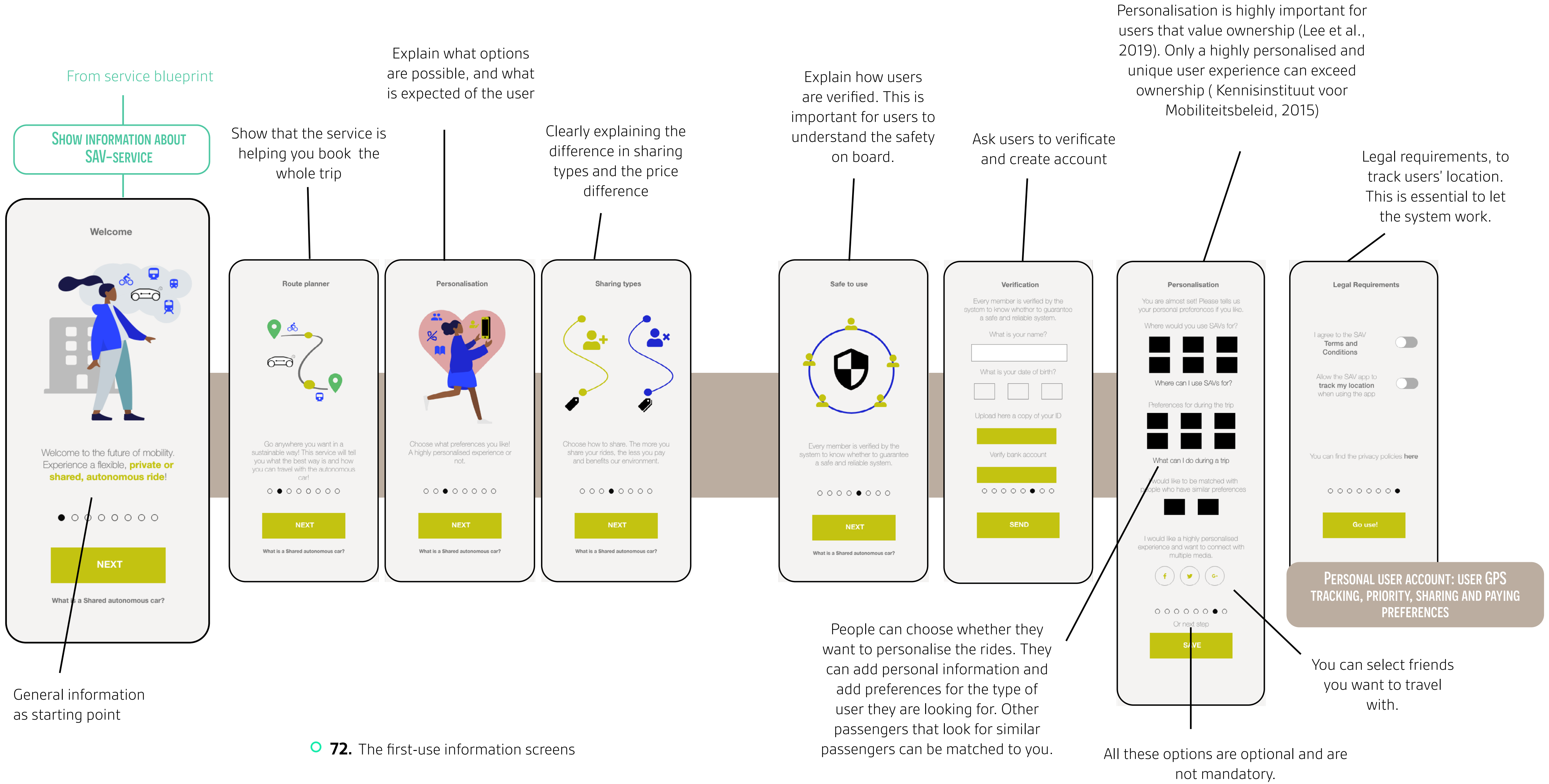
8.4.1 The digital service

The system elements and interactions from the service blueprint can be used to design the digital service. The digital service exists of an app that can be used on a phone, digital service screens at hubs, and in other PT (see figure 71). In those applications, **information can be found, bookings can be made, changes can be indicated relating the current trip and personal preferences can be adjusted**.

All screens showing in figure 72 to 76 are examples of what it could look like. These are only create for explaining which information is should be shown.



71. The digital services



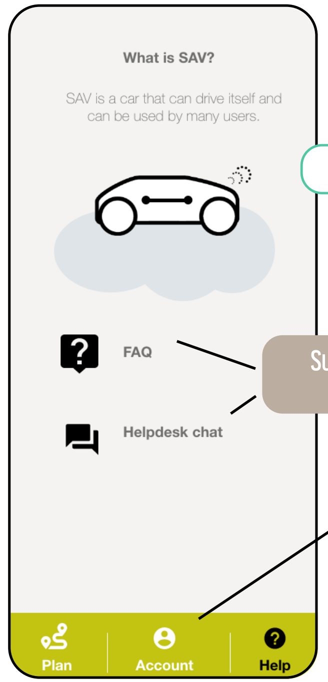
72. The first-use information screens

First use and informing people

The first use is critical as the service is still unknown. Inspiration was sought at the MaaS app Jelbi (Jelbi, 2021) because this Berlin-based MaaS app is quite intuitive to use. The user gets told the most critical aspects of the service for the first use and what it could bring them, shown in figure 72. The app can be used as a route planner, highly integrated to other PT, it can be used to personalize the experience, it explains how sharing works and that it is safe to use. These screens will only be shown for the first use. After verifying the user and agreeing to legal requirements, the main screen will be displayed, which can be found on the next page.

Help overview

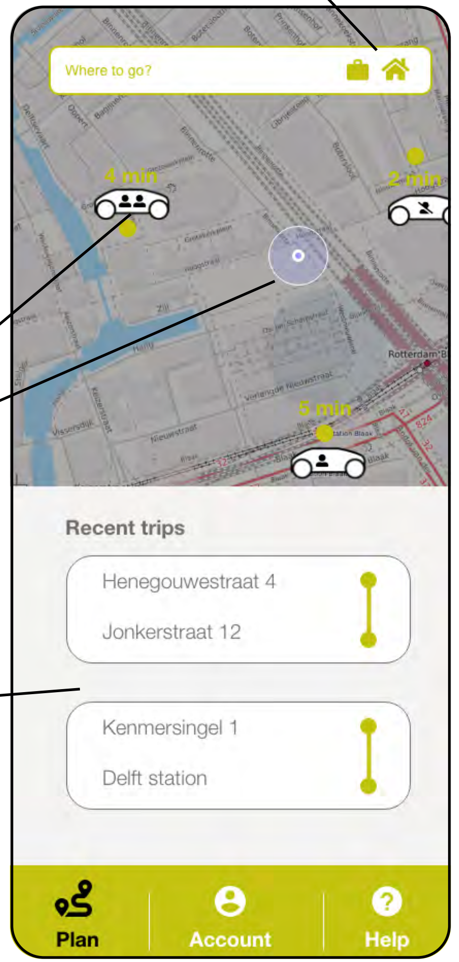
Giving information is highly important for the adoption (Lee et al., 2019). The help section, shown below in figure 73, can give users more information about SAVs and answer common questions. There is also **a helpdesk chat** for more complicated questions as in evaluations, users noted that this would help them.



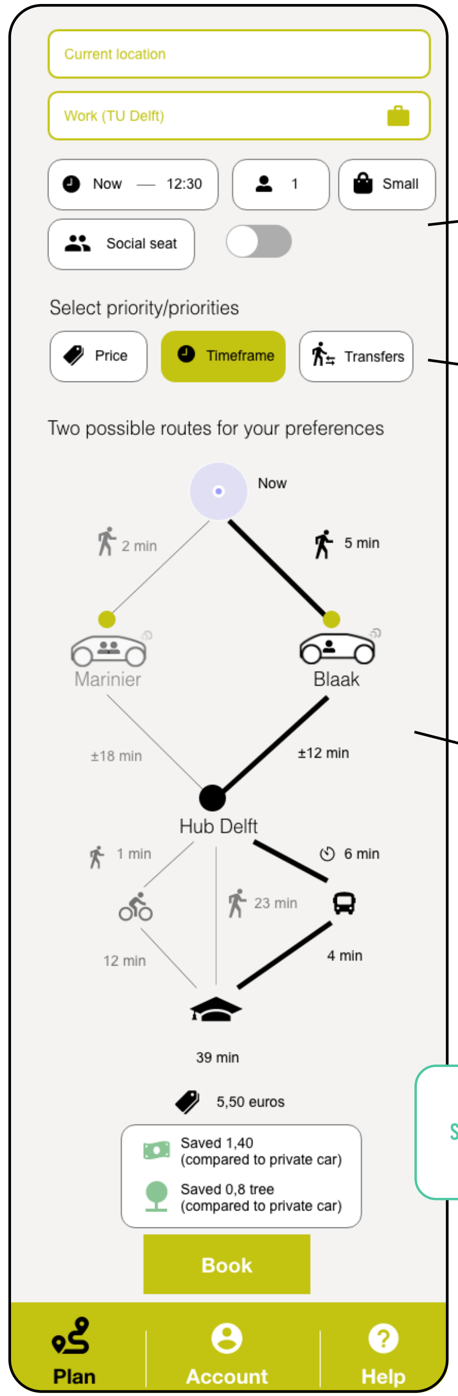
73. The help overview

The home screen and selecting a trip

The home screen, shown in figure 74, shows the real-time available vehicles around the user. The **flexibility** is important for users and therefore this should not feel as a reservation screen. It is important for users how far they have to walk to the meeting point. People do not want to walk further than 5 min and therefore only vehicles are shown within that range. People prefer transparency when it comes to sharing and therefore the availability of seats is shown too.



74. The home screen



75. The trip planning screen

Trip planner

The trip planner, shown in figure 75, shows both **practical as emotional demand criteria** the user can choose from. Also, the **price, time frame, and transfers should be prioritized**. Prioritisation is essential to create a system that can **control the crowdedness at places**. Therefore, in cities, livability can be assured. If someone wants to prioritize the price, the cheapest possible route is chosen, such as a ride-share, many transfers, and possibly longer routes. It is also possible to set two priorities.

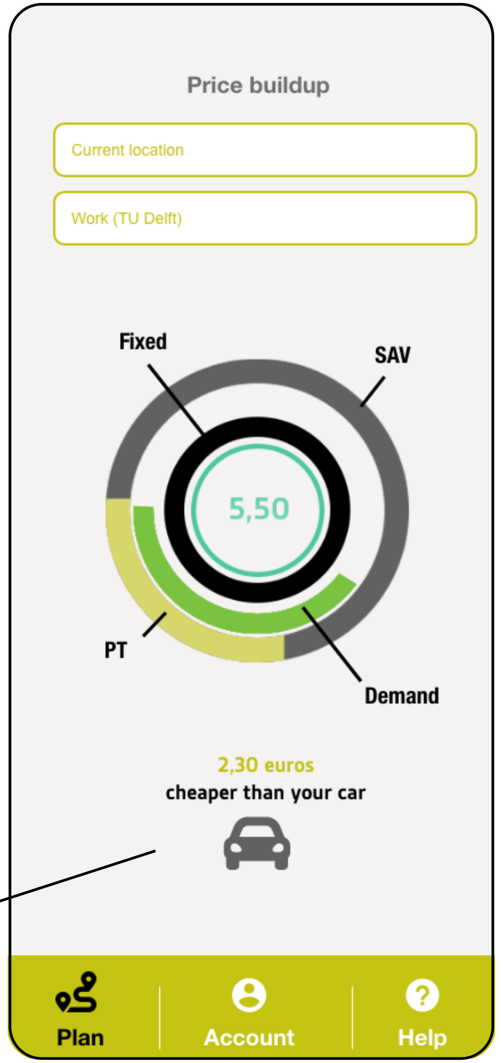
The routes shown in figure 75 are a selection of what users could book within the set preferences. This **choice gives the user some control** over the trip. It will automatically update in real-time. It offers the best option but also other options the user can choose from. The user feels in **control** over the trip and **experiences flexibility**. They could suddenly consider to walk because the weather is nice or will take the bus because they are tired. Those changes should be made possible. These **irrational elements should be incorporated in the selection tool to let the user feel involved yet supported**.

Price buildup

Price buildup is also very important considering the user experience. The **real-time price** should be visually shown and an example can be found in figure 76. Showing and comparing the price buildup (both within the system and beyond the system) is highly important for two things.

First, it should be **competitive** to prices people used to pay for **other mobility** solutions for people to adopt the service. Users compare the price with different solutions, and as sometimes, this comparison is not actually accurate, this could lead to deceptions. For instance, people do not take into account the all-in costs for owning a car.

Second, as the price will be **highly variating** because it variates on-demand, sharing, and the destination, it is **crucial to give users a transparent overview**. The user can click on the price and see an overview of the buildup.



Vehicles you own can be inserted in the app to calculate the trip difference.

76. The trip planning screen

Conclusion

The digital service should be as **intuitive and straightforward** as possible to be accessible for all users. Users should experience a supportive and involved service and the service should enable people to control their trip.

Information should be easy to find, and a supportive helpdesk can answer all questions. The screens shown in figure 72 to 76 are examples of how to design such screens. Many more functions are mentioned in the service blueprint that needs to be considered, in order to create a good user experience for a SAV-system. These functions are listed in figure 77.

THE ACCOUNT

- Personal information
- Ownership of vehicles and where they are parked
- Profile photo
- Verification tools
- Trip priorities
- Recent trips
- Most visited locations

INFORMATION ABOUT THE CAR

- Evaluation of the car (cleaniness)
- All functions inside the car
- On-board entertainment and how to connect to your phone

EVALUATION

- Evaluation tool for each trip
- Overview of the past trips

TRIP OVERVIEW

- Realtime trip
- Possible changes a user can make
- Current location
- Estimated real-time price
- Preferences
- Estimated time of arrival
- Changes on the trip

TRANSFERS

- Info about the transfer
- Walking route to new transport
- Detailed facts about the transfer

77. Other screens' content that are part of the digital service

8.4.2 Physical infrastructure

Vehicle technology and infrastructure

The **velocity, intersections with other traffic, accessibility, and human behavior** are the four factors that are the hardest to solve according to the 2GetThere expert (Appendix A7). To get a fully autonomous car to drive safely, these four factors should be minimised. Therefore, the vehicle is not interacting with other traffic by **moving in specific lanes**, and the accessibility should be kept as limited as possible for people. In cities this is quite hard to create as there is **already extensive infrastructure**. However, existing lanes and tram lanes can be re-build into AV lines. Thereby, parking spots on the streets can be turned into other areas.
The technology to let the cars drive will work on the 5G network or newer communication networks that enable vehicles to communicate with each other (Cybercom, n.d.). Also, information is shared from specific infrastructure points, roads and buildings, to create a safe system. A combination is needed of V2V, V2I, and vehicle sensors.

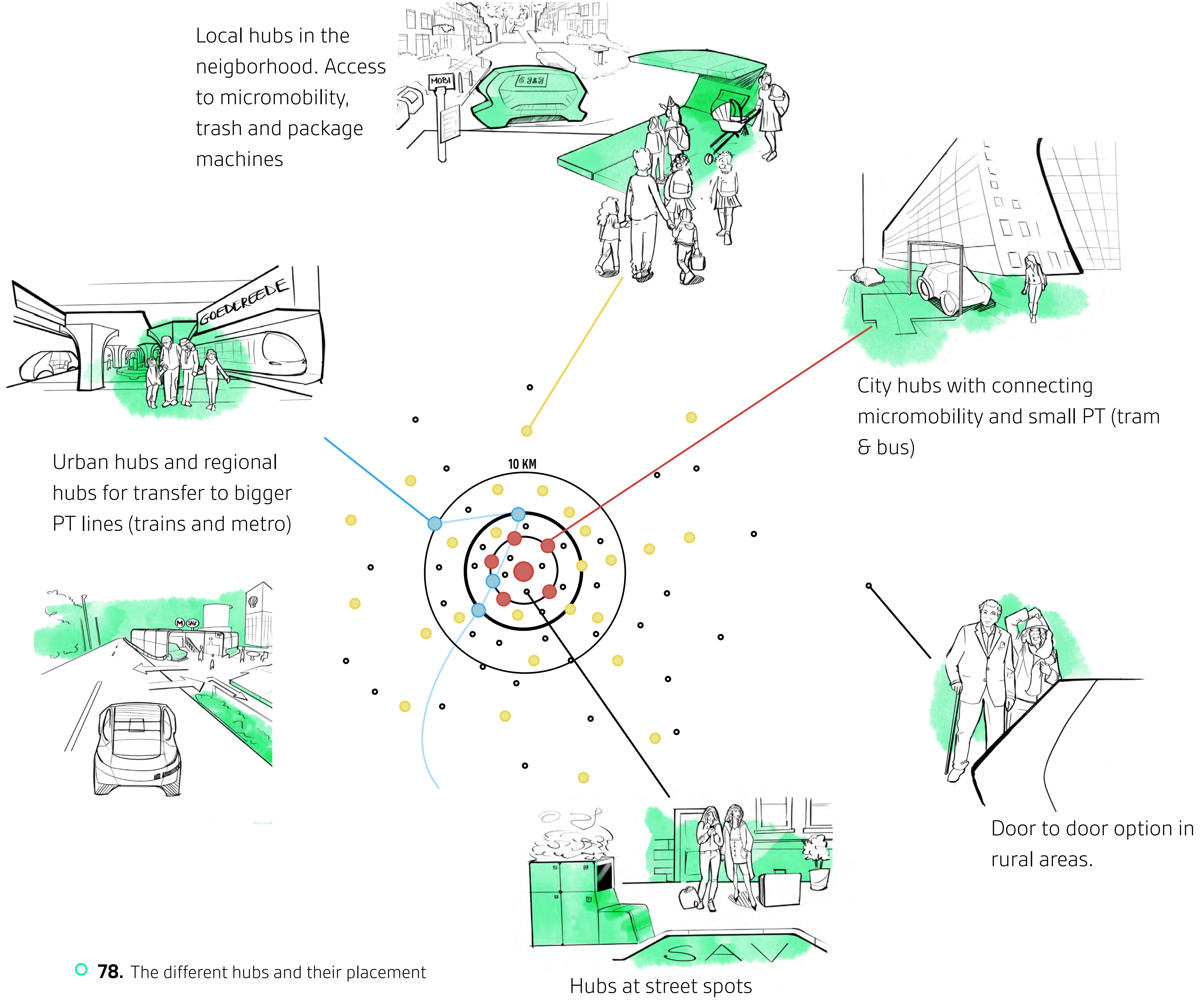
Hubs

The different hubs are shown in figure 78. The placement of hubs is quite relevant as the hub design can add much to the perceived safety of users. The feeling of safety can be enhanced by having **blue light, a clean hub and a lay-out creating transparency yet shelter**.
The amount of **shelter will be increased when transfers are more used** (at bigger lines).
And the more local the hubs are, the more **multifunctional** they can be. As already, trash bins are mostly centrally placed, the hub can also be placed there. Together with parcel lockers and other sharing mobility.

Parking and charging

Ideally, cars should not be driving around all the time looking for users. Therefore, they should be efficiently parked, which can be **closer to each other, within less space, in remote areas and vertically stacked** (Systematica Srl, 2020). The system can learn when high demand at certain moments and areas is required. More cars can be parked around those areas to wait for users. The system can therefore minimize empty cars driving around. There should be a **balance between the waiting time and the approaching time and distance of cars**. At parking spots, cars will also be charged.

Existing parking structures can be retrofitted and also accommodate other functions such as **playgrounds and public space for recreation** (Systematica Srl, 2020).



78. The different hubs and their placement

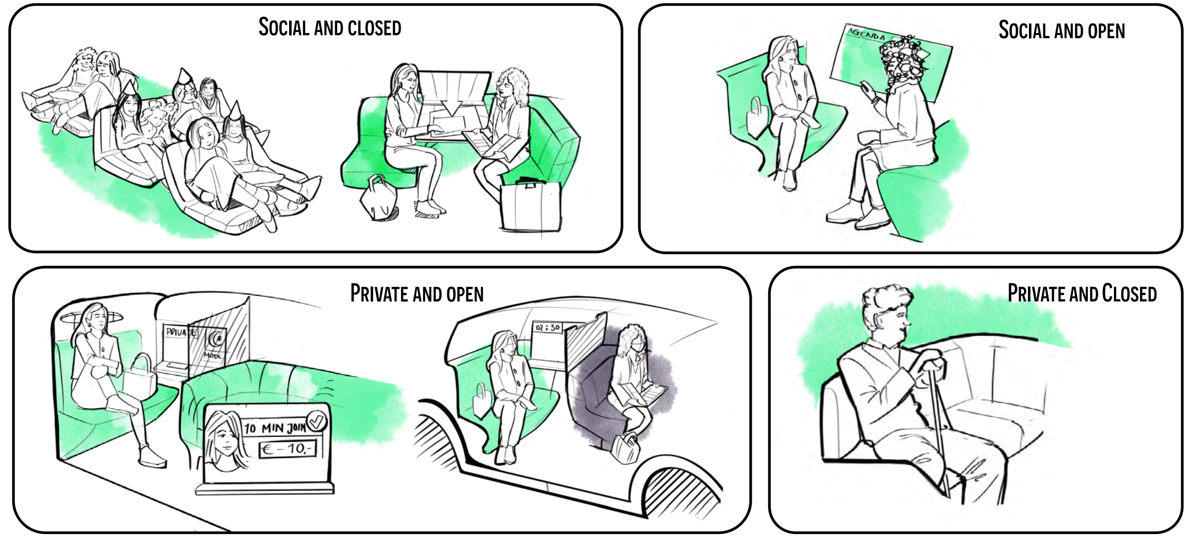
8.4.3 The vehicle

Four options for different needs

The interior should be more **private** in situations where **people seek relaxation** (must travelers). The interior should be more social when people want to interact and have a social moment with others. The car could be open or closed. A closed SAV is reserved for a group of people that know each other. This is more expensive for users. An **open SAV is accessible for all verified users**. In **default**, the car is private and available for all users functioning as a ride-sharing service. This is also the most desirable option from a sustainable point of view.

Different needs fitting one interior

The interior is **easy to access, and multiple activities** should be facilitated in the vehicle (Pfleging et al., 2016; Pudāne et al., 2019, p. 230). In figure 79, multiple activities are shown in relation to the interior set up. The interior **should facilitate different activities** and is therefore quite challenging to design. Designing multiple vehicles for other purposes is not an option as this requires the system to be much more extensive with more cars.



79. The different interior set ups and different activities

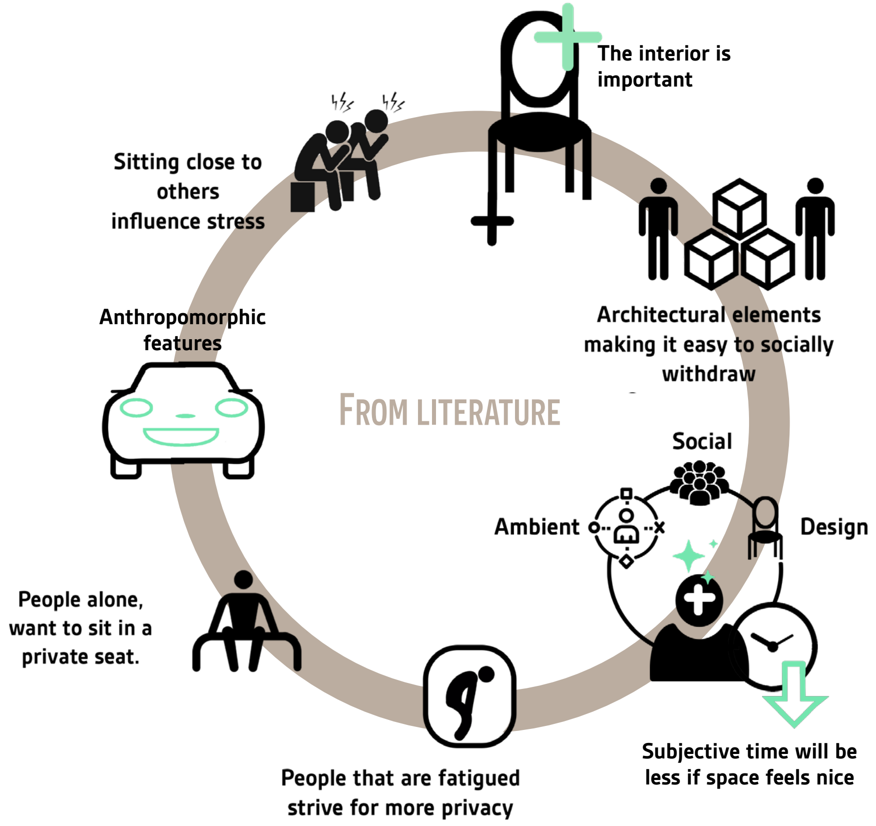
Interior Design

From literature (Milgram, 1970; Evans et al., 1996; Evans & Wener, 2007, p. 93; Staats & Groot, 2019; Lee et al., 2019; Kraus et al.,2009, p.1) and evaluations we know that the interior is highly important for safety and comfort. This can also be seen in figure 80. By creating an ambient space, also the perceived time will go faster and people would opt for using SAVs in the future as well.

With elements, people can perceive a space as more privately and by creating a human-like design, both in looks and interaction, the vehicle is trusted more.

Exterior design

The exterior design of the vehicle is less important. It needs to look friendly and human-like but it just can follow the shape of the interior.



80. Information from literature that has impact on the interior design

Ideation for inspiration

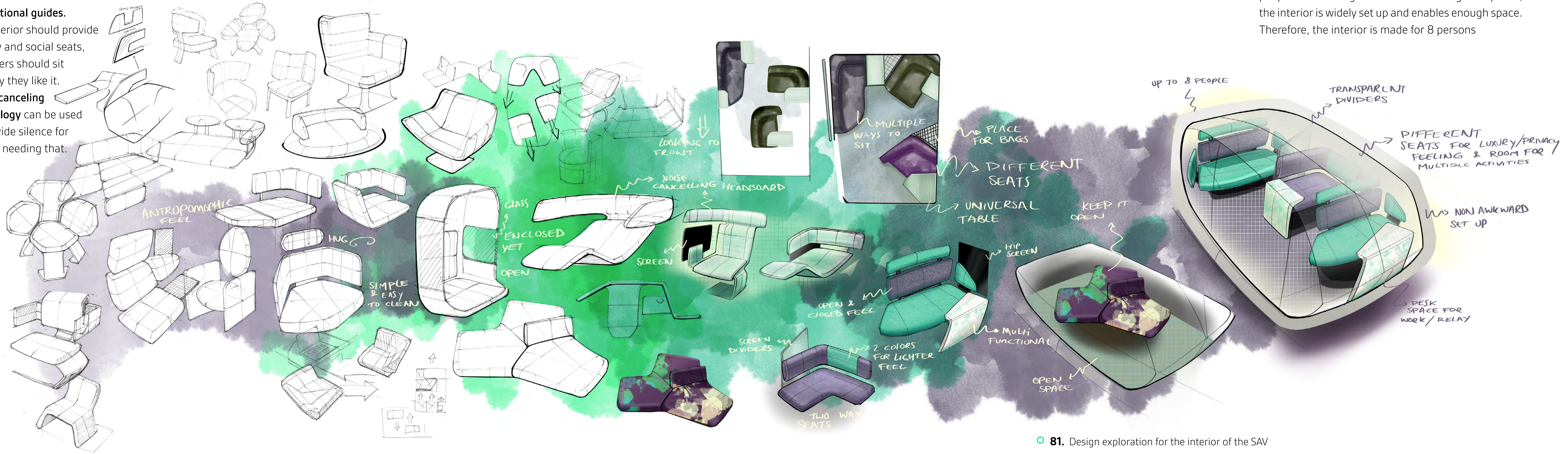
These ideas shown below in figure 81 are **examples** of how the interior could look like. These can be used as **inspirational guides.**

The interior should provide privacy and social seats, and users should sit the way they like it.

Noise-canceling technology can be used to provide silence for people needing that.

Size of an 8 person van

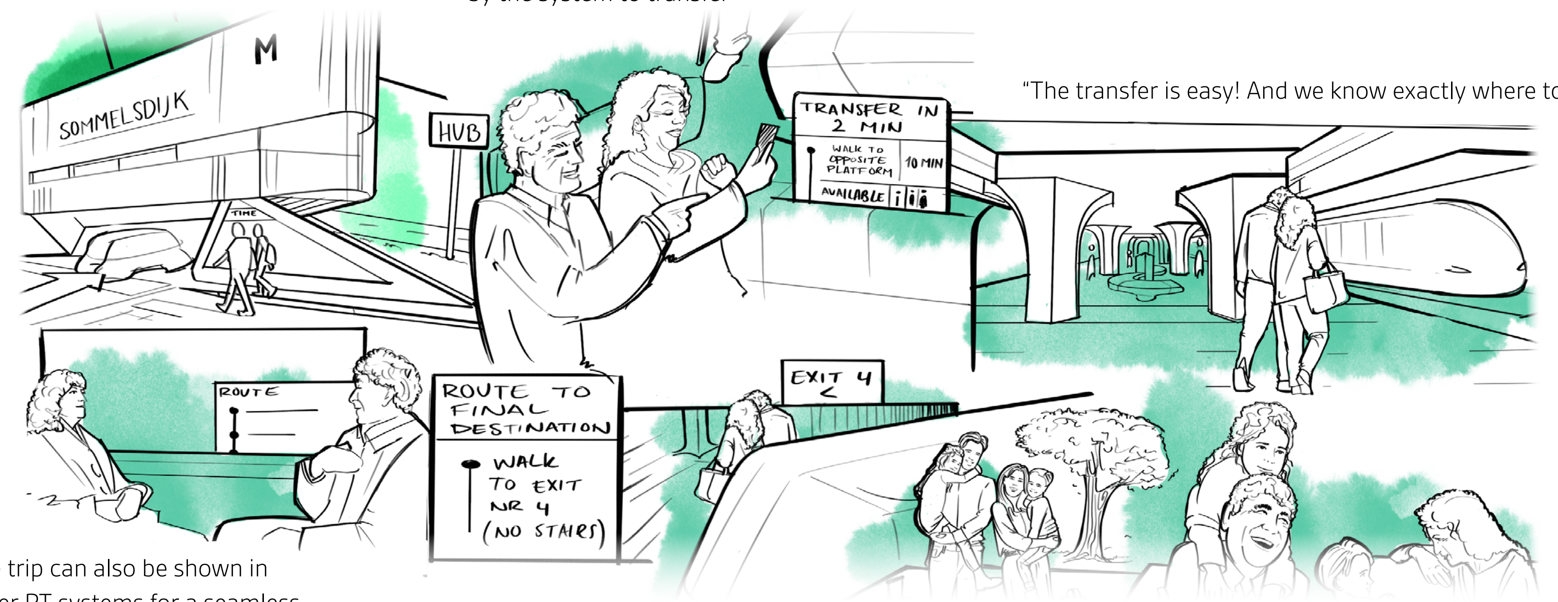
To facilitate multiple people and prevent two or three people from feeling awkward while using the system, the interior is widely set up and enables enough space. Therefore, the interior is made for 8 persons



81. Design exploration for the interior of the SAV

8.4.4 Integration with other mobility

Integration is a critical factor in the SAV system and is highly important for the system to be successful (Kennisinstituut voor Mobiliteitsbeleid, 2015). The reliability is dependent on **punctuality**, so transfers need to be **seamless and without much interruption**. **Details** about the transfer should be made clear to the user; see figure 82; this can be shown in the app and vehicle. For instance, when a transfer is needed, the user gets a notification that they need to transfer with all the transfer details. Also at the final destination, detailed walking information is provided.



82. The smooth transfer scenario

8.4.5 Communication tools for SAV adoption

The system is new and unknown to people, so communication towards possible users is essential. Figure 83 shows an overview.

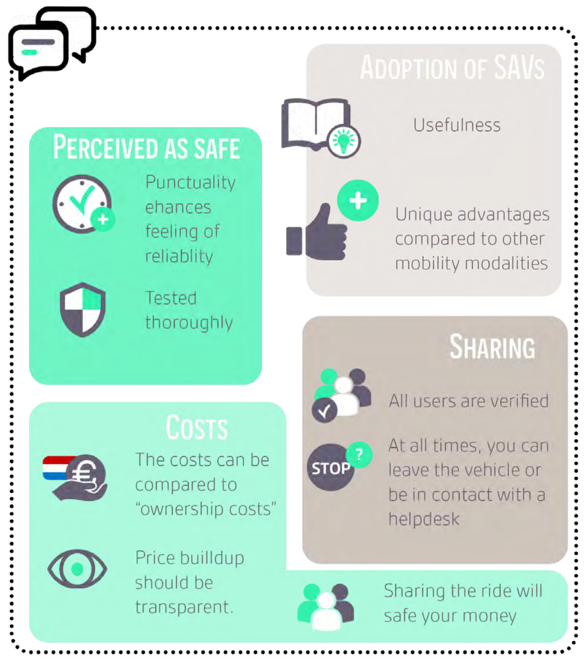
What should be communicated and why

First, it should be clearly communicated that the system is **reliable and safe** at all times. Reliability is practically improved when the system is punctual, and a system is perceived safe as it **looks familiar and human-like and is tested thoroughly**.

Second, the system's **usefulness and unique advantages** should be apparent—both for users personally as for society. For instance, people can effectively use their time while traveling, and they travel in a sustainable and accessible way.

When it comes to ride-sharing, the main concerns should be taken away; **all users are verified, users have control what happens during the ride, there is private seating, and the vehicle is neat**. Not to forget, it is cheaper to share the ride!

Lastly, Dutch people are materialistic and stingy, informing them about the **system being cheaper** compared to owning a car would be beneficial.



83. Communicative considerations for fast adoption of SAVs

To who and where?

When people **experience life changes**, such as having a first child, moving, or pandemics, the **mobility behavior patterns can be broken** more quickly (González, Hidalgo, & Barabási, 2008). At those moments, SAV systems should be introduced in their lives. People should be informed and have the option to choose SAVs instead of buying a car.

As **young city dwellers** should be targeted (Dieten, 2015), they might be most willing to use SAV-systems. Also, **high educated and culturally focused people** are more open to SAV-systems. These user specifics can be firstly targeted, and even SAV-systems could be emphasized at universities and musea locations. The unique advantages of the vehicle can be noted at places where these outshine other mobility modes. For instance, there can be focused on the **safety-at-night elements of the SAV in a shady area**. Also, in business areas, there can be emphasized upon working components SAVs have to offer.

8.5 Expert evaluation of design proposal

8.5.1 Goal and method

Goal of the evaluation

The evaluation's goal was to determine whether assumptions made in the service blueprint sounded feasible, desirable, and viable. Also, the evaluations were used to come across barriers for implementation.

Method

I asked six experts, each with different backgrounds, to evaluate the design proposal. The sessions were held via Zoom. I presented the goal of my project and of the evaluation session. Then, some background information was given about the future contexts and the insights gathered from the scenario evaluations, following the complete service's overview. Then, each user step was further elaborated upon, based on their expertise and what they pointed out as interesting. The conversation was kept quite open to invite the expert to think out loud.

Experts

6 experts evaluated my proposal. They all had different backgrounds: Corporate Design Renault, automotive researcher TU Delft, journalist Volkskrant, urbanist VenhoevenCS, MRDH, and Rijkswaterstaat. The evaluations can be found in Appendix H3 to H5.

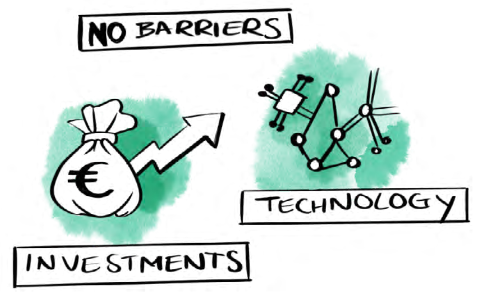
8.5.2 Barriers for the system

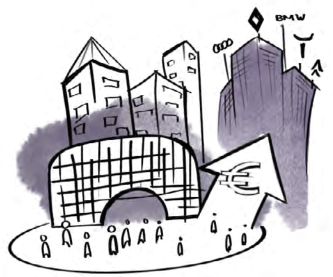
All experts mentioned that the whole user journey was a logical scenario.

The director of the urbanism studio and the automotive research expert mentioned that they did not see barriers in technology and finance aspects. The system is relatively easy to build.

Scale

The barriers are lying in the scale of the system, three experts mentioned. The system should **work in different contexts** so a lot of users can use the system. One of the experts noted that the MRDH is an area with many other zones, and it should work in all of them to **create mass** to use it. Most experts mentioned the system's scale can only be developed on a **European or even world scale**. From an industry-point-of-perspective, the Senior Vice President of Corporate Design Renault Group noted that **industry** will probably prefer to start **in cities**. Scale is essential to consider.

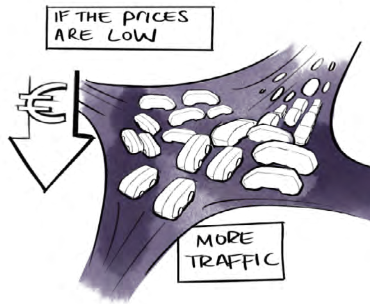


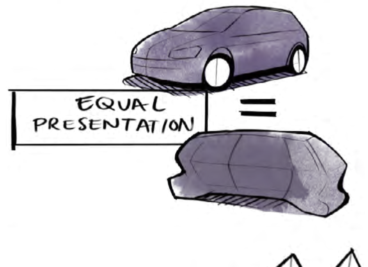


Price and costs issues

A different barrier is price and costs. SAVs should be competitive with privately owned cars. **Owning a car is relatively cheap at the moment,** according to three experts. Users owning vehicles will not easy consider using a SAV-system. This should also be addressed by making it **less attractive to drive a private car**. This can be done financially (by rules and regulation) and by addressing the disadvantages of driving a car yourself, two experts mentioned. Also, you can emphasize on the advantages of the SAV system instead. Thereby, **both private and shared cars should be equally presented in a transition context**. For instance, next to parking the private car in front of your house, it should be made possible to also meet an SAV closeby.

On the other hand, SAVs should **not** be **too cheap** because that could also lead to undesirable situations in which people only will use the SAV-system and use mobility more often. Therefore it is essential to consider **system regulation** within urban areas to block cars from going into the city **when it is too busy** and adjust





the price somewhere between private vehicles and PT. Otherwise, this could have **undesirable effects on quality of life** in cities.
The **government** should take the **lead** in this, two experts mentioned, by creating this push (parking norms, etc.) and pulling, by building SAV-infrastructure next to new housing to give users momentum to use these systems.

Sharing data for integration

Three experts mentioned that **sharing** all **stakeholder's data** is a critical barrier to creating a highly integrated system. For realising MaaS apps, this is the hardest to establish. **Data sharing norms** should be considered by **governments to push stakeholders to share their data**.

Also, from a user-centered perspective, sharing user's data is critical for the system to work. Our **attitude towards data could change in the future** , and it is crucial to understand the uncertainty. Therefore, the **norms** should not be strictly regulated as these can be **outdated** in 2040; they should be **flexible and adaptive.**

Inclusive and social responsibilities

The two experts from the government mentioned that the **government** should be responsible for the system's **inclusiveness**. It is undesirable if the system is only usable for higher educated, wealthy, and healthy people.

Also, when **demand would be suddenly low**, for instance, in a crisis, the government should **still provide mobility** to users if they make themselves **dependent on the system**.

Also, it is the government's task to provide **mobility to everyone living in rural areas**. One expert mentioned this system would be more beneficial than a more extensive bus line driving with no people.

Infrastructure and system standardisation

There seems to be a fear of standardisation and **integration**, one of the experts mentioned. There should be one institute arranging these barriers. This should be a government. However, the disadvantage could be that the **standardisation will eventually be outdated** and actually counteracting just as data sharing norms.

Powergrid and infrastructure

The MRDH expert emphasized that the first step is to set up the **power grid** to assure electric vehicles to drive around. Similarly, for autonomous cars, the **infrastructure** should be created or adjusted.

All experts concluded that this system should **balance industry, government, and society.** However, my proposal shows the ideas' **concreteness** and can be used as a starting point to think about all these elements involved.

8.5.3 Design implications for the system

Experts also mentioned some ideas for the system design itself.

Buffers at hubs

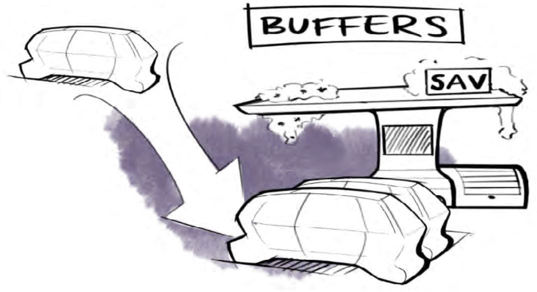
The urbanism expert mentioned that vehicle buffers can be needed as you do not want vehicles to drive around empty.

Cleaning and maintenance

Two experts mentioned that cleaning and maintenance are important considerations to make in the design. These are also important in the stakeholder collaboration because some stakeholder has to take care of it. There might be "self-cleaning" tools in 2040, one expert noted, which would be solved.

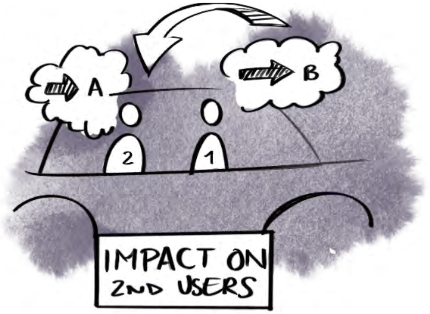
Very detailed transfers

The government expert mentioned that this seamless and detailed transfer design is crucial. At the moment, the details are mostly forgotten. For instance, when you have to transfer, you need to go with the stairs to a different section; those details should be mentioned and explained for all users to use the system and transfers.



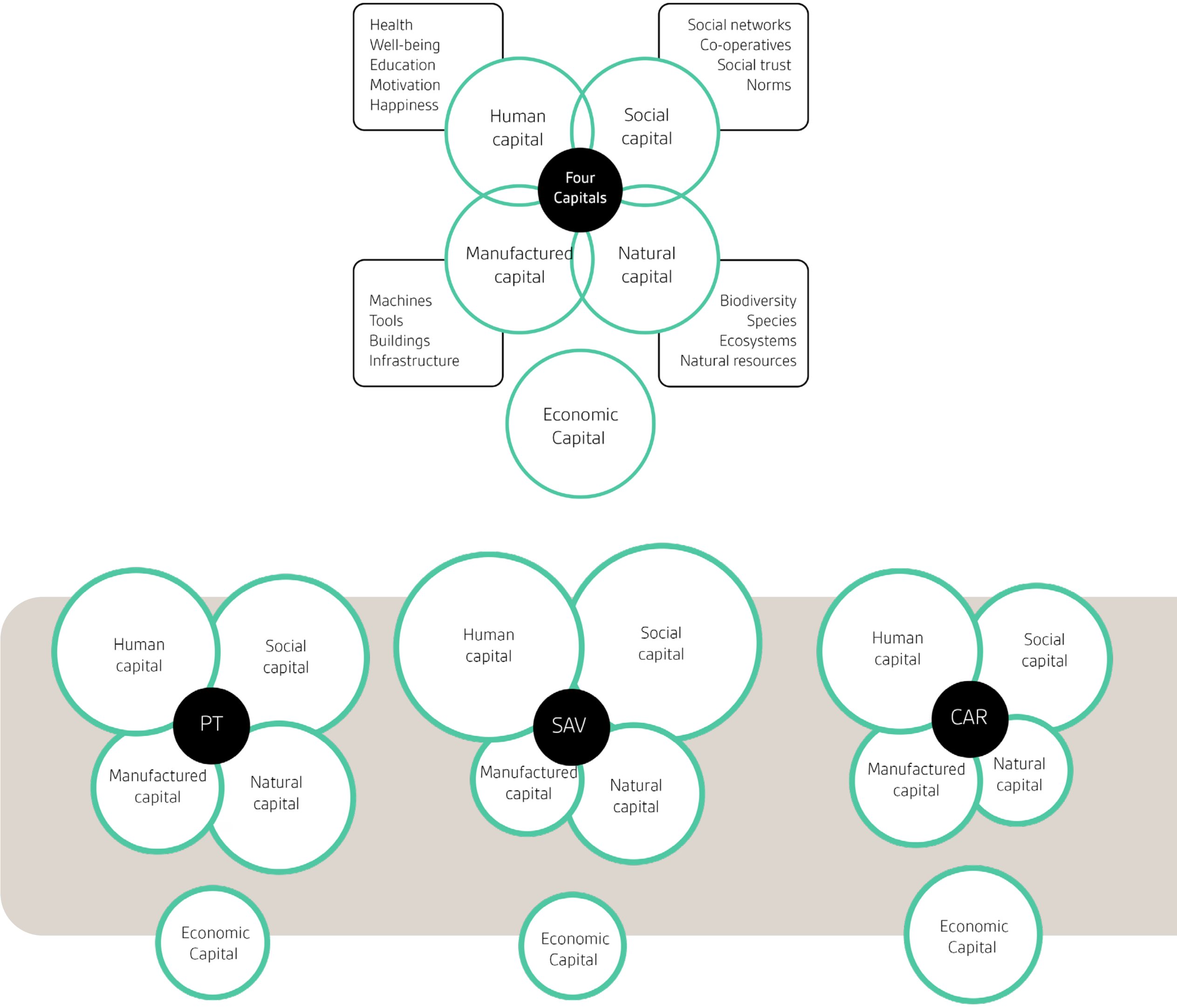
Indirect impact on other users

The automotive research expert mentioned that it is essential to keep in mind the system's indirect users. When changing the trip or transfer to another mobility, the "other" user could experience hassle or discomfort. Especially when the system is built upon the idea that you will not have to transfer if you pay more. If another user is spending less and the second user has to wait for the first user to move.



8.6 CONCLUSION ON DESIRABILITY

The four capitals model is used to **evaluate on sustainability** and, therefore, the design' desirability. This is **compared to the private car and PT systems** based on insights from the experts. This comparison is shown in figure 84. The SAV-system has the potential to, in the end, **be more sustainable than personal car systems** and can be **competitive with PT** systems. The circles indicate how the capitals would grow per modality. As shown in figure 84, the **capitals human and social** will grow immensely for the SAV-system **as more people would have mobility access**. A condition is the **system's inclusiveness and availability in areas where PT is not present.**
Compared to car usage, the natural capital could grow because we could **better preserve and regulate our nature within cities** and put **less pressure on our landscape by decreasing the formation of highways**. The SAV system needs different infrastructure, which needs many **investments**. However, there could be sought to solutions to work with existing infrastructure to **minimise the investments and the emissions** accompanying the building works.



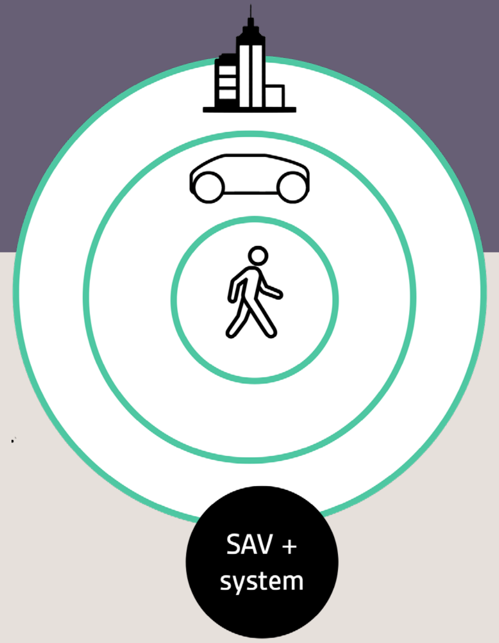
84. The four capitals model used for comparison of SAV-systems to PT and car systems (Ekins et al., 2008, p. 72)

9 FINAL DESIGN VISION

A USER CENTERED VISION FOR THE ECOSYSTEM OF SAVS IN 2040 IN THE MRDH

In this chapter, the final design is presented. It shows the user-centered perspective on how "we" would like to use SAVs in the future. One of the three use cases is used to explain the vision. Essential elements of the vision are featured and described. Finally, the implementation steps of this vision are described.

THE SAV ECOSYSTEM SHOULD BE A **FLEXIBLE, ACCESSIBLE, PRIVATE AND INTEGRATED SERVICE** CLOSE TO HOME THAT ENABLES PEOPLE TO **FEEL AT EASE, INVOLVED AND SUPPORTED** BY CONTROLLING THE WHOLE TRIP.



The user centered vision
For SAVs in 2040

What
The designed vision is an **autonomous ride-sharing and car-sharing system** that enables a flexible, accessible, private, and integrated service for users in 2040. Users should feel in **control, involved, supported, and at ease** when using the service. The service is widely available in cities and rural areas and close to home by enabling hubs in every neighborhood.

Why
The **quality of life** in cities and rural areas will improve because extensive car infrastructure, such as parking spots, can be retrofitted into green and public recreational spaces. In rural areas, people can finally enjoy easy access to flexible mobility without buying a car. The quality of individual lives also improves as travel time can become spare time, and the SAVs can be used for meaningful activities with family and friends or alone.
Thereby, the system is **more sustainable** than private car usage and is a helpful supplement to existing PT systems.

How
The desired future vision is showcased through one of the three explored user scenarios.
This scenario shows the complete story and how users experience the system.
In the end, a lot of different users can use the system.

The four crucial elements

The vision contains four crucial elements;

Flexibility is about filling the gap between PT and cars. It enables people to enjoy a flexible and adaptable service and go anywhere without constraints. Users also experience a flexible, easy feeling as the interior can be used for many activities.

Accessibility is about the inclusiveness of the system and service. The service can be used by everyone and is close to home. Users experience the service as involved and supporting.

Integration to PT is about facilitating different needs that PT fulfills and therefore supplementing the PT system. The system will be easier to use when high integration is realised, and it will, in the end, be a more sustainable personal mobility system.

Privacy is about being in control of social interactions. This is important because those needs are now fulfilled by private cars only. Also, by increasing privacy, the unique benefits of AVs will be used. People can work and eat, for instance.

Flexible
Fill gap between PT and cars
For many activities
Easy to adjust trip

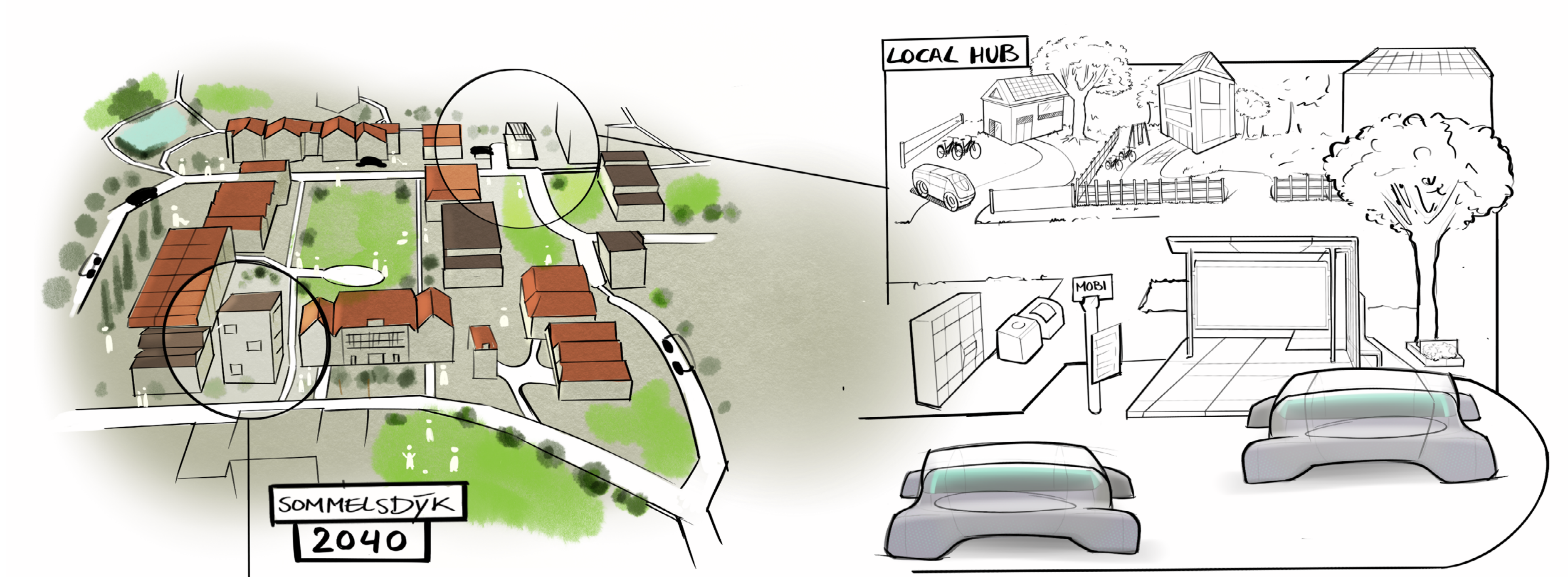
Accessible
Inclusive
Close to home
Human like interaction

Integrated
Connected to PT
Easy to use
Sustainable

Private
In control of interactions
Fully enables possibilities of AVs

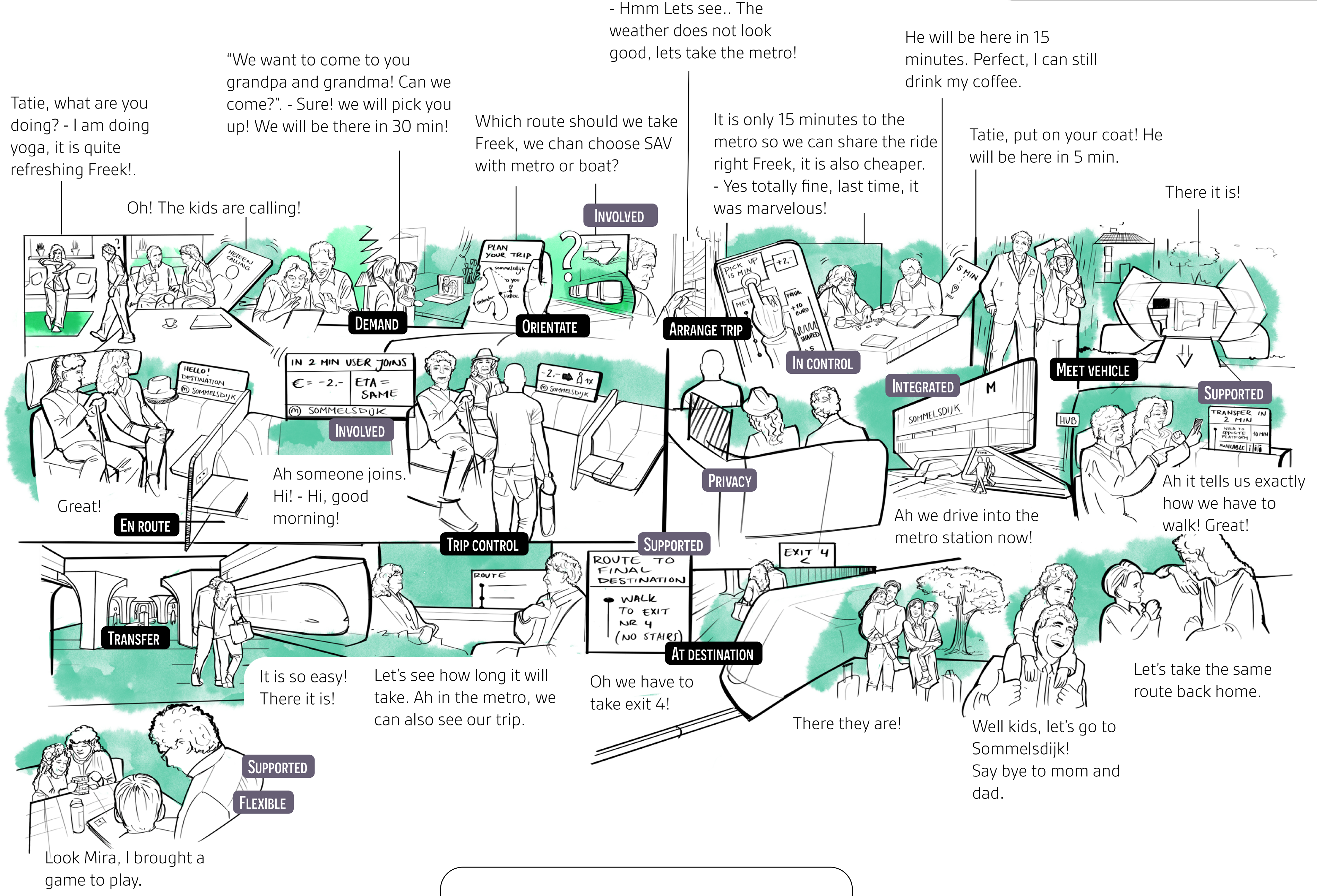
Desired user scenario 2040

For the SAV-system in rural area in MRDH

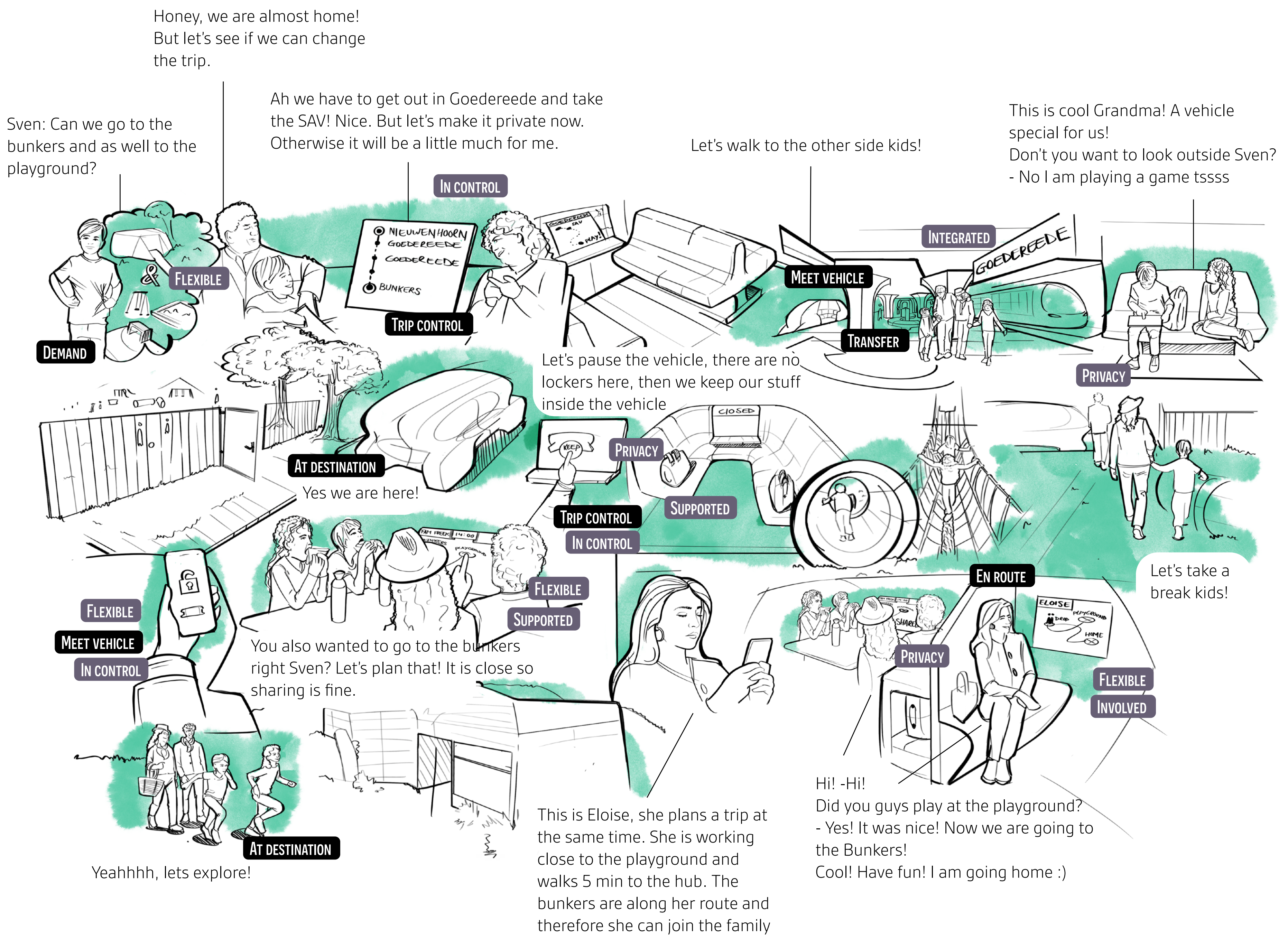


Tatie and Freek living in Sommelsdijk

Tatie and Freek do not have a car, and the PT is insufficient in Sommelsdijk. They use SAVs to be able to do fun activities with their grandkids. The hub for the SAV is close to home. However, they live in a calm area, so the SAV can also pick them up from home. That is handy because Freek has had knee surgery. Their grandkids often visit them, and they always pick them up from Hellevoetssluis. The trip is made much more accessible than before, and therefore they like to travel around. They feel free and flexible again.



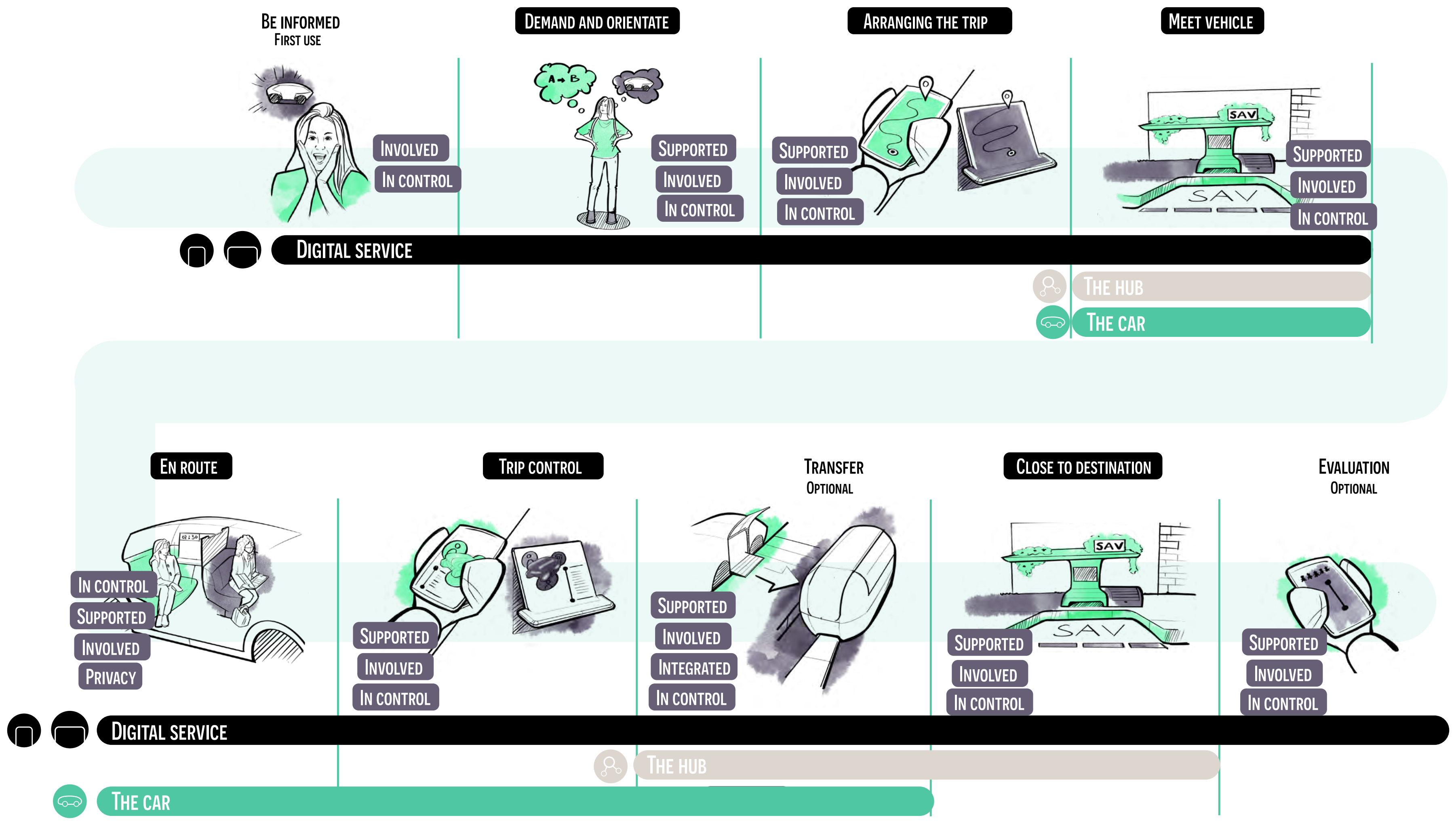
Legend
User journey steps
Vision elements



THE USER JOURNEY

WITH UNDERLYING ECOSYSTEM ELEMENTS

The service journey is the general service that provides a desired user journey for all type of users, such Tatie and Feek. Based on this general user journey, the underlying ecosystem elements are explained.



THE DIGITAL SERVICE
EASY TO USE AND CONTINIOUS GUIDANCE

SUPPORTED

INVOLVED

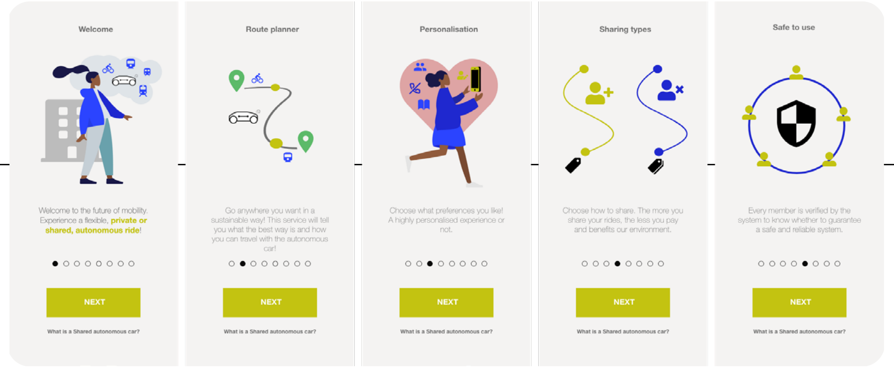
IN CONTROL

GET INFORMED

Provide information

The main benefits are: the flexibility it offers, the personalisation option, that it fits to personal needs, competitively priced and that it is more sustainble.

Unique benefits of the service



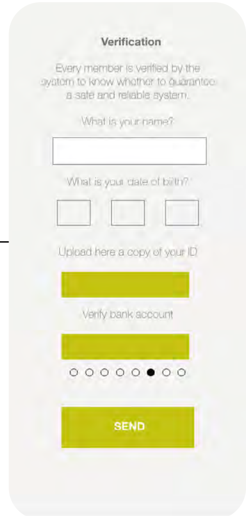
Helpdesk

DEMAND AND ORIENTATE

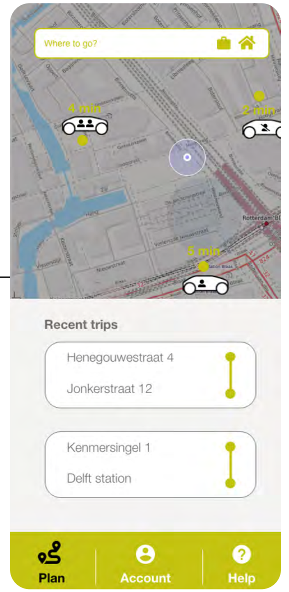
Plan on trip

First, the user need to verificate themselves to guarantee a safe system. Then they can orientate on rides and book.

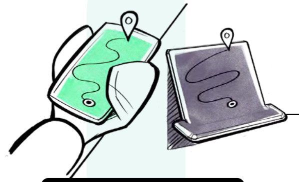
User verification



Orientate on rides

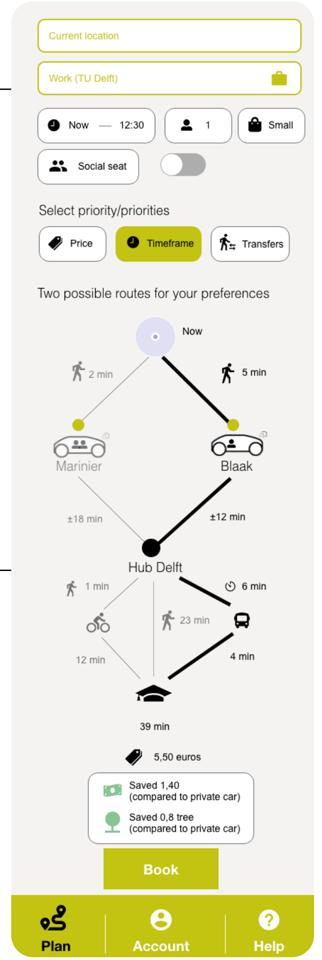


Available rides closeby are shown. Information is updated real-time.

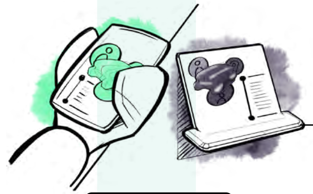


ARRANGING THE TRIP

Choose or adjust a trip



The app is used as route planner. Practical and emotional choices can be made. Users can select a priority if they want to limit the price, the timeframe and transfers.

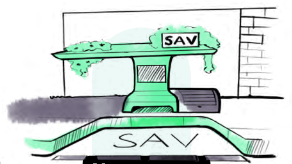


TRIP CONTROL

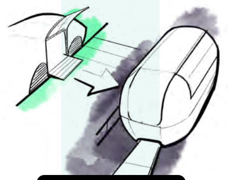
Possible routes are shown and users can choose the one they like. They can change their trip anytime.

EVALUATION

After each trip, users are able to evaluate the trip and adjust preferences.



MEET VEHICLE



TRANSFER

Users will be guided to locations if they have to walk or transfer. Detailed information is given about how to walk and how long that will take.

CLOSE TO DESTINATION

The hubs
Safe, comfortable and closeby

Supported

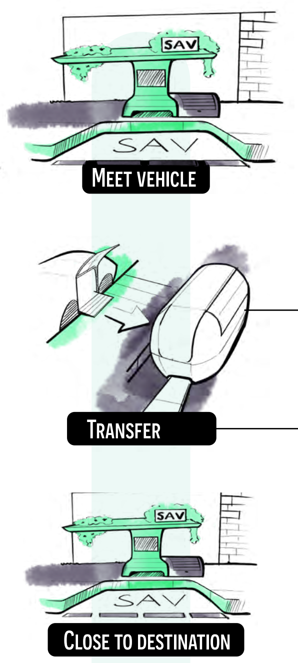
Involved

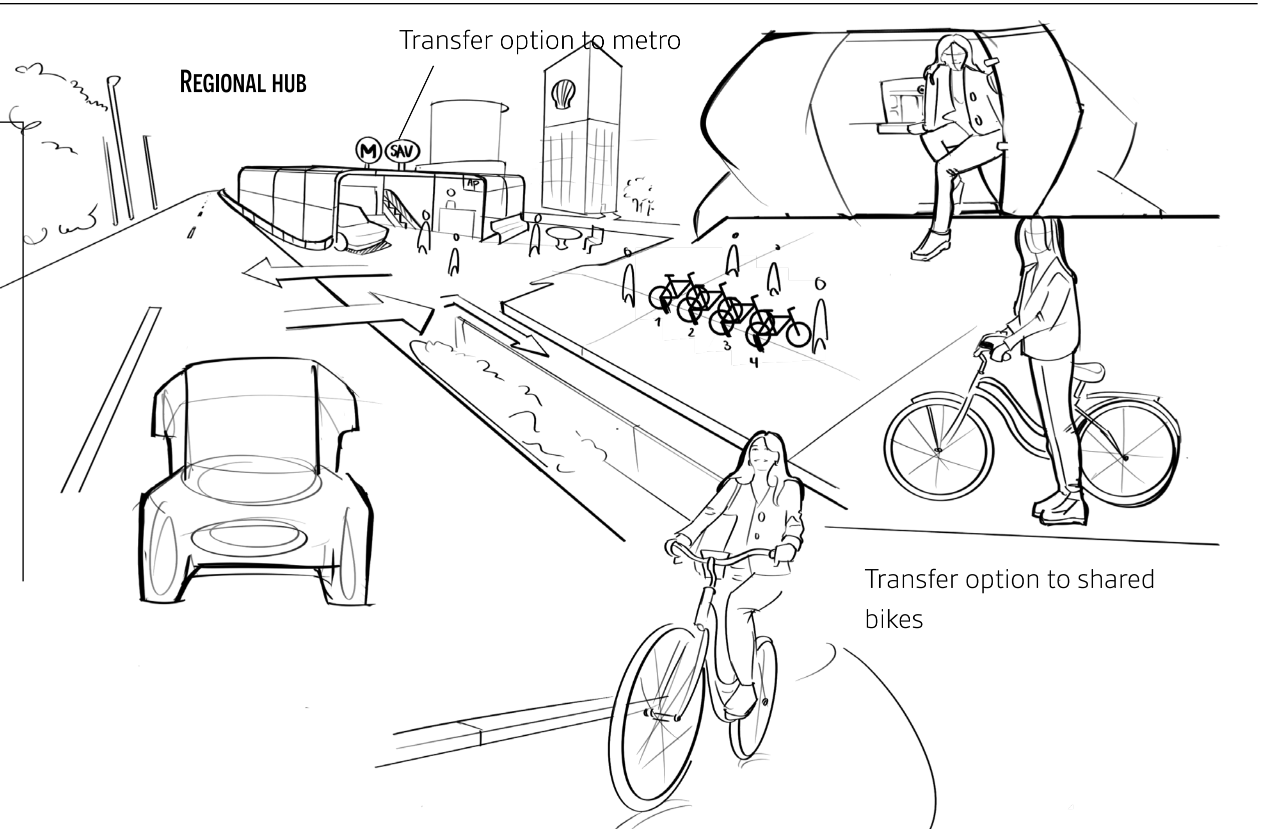
In control

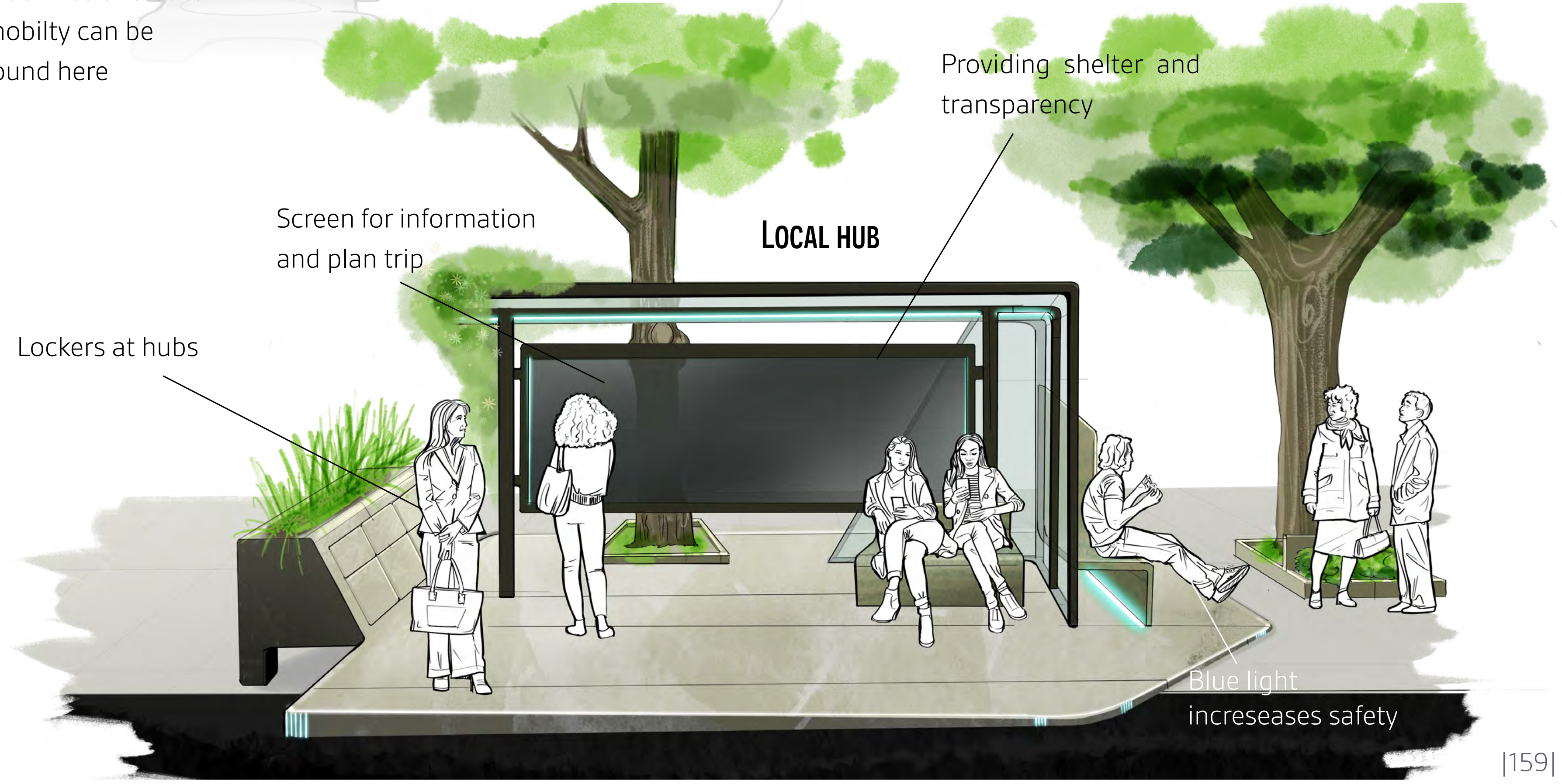
Integrated

There are four different types of hubs from which the user can meet the vehicle.
Local **(In rural areas and cities)**
Regional
Door to door **(when technology is ready)**

Regional and city hubs also function als transfer hubs. At these hubs, transfers can be made to other mobility, such as PT and bikes. This is arranged in such a way that users gets detailed information about the transfer and is supported during the tranfser.







The vehicle

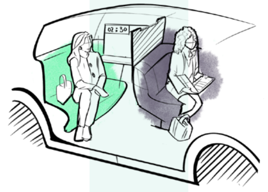
Private and social, open and closed

Supported

Involved

In control

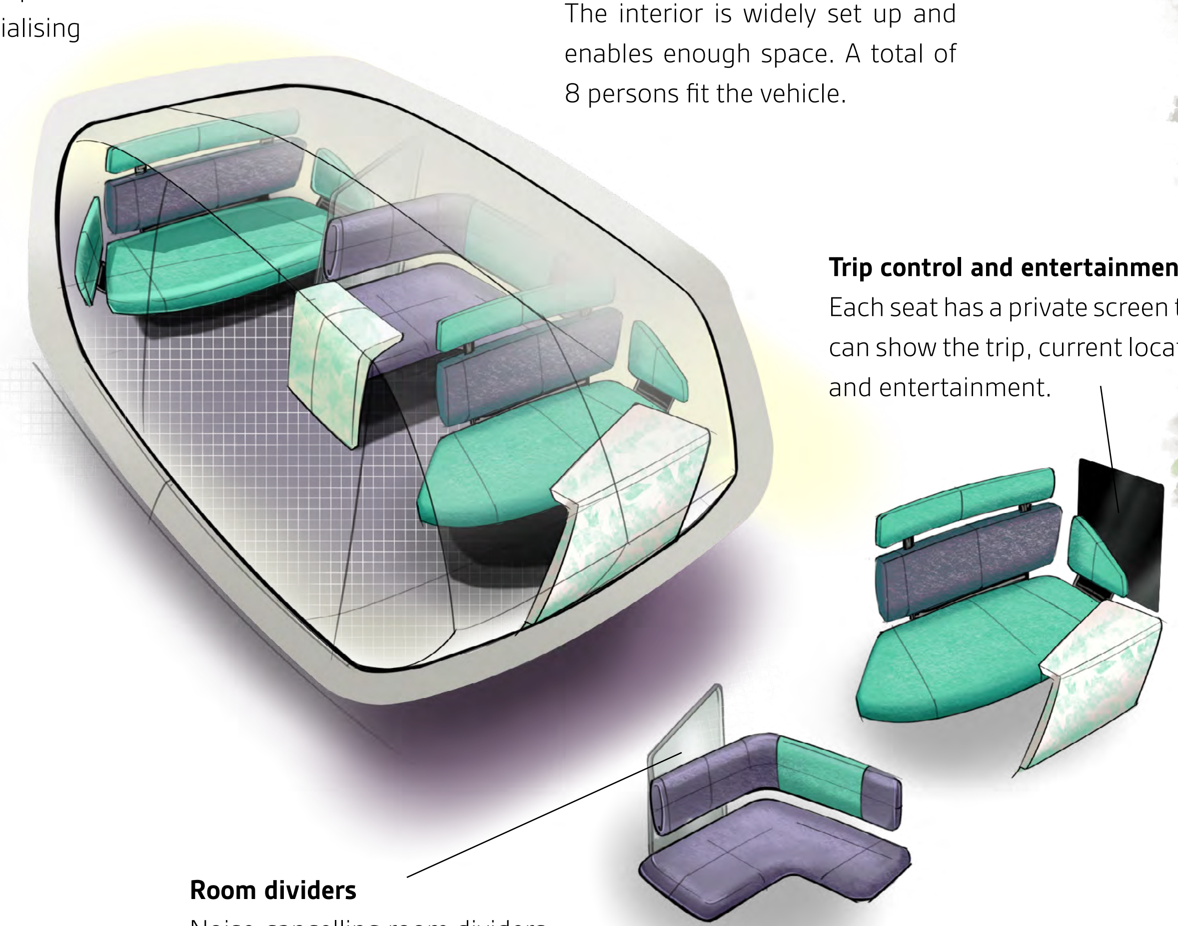
Privacy



En route

Ride-sharing and car-sharing
The interior is privately set up but can also be used for socialising purposes.

Facilitator of different needs and activities
The interior fits to many needs. Both social as private settings can be created and users will feel at ease and comfortable, also when sharing the vehicle with people they do not know.



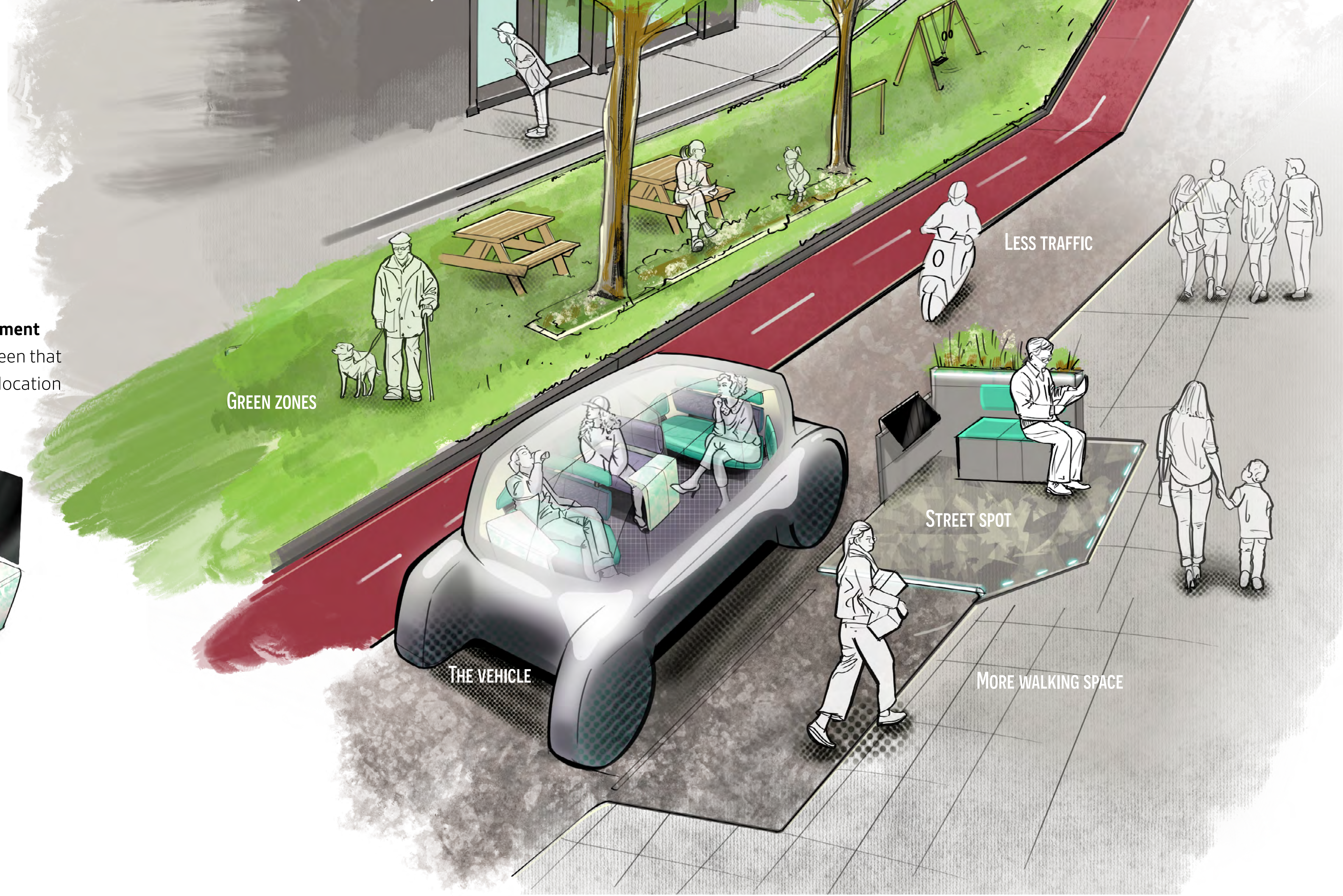
Van sized
The interior is widely set up and enables enough space. A total of 8 persons fit the vehicle.

Trip control and entertainment
Each seat has a private screen that can show the trip, current location and entertainment.

Room dividers
Noise-cancelling room dividers provide a feeling of privacy.

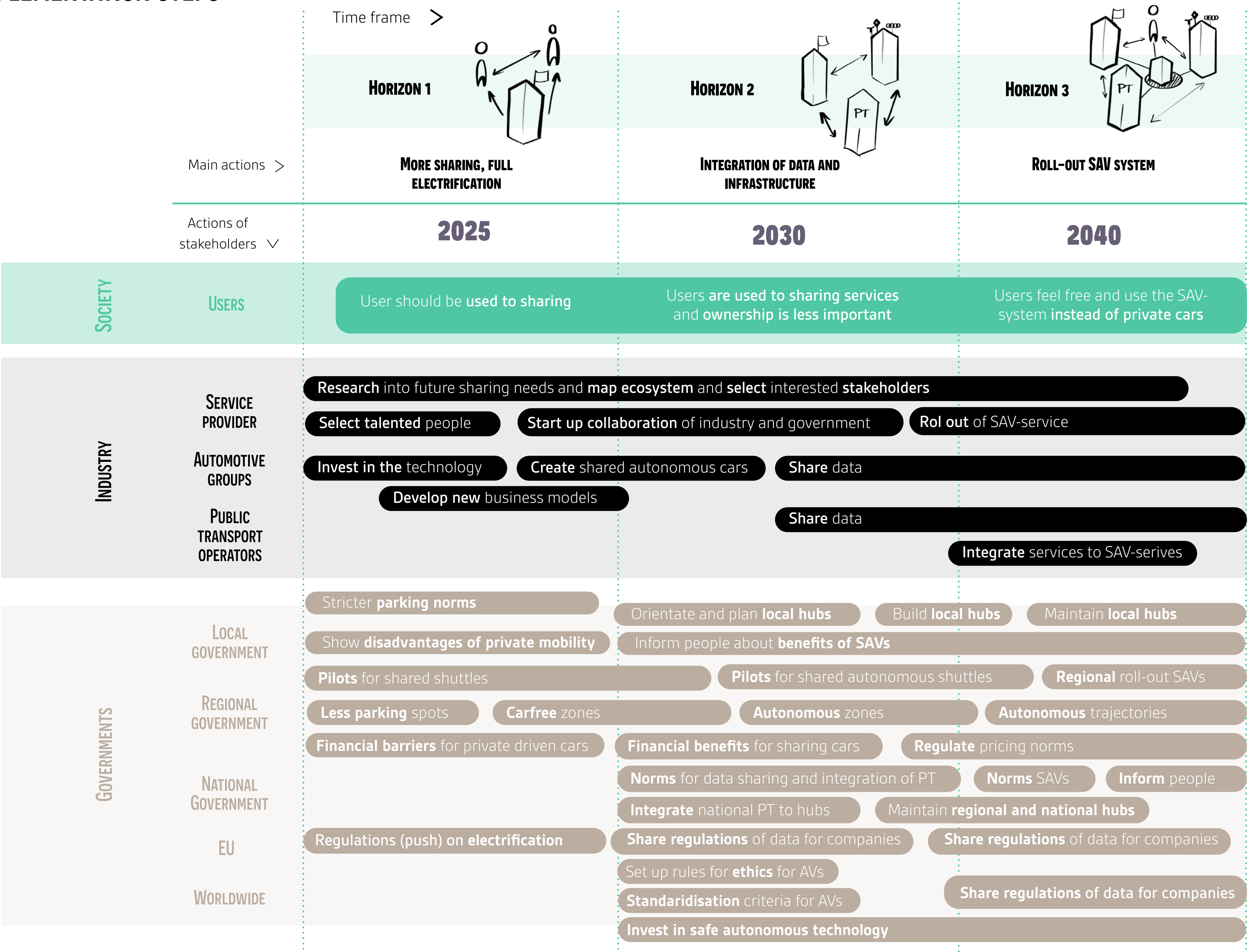
The desired SAV-service

Flexible, integrated, accessible and private



ROADMAP TO REALISE VISION

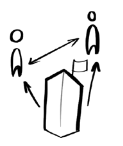
IMPLEMENTATION STEPS



The implementation outline

The roadmap on the left gives an overview of the stakeholders' actions and steps to implement the vision for SAVs. The activities are split up into three sections; users, industry, and governments. This roadmap provides the outline and guides of what general steps need to be taken.

HORIZON 1

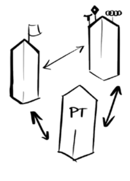


MORE SHARING, FULL ELECTRIFICATION

Strengthen current innovations, orientation AVs

In horizon 1, current innovations should be fully implemented, and preparations are made for the SAV system. The provider of the SAV system should start a collaboration with other industry stakeholders and governments. Industry stakeholders should invest in autonomous technology and business models. Governments should emphasize (on a European and national scale) curtailing private ownership of cars. Thereby, pilots should be set up to learn about the implications of autonomous technology.

HORIZON 2

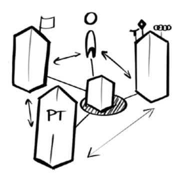


INTEGRATION OF DATA AND INFRASTRUCTURE

Integration

Horizon 2 is critical as collaborations need to be built with all stakeholders involved. Technology and business models are being developed by industries, and simultaneously norms and regulations are created by governments. Sharing regulations are necessary to get stakeholders to collaborate on the data level. In horizon 2 also standardisation and ethical aspects need to be defined on the European or world level.

HORIZON 3



ROLL-OUT SAV SYSTEM

Moment to integrate, built and test

Scale is essential, and therefore the SAV system should be rolled out nationally, preferably also in Europe. Hubs need to be build and stations upgraded to the integration standards. Maintenance agreements should be made, and prices should be determined. For pricing, the national government should guide if the pricing system is inclusive and needs subsidies. The design should be announced to possible users.

10 Conclusion

Discussion and recommendations

This chapter draws and discusses the conclusion of the project. It discusses the limitations and recommendations of the project. It finalises with the next steps and implications for stakeholders to implement the desired vision.

10.1 Conclusion

In this graduation project, I aimed to design a **user-centered vision for the ecosystem of shared autonomous vehicles in 2040** within the MRDH context. The overarching goal is to develop a **supplemental mobility system** that is more **sustainable** than private personal mobility systems now.
Broad research was conducted to find future **user needs** and identify **elements** and factors necessary for the **ecosystem** design. These insights were used in the **scenario-based exploration phase** to develop the ecosystem design vision.

Current sharing, electric and autonomous vehicles show shortages in **integration, flexibility, and fulfilling needs** for users. Therefore, the design goal is to present a **flexible system that is highly integrated with other mobility that fulfills users' future needs** traveling with private mobility modes now. The user should feel at **ease, supported, involved,** and **have complete control** over the total journey and interactions. Users have control over the type of sharing by selecting **ride-sharing or car-sharing** trips.

The system requires **continuous collaboration of government (both local as european) and industry**. From other complex innovations, we learned that **standardisation and integration** of services are crucial and can only be realised if **governments regulate with push and pull strategies**. Also, governments should take responsibility for creating a fair and **accessible priced system** and for **continuous supply** if people make themselves dependent. Scale is essential for standardisation purposes. Therefore European level roll-out could be the way to go for standards, regulation, subsidies and programming. At the regional level (f.i. cities) authorities must be involved in infrastructure, regulation and services.

Decision-makers should **use an user-centered approach to keep monitoring human needs**. The system's pitfall is to rationally approach it and lose the richness and desirable elements for users, creating an undesirable system which is not supplemental to the mobility systems we already have.

10.2 Discussion

10.2.1 Project

Qualitative user-centered approach
The project was set up from a user-centered perspective and gathered **qualitative information** to create use-case scenarios and finally design the vision. Although the designer chose the three use-scenarios based on scientific research, the morphological chart, SWOT method and opinions of experts and users, the **designer's interpretation** steered the final design in a specific direction. Thereby, the scenarios are developed in three different future contexts based upon the translation from trend research. Choosing different scenarios and future contexts could have caused a **different outcome**.

The **qualitative approach**, however, is **needed** in a complex system for multiple reasons. First, to approach the emotional and irrational elements of the mobility design; it **gives meaning** to someone's life. Second, creating something that fits human needs is of **high importance for adoption**.

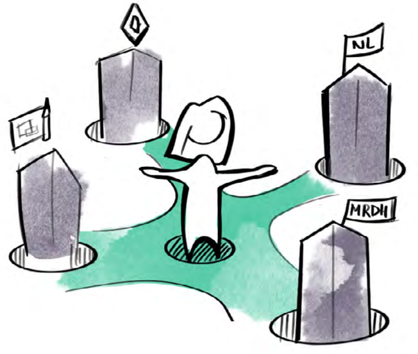
Thirdly, use scenarios and visuals of future contexts are helpful for **communicative goals**. Because ideas can be abstract and high-leveled, **concreteness is needed** to let stakeholders envision the possibilities. With storytelling, you emerge people into ideas, the user-perspective, and get concrete discussions.

More complex future
This project mainly focused on the user perspective but recognised the holistic approach and incorporated as many stakeholders as possible. The industry and governmental tasks are mentioned briefly but are **recognised to be critical** for the system design and are therefore essential to look further in.
The **mobility industry and the governmental** tasks will become even **more complicated with these new innovations**.
Company stakeholders will not only be car-making companies but also electrical, maintenance, and service companies. So within the pillar of "industry," more stakeholders will be involved. As the complexity rises, the problems and questions will also be more complex. Some questions might even be too hard to answer as they are of **ethical nature**. Within governmental institutes, the complexity rises too, and more opinions should be dealt with. The scale is important and therefore on European level decisions should be made.

Expert involvement and Delphi Method

Because the ecosystem of SAVs includes **complex stakeholder interests**, these interests should come together to implement the vision. The Delphi method (Hirschhorn, 2018) recognises and seeks value in the varying and even **contrasting visions of these stakeholders** and is therefore highly relevant for topics like this. Because of time limitations, I could not use the Delphi Method (Hirschhorn, 2018). The Delphi technique is a **participatory approach** that recognizes the varying and contrasting visions of stakeholders. A sequence of questionnaires is distributed to experts; after that, answers were shared with other stakeholders and then reflected upon to let the experts reconsider their opinions. This iterative approach is used to find solutions with stakeholders for complex policy matters.

Instead of the Delphi method, I **interviewed experts and exposed them to other stakeholders' perspectives** to see their reactions. This was also very useful to display the pain points and create a clear overview of the different interests.



10.2.2 Vision elements

The vision contains four main elements; integration to PT, privacy, accessibility to all users, and the perceived flexibility.
Also, it is crucial to understand the sustainability aspects and possible unintentional impact.

Integration to other PT systems

To create an integrated PT system, both systems and underlying companies **should share information**. This is the main challenge. Then, the **platforms and hubs** should be built into **shared spaces** so that all providers can use them.
The **local and national governments** can help overcome these two challenges by supporting the building and designing hubs and pushing companies to share their data. This can even be regulated by **European** pressure.

The system vision is created **based on current systems**, and if new mobility innovations rise (hyperloop and other autonomous micro-mobility), the reason d'être of the SAV-system can change. Therefore, being continuously aware of the users' needs and the SAVs position in the mobility network is vital.

Privacy

Fulfilling privacy is essential for the system to work. In PT, privacy is also quite high as users merge into the mass and therefore have quite some privacy. However, there is not much physical privacy as people are sitting quite close. In this project, **the conditions are set to create a private area in a shared car.**

Accessibility

The system should be accessible for all users, physically and financially.
The system should be **inclusive,** and people with disabilities should be able to use the system. Transfers should be easy, and the hubs should be accessible and close to home. In this project, **different needs are facilitated** in one interior. This is a big challenge. There will not be multiple vehicles for other purposes in the first roll-out as the system first needs to be extensive.
Then various companies probably start to **exploit different vehicles on the system**, people can choose which car or brand they would like to take.

Governments have the task to **set norms for these vehicles** to maintain the user's needs fulfillment. Industries will also naturally search for gaps in the needs to create vehicles. So this will reinforce eachother.

Governments should also set **norms for pricing to keep it accessible** for all users. Subsidies are needed to create an accessible price. An accessible system also generates **social cohesion, higher quality of life and social involvement** of people as they can reach more places. **High demand areas can be used to finance low demand areas** as prices will be higher when crowded, people want a private car and door-to-door travel trips.

Flexibility

At the moment, users car park in front of their house. Also, every destination can be reached by car. These **conditions determine how people perceive the flexibility of this system**. By decreasing the flexible advantages of privately owned vehicles, the perceived flexibility of SAVs will rise.

Sustainability

The vision on the system of SAVs has the **potential to be more sustainable than our private personal mobility systems.** However, sustainability is hard to measure, especially in a future context.
One of the critical elements for users is behavioral and attitudinal changes. Change does not happen by itself. Financial pushes from governments are needed to push users to choose sustainable options. For instance, to **minimise ownership and lower prices** to seduce people to start sharing mobility.
Next to the sharing element, integrating the system with PT systems can increase people's trip chain behavior and, therefore, lead to more sustainable behavior.
Lastly, by creating a closed system, cities' crowdedness and our energy usage can be monitored and controlled. Therefore, living areas can be kept livable.
In potential, **we could re-arrange our public space and create a less energy-consumable system and a green living area**.

Unintentional impact
Some uncertainties of the future might have an impact on the system in an unintentional way. In the end, mobility is a mirror of peoples' behavior, and **significant events can change people's traveling behavior** (such as the Coronavirus).
The system itself can also impact how people behave. For instance, with AVs' given possibilities, people could **live further from work and thereby travel further.** People can make more **fun trips** while doing other activities like working and driving to the beach to see the sunset. It even could evolve in **carsharing working rooms circling around cities**. The question is if that is desirable.

The social impact should also not be forgotten. We **face many challenges to prevent loneliness**, for instance. Instead of a social SAV system, it could also **support people's individualistic approach to mobility.**
Like the carsharing working spaces, people could just go fun riding with their friends instead of hanging on the streets and **causing trouble** for people who want to use the SAV-system.

Accessibility for everyone is great on the one hand, but it also provides mobility for people with **wrong intentions or people abusing the systems.** These systems could be used for **criminal interactions**, for instance. This should be kept in mind and further explored to prevent abuse.

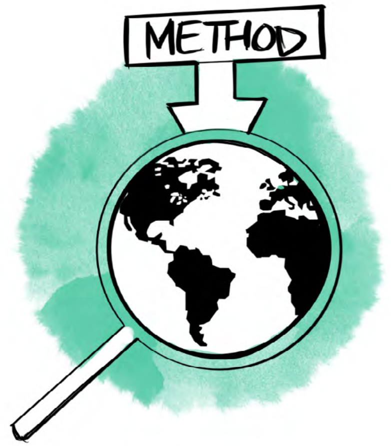
10.3 LIMITATIONS

Practical constraints
This project was executed by one designer within a limited time. Therefore, the number of interviews and evaluation sessions with users was limited. Also, it was harder to test and evaluate ideas as sessions could only be held online because of Corona constrictions.

User centered approach
The project was focused on the user experience of the vision for SAVs. Therefore, aspects regarding business and technology are less dominant and thoroughly researched.

Uncertainty of the future innovations
The vision is created based on current knowledge. As unforeseen developments could rise, the vision's reason d'être could or should be adapted to these developments in the future. The uncertainty is one of the limitations of this project.

Implementation in other contexts
This project was conducted with a **focus on the MRDH** area. Although the system is quite generally set up, it can be **different** in other metropolitan areas such as Amsterdam.
Within the Netherlands, these differences could be minor but can be more significant in other countries. As the attitudes towards mobility and ownership can differ per country. The **demographics, landscape, and cultural differences play a role in designing mobility solutions** (Hofstede-Insights, 2020). The method and approach used in my project can be used by other designers to create designs for different contexts.

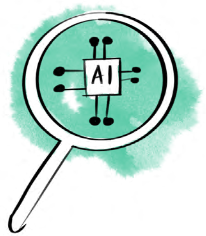


10.4 Recommendations

Further exploration of SAV-system elements
The service design presented is only a start and should be developed and detailed further. The digital service, the buildup of hubs, interior design, people's behavior, ownership, lifestyles and for instance gender studies should be further explored. First theoretically and then practically by tested with multiple users. These subjects can be further elaborated on in future (graduation) projects within the lab and externally.

Explore business viability
Pricing is one of the main barriers to the concept. More research needs to be done into future business models, fair pricing, and financial interest for many stakeholders.

Explore technological feasibility
The first step to create the vision is making autonomous technology. More exploration must be done into how and what this autonomous technology will be and what infrastructure is needed. Based on that, investments can be made into new and re-arrange of infrastructure.



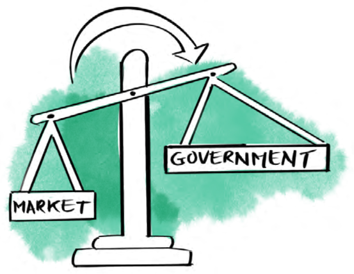
Keep user-centered approach
Service designers, governments, and other stakeholders should keep the focus on usability and user needs. As the future is not here yet, continuous consideration of future needs is essential.

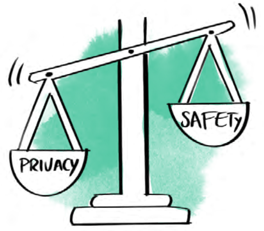
Pilots
The theoretical framework needs to be tested in context. Therefore, many pilots should be roll-out, not only focusing on the MVPs but also on detail level. The details matter and give meaning to users.

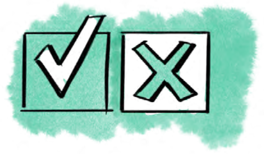
Collaboration
Collaboration is essential to create a working and desirable SAV-system. In the next section, more is explained about what, why and how this can be arranged.

The market vs government dilemma
There should be searched for a balance between market and governmental roles. Will, the government, be a stakeholder, or will they become the client? Should the government regulate more, or will the market decide? These questions should be further researched.

The privacy vs. safety dilemma
Another dilemma is the privacy vs. safety dilemma. To what extent can the system guarantee safety without knowing too much about an individual. This dilemma is dynamic, and the balance could be very different in 2040. Our attitude could change towards privacy and safety. Thereby, people do not rationally approach these topics. Therefore they are hard to measure.







The ethical dilemma
Because decision-making is done by a designed algorithm, the programmer has to deal with ethical questions. We have to program how the car will respond to extreme situations and responsible when errors occur. Although the system can be much safer than driving a car yourself, people are hesitant towards machines taking over decisions. Would the vehicle set priority to you or the pregnant lady overpassing the street? A clearer understanding of how humans perceive machine intelligence making such choices is essential.

The collective vs the individual dilemma
The last dilemma is the collective versus individual topic. To create a sustainable and inclusive system, sometimes it is needed to put the collective as a priority above the individual. However, the system will only work if the individual feels understood and supported. This is also closely related to the market vs. government dilemma as it is affiliated to politics.

10.5 Implications and next steps for stakeholders

Shared benefits
Collaboration is possible as the system provides shared benefits for all stakeholders.
The government needs to create **accessible mobility for everyone** (rural areas) and therefore needs a system that provides mobility to rural areas. The automotive industry and other mobility partners want to make profit and mainly **identify possibilities in cities**, however, they **see the importance of collaboration** with PT stakeholders.
Public transport stakeholders have interest in **making their lines more attractive and accessible.** Precisely those non profitable lines **in rural areas**.
All stakeholders have interest in creating a more **sustainable business and system**.

The main challenges
The main challenge is to create the **collaborations, although they have shared interests**. The most important barrier to overcome is to start **sharing data**. This can only be realised by pressure from European governments.

The second important step is to **standardise the system** to create a seamless experience for users. This standardisation should also be arranged on European level.

The next steps for SAV-service providers
Start a collaboration of intelligent experts, from different perspectives to start vision building for SAV-systems.
Further research based on insights.

Local government
Stricter parking norms are important. Pushing people to share cars.

National government
Start pilots with carfree zones. Build less parking areas close to new buildings.

European government
Create regulation for sharing data of companies and standardisation norms. Invest in autonomous technology.

Automotive groups
Invest in autonomous technology, create designs for models and test with users. Create businessmodels useful for SAVs.

PT operators
Should provide their data.

Epilogue Reflection

Before I started my graduation project, I set four goals. The first was to **design a combination of mobility design and architecture**. I like the topics of pedestrian space, routing, public space, and urban architecture. Although my project did not thoroughly go in on these elements, I did talk to urban planners and incorporated architectural details in my design.
The second was to design **an implementable vision**. In previous projects, I created concepts with a lot of imagination and inspiration but lacked feasibility and viability. I am proud to say that I made a vision that feels realistic and less disconnected from reality.
The third goal was to get to know the **municipality and governmental work environment**. The MRDH was a partner and I talked to experts from the government. Although I did not physically go to these work environments, I have seen enough to know I would not be made for this kind of work: **too much politics and bureaucracy for me**.
The last goal was to approach the project from **different interests**, and also, that worked out quite well! I talked to many various experts, and it was interesting to see how complex designing such systems are. I even managed to speak (twice!) with Laurens van den Acker, head of design Renault Group and many more interesting experts.

Corona was not stimulating the inspiration much, but **I am proud of what I have accomplished**. During this project, I went through an emotional and physical rollercoaster as I got the coronavirus, went into a lot of quarantines, moved from Delft to Rotterdam, and won the lottery. The last one is sadly not true...
But I had good luck with my supervisory team!
I want to thank my chair and mentor, Suzanne en Jasper for their supervision and personal involvement in my project and monitor my mental state. Thanks for all the advice, the discussions, and help during the project.
I want to thank the other lab members, especially Amber and Laura, for the lovely coffee breaks and discussions.
I also want to thank Lobke Zandstra, from the MRDH, for the discussions and input!

My special thanks go to all experts and the participants who took the time to get interviewed by me and evaluated my concepts.

Finally, I want to thank all my friends and family for helping me with my project. By supporting or just listening to my complaints. I especially want to thank Victor for his help and thoughts about my project and for reading my report.

Now, a new adventure starts at Lightyear.

Evita Goettsch
April 1st, 2021

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Faculty of Industrial Design
Engineering Landbergstraat 15
2628 CE Delft

www.io.tudelft.nl