The Dynamic Human Vehicle Relationship through Robotic Interaction Systems

An exploratory look into how robots can add value to the interaction with fully autonomous vehicles.

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Master Thesis

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Preface

This graduation project serves as the capstone of a magnificent two-and-a-half years as a master student at the faculty of Industrial Design Engineering. These years have been full of experiences that deepened my knowledge about design, innovation and human experiences, but it also unearthed some new (design) interests. I am greatful for all the wonderful opportunities that arose, from working with large multinational companies to being part of a European research consortium. These project involved exploring different topics, ranging from highly technical to very human-experience focussed. After this journey, I can confidently say that the latter has remained to be my largest interest, which is why I would like to dedicate the start of my design career to user experience research.

Acknowledgements

First and foremost I would like to thank my supervisory team for all of their efforts in supporting me and my progress in this project. I am greatful for the deep and extensive discussions we had about topics regarding my thesis, and the great insights that arose from those discussions. I'd also like to thank them on a more personal level, for being so understanding and helpful when some difficulties arose.

Secondly, I'd like to thank all of the participants and experts that helped me gather my insights. Without you, coming to the end result would not have been possible. To the users in the co-creation workshops: thank you for giving me your time and effort, and thank you for participating with all your enthousiasm. Your work was key in understanding the user needs and wishes regarding autonomous vehicles in a community setitng. To the experts that participated in the critique sessions: thank you for your valuable time and for providing a critical view on my work. Your insights and discussions helped round off my findings and helped see them in a deeper light.

Lastly, I'd like to thank my fellow students that supported me on a personal and professional level throughout the project. I am greatful for the discussions with all of you, that helped me make decisions, take on new perspectives and deal with the stressful times.

Abbreviations

AV Autonomous Vehicle
HVI Human Vehicle Interaction
HVR Human Vehicle Relationship
NDRA Non Driving Related Activities
OEM Original Equipment Manufacturer
SMS Shared Mobile Space

Executive Summary

With the imminent rise of vehicle automation the human driver will have increasingly less responsibility for driving. At one point this will even mean that cars will be able to fully drive themselves, so that the driver is relieved of all driving related tasks. In this situation the car effectively becomes a robot, resulting in a novel relationship between human and car. This project explored that relationship by looking at the possible overlap between autonomous vehicles and robotics, aiming to answer the following research questions:

What emerging phenomena can be identified from the combination of AVs and robotics?

In what way could the combination of AVs and robotics add value to humans' lives?

The project started by reviewing previous shifts in this relationship that came about with technological developments, and a similar analysis of robotics and its relationship to humans. After providing historical context and formulating the current state, the project continued with an exploration of existing work in academia and industry. The findings from this initial exploration helped define a further focus into the relationship between an AV and a community of people that surrounds it.

To gain user insights a co-creation workshop was conducted. In these workshops the participants were all part of a certain community, and their task was to envision how a 'shared mobile space' (an abstract term used in substitution of AV) and robotics could add value to their lives. The outcomes of these workshops were analysed and together with insights from the related work review they served as input for finding a design analogy for the envisioned future role of the AV. The selected analogy was that of a language buddy, which acts as a sort of catalyst for expats or refugees to be included in a community.

To finally bring all findings together and link them to the envisioned future role, a set of design principles was created. After iteration with mobility-related experts they were formulated as follows: when researchers and designers are working on future AVs, they should keep in mind that AVs should be considered shared mobile spaces rather than self-driving cars. Because of the robotic characteristics of the AV, its use-opportunities are far greater than just an evolution of current-day car use. To help with this notion, the following principles should be followed:

- AVs provide opportunities for interest-based communities to be **nonsimultaneously connected** in a physical space;
- **Tailored** NDRAs should be used to catalyse community inclusion;
- **Adaptability** should be a core characteristic of an AV, therefore also of its design process.

The work that is presented aims to contribute to both academia and industry. Firstly by shining light on the overlooked community perspective on AV design. By providing the aforementioned design principles this work advocates researchers and practitioners to take on this perspective, to ensure a positive impact on the community level as well. Secondly, by promoting a less car-centric approach to AV design, broader and more experience-focused AV use opportunities may arise.

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01 **Introduction**

In this chapter you can find an overview of the background of this project, and why it was performed.

01.1 **Rise of the Automobile**

The history of the autonomous car begins some 5500 years ago with the invention of the wheel. Though first used in rather utilitarian vehicles for transporting goods, soon after (horse-drawn) carriages provided a comfortable way of transportation for those who were privileged enough to use it. From a technology perspective the link between these carriages and autonomous cars can seem very far removed, yet from a user perspective there are a lot of similarities. After all, the main user (in this case a wealthy or influential person) would tell the vehicle - i.e., the driver/jockey - where to go, board the vehicle and be transported to their destination without being involved in any of the tasks that were related to controlling the carriage.

The invention of the steam engine led to the development of the first vehicles that weren't powered by muscle (be it animal or human). The first steam trains were introduced in the first half of the 19th century, but the translation of this technology to smaller, individual vehicles came later towards the end of the 19th century (Pfleging, 2016). The first and probably most well-known example of this was the Patent Motorwagen developed by Carl Benz in 1886 (Fukuda, 2019), which is seen as the first modern automobile. While his initial intention was to replace the horse, in the first years the technology was still largely experimental and rather expensive and mostly reserved as a toy for the wealthy early adopters. The difference between these early-era cars and the luxurious carriages was stark: instead of moving around without any effort, the main user was now in charge of operating, driving, maintaining and repairing the car. Because of all this required effort the car was mainly used as a hobby, as something to pass the time with. We see this quite clearly in the packaging of these early vehicles; as the vis-à-vis (meaning face to face, see figure 1) layout was popular. This suggests that the main goal of these cars was to enjoy time and have conversation, rather than transporting people from point A to point B.

As the technology matured through continuous development and mass production, cars became more utility-focused as they established themselves as a reliable, fast and easy way of getting around. The relatively cheap Ford Model T can be seen as one of the main catalysts for this shift as its simple, sturdy and versatile design made it possible to use it in a multitude of ways. In other words, it helped to define the car as a tool for getting around, conducting business or providing services (see figures 2 a, b, c, respectively).

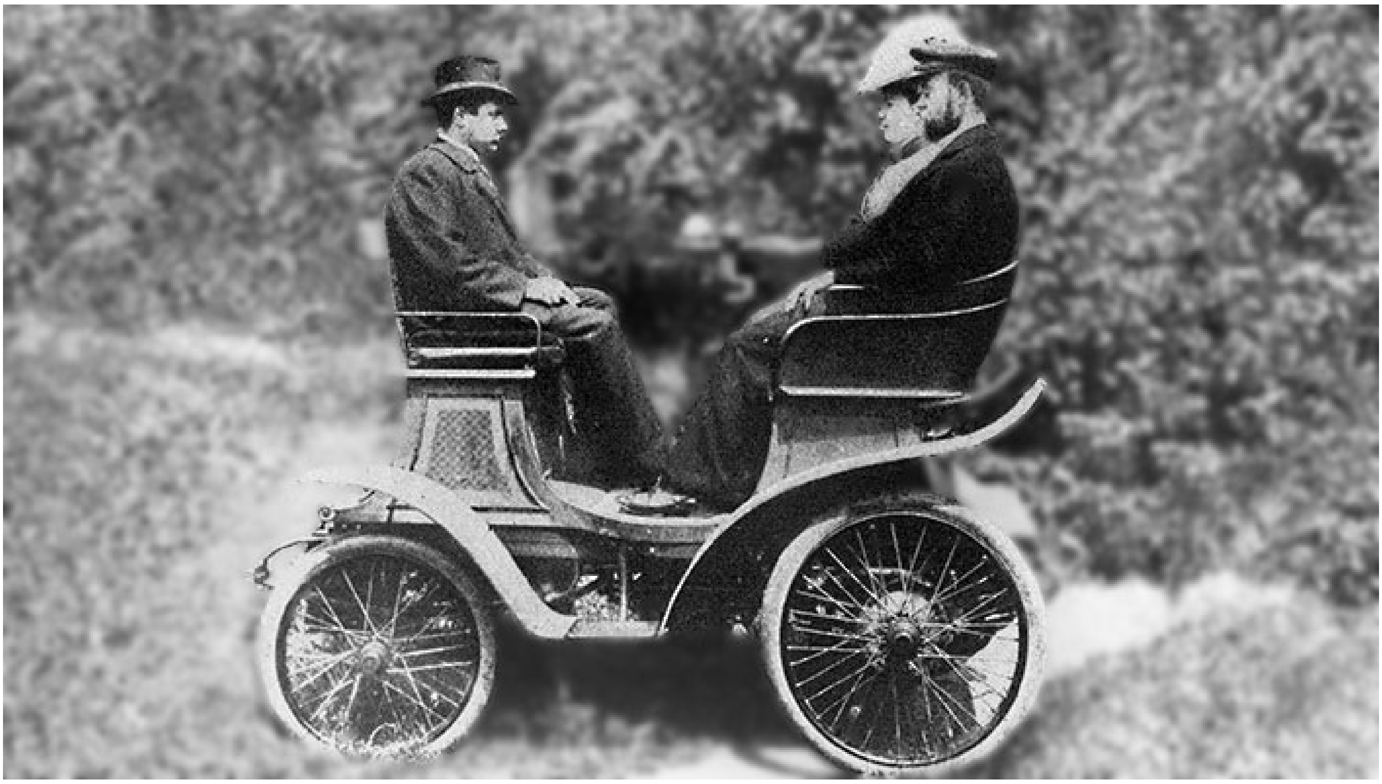


Figure 1: Vis-à-vis layout

Figures 2 a,b,c: Three versions of the Ford Model T

01.2 **From Automobile to Private Space**

A big shift in our view towards the car came with the introduction of the radio. First outfitted in the 1920's but popularised a few decades after (Pfleging, 2016; Bull, 2001), it brought one of the comforts of the home to the car. At first, people found it unsettling because the radio and the car were two different technologies from separate spheres that could not possibly match (Bull, 2001). However, over time people accepted the new application space of the radio and the car-radio became mainstream (Messbauer, 2017). In fact, nowadays it is hard to imagine driving a car without the radio or music playing in the background. It transformed the car's interior from the utilitarian space that among others the Ford Model T had cultivated into one that felt desirable like home.

The effect of this home-like feeling still can be observed in the present day. A study on preferred travel mode for commuting showed that travelling by car (as passenger or driver) has a higher positive effect on mood than travelling by train or

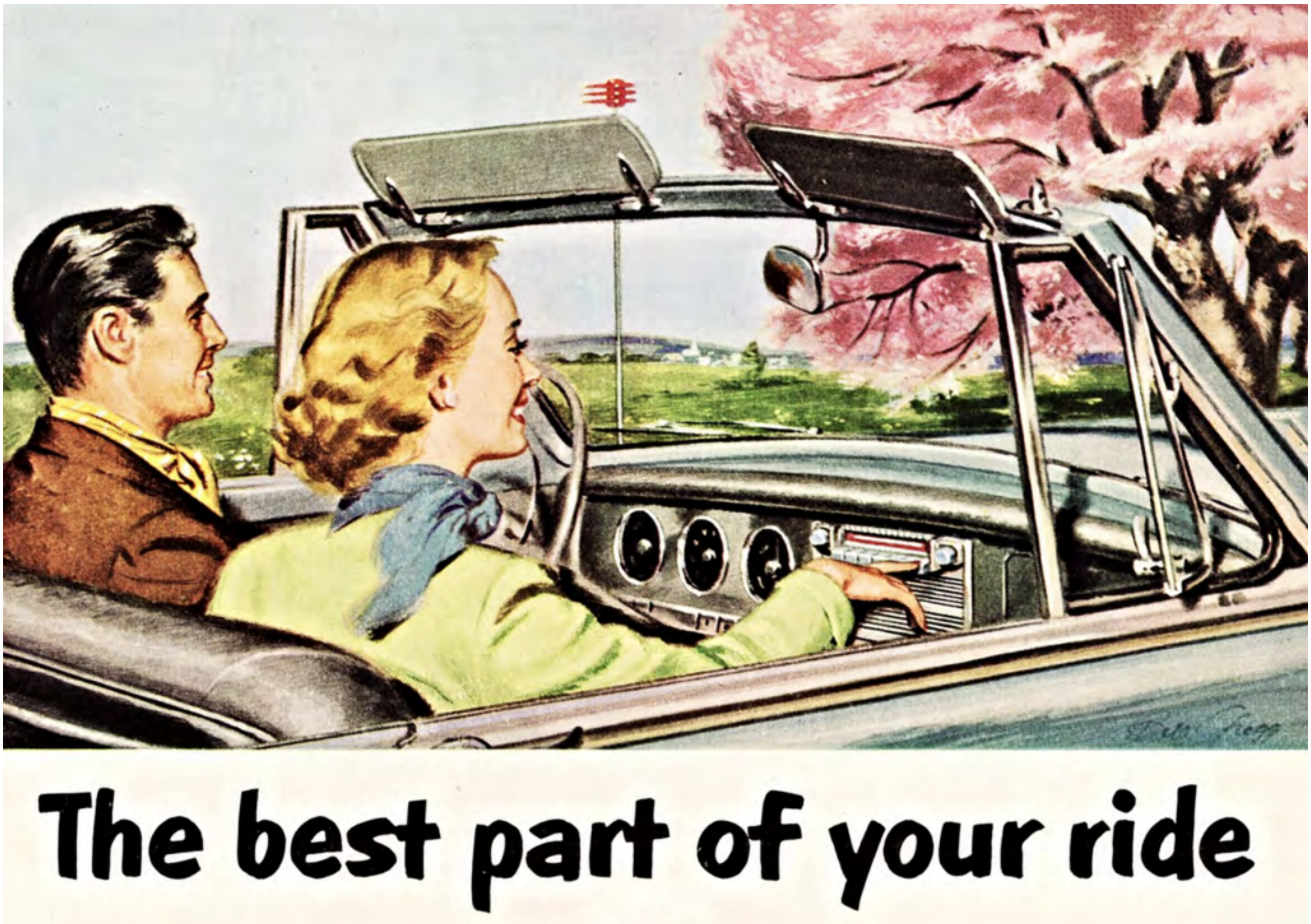


Figure 3: Motorola car radio ad from 1951

bus (Morris & Guerra, 2014). Morris and Guerra explain this by emphasising the private nature of the car. Rather than sharing the space with others, the car lets the user be in charge of creating a space that's meant only for themselves. This view is shared by Messbauer (2017), who describes the phenomenon of acoustic cocooning, which is when a driver envelops themselves in a personally curated acoustic landscape that makes the car feel like a very private and comfortable environment. Music lets the user drown out unpleasant noises like traffic and wind, while simultaneously being able to have full control over the sonic landscape (Bull, 2001; Messbauer, 2017).

More recently, another shift in the relationship between the car and human is happening with the digitalisation of the car's controls, beginning around the 1980's (see figure 4). Where previously all controls in the car worked via bulky mechanical linkages, it then became possible to separate input (buttons, dials, etc.) from actuators (motors, lights, sounds, etc.). Together with the electrical components becoming increasingly smaller, it became possible to control more parameters in the car. For example, the driver can now adjust their seats in several different ways, they can adjust the suspension hardness, steering response, interior lighting, audio equaliser; the list goes on (for example, see Renault's infotainment system simulator (Renault, n.d.-a)). This could theoretically improve the bond between user and car because they can make the car fit perfectly to their wishes. However, in practice we see that oftentimes many of these functions are only adjusted once, or not even used at all. To facilitate the large number of new functions and features, touch screens are becoming the default interaction modality. While first introduced as a necessity (after all, there is only a limited amount of space for buttons, sliders and dials on the dashboard), car companies are starting to move all controls to a central touch screen. Perhaps the most well-known example of this is Tesla's Model 3; it has only buttons to control the very basic features (windows, turn signals and wipers), the rest is all controlled via the touch screen. This relocation of the car's controls can be frustrating to users, as completing simple tasks takes longer (Vikström, 2022). The touch screens' user interfaces are sometimes hard to understand, and users may have to click through multiple levels of menus to access simple features. Additionally,

Figure 4: Early digitalisation of the car's interior, Subaru XT (1985-1991)

interaction through touch screens requires more direct attention from the user, as they cannot rely on their sense of touch and muscle memory anymore to access the car's controls.

In addition to changing the Human Vehicle Interaction on a small scale as described above, the digitalisation also ushers in a larger scale shift. With sensors becoming smaller and smaller, and the computers behind them are more powerful than ever, this means that the car could sense its environment and react accordingly. For example, even though cruise control was introduced many decades earlier (Pfleging, 2016), the digitalisation made it possible for the car to 'see' the car in front of itself and change its speed to keep a safe distance. The car needs increasingly less input from the driver, becoming more autonomous. When the car finally doesn't need human input anymore, a number of scholars argue that it can be seen as a robot (Amanatidis et al., 2017; Meschtscherjakov et al., 2015; Thrun, 2010; Tscheligi, 2014). According to Kaplan (2005) a robot should possess three features: (1) it is a physical object, (2) it functions autonomously, (3) and it should be able to perceive and manipulate its physical environment. Comparing these characteristics to an AV, we can indeed see that it can be classified as a robot.

While the aim of autonomous driving was initially to make car travel safer (NHTSA, n.d.; Pfleging, 2016; Staricco et al., 2019), its widespread implementation will have many more influences than safety. For example, high or full automation also frees up time that the driver previously needed to spend on performing driving-related tasks (Detjen et al., 2021; Fleischer & Chen, 2020; Pfleging, 2016). In this time the user can now engage in non-driving related activities (NDRAs). Eventually, when technological development allows it, the driving related tasks will even become fully obsolete (Litman, 2022). This shift in activity during car travel changes the user's perspective on time and space regarding the vehicle (McCarrol & Cugurullo, 2022). The car might no longer be just a medium that we use to get from one activity to the other, it can now be (part of) an activity itself.

Figure 5: The car becoming a robot

01.3 **Functional Utilitarianism to Social Utilitarianism**

Currently, we see a shift in the application space of robotics. The term robot was first used by the Czech author Karel Čapek in his 1920 theatre play Rossum's Universal Robots. It was derived from robota, the Czech word for forced labour (Băjenescu, 2019). This vision of robots signifies well how robots were mainly used historically; namely as an autonomously acting substitute for human labour. Robots have been an important accelerator of our (manufacturing) industry, and this application has remained the main research field in robotics until around the 1990's (Garcia et al., 2007).

Although robots have been invented to help relieve human effort in industrial settings like factories, Garcia et al. (2007) find a shift in robotics research focus from the mainly utilitarian industrial domain to the service domain. Researchers and designers are finding new applications for robotics, which is signified by the ubiquity of robotics in our daily lives. This is seen most prominently by the robots in our home environment: a Roomba cleans our floors, our kids play with Pleo, an Astro keeps an eye on everything and a Husqvarna mows our lawn. In homes for the elderly, robots are used to keep the inhabitants company, as they are quite vulnerable to loneliness (Wood & Dillenbeck, n.d.). Aside from the home, this shift in robotics is also seen in other parts of our daily lives. In the hospitality industry, some tasks that were traditionally carried out by human personnel are now taken over by robots. An example of this is the Savioke Relay (Relay Robotics, Inc., 2022); a robot that helps hotel guests find their rooms and can bring them any (small) amenities they need, such as a toothbrush. A robot that fulfils a similar function is ARI by PAL Robotics, which is a humanoid robot that uses AI to sense and react to human behaviour, in an effort to bridge the gap between the digital and physical aspects of a service.

When we look back at AVs as robots, we see that this view is still quite functionally utilitarian. The robot is there just to take the responsibility of driving away from the user, but the user doesn't directly interact with the robot. Perhaps, by taking the aforementioned social shift in robotics and applying it to other interaction spaces in AVs, robots could serve a role in the Human Vehicle Interaction resulting in an enhanced AV experience.

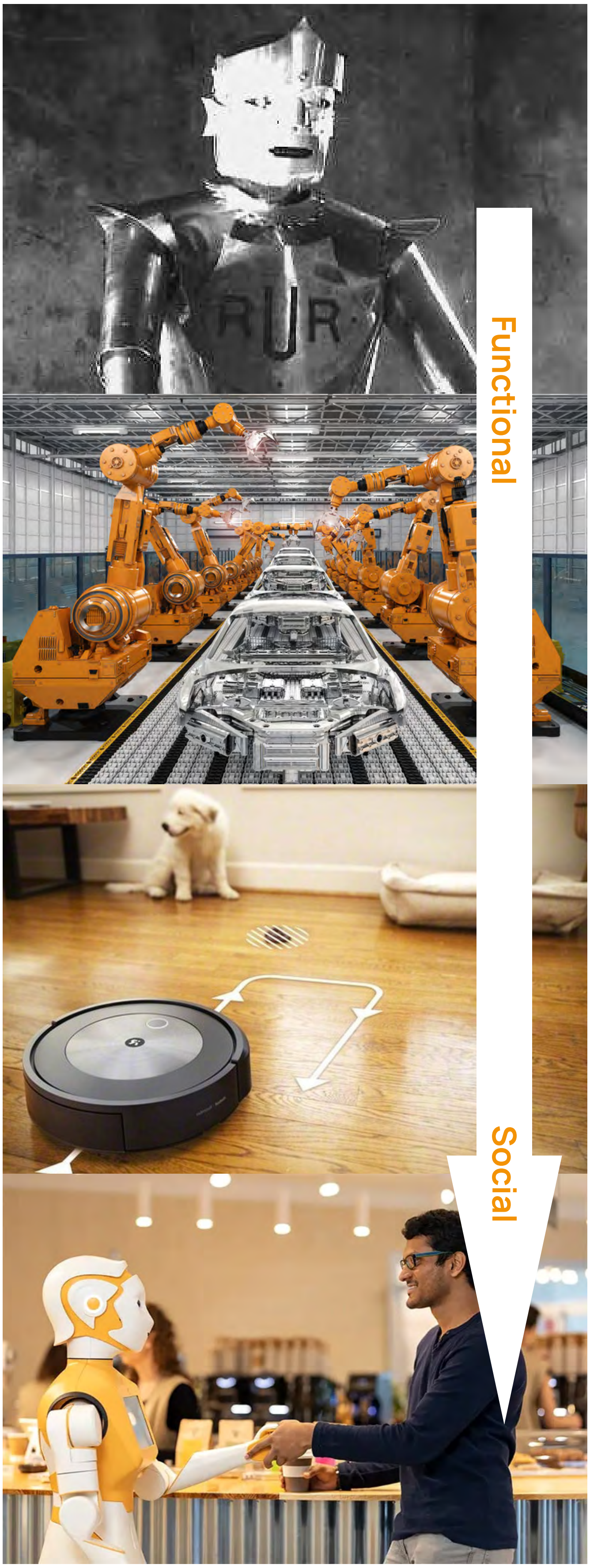


Figure 6: Shift in robotics

01.3 **Project Overview**

This project aims to explore the human-vehicle interaction design space that emerges when vehicles are viewed as being robots. In the present, we have the great opportunity to thoroughly research what the effects of the introduction of automated driving technology could be. Instead of blindly adopting the technology and hoping for a positive impact, through human centred research we have the possibility of assuring that the technology will in fact have a positive impact.

Although autonomous driving technology is still under development, semi-autonomous vehicles are already being introduced to our roads. These vehicles still need human drivers to take over control when necessary, but once the technology matures and human input isn't required anymore, our relationship with the vehicle may be completely different. To fully focus on this post-human controlled vehicle future, semi-autonomous vehicles will be considered out of scope in this project. Because the human may still need to take over control from time to time, there are many (somewhat technical) factors that influence what interactions are and are not possible. These factors often regard topics around cognitive ergonomics, situational awareness and control takeover, which are topics that are already being researched quite extensively in projects like Hadrian (Hadrian Project, 2019) and Mediator (Mediator, 2023).

This project will add to the field of AV research by taking a more focused perspective on AVs: namely that they are considered to be a robot. Taking this as a ground principle, we investigate the shift in robotics' role from utilitarian to social and mirror that to the AV domain. Instead of the AV being something that just provides functional mobility, we explore whether it can be seen in another light, one that focuses on a more experiential role of mobility and the AV. The research questions that are defined for this are:

RQ1: *What emerging phenomena can be identified from the combination of AVs and robotics?*

RQ2: *How could the combination of AVs and robotics add value to humans' lives?*

By looking at the human-vehicle relationship (HVR) from different perspectives, we set out to investigate and design for added value in AVs. The perspectives that will be taken are from micro-, meso- and macro-levels. By taking these perspectives, a more complete and deeper understanding of the technology can be formed (Li, 2012). These levels will be defined via literature research and then three consecutive design sprints, which will yield a comprehensive overview of related work. When this work is mapped, an interesting or promising direction can be identified. The synthesis phase then starts, following the Reflective Transformative Design Process (Hummels & Frens, 2009). As a first step, user insights will be gained from a set of co-creation workshops with projected end-users. The takeaways from both the related work review and the co-creation workshops serve as input for an ideation phase, where a set of design principles is formed through iteration and reflection, with input from users and experts in related fields.

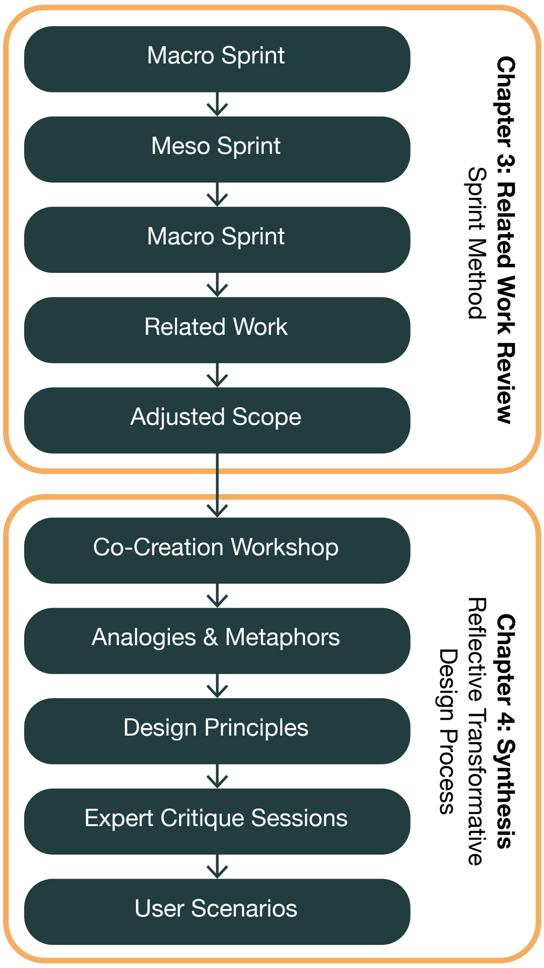


Figure 7: Overview of the steps in this project

02 Design Summary

This chapter provides a summary of the design principles that were formulated as a final step in this research. Each principle is explained with an example scenario that illustrates what applying such a principle could look like in practice.

Ever since the conception of the first car in 1886, it has undergone many technological advancements. Each one of these advancements added a new aspect to the car, or made it possible to operate in new domains where it wasn't before. This also means that the way we as humans view the car changes with each step. At every step, the role that the car fulfils in our lives changes. It was conceived to replace the horse, but then quickly became a toy for the wealthy. As it became more commonplace and affordable it became a workhorse; a tool for achieving mobility, prosperity and safety. Comforting technologies helped foster a home-like environment, resulting in a whole culture around the car, where the car is a symbol for personal comfort and an expression of status.

Currently, we are on the verge of another key technological advancement, which is the introduction of automation. While the reason for introducing these self-driving capabilities was initially to make car travel safer and more efficient, we see that it may have a much greater effect than just that. This project explored what this effect could be, and what the future role of a robotic car could be.

AVs should be considered 'shared mobile spaces' rather than 'self-driving cars'

Nonsimultaneously Connected ***Tailored*** ***Adaptable***

When envisioning or designing for a future technology that is as disruptive as AVs, we have to be mindful of the setting in which the design research takes place. Especially when involving (projected) users, the current state of technology could influence the mental boundaries about a possible future. Even though the AV is an evolution of the current-day automobile, the AV's robotic aspect means that its use case can be much more than an evolution of the automobile's use case. To reflect this, designers and researchers should not regard AVs as self-driving cars, rather as shared mobile spaces. This terminology and mindset better reflects the use and experiential opportunities that AVs present.

In this case 'shared' doesn't necessarily refer to ownership of the vehicle, rather it is aimed to reflect that it is something that can be used and enjoyed by multiple people. The current view of the automobile is largely from an individual perspective. Often it is still the norm that a car is owned by one person, and for the most part used by that person alone. In future AVs this notion will be challenged, with shared mobility becoming more and more commonplace. In this situation, taking a community perspective towards vehicle design becomes key. Especially when taking the standpoint that an AV is a robot, there is great opportunity for exploring a deeper, more experience-focused meaning of an AV within a community. It is able to be an autonomously acting part of the community, taking on a helper-role. Because of its mobile and shared character, an AV can bring people from a community together, and generate a shared experience for them.

To fully unlock the value that an AV can have as a shared mobile space, the following design principles should be taken into account.

Nonsimultaneously Connected

An AV can be the physical space that interest-based communities can nonsimultaneously enjoy.

Communities are groups of people that are connected through commonality on some level. Often this commonality is a shared physical space that is location based, like a city or neighbourhood. Communities that have a different type of commonality like a shared hobby or activity, often don't have this shared physical space. Because we regard an AV to be a shared mobile space, it is able to provide extra value to those communities by adding an extra layer of interaction that they didn't have before. This can help elevate the community's feeling of togetherness and add an extra dimension of experience.

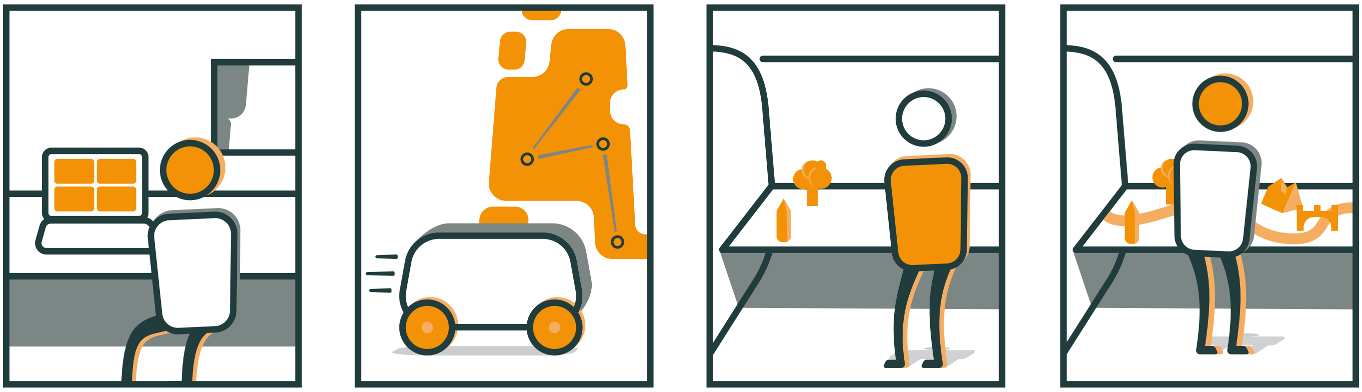


Figure 8: Dungeons & Dragons community scenario

To see what applying this principle to practice could look like, we take the example of a community that plays Dungeons & Dragons (D&D) together. This is a tabletop fantasy game, in which the players go on adventures together that involve completing several quests. The openness of the game allows for the players to build the world in which the game exists themselves. There is one so-called Dungeon-master, which facilitates the game by keeping a log and rulebook, and tracks the players in the world. Because the game only needs to physically exist with the Dungeon-master, a large number of D&D communities play online. This results in some D&D communities being spread out geographically. In this example, we take a look at one of these online D&D communities. Their Dungeon-master enjoys creating the world they play in, but the other players feel like they want to contribute too, as they sometimes feel like they don't fully understand the world. Without having a physical space to work in, creating a world could prove challenging. In this scenario, the AV can fulfil that function of being the physical space that they share. Even though the member of the community are in different locations, the AV can move between them. As each player enter the AV, they can see the parts of the world that have been created already, and add or modify it to their liking. By moving between member and letting them add their piece, the AV provides an extra level of connectedness and harmony.

Tailored

Specific NDRAs should be used to catalyse community inclusion.

For an AV to fully create meaning to a community, it should also fully use its core characteristics. A large part of what makes an AV an AV is that it's possible for users to engage in NDRAs. Because the AV is a shared mobile space, the possible options for NDRAs are virtually endless. This means that each user can be able to perform a specific activity that is tailored especially to them and their goals. If we take this goal as community inclusion, we should then also tailor the NDRAs very specifically to reach this goal. So, instead of bringing people together in the AV and leaving their activity and connection up to chance, a targeted NDRA should be used to accommodate the users' wishes, needs, shortcomings and strengths.

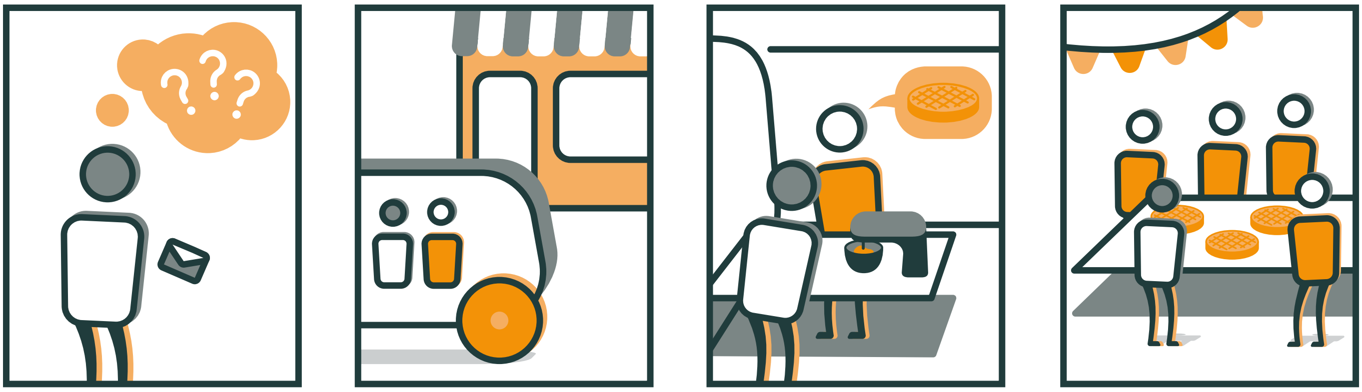


Figure 9: Community event scenario

In practice, the design principle can be illustrated with the following example. A person moves into a new neighbourhood, in a culture that is different from theirs. Their neighbourhood has some traditions that are unfamiliar to them, like a competition for baking a regional pie. When the person gets invited to this competition they are unsure what the tradition means and how they would bake the pie. To help them overcome this hurdle of unfamiliarity, the AV pairs them with an existing community member for their morning commutes. During this commute, the AV takes them past all the specialty stores in which the community member gets their ingredients. These ingredients are carefully selected as part of a recipe that goes back several generations. This ingredient haul is the first step of familiarising the new member with the community tradition, as it gives them practical knowledge about where to get good ingredients, but it also invites the old and new member to connect socially by discussing and learning about the tradition. Over the next days the AV will continue to offer both members a ride for their commute, each time providing the perfect environment for the next step in the pie-baking process. This is for instance providing a workspace and mixing equipment for making the dough, a proofing setup, tools for creating the perfect lattice crust; and so on. With each step the new community member becomes more and more familiar with the tradition, and develops a deeper and deeper bond with the old community member. Finally when the pie is baked and the contest starts, the new member has crossed their initial barrier and can now participate with full confidence.

Adaptable

Adaptability should be a core characteristic of an AV, therefore also of its design process.

The touching point of AVs and robotics can be in the role that they fulfil towards humans; as they are both helpers or facilitators that autonomously accommodate humans' needs. There is however another, perhaps more technical, touching point. We see that an AV should be a tailored and targeted environment for the users. This means on the one hand that it should feel like such an environment, but it also means that the physical space should accommodate this as well. As different use scenarios would require different physical layouts or setups, the AV should be able to adapt itself to each variation. Looking at the core characteristics of robotics in the traditional sense, it seems that this technology can be perfectly used to achieve the desired adaptability. After all, the AV should know or sense what use scenario it should adapt to, and then autonomously perform this physical adaptation.

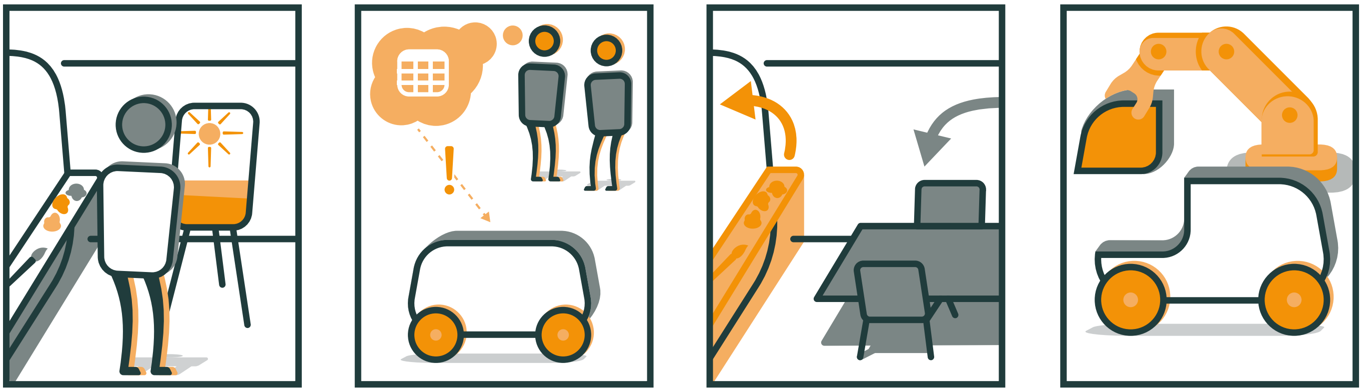


Figure 10: Campus colleagues scenario

To illustrate this, we take a look at a group of colleagues that work on a large campus. They often have to move between different buildings for scheduled meetings or inspections. When these trips are provided by an AV, the users can spend this time taking leisurely breaks or turn them into working time, whichever they prefer. In this example, we see that a person chooses to spend their trip time on painting, one of their favourite hobbies that helps them unwind in between hectic meetings. The AV provides them with an easel that has their work stored on it, and all the painting supplies they need. When their trip is over, the AV is summoned for another trip in which the users want to hold a meeting. To prepare for this trip, the AV robotically adapts itself to perfectly fit this next group of users.

03 Related Work Review

In this chapter, the first stage of the project is explained. First you can read about the methods that were used, followed by an elaboration on three Design Sprints, and concluded with a summary of the related work.

03.1 **Method**

The first stage of this project was concerned with gaining an understanding of the research and design space that this project sits in. To begin, a review of related work from literature and industry was performed to explore the breadth of the topics that are related to this project. This includes topics such as autonomous driving, non-driving related activities (NDRAs), robotics and human technology interaction.

Once a general knowledge of these topics was formed, they were explored more in depth through desk research sprints, based on the Design Sprint method (Knapp et al., 2016). Each of the sprints is performed using a different perspective, i.e.: micro, meso and macro. Traditionally, Design Sprints are used to quickly iterate on existing products or problems (Knapp et al., 2016). In this case, they are used not to generate a design, rather to guide a deep dive into research. Table 1 describes how the Design Sprint steps are translated to the Desk Research Sprint steps that will be used in this project. Following these days will result in a thorough scan of the related work that has already been found, after which gaps can be identified.

Day	Design Sprint	Desk Research Sprint
Day 1: Map	Set sprint goal. Map user/product journey; find problem area or opportunity for improvement.	Set starting definition for level of relationship (Micro, Meso, Macro). Identify and map gaps in initial literature research.
Day 2: Sketch	Quickly generate a large number of solutions or new ideas.	Quickly generate a large number of ideas that can be used to find data or user insights.
Day 3: Decide	Analyse and decide what solutions or ideas to go forward with, generate a scenario.	Analyse and decide what ideas can lead to the most useful insights, and provide a complete literature review. If necessary, generate a scenario.
Day 4: Prototype	Integrate scenario into a prototype.	Perform literature review, or refine initial idea/scenario.
Day 5: Test	Test prototype with intended users and analyse the outcome	Perform literature review, or perform user/expert interviews. Analyse results and redefine the level of relationship.

Table 1: Sprint method applied in this project

03.2 Defining Micro, Meso, Macro

Li (2012) and Lainfesta et al. (2019) argue that when introducing a new emerging technology it is important to investigate what effect its adoption can or will have. To get a thorough understanding of this, we can view the human-technology relationship on three levels: micro, meso and macro (Sanderson et al, 2012). As there is no set general definition for these three levels, they should be specified related to the scope of the project. The macro level is regarded as the highest possible level, this defines the scope of the project. There shouldn't be any higher perspectives to take than this. The micro level is then the smallest possible level; there shouldn't be any perspective that is more detailed than this. The meso level falls in between the two, acting as a bridge between them (Sanderson et al, 2012). As seen in figure 11, there could be multiple nestled meso levels.

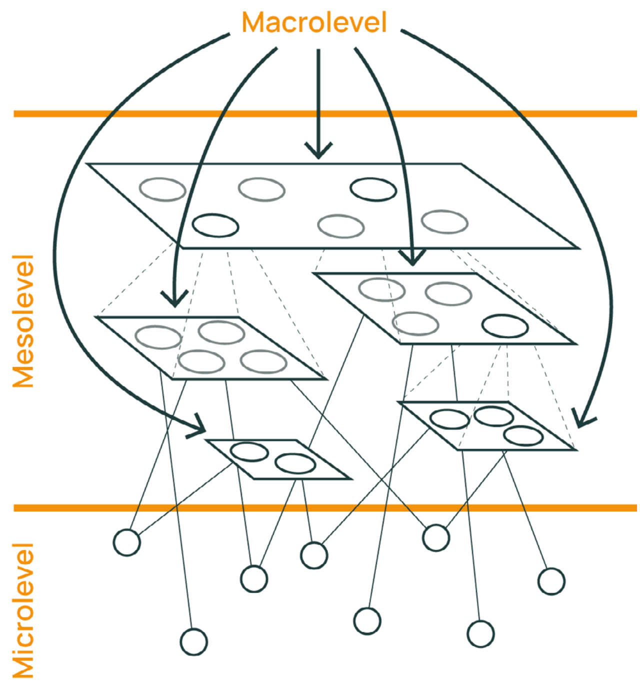


Figure 11: micro-meso-macro framework

Sanderson et al. (2012) define the micro-, meso- and macro levels as follows:

- The micro level deals with individual behaviour, providing intelligence to the vehicle.
- The meso level is concerned with collective decision- making within groups or clusters of vehicles.
- The macro level deals with infrastructure or system-wide goals.

These definitions will be used as the basis on which this project's starting definitions are based. Where Sanderson et al. (2012) focus on the systemic aspects, this project will focus on the human vehicle interaction in autonomous vehicles. Therefore, the definitions are adapted slightly to better reflect this different focus (see also figure 12):

- The micro level deals with the relationship between one user and their vehicle.
- The meso level deals with the relationship between one vehicle and a group of people.
- The macro level deals with the relationship between autonomous vehicles as a holistic concept and the built environment.

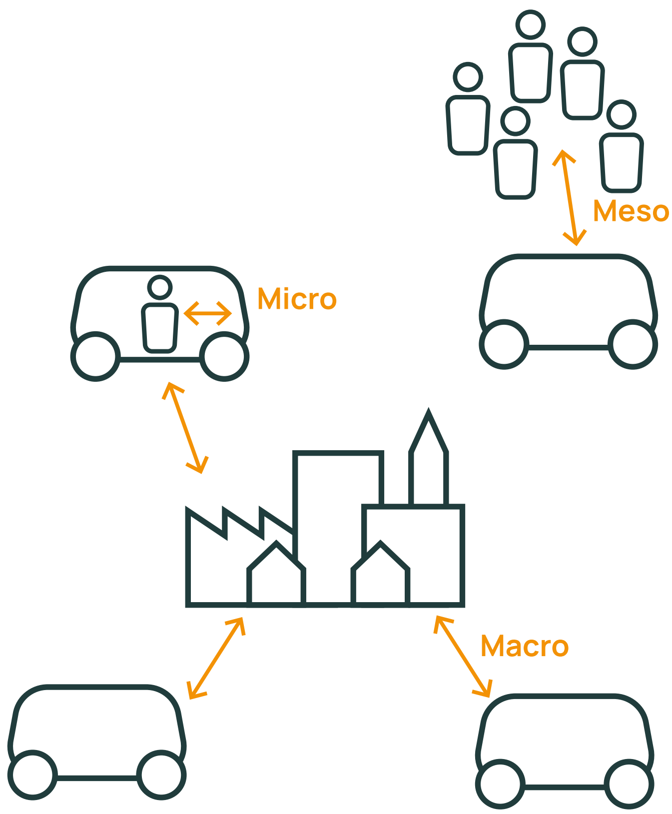


Figure 12: proposed levels of interaction

03.2.1 Micro Level

As a starting point for the first sprint, the micro level was defined as the relationship between one user and their vehicle; both direct and indirect. Direct in this case means interaction with the infotainment system, operating climate controls, changing settings, etc. With an indirect relationship we mean one where the vehicle serves as a medium or environment, in for instance assisting in NDRAs. In the *map* stage of this sprint, this definition was used to formulate the mail goal for this sprint: to investigate what role robotics could play in improving an AV's primary user's human-vehicle interaction (HVI). When thinking of micro-level HVI, what comes to mind first are non-driving related activities (NDRA). Though there are some NDRAs that people can engage in in conventional vehicles such as listening to the radio, it is widely agreed upon that AVs offer great opportunity for engaging in a multitude of new NDRAs in order to make the most of the user's time in an AV (Hecht et al., 2019; McCarrol & Cugurullo, 2022). Taking into account the limitations of existing research in this field; this sprint aimed to leverage the defining characteristics of robotics to optimally assist users in their preferred NDRAs.

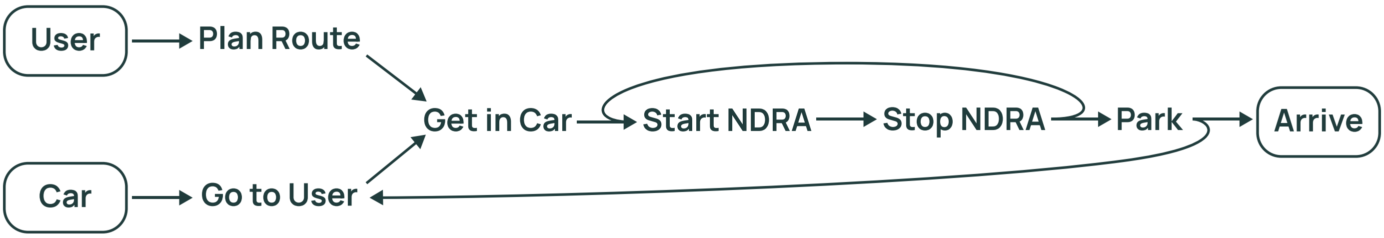


Figure 13: micro level map

The sketch phase is used to first generate a number of How Might We notes (Knapp et al., 2016), which were then used as input for ideation. In this sprint, it yielded a number of solutions and ideas that elaborate on the aforementioned link (see figure 12), which in turn gave some notable insights. This project focuses on autonomous vehicles (or SAE L5; SAE International, 2021), a technology which scholars and experts in the field (Litman, 2022; Papa & Ferreira, 2018) predict may still be decades away from being ubiquitous. One can argue that this prediction makes current research on NDRAs irrelevant, as they focus on activities that people currently engage in. For example, Detjen et al. (2020) find that most people want to use their smartphone during an autonomous ride, but if this study was done 15 years ago - before smartphones existed - it would have gotten very different outcomes. In other words: if we design for what people currently report they want to do in an AV, we might end up with vehicles that are perfectly designed to assist in or accommodate an outdated NDRA. In the decide phase of the sprint, this was the main reason for choosing the idea to go to the prototype phase with. The concept that was developed uses interchangeable 'activity modules' (see figure 15) to omit the AV becoming designed for outdated NDRAs. By taking this adaptive approach, the vehicle can always be outfitted to accommodate contemporary and/or ultra-personalized NDRAs. In this concept robotics plays a facilitating role; as the definition of a robot is that it is able to manipulate its physical environment, it can assist in changing the activity modules to provide a seamless user experience. The concept of modularity or adaptability of cars isn't a novel one; for examples see section 2.2.8. What this work lacks however, is a focus on the user experience within the vehicle. Therefore, the concept mentioned above can be considered as novel.

With this concept, an interview-based test was carried out (n=3) with the following research question: "How do people decide and communicate what non-driving related activities they want to perform, when the possibilities for such activities are endless?". The concept was used in this case as a conversation starter. Four variations for choosing the NDRA were discussed, namely:

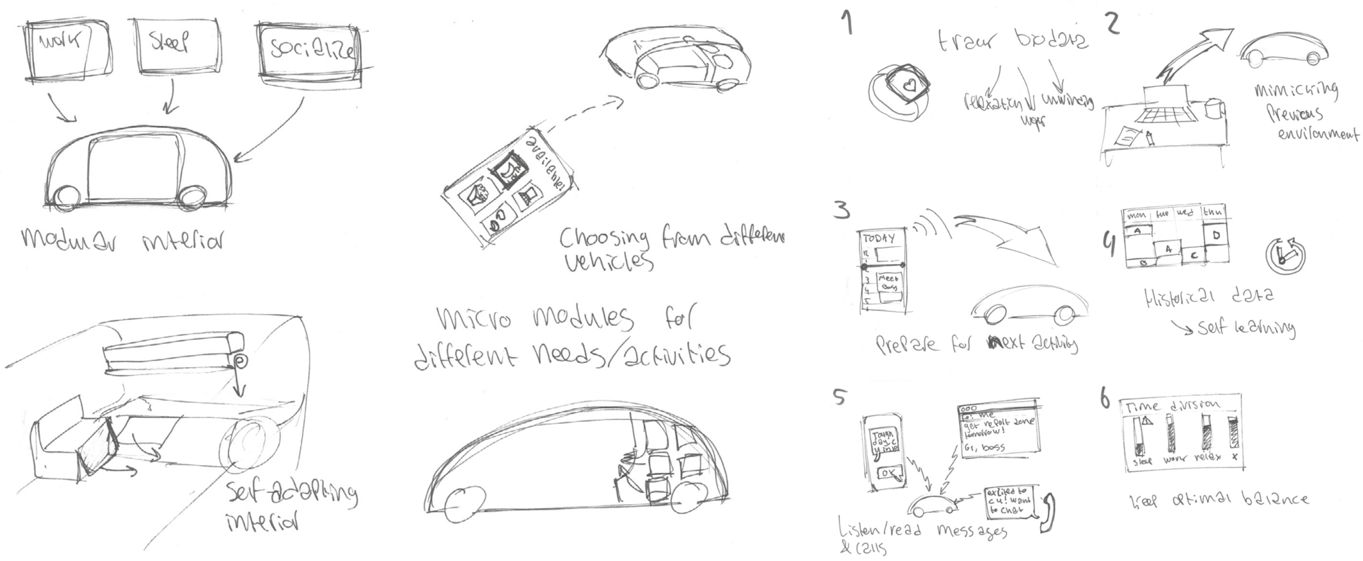


Figure 14: ideas from the sketch phase

1. Before starting the journey, the user can choose one activity they want to perform. This can be done through an app (see figure 15), which has a library of activities. When the vehicle arrives, it will be outfitted to perfectly accommodate this activity.
2. Before starting the journey, the user can choose five activities they want to perform. This can be done through an app, which has a library of activities. During the ride, the user can switch between these five activities When the vehicle arrives, it will be outfitted to perfectly accommodate all five activities.
3. The user has no choice in activity, rather an AI programme is used to outfit the vehicle for one suggested activity. Input for this AI programme can be things like biodata, the user's calendar, historical data on activity preference, etc.
4. Before starting the journey, the user can choose three activities through an app with a library of activities. Here will be displayed three activities suggested by an AI programme, the input for which can be things like biodata, the user's calendar, historical data on activity preference, etc. The user is free to choose different activities, and can switch between activities during the ride.

The results for this exploratory interview were collected and mapped together into statement cards. Each statement is generated by compiling similar quotes and thoughts from the participants, which are then summarised in a short sentence. Visualising the data in this manner yields a comprehensive overview of the test's outcome. The most notable statements are collected in table 2, with the concept they relate to.

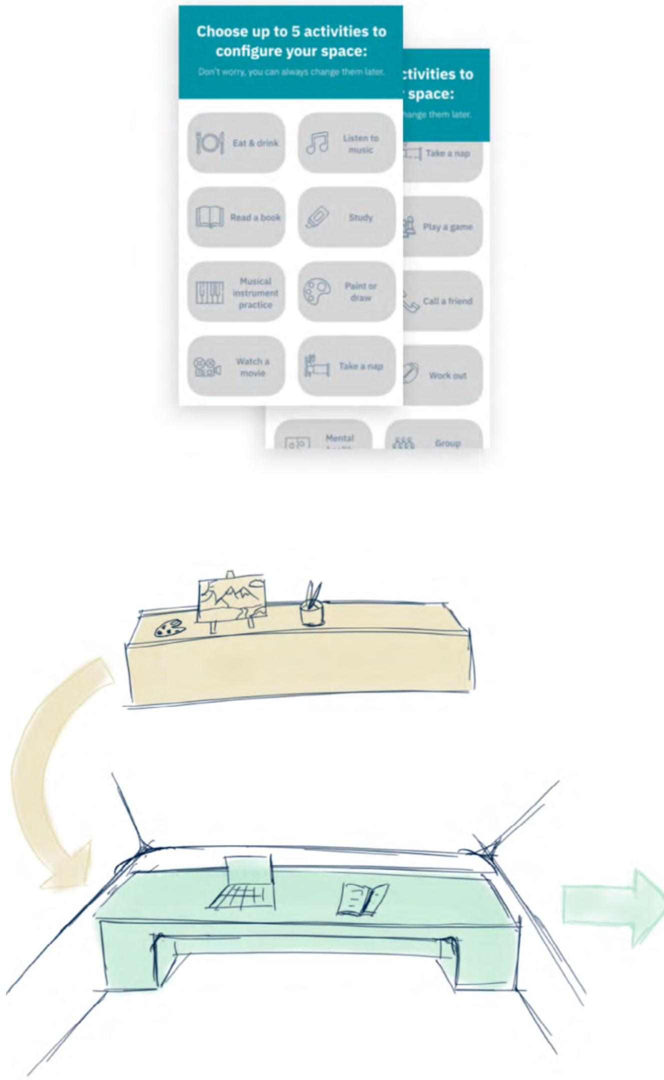


Figure 15: changing activity modules

Statement	N=
[Concepts 1&2] If I had unlimited choice of activities I would try to explore ones I have never done before	3
[Concepts 1&2] If I had unlimited choice of activities I could get overwhelmed and default to something I have done before	2
[Concepts 3&4] I would be suspicious of doing only one suggested activity: why does the AI want me to do this? Is there an ulterior motive?	3
[Concepts 1&3] What would I do if I don't like the activity?	2
[Concept 4] This could help me narrow down my choice	2
[Concept 4] This feels like the right balance between all of the concepts	1

Table 2: statement cards

The findings from this small scale test suggest that when the possibilities are endless, people would want to explore new activities rather than sticking to ones they have done before. This is an interesting find when related to the work by Detjen et al. (2020) who only take into account already known activities, yet it does underline that AVs provide opportunities for novel NDRAs; a notion that is presented in other related work by for example Hecht et al. (2019). However, the possibility to choose between an unlimited amount of activities could have a contradictory effect, as some participants stated that they could get overwhelmed and default to known activities. A more curated selection of activities could alleviate this issue, though user trust has to be taken into account when using technologies like AI for example.

03.2.2 Meso Level

The second sprint started again with the map phase, this time taking the meso-level perspective. This was defined as the relationship or interaction between one vehicle and a group of people. This level addresses aspects like the effect of one person's vehicle on the people directly around them, or shared use of a vehicle. For example: the interaction between people in a neighbourhood and the vehicle that belongs to one of their neighbours. From this perspective arose the following sprint goal: 'using AVs to create value beyond the primary use and user'.

The sketch phase of this sprint was used to map out a number of possible functions that an AV could serve within a community (see figure 17), which were clustered into four categories:

1. Delivering supplies
2. Providing (novel) activities
3. Bringing service to people (instead of the other way around)
4. Providing care

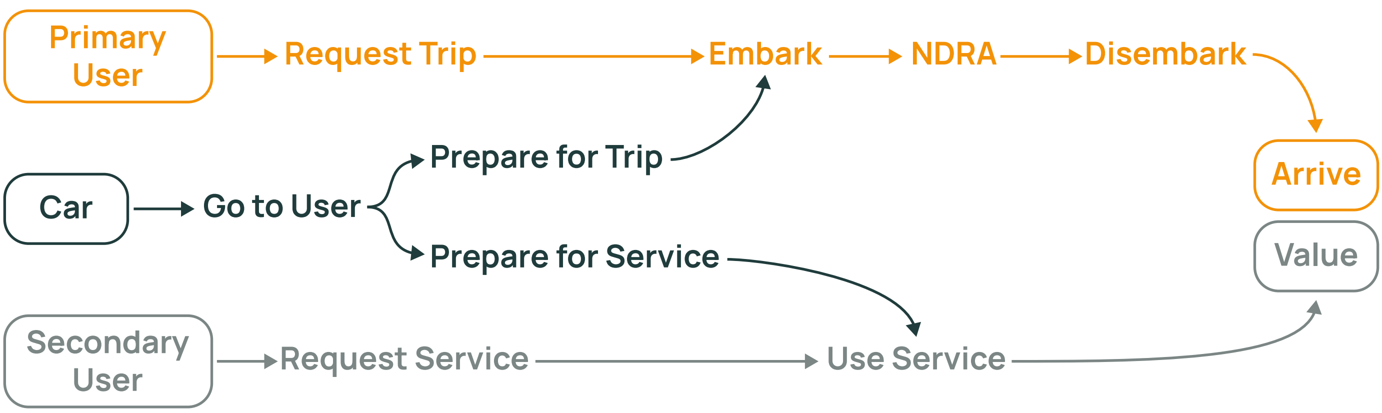


Figure 16: meso level map

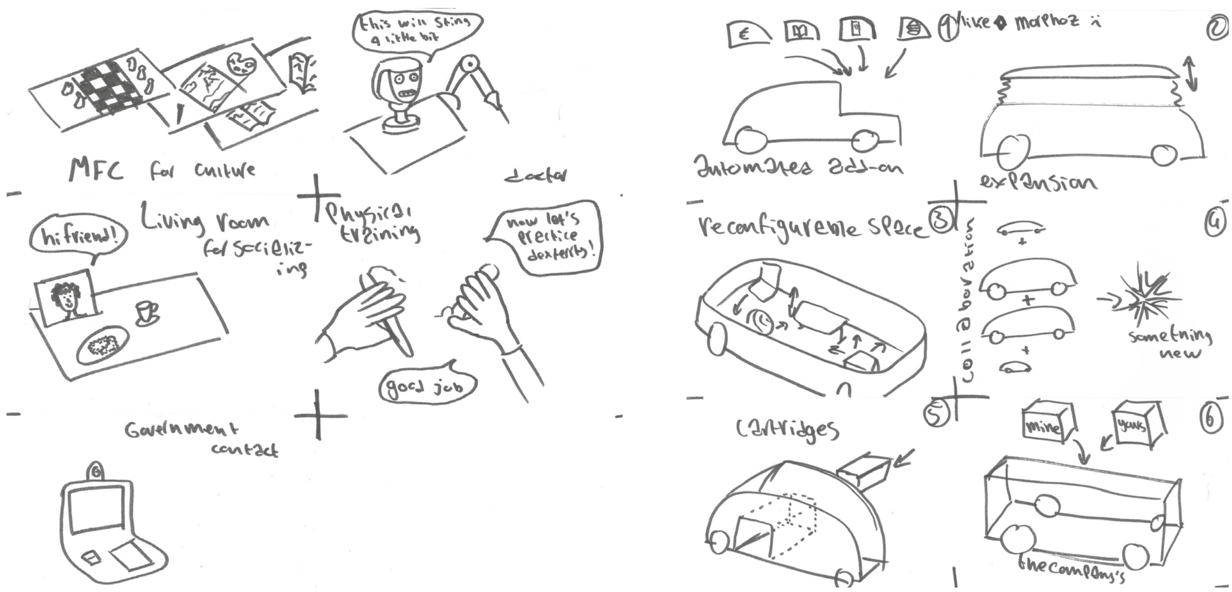


Figure 17: ideas from the sketch phase

In the decide phase, some insights came to light. The first category is one that has already been explored quite thoroughly; for instance with concepts like food & grocery delivery vehicles (Nuro; figure 18a) mobile parcel lockers (Rinspeed Citysnap; figure 18b) and mobile shops (Space10's farm on wheels; figure 18c).

The other three categories may be less explored, yet when developing them further some issues arise too. As mentioned in section 3.2.1, autonomous driving is predicted to still be decades removed from being ubiquitous. In that timespan, it is hard to predict what societal problems or opportunities will be present without speculating too much. However there is one aspect that can be predicted with near certainty: the elderly population will be much larger than it is currently. Though this gives some direction in terms of what and who to design for, there are still many unknowns about this population. The problems that they face now might not exist in the future. For instance: elderly people currently often struggle with digital services, but the people that will be elderly in the future are already used to the digitization of services. This digitization also (partly) takes away another problem that the elderly face today; namely the need for transportation to banks, government agencies or even doctor's offices. An expert in the field of design for the elderly (±5 years of experience) shared this view in an interview, saying that in their field it is common practice to design for the current situation; they rarely design for a scenario that is more than 5 years ahead. The concept that is proposed in the previous section 3.2.1 has potential to work with this consideration. As the 'activity modules' are interchangeable, they can be constantly updated and redesigned to

Figures 18 a,b,c: examples of an AV delivering supplies perfectly fit the user's needs, eliminating the need to design them beforehand. This same idea can be used to create value on a meso-level as well, though the 'modules' should be on a larger scale.

In the prototype phase of this sprint more literature research was performed on topics related to this sprint, for example using AVs to the benefit of underserved communities, shared use of AVs and social robotics. Additionally, to understand more about how groups of people interact with a car, an interview was conducted with an expert in the field of cooperative car sharing (10+ years of experience). This means that the cars that are shared aren't owned by a large corporation like Greenwheels or MyWheels, rather by the people that use the car. In this case, 5 cars are shared among 25 households in a neighbourhood. When elaborating on the process of setting up this 'sharing group', the expert explained that the households held multiple meetings in order to pick locations, car models, pricing, rules and numerous other aspects of the agreement. In these meetings it was the goal to create a common consensus about the agreement, so that everyone's interests were taken into account equally. The expert further explained that they thought this process also made the participants more attached to the cars; resulting in everyone taking very good care of them.

The last point the expert made touched upon the notion of 'psychological ownership', which is an area of concern in shared mobility (Lee et al., 2019; Golbabaei et al., 2020; Bozzi & Aguilera, 2021). It is often seen that shared or rental vehicles have relatively short lifespans, as the people that use them do not own them (Jorritsma et al., 2021), therefore do not feel like it is their job to take good care of them ("don't be gentle, it's a rental").

Figure 19: a vehicle for the community

Cooperative car sharing programmes can arguably counter this, as all users are also part-owner of the vehicle, thereby introducing psychological ownership.

In the test phase the literature research was finalised, and all insights were gathered and analysed. Taking them into account, the concept mentioned in the previous sprint was modified. Where previously the 'activity modules' were only accessed from the inside, the modules could also be accessed from the outside, almost becoming building blocks for the AV. Instead of the user being able to change the modules as they go, this concept would require a group of people to work together to build one vehicle that takes all of their interests into account. When changes need to be made, it needs to be done so through collaboration.

Reflecting back on the initial definition of the meso-level, it can be argued that the term 'group of people' may not adequately reflect that the people in the group have some type of bond between them. The term 'community' is more suitable, as it implies that the people within it have something in common that binds them together. It is defined as "a group of people living in the same place or having a particular characteristic in common" (Oxford English Dictionary, n.d.). This definition states clearly that the people within a community have a connection. What this connection looks like, can be divided into two categories: linked to place of residence or linked to other parts of their lives. The Cambridge Dictionary defines the latter in some more detail. Their definition for community is as follows: "the people living in one particular area or people who are considered as a unit because of their common interests, social group, or nationality" (Cambridge Dictionary, n.d.). To summarise the distinction between the two types of community in a more succinct manner, they will be named 'location based communities' and 'interest based communities'. The former relates to communities that are formed via place of residence (e.g. a neighborhood), while the latter relates to communities that have a shared activity, hobby or social group; i.e. interest.

To reflect the above mentioned notion about the importance of group connection, the meso level definition is changed to:

"The meso level deals with the relationship between one vehicle and a community"

03.2.2 Macro Level

The final sprint was meant to gain insight into the macro-level perspective of human-vehicle interaction. At the beginning of the map phase it was defined as the interaction between AVs as a holistic concept and the built environment. This concerns aspects like the effect of AVs on walkability of cities, urban sprawl, the potential need for new property development and the effect of AVs on other modes of transport. It should be noted that generally there should be no level above the macro level (Little & McGivern, 2014); which in this case would mean that this level would entail the interaction between AVs and the world or humanity at large. However, due to the large variety in culture, role of the car and distribution of wealth, this scope would be too generalising for it to have any meaning. With this in mind, the goal of this sprint was to investigate what macro topics AVs could have an impact on, and what that impact could look like.

The sketch phase was used to explore what topics AVs could have an impact on. There is quite a high number of articles that investigate this too, yet there isn't a shared view of what exactly the impact of AVs will be on our cities and society (Yigitcanlar et al., 2019). An aspect that is generally agreed upon is that more people will be able to drive (Loke & Aliedani, 2018; Floridi, 2019; Litman, 2022), but there are differing views on what the impact will be on other related topics.

The breadth of literature focus areas and findings proved to be a hurdle in the decide phase, as all findings are somehow related to each other. Therefore, instead of generating a design, the prototype stage was used to create a comprehensive map of the impact that AVs could have on multiple topics, seen from both a pessimistic and optimistic view.

During the test phase, the map was finalised and the findings were analysed. In table 3 we can see that it brought to light a few topics that would not fit in the previous definition of the macro-level interaction, as this was only concerned with the built environment. However, we can see that AVs could have a significant impact on employment rates; a view that is also shared by Yigitcanlar et al. (2019). Additionally, McCarrol & Cugurullo (2022) find that AVs can have a significant impact on the way we perceive time, as it further blurs the boundary of what is and what isn't work time. In light of this, the definition of the macro-level interaction was changed to encompass these other topics:

"The interaction between AVs as a holistic concept and how people live their lives."

Topic	Pessimistic view	Optimistic view
Expanded car-user base	AV is the default mode of transportation; people use it to go everywhere. High individualisation of society.	Providing mobility to those who couldn't before. The elderly are less dependent, and children can enjoy more activities outside the home.
Social exclusion	AVs are expensive, and therefore only for the wealthy. They get the extra mobility opportunities, while the others are left behind.	Through social systems like car sharing or subsidies AVs are accessible to anyone, and those with extra (mobility) needs are helped to achieve those needs.
Public transit	Demand for PT will drop, leading to cost-cutting measures and eventual demise of PT.	AVs are used seamlessly with PT. Longer distances and inner city travel are served by PT, AVs are used for first- and last mile transport.
Employment	Many people lose their jobs due to AVs: bus/taxi drivers, parking attendants, etc. Unemployment rates rise significantly.	The transition to AVs is used to create extra jobs, for example digital maintenance or through embracing new emergent job fields.
Land use	Public space is seen as the AVs domain. Prioritisation of AV needs over human needs	AVs are seen as an enabler for humans to enjoy the city. Designated AV routes can transport people to car-free and walkable city centres.

Table 3: pessimistic and optimistic AV scenarios

03.3 **Related Work**

In the first stages of the project, extensive desk research was conducted to get an overview of the related work in both research and practice. This section summarises the most important work, including work that was identified in the three desk research sprints (section 3.2). Table 4 shows an overview of the works that are mentioned in this chapter. Their colour distinguishes between research (dark green) and practice (orange). The columns refer to whether they exist on the micro, meso or macro level, and the rows represent the different topics. This order of topics will also be followed in the following subchapters. The first 4 topics relate to HVI, which starts with the mobility aspects of the HVI (Future Car Use and Shared Mobility), after which a higher level of interaction with mobility is discussed (Meaning Beyond Mobility and NDRAs). The following three topics relate to robotics, starting with an introduction into the history and current state of robotics, followed by an alternative look towards robotics. Then, the existing links between robotics and cars are discussed. Lastly, some work on modularity is presented, a topic which was found highly interesting in the desk research sprints.

		Micro	Meso	Macro
Human Vehicle Interaction	Future Car Use			Tillema et al. (2017); Loke and Aliedani (2018); Floridi et al. (2019); Litman (2022); Yigitcanlar et al. (2017); Vardaki (2021); McCarrol and Cugurullo (2022); Lyons (2022)
	Shared Mobility	Lee et al. (2019); Bozzi and Aguilera (2021); Ong et al. (2019)	Fu et al. (2021); Greenwheels; Lynk & Co	Golbabei et al. (2020); Jorritsma et al. (2021); Shaheen and Cohen (2012); Whittle et al. (2019)
	Meaning Beyond Mobility	Geiser and Kim (2021); Gomez Beldarrain (2022); Van Hoven and Meijering (2019); Giacobone (2022); Lehtonen et al. (2022)	Nuro; Space10	
	NDRA	Hecht et al. (2019); Detjen et al. (2020); Mediator (2023); Tang et al. (2020); Audi; Volvo; Renault	Mercedes; BMW; MINI	
Robotics	Traditional Robotics	Kaplan (2005); Bajanescu (2019); Hegel et al. (2019); Garcia (2007)		
	Alternative Robotics	Alexander et al. (2018); Rus and Tolley (2015); Hawkes et al. (2021); Fortunati et al. (2015); Kim et al. (2013)		
	Robotics in Cars	Daher et al. (2021); Nadri et al. (2022); Hyundai; NIO	Exigen; JLR; Continental	Amanatidis et al. (2017); Thrun (2010); Tscheligi (2014); Meschtscherjakov et al. (2015)
Modularity		Daihatsu; Rinspeed	Ulrich et al. (2019); Rinspeed; Mercedes	Gecchelin and Webb (2019); NextFuture Transport Inc. (n.d.)

Table 4: related work map

An important note that should be taken is the widely varying terminology regarding different levels of autonomy. As there isn't yet one standardised consensus about the classification of automation levels, there also isn't a standardised lexicon. The most commonly used classification is the one from the Society of Automotive Engineers (SAE International, 2021), which is often used by OEMs and institutions like the US-based National Highway Traffic Safety Administration (NHTSA, 2013). The Mediator project argues that this classification is quite technocratic (Grondelle et al., 2020), and that a more user-centred classification should be used and standardised. They propose a classification that uses short descriptions rather than numbers, to minimise mode confusion. EuroNCAP uses a similar rationale, but simplifies it even further (Schram, 2019). In table 5, the three above-mentioned classifications are compiled, showing the overlap between them. In this report the EuroNCAP classification will be used, as it is the simplest classification that includes fully automated driving, which is the focus area of this project.

SAE	L0	L1	L2	L3	L4	L5
Mediator	*Does not consider*	CM: Continuous Mediation		SB: Driver Standby	TtS: Time to Sleep	*Does not consider*
EuroNCAP	*Does not consider*	Assisted		Automated		Autonomous

Table 5: different autonomous driving classifications, adapted from Grondelle et al. (2020)

03.3.1 Future Car Use

The widespread adoption of autonomous driving technology will have a great impact on human mobility. However, aside from agreeing on the fact that the impact will be great, it seems that scholars don't agree on what exactly this impact will look like (Yigitcanlar et al., 2019). Yigitcanlar et al. (2019) analyses the problem by compiling a multitude of works into a set of scenarios, which show optimistic and pessimistic possible futures when AV technology is widespread.

This general concern is shared by Lyons (2022) who argues that the lack of knowledge about widespread AV adoption is due to a lack of interaction between actors with different views. Where Yigitcanlar et al. (2019) presents differing visions, Lyons (2022) introduces the Emulsion Methodology which is aimed at bringing together people with these differing views that do not typically mix (oil and water). The term 'emulsion' here underlines that the different perspectives that are present require a lot of energy and effort to be combined and transformed to a uniform view.

A large amount of the work that examines the future car use scenarios takes on the viewpoint of urban planning. This is true not only for scholars, but also for governments. For example, a report of a branch of the Dutch national government outlines five possible transitional stages towards an autonomous future (Tillema et al., 2017). In each of these steps it is outlined what impact the increasing levels of autonomy could have on the society and the built environment. It takes on a rather optimistic view, serving as a goal or vision to collectively work towards.

Aside from this built environment perspective, a number of studies also touch upon more anthropological aspects of increased autonomous vehicle usage. McCarrol and Cugurullo (2022) describe how widespread adoption of AVs could influence our perception of time, by further blurring the boundary between work and leisure time. Currently, the commute between work and home acts as a sort of transition period between these times, but when it becomes possible to work or relax during the commute, this buffer disappears. A study by Vardaki (2021) also takes on this anthropological perspective and similarly finds that our temporal perception may change. They additionally find that because an AV is essentially a robot that does everything for us, our skill for navigating the physical world will further decrease. This may eventually lead to deterioration of our memory process, skill of reading and spatial awareness (Vardaki, 2021).

03.3.2 Shared Mobility

As autonomous driving technology becomes commonplace, new opportunities for improving car-sharing experiences arise. Car-sharing companies like Greenwheels (Greenwheels, n.d.) are already well-established, providing users with the possibility of using a car without all of the associated cost. A drawback of these services is however are location based, which means that the vehicles have to be picked up and returned to the same location. With autonomous vehicles this drawback can be completely omitted as the vehicles have the possibility of getting to the user at any given location (Fu et al., 2021), essentially becoming driverless taxis. There is, however, another drawback of car-sharing that is not easily omitted with the introduction of autonomous driving technology, and that is the absence of psychological ownership. This is already an issue in current shared mobility programmes like the Lime E-scooters (Johnston, 2019), and is seen to result in a drastically lowered lifespan of the vehicles (Jorritsma et al., 2021).

A study by Whittle et al. (2019) investigates user decision making across different forms of mobility (including shared and autonomous mobility), and finds that vehicle ownership is an important factor in meeting the users' feelings of autonomy and identity expression, a finding that also applies to AVs. Accordingly, they find that shared mobility reduces these aspects, which may therefore lead to a resistance in adoption of shared mobility. Lynk & Co. provides an interesting solution to this issue, where owners of one of their cars can make their car available to be shared with other Lynk & Co. owners. On the one hand this may reduce the number of vehicle kilometres travelled as owners do not need to take their cars on vacation for example (they can just use a local Lynk & Co. at the destination), but they can still feel 'connected' to the car, as their shared car belongs to a person that they can identify with.

Work by Ong et al. (2019) also investigates future ride sharing experiences, and finds that important user needs to tackle are safety, privacy and comfort. Similar to the absence of psychological ownership (as described above), these identified needs are specific to shared mobility. When a user owns the vehicle, they are the primary user and therefore can decide who enters it. In an effort to ease the seemingly inescapable shift towards shared mobility in the future (Shaheen & Cohen, 2012), Ong et al., (2019) present a concept that fulfils the previously identified unmet user needs. Their adaptable interior concept consists of swivelling seats and a retractable partition that enables the users to decide themselves if they want to interact with all other passengers, just one other passenger or create a private space.

03.3.3 Meaning Beyond Mobility

Though transportation has been the main goal of the car for the lion's share of its existence, more and more researchers are interested in seeing the potential meaning of the car beyond mobility. For example, a preliminary article by Geiser and Kim (2021) explores the theory of Thirteen Fundamental Needs (Desmet & Fokkinga, 2020) from the perspective of mobility. They present a toolkit that encourages designers to think about mobility from different perspectives, one that looks beyond the needs of human individuals.

A recent master thesis at the faculty of Industrial Design also explores the theory by Desmet and Fokkinga (2020), but takes a more focused look on automotive user interfaces (Gomez Beldarrain, 2022). This work presents a set of co-creation workshops that link automotive user interfaces to the thirteen fundamental needs, finding that the needs for 'autonomy', 'community' and 'fitness' stood out.

A work by Lehtonen et al. (2022) examines user's reasons behind travelling more or longer using AVs. They find that these reasons are mainly to do with perceived usefulness of the AV; if an AV can provide time for leisure activities or can fulfil currently unmet (travel) needs, there will be a large potential for significantly increased AV travel. Van Hoven and Meijering (2019) describe such unmet travel needs from the perspective of older adults, for whom mobility can have the greater meaning of feeling secure, confident and engaging in social activities.

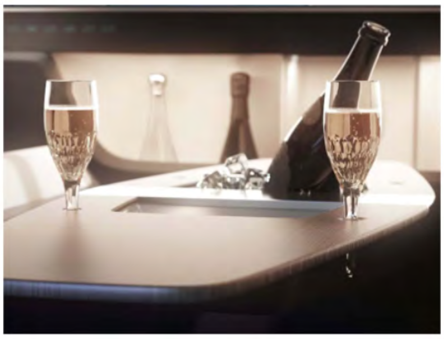
Giacobone (2022) explores AVs from the perspective of older adults, providing some examples how they can benefit from AVs other than mobility-related aspects. They study the Audi-funded AutoPlay project (Krome et al., 2017) which is originally intended for the general public, but Giacobone (2022) envisions how it can be used to the benefit of older adults. For example, the AutoGym concept could be a tool through which older adults can use their normally quite unhealthy car travel time to perform mini exercises, which could increase their feelings of autonomy and competency (Giacobone, 2022).

03.3.4 NDRA

A large topic of interest in the automotive research field is the effect that NDRAs have on the driver's performance regarding DRAs and the takeover procedure (for example the Mediator Project (2023). These studies focus on automated, not autonomous driving. As this project focuses on autonomous vehicles, there will be no switching between driving and not-driving. Therefore the outcome of these studies are not quite relevant to this project. NDRA research in autonomous vehicles is more limited but still well represented. Since AV technology has not yet reached the point where it is ubiquitous on the roads, much user research in this field is done in a lab-environment (Detjen et al., 2020; Tang et al., 2020). Detjen et al. (2020) try to circumvent this by conducting a Wizard of Oz experiment in which test participants take place in a vehicle where they cannot see the driver during the ride, leaving them to think that the car is driving. They argue that this way the test conditions are as close to reality as possible. They observe the participants during trips they chose themselves, analysing what NDRAs they are performing. They find that the majority of the time (55.47%), people are just watching out of the window (Detjen et al., 2020). Tang et al. (2020) observe users in a simulated AV environment, and analyse the difference in user activities when the users are alone or when they share the ride with another user. Similar to Detjen et al. (2020), this study also finds that in both use cases, the users most common activity was 'resting' (55% for sitting alone, 53% for a shared ride).

In practice, we notice that a large number of OEMs are interested in showing their visions of AVs and the possibilities for accommodating NDRAs. Most focus on automated driving (Mercedes F 015, BMW Vision iNext, MINI Urbanaut, Audi Grand Sphere; see figures 20), however they are still have relevance to this project, as they provide an insight into what NDRAs OEMs think the users will want to engage in.

Figures 20 a,b,c,d: (clockwise from top left) Mercedes F 015, Audi Grand Sphere, MINI Urbanaut, BMW Vision iNext



Figures 21 a,b,c: the Volvo 360c's three different interior styles

Other OEMs present autonomous concepts that are solely focused on accommodating NDRAs. In these concepts there are three popular NDRAs that are designed for: socialisation, work, and relaxation. Volvo presents a vision of this with their 360c; a pod-like vehicle that can be outfitted with several different interior styles that accommodate different NDRAs: enjoy, work and sleep (Volvo Cars, n.d.). Renault presents a similar concept with their EZ-ULTIMO (Renault, n.d.), featuring comfortable opposed seating, mimicking a living room or high-end office (see figure 22). The approach between these two concepts is different; where Volvo presents a vehicle whose interior can be changed according to which NDRA is preferred, Renault designs its interior to accommodate a range of NDRAs, allowing the user to switch NDRA during the ride.

Figure 22: Renault EZ Ultimo interior

03.3.5 Robotics

Kaplan (2005) defines robots as follows: a robot is an object that possesses the three following properties: It is a physical object, it is functioning in an autonomous and situated manner. The Robot Institute of America (RIA) defines it in a similar manner, namely: a robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specialised devices through variable programmed motions for the performance of a variety of tasks (Hegel et al., 2009). From these definitions we can summarise the defining characteristics of a robot as follows:

1. It is a physical object;
2. It functions autonomously, but its behaviour is programmable;
3. It is situational: it perceives its (physical) environment and is able to manipulate it.

Types of robots can be divided from multiple perspectives. Băjenescu (2019) divides the robotics sector into 3 distinct markets based on application: (1) industrial and agricultural, (2) defence and security, (3) service and personal. Garcia et al. (2007) divide based on physical form, also in three categories: (1) robot manipulators, (2) mobile robots, (3) biologically inspired robots. Because these two make the distinction based on different factors, they can be used alongside each other.

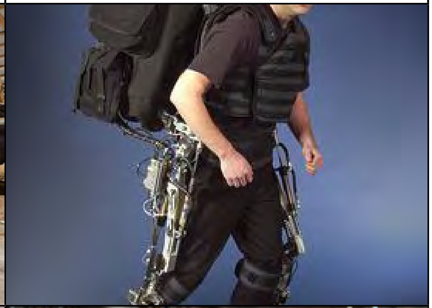
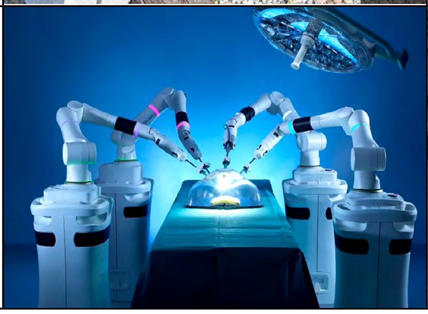
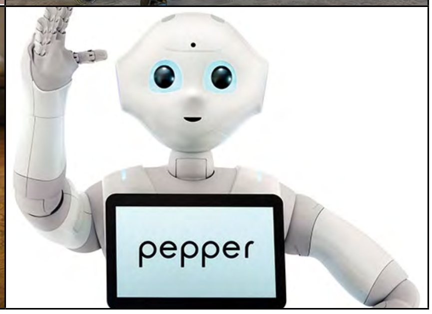
	Robot Manipulators	Mobile Robots	Biologically Inspired Robots
Industrial and Agricultural			
Defense and Security			
Service and Personal			

Table 6: robotics mapped horizontally according to Garcia (2007) and vertically to Bajanescu (2019)

03.3.6 Alternative Robotics

If we look at robot's defining characteristics mentioned above, shape changing interfaces (SCI) can also be classified as robots. Alexander et al. (2018) define SCIs as having the following characteristics:

1. Use physical change of shape or change in materiality as input and/or output;
2. Be interactive and computationally controlled;
3. Be self-actuated and/or user actuated;
4. Convey information, meaning, or affect.

Putting the robot's characteristics (R1, R2 & R3) next to the CSI characteristics (S1, S2, S3 & S4) we see overlap. S1 makes an SCI a physical object, therefore meeting characteristic R1. S2 and S3 make that SCIs meet characteristic R2. If we interpret an SCI to be both an input and output device as mentioned in S1, then R3 is also met. S4 does not relate to any of the robot's characteristics, rather it has to do with SCIs being interfaces.

SCI's are often made possible through soft robotics. Soft robots have a continuously deformable structure with muscle-like actuation that emulates biological systems and results in a relatively large number of degrees of freedom as compared to their hard-bodied counterparts (Rus & Tolley, 2015). One of the main enabling technologies of soft robotics is the McKibben actuator, invented in the 1950's (Kim et al., 2013), which is an artificial bio-inspired muscle. Though this actuator has been invented multiple decades prior, the research field of soft robotics only started to gain popularity around 2011 (Hawkes et al., 2021). This rise in popularity is a signifier of a change in perspective that we have towards the application and meaning of robots, and the relationship that we hold with them.

This change in perspective can also be identified in our archetypical view of robotics. A quick Google-search for "robot" yields the results shown in figure 23. Nearly all results are anthropomorphic machines, emulating human behaviour. This vision of what a robot is or what it should look like is mirrored in its definition in the Oxford Dictionary of

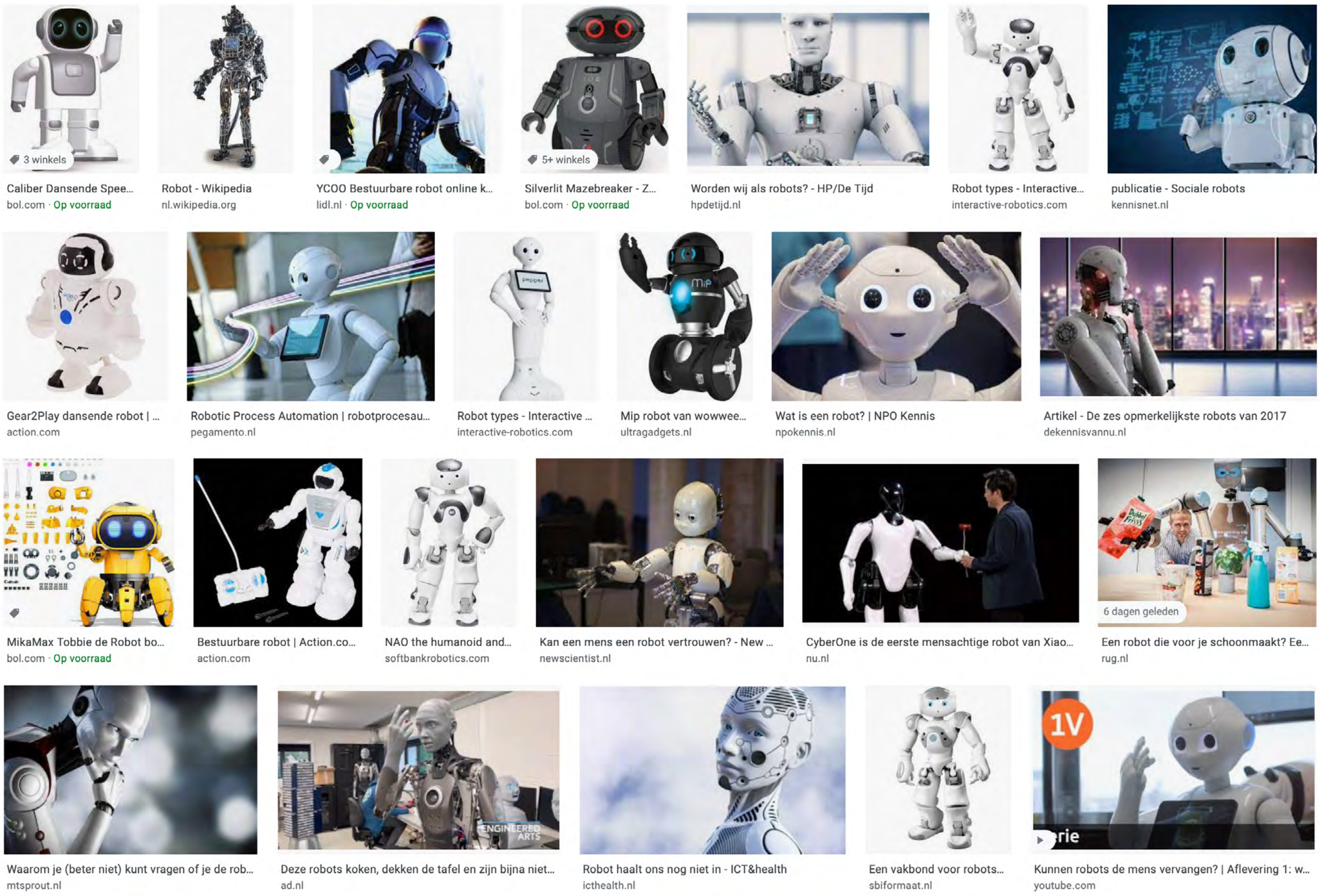
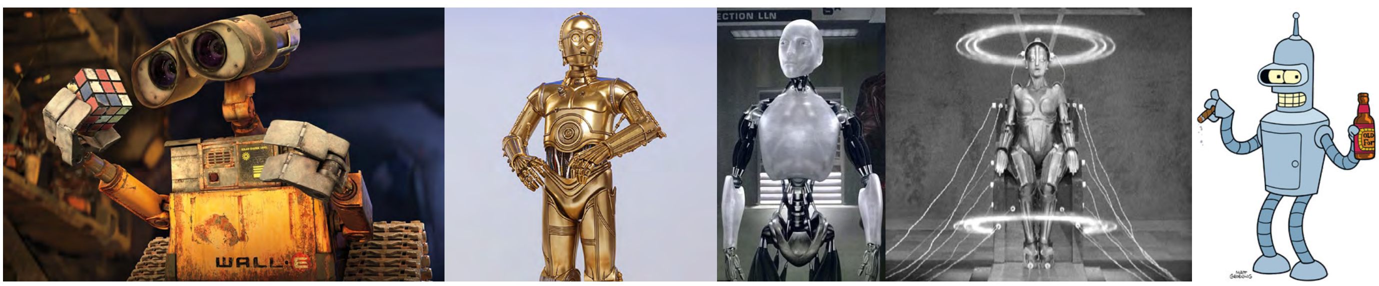


Figure 23: Google search for “robot”

English: “a machine resembling a human being and able to replicate certain human movements and functions automatically” (Oxford English Dictionary, 2003). Analysing the Google Search results a bit closer we can see that most do possess the characteristics as mentioned (R1, R2, R3), making them indeed robots in the traditional sense. However, they can all be placed in the lower-right ninth of table 5, representing only a small part of the variety of what robots could be. When looking at robots in popular culture, we see a similar trend. The imagery about robots that we receive from the media is characterised by anthropomorphic shapes, bodies and by human-like cognitions, feelings and behaviour (Fortunati et al., 2015). Examples of this include Wall-e, C3PO from Star Wars, Sonny from I, Robot, Maria from Metropolis, and Bender from Futurama (see figures 24).



Figures 24 a,b,c,d,e: robots in visual media

All of these robots possess some kind of anthropomorphic aspects, be it in their physical form or their behaviour. In figures 21 we recognise this in the human-body shape that some of the robots take, or in the fact that Bender smokes and drinks (behaviour that is obviously not necessary for a robot to function). Their core purpose should be to serve humans, to assist them in a way that is beneficial to them. This can for example be seen in Wall-e, whose purpose it is to clean up planet Earth so that humans can once again return to it. Following this view of robots, three alternative defining characteristics for robots can be formulated (AR1, AR2, AR3):

1. A robot should function autonomously, emulating a free will;
2. It should display anthropomorphic physical features or behavioural traits;
3. Its core purpose should be assisting humans.

It should be noted that AR3 is sometimes hard to identify. For instance, Sonny is suspected of killing a human in I, Robot which would make it seem as though Sonny is not assisting humans. However, the reason why robots like Sonny were developed in the first place was to serve humanity.

If we follow this definition, we can identify a new group of 'alternative robots', which would not fit in the traditional definition of robotics as mentioned above. For example, the Chinese car brand NIO integrates a digital assistant in their cars called Nomi (see figure 25). Nomi is shaped like a sphere with a circular display on the front, sitting atop the car's dashboard. On the display the user can see eyes that move to emulate emotions, and Nomi's body (i.e.: the sphere) can move around. When, for example, you speak to Nomi, it will turn towards you. We can see that all three characteristics of alternative robotics can be identified here.

Figure 25: Nomi by NIO

Figure 26: JLR concept

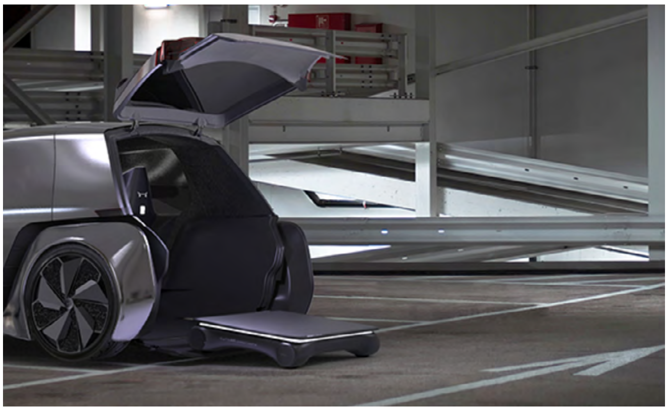


Figure 27: robot emerging from EXIGEN

Figure 28: Continental delivery concept

03.3.7 Robotics and Cars

As mentioned in section 1.2, a number of scholars argue that AVs are indeed robots (Amanatidis et al., 2017; Meschtscherjakov et al., 2015; Thrun, 2010; Tscheligi, 2014). The shift in robotics from utilitarian to social is touched upon in some work, for instance in Daher et al., (2021) and Nadri et al., (2022), who present (the plans for) workshops on empathic automated vehicle interaction. Though this is focused on automated vehicles, it is interesting to see how the alternative view on robotics (see section 2.3.6) is recognisable in this work. By looking at empathic interaction, they bring in an anthropomorphic aspect into the robot-vehicle. Along a similar line of thought, Jaguar Land Rover presented an AV concept in cooperation with Aurrigo that used anthropomorphic aspects on its exterior to communicate with other road users (JLR, 2018). This too reminds of the archetypical view of what a robot is, and further corroborates the thought that an AV is indeed a robot.

In contrast to this, we can also identify automotive concepts that use robots in a more traditional sense. In these examples, robots are used as an addition to a car, in order to perform an additional task that may be undesirable to humans. In the EXIGEN concept car (Spears, 2019) a small robotic platform can emerge from the car, on which the user can put their luggage so that they don't have to carry it out themselves. Continental AG (2019) presented a delivery concept that relies on the same relationship between robot and car. Their concept consists of a larger autonomous parcel carrying vehicle, from which robotic ‘dogs’ emerge that bring the parcels to their exact delivery point. More recently, Hyundai Motor Group presented their Auto Charging Robot (ACR) concept which deploys a robotic arm to connect an EV to a charging station (Hyundai Motor Group, 2022). This robotic arm is not dissimilar to ones that are used for manufacturing purposes.

Figure 29: Hyundai’s ACR

03.3.8 Modularity

In the micro-level sprint the concept of modularity was explored. In this case, modularity does not refer to the construction and manufacturing of vehicles via modular platforms as described by for example Ganesh & Venkatesan (2021). Rather, it relates to the interchangeability of parts of a vehicle during the use phase. Some OEMs have already brought cars to market that incorporate some kind of modularity (For example, Daihatsu’s Copen). All of these examples focus on changing the look of the vehicle, not necessarily on changing the functionality. In contrast, Swiss company Rinspeed presented a concept called the Dock+Go, which added “backpacks” (see figure 31) to a small city car that carry out their assigned tasks based on the current need (Rinspeed AG, 2012). For example, a luggage-backpack can be attached to create extra storage space when needed, or a backpack with extra batteries to enhance the EV’s range. Rinspeed calls this “mobility à la carte (Rinspeed AG, 2012), meaning that the car does not carry around unnecessary weight and material.

Figure 30: Daihatsu Copen in three bodystyles

These previously mentioned cars are all production and/or manually driven cars, but the topic of modularity also exists in concept AVs. Mercedes Benz’ Vision URBANETIC is an autonomous driving platform that can be outfitted with a cargo module or a people mover module (Mercedes-Benz AG, 2018). Because of these modules the platform can serve two functions, to maximise its efficiency. When the vehicle has dropped off people at their destination, it can change into a cargo vehicle to help in the logistics chain. Rinspeed also presented a range of concepts that follow the same philosophy. Their Snap, Microsnap, Metrosnap and Citysnap (see figure 18b) are a family of (autonomous) vehicles that all use some sort of driving platform with interchangeable modules on top that make the vehicle fulfil different functions.

Figure 31: Rinspeed Dock+Go with two backpacks

By separating the intelligent and thus quickly ageing components (placed in the skateboard platform) and proportionately expensive components from the long-lasting vehicle components (placed in the pod), Rinspeed aims to resolve the problem of a whole vehicle becoming obsolete because of new technological developments (Rinspeed AG, 2018). Ulrich et al. (2019) present an on-the-road modular vehicle comprising a driveboard and various capsules. The driveboard contains all the necessary technology to drive autonomously and lift up the capsules, which are applications optimised to be used as for example people movers, cargo movers, or for individual transport (Ulricht et al., 2019). Interestingly, in this case the capsules (or modules) are considered a low-cost part that can be replaced and upgraded quickly, whereas Rinspeed regards the modules as expensive and the driving platform as the part that should be upgradable.

Modularity in AVs can be interpreted in another way too: as Modular Dynamic Ridesharing Systems (Gecchelin & Webb, 2019), an example of which is the Next Future Transportation System (NextFutureTransport Inc., n.d.). This system consists of a number of autonomously functioning vehicles with a capacity of 10 passengers. These modules can physically link together to create a larger vehicle with a capacity of up to 15 modules. Systems like this have the potential to reduce congestion through decreasing the size and number of vehicles at particular periods of the urban transport cycle (Gecchelin & Webb, 2019).

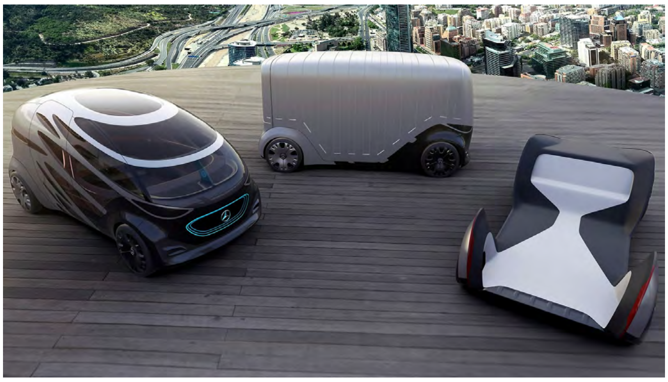


Figure 32: Mercedes Benz Vision URBANETIC

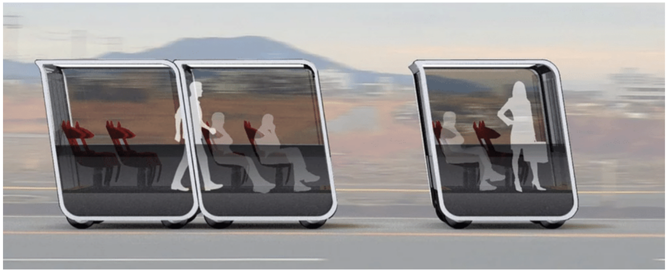


Figure 33: Next Future Transport System

03.4 **Adjusting Scope**

At the end of the exploration stage, the wide nature of the AV research and design field became even more apparent. In order for this project to create depth, it was decided that there should be a focus on one of the levels of interaction (i.e. micro, meso, macro). After all, if all levels are taken into account, it is imminent that the project stays quite general. All three levels have presented ample opportunities for focus, but scope was narrowed to the meso level. Firstly because we see that the micro-macro framework is still very common among scholars and engineers, when Li (2012) argues that adopting a micro-meso-macro framework can ensure a more cohesive knowledge space. In this three-levelled framework the meso level becomes key, as it is the one that binds the higher and lower level together. By setting this project in the meso level, it can provide insights on a perspective that may be overlooked in the traditional, two-levelled framework.

Additionally, because of the autonomous nature of an AV together with other developments like rising interest in shared mobility, there are more opportunities for community aspects of interaction. Future vehicles may not be owned by an individual, and can move autonomously between different community members. In the exploration stage, little work was identified that focussed on this emerging opportunity; this project can fill that perhaps underrepresented area.

03.5 Key Takeaways

- The focus of this project is going to be meso level interaction, so that means that creating a community feeling is important. After all, the meso level is concerned with the interaction between a community and an AV.
- Existing work on the meso level is mainly focussed on creating added functionality, not necessarily on creating an enhanced experience for the users. Therefore, this should be a focus in the coming process.
- The future is uncertain, therefore it is imperative that we design for adaptability, so that we do not end up with an AV that is perfectly designed for an outdated scenario.
- The rise of autonomous driving technology does not just mean that car travel will become safer, but it also provides an opportunity for the user to engage in a new range of activities that they were previously unable to do in the car.
- In robotics we see a shift from functional applications to more social ones. The AV can be considered a robot, therefore we should also look at the AV in a more social setting, where it fulfils a facilitatory role.

04 **Synthesis**

With the exploration phase finalised, the synthesis phase was started. In this phase, the findings from the related work review were used to iterate upon, a set of design principles was formulated and finally example use-scenarios for each design principle were conceptualised.

Reflective Transformative Design Process

The design phase of this project follows the Reflective Transformative Design Process. This is a design model that gives the designer a grip on the design process, but because of its openness it leaves room for innovation (Hummels & Frens, 2009). The model consists of five activities, with ideating as the central activity (see figure 34); the other four activities are used to support the central activity. There is no set order to these activities, rather it is up to the designer to decide which activity to do next through constant reflection. This notion is visualised in figure 32 by the lines between every activity. The flexibility of switching activities through reflection supports 1) transformation; 2) flexibility and individuality; 3) the integration of knowledge, skills and attitudes; and 4) the creation of moments of reflection (Hummels & Frens, 2009).

Within the RTDP, the designer has the freedom to define what activities they undertake in each phase, thereby tailoring their design process to best fit the specific project. The RTDP can thus be seen as an overarching or high-level structure, rather than a specific design activity. To make this notion clear throughout this chapter, each sub-chapter will be named in the following manner: "[phase of RTDP] : [activity]". Figure 34 shows a summary of the steps that are taken in this chapter, starting with sensing, perceiving, doing and finally ending in ideating, integrating, realising.

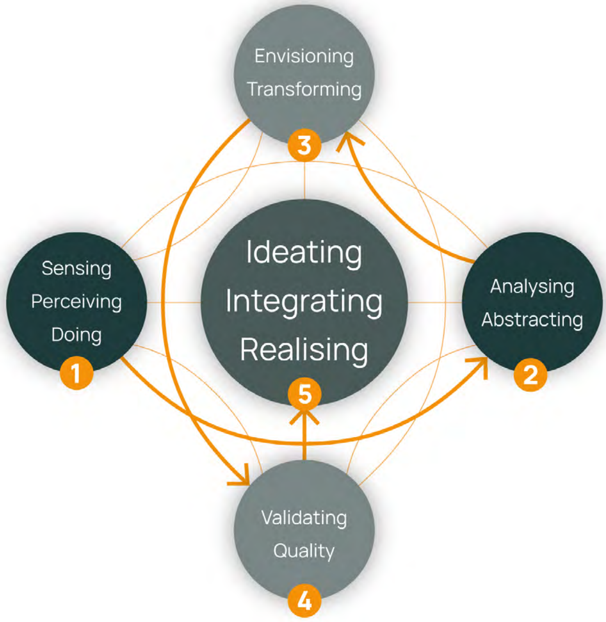


Figure 34: Reflective Transformative Design Process, with the steps that were taken in this project.

04.1 **Sensing, Perceiving, Doing: Co-Creation Workshop**

The design process is started with analysing and abstracting (right circle in figure 34), by conducting a test with (projected) AV end-users. The insights that are to be gained from this test are twofold. First, we would like to observe how people collaborate on something that is meant to add value to each person's life. Second, we would like to see what opportunities and considerations people perceive when thinking about the use of an autonomous vehicle, beyond mobility.

04.1.1 Goal and Activities

To gain these meso-level insights, two groups of 4 people (plus an additional group of 4 for a pilot test) were asked to participate in a 90-minute workshop in which they were given the task to create a scenario where a 'shared mobile space' equally adds value to every person's life. The participants should emulate the focus area as well as possible, which in this project is the meso-level HVR. It is defined as "the relationship between one vehicle and a community", therefore it is important that all participants of a group should know each other. They should be part of a community.

In other user research into NDRAs (e.g. Detjen et al., 2021) it is often very clear to the participants that the goal is to find new activities to do in a car, either through the test setup or the terminology that is used to describe the test's goal to the participants (for example asking them: “what would you want to do in an autonomous vehicle?”). It can be argued that using this terminology may (subconsciously) limit the participants to think about activities they see themselves doing in a conventional car. By not using any references to cars in this workshop’s explanation and using the term ‘shared mobile space’ instead; we aim to expand the user’s mental opportunity space.

The activities that the participants will do in the workshop are based on the first three days of the Sprint method (Knapp et al., 2016). In these days the sprint-team is tasked to figure out what their design problem or area is (Day 1: Map), then to quickly ideate solutions or opportunities (Day 2: Sketch), and finally to decide what idea to go ahead with and create a storyboard with this (Day 3: Decide), which will act as the final deliverable that the participants are working towards. Usually this is followed by two days of building a prototype (Day 4: Prototype) and testing with end-users (Day 5: Test) however these two days go into deep technical detail and design, which is not the aim of this workshop. Rather, we want the participants to think about the use of the ‘shared mobile space’. Additionally, the participants are not experts in the field of design or technology (for elaboration see section 4.1.2), therefore asking them to think about design or technology would not yield helpful results. To make sure the participants don’t go into the mindset of designing a physical vehicle, no prototyping or tinkering materials will be provided. A second reason why a storyboard is a good deliverable to work towards in this workshop, is that it is a very common tool in UI/UX design. This design discipline focuses very much on usability and interaction journeys instead of the physical and technical aspects of the design. After this storyboard is completed, the participants are asked to reflect on it, and perform a short iteration on it with the question in mind: how could robots or robotics be applied in this scenario? The procedure of the workshop is outlined in figure 35, the full procedure can be found in appendix A.

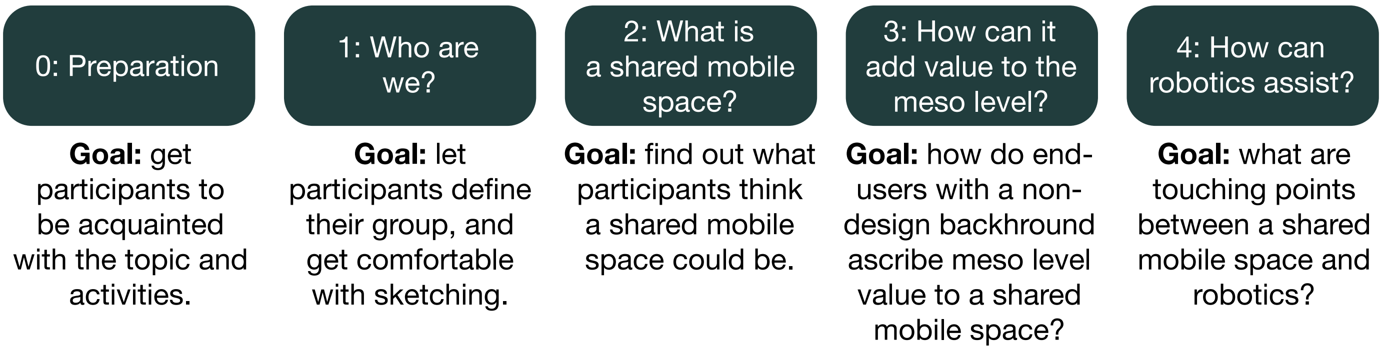


Figure 35: workshop procedure outline

04.1.2 Participants

In related work, participants in workshops or co-creation sessions often (partly) comprise experts or design students (Gomez Beldarrain, 2022; Nadri et al., 2022). Though it is true that they may have experience with the test’s activities or have more knowledge of the topic at hand, it is hard to gain true user insights from these people. Therefore in this test, the participants should be laypeople, as close to real-world users as possible. To mitigate the participant’s lack of knowledge about design methods, a preparation document is sent to the participants ahead of time. In this document each of the activities that will be used is explained, as well as some examples for each activity (see appendix A).

As the aim for the workshops was to investigate autonomous vehicle interaction on the meso-level, the participants of each session should all know each other, emulating a community. These groups of participants were recruited first through the researcher’s personal network, after which they recruited other people to form a group (snowball sampling). A total of 12 participants were selected (8 plus 4 for the pilot). There was no set target group, so the selection process was aimed at recruiting participants from various backgrounds, ages, genders and nature of connection between them. The latter criterion was the most important one, as the notion of community lies at the core of the meso-level of interaction. In section 3.1.2 it is described that there are location-based communities and interest-based communities, both of which are represented in this study. Group 1 is a location-based community; they are housemates. Group 2 is an interest-based community; they follow the same study programme and became friends because of that. Apart from being in the same age group (20-30), there is a good mix of background factors among participants and participant groups, as outlined in table 7.

	Pilot (P1, P2, P3, P4)	**Group 1** (P5, P6, P7, P8)	**Group 2** (P9, P10, P11, P12)
Gender	3 female, 1 male	2 female, 2 male	1 female, 3 male
Occupation	4 working full time	2 studying full time, 2 working full time	3 studying full time, 1 studying + working part time
Nature of Connection	Friend group, from high school (±12 years)	Housemates	Friend group, from university (± 3 months)
Proximity	Spread out over 4 cities, 50-100 km between them	Live in the same house	Spread out over 2 cities, 10 km between them

Table 7: background of the participants

04.1.3 Data

There are two data sets that are collected from the workshops: (1) the written transcript of the entire workshops, and (2) the paper on which the workshop activities are performed. The transcript will serve as the main form of data, the paper is used to support it. The transcripts are analysed, with the aim to uncover and map the participants' reasoning behind their storyboards. The Iceberg model (ecochallenge.org, n.d.) is used as a tool for this. All data is collected, analysed and stored in accordance with a data management plan that was previously approved by the Human Research Ethics Committee of the TU Delft.

04.1.4 Pilot Test

After a first version of the test setup was formulated, a pilot test was conducted to see if there are any aspects of the test that need to be changed to reach the desired outcome. Some issues were indeed found, and the test plan was revised accordingly. First, the pilot participants sometimes felt a little lost in the process; they were unsure in what step of the process they were or what steps to take next. To mitigate this in the following workshops, the activities were cut into smaller sections, so that the participants only have to think about one activity at a time. Second, even though the test participants were tasked to think only about the use of the shared mobily space, they often discussed technical details (for example: "no we can't use it like that, it's impossible to make it do that"). This meant that in the next workshops more involvement and steering from the researcher was needed, in order to keep the participants away from thinking about technical solutions. Third, the user scenario that the participants came up with was quite an obvious one, namely a shared party space. Even though this outcome does have valuable reasoning behind it, there might be more out-of-the-box use cases that the participants now did not think about. Therefore, the next participants were asked not to think of one use case, rather to come up with two or three. The reasoning behind this is that they would get the most obvious solution out of the way, leaving room for other, perhaps more creative use cases. A more detailed report of the pilot test can be found in appendix B.

04.1.5 Results

04.1.5.1 Workshop 1: Location-Based Community

The participants of the first workshop defined themselves first and foremost as housemates. They each rent a room in a building in a city where they all went to the same university. Currently only two of them are still studying; the other two have full-time jobs. This means that they don't see each other very often during the day, mostly only during evenings if they have dinners together. Sporadically, they have game- or movie nights. They all express that they would like to do more activities together, also during the day. However, their house is quite small, especially the common room. There is no table or comfortable chairs there, so it is hard to play more elaborate games or study together.

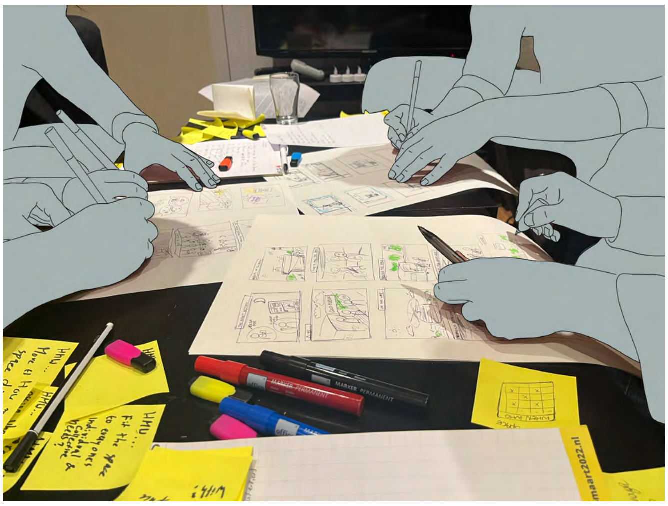
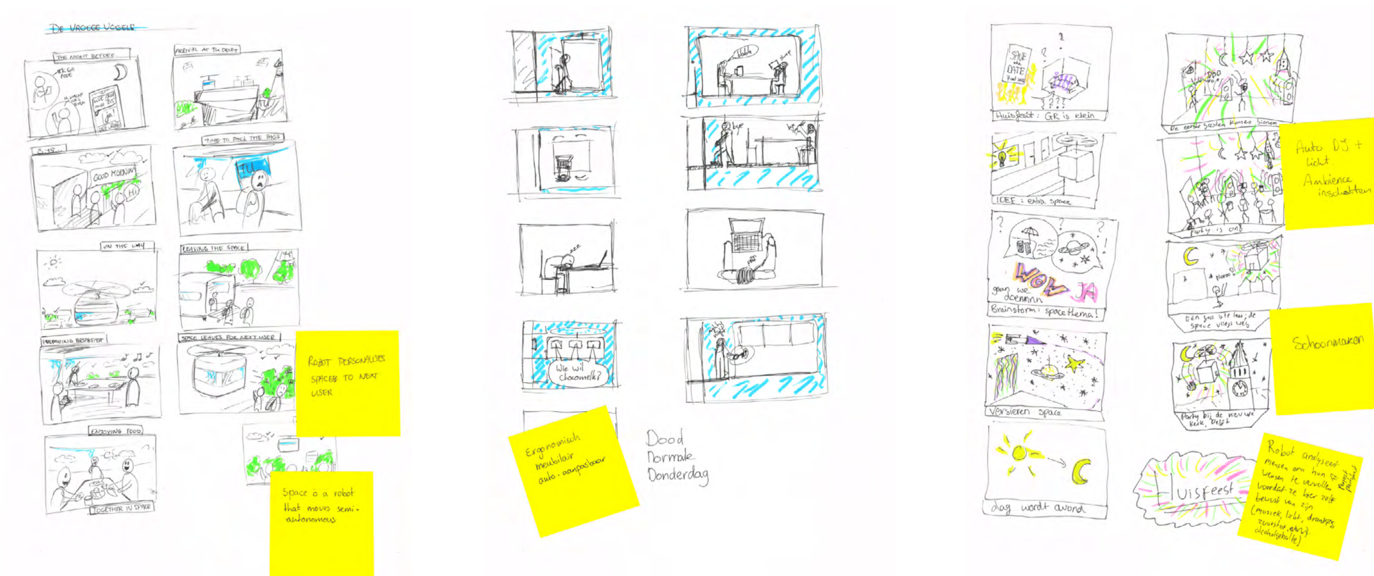


Figure 36: group 1

This group defined the shared space as a "physical entity that can be moved around with some ease which allows humans or things to use the space, although not necessarily at once". Additionally they discussed that the space should move autonomously; the user(s) should not have to put any effort in moving it. How this space could be used was explored first through Crazy 8's. What stands out here is that three out of four participants explored different ways of scheduling the use of the space. An explanation for this can be found in the nature of their connection. Since they live together, they share a number of duties (cleaning, groceries) and facilities (bathroom, kitchen, shower). Because of this they often think about how to distribute shared things equally or fairly.

After discussing ways to distribute the shared space, the group thought about what experiences the shared space could add to their lives. As a ground for this, they looked at what they were currently missing in their lives and environments, which was (as mentioned before) a comfortable common room. The participants felt like they wanted to study or work together, or perhaps have a house party that would bring all of their friends together. These needs and wishes finally resulted in three scenarios: (1) the space would provide breakfast to everyone, and transport them together to each person's respective place of work or study; (2) the space would provide extra workspace with a large table and other amenities, so the users can study, work and socialize together; (3) the space would be the setting for a house party, which would fly over the city to provide the party goers with nice views.



Figures 37 a,b,c: three scenarios

After the scenarios had been worked out into more detail, they were discussed with the participants in an effort to understand their decision making and the needs that lie at the base of these scenarios. To visualise this, the Iceberg Model (ecochallenge, n.d.) was used (see figure 38). The core needs were identified as follows:

- The participants all feel like it is important to keep up social contacts outside of their work or study. On the one hand these contacts can be the housemates, with whom they all would like to spend more time together in a more relaxed setting. On the other hand they also include friends that may live further away, who they would like to invite over without having to worry about the amount of space that is available.
- As the participants all studied (or still do) at a university, they think that attaining a good career is important and that education is important in reaching that goal. In their current living arrangement, they feel like they cannot spend their time most effectively. This results in a worry that maybe they aren't attaining the results they would like to.
- Related to this, the participants also find it is very important to have a clear separation of work and relaxation. As they have no place to work or study outside their bedroom, they feel that the lines are getting blurred and therefore can never fully unwind from a hard or stressful day of work.

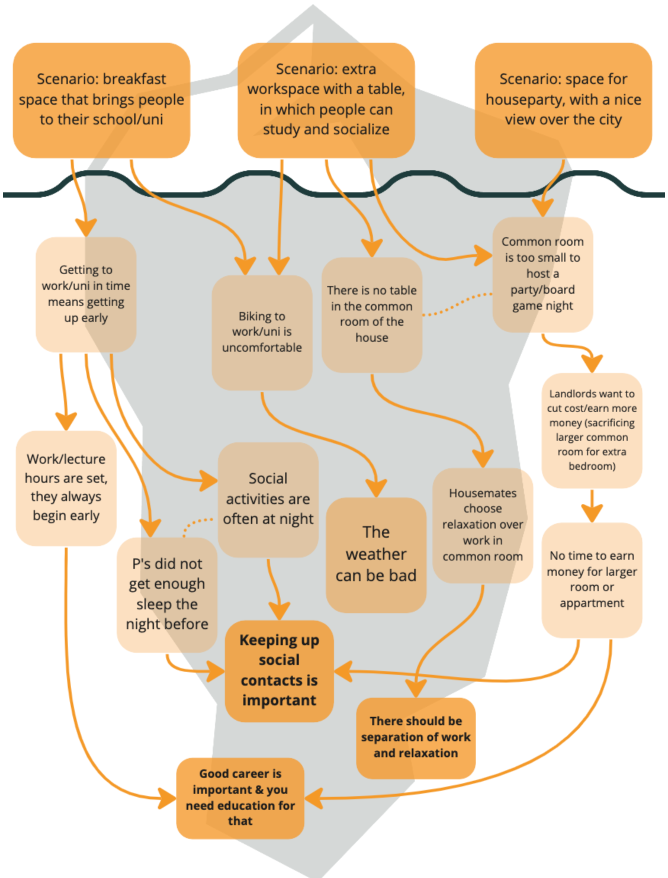


Figure 38: Iceberg Model for the first workshop

04.1.5.2 Workshop 2: Interest-Based Community

The participants from the second workshop identified themselves as a group of friends, who met during the introduction programme of their new Master's study. They met roughly 3 months prior, in these months they joined multiple social activities together that were organised by the study association. They also go to classes together, as they are all studying the same Master's. The group doesn't live very close together: two of the participants live in the same city as the university, the other two live in a different city (roughly 10 km away). Because of this, they mostly hang out at the university as the distance between them poses a hurdle. They expressed the wish to hang out more together outside of the university. All four participants were new to the area; two moved there from other parts of the country and the other two are internationals. This group defined the shared mobile space as something that possesses the following characteristics:

- The group should be able to use it together or separately;
- It should be able to move itself (autonomously);
- It should be a physical thing which the users can enter;
- It should provide the users with amenities that are useful to them.

Figure 39: group 2

In the individual phase of idea generation, the participants explored quite different topics. They too all wrote down How Might We notes regarding how to share the space equally, but only one participant ideated on this with Crazy 8's. Most Crazy 8's were concerned with how the space could be used to connect all participants together. This finally resulted in two scenarios: (1) the space would pick everyone up from their houses, during and after travelling the people would do activities together; (2) the space would provide a mixed-reality environment where people can be together online or in person.

From the discussion and analysis of the second workshop's scenarios, another Iceberg Model was made (see figure 41). The core needs that were identified here were:

- The participants feel like moving to a different place or country for their studies will give their life extra experience and value. They express that in addition to choosing this specific study programme, they also wanted to move to a new place to have new adventures or experience in life.
- While it may enrich their lives, moving to a new environment can also be quite scary and insecure. There are many new things and people to explore, and in the beginning it may feel like they have to put in much effort to settle in.

Figures 40 a,b: two scenarios

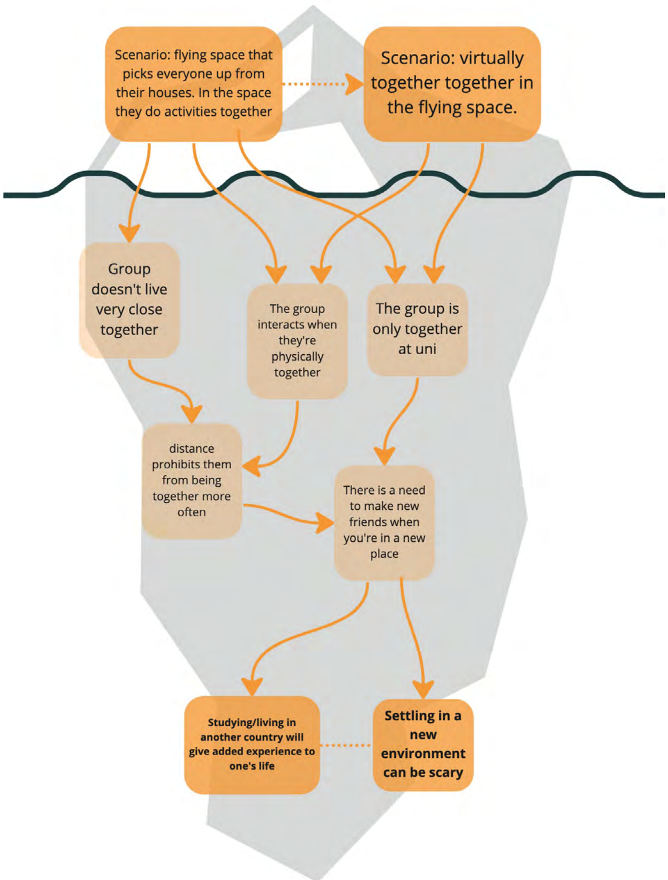


Figure 41: Iceberg Model for the second workshop

04.1.6 Key Takeaways

Taking the above mentioned core needs and the workshop transcripts into account, a few key takeaways can be formulated.

- The first key takeaway can be found in the answer to the first research question: "how does a group of end-users collaborate on defining the use of a shared mobile space, with the goal to add value to every person's life?". The participants saw the space as a problem solver. In the workshops they were asked to find a (shared) use for this space, yet all scenarios that the participants presented solved some kind of shared problem. The first group all perceived the problem of their living space being too small, so they used the space as 'real estate on demand', giving them flexible extra living space that would cater perfectly to their needs. The second group found it hard to do activities together outside of university due to their geographical differences, so they used the space as a connector that would make it far easier for them to be together in a social setting.
- The second research question ("what opportunities and considerations do people with a non-design background see when thinking about the future use of autonomous vehicles?") gives the second key takeaway. By using the term 'shared mobile space' instead of 'car' or 'vehicle', it seems that the participants were successfully guided away from thinking about the automotive domain. In both workshops, there was only one participant that mentioned the word 'car' in the discussion. Additionally, the participants' discussions did not reflect any hesitation in choosing activities that would not be possible in a conventional car (for example: having food around the table, organising a dance party)
- Third, the nature of connection plays an important role in how the participants ascribed value to the 'shared mobile space'. As both groups had a different type of connection, they both had different needs they wanted to fulfil.
- Finally with regards to robotics, the participants seemed to mirror the shift in application towards a more social one. In the last step of the workshop they discussed possible uses of robotics in their scenarios; in all of those the robot would be a sort of helper that makes the life of the users easier or more comfortable. In fact, both groups describe a robot that possesses all three defining characteristics of alternative robotics (see section 3.3.6). Additionally, both groups identified the space itself as being a robot, as it operates autonomously. This reflects the notion of Meschtscherjakov et al. (2015), who describe autonomous cars being studied as robots.

04.2 **Analysing, Abstracting: Analogies and Metaphors**

Until this point in the process, a large amount of knowledge and insights were collected through literature and related work review, and co-creation workshops. The following step was then to combine all of this, aiming to identify a promising design direction. In this section, three analogies are selected and abstracted, which will serve as input the creation of a future vision about the human vehicle relationship.

To combine the user insights with the insights from the previous related work research, the activity of Analogies & Metaphors was selected (Boeijen et al., 2014). This activity is used to look at existing opportunity areas through the lens of another inspirational domain, thereby finding new novel relations or properties to apply to the opportunity area. It should be noted that in design, the terms 'analogy' and 'metaphor' are often used interchangeably. In linguistics, analogical language comprises the use of metaphors among others (Analogy - New World Encyclopedia, 2021), meaning that 'analogy' is an overarching term. In this report, the term 'analogy' will therefore be used to refer to all language that identifies a similarity between two or more concepts.

To find relevant analogies, key takeaways from the literature and related work review and from the co-creation workshops were gathered into a number of important characteristics that the analogies should contain. These characteristics are divided in two categories; the first are qualities to emphasise which were identified from the literature and related work review, the second are user needs and wishes that emerged from the co-creation workshops. The list below explains each characteristic, and why or where it was identified.

The method does not provide a set path to finding analogies that fit with the given characteristics, which Boeijen et al. (2014) mention as a limitation. Because of this, it can take much time to find an appropriate inspirational domain. In an effort to mitigate this limitation and to structure the search for analogies in this project, random connections were made between the characteristics to narrow down the search. These connections consisted of two random QtE's and two random UNaW's. It is important to note that all characteristics are considered equally important, therefore one analogy can not be considered more important than another one. Even though these analogies were found through the connection of just four characteristics, that does not mean the others can not be identified in the analogies. In the following three sections, each analogy is explained into more detail, elaborating on which characteristics apply, and how they apply.

Qualities to Emphasize (QtE)

1. **Feeling of community:** in a traditional micro-macro framework, developing community value sometimes is left behind. Yet, the robotic nature of an AV can present meaningful opportunities here (see section 3.4 Adjusting Scope)
2. **Focus on experience:** the work that does exist on the meso-level interaction is primarily focused on creating added functionality, not experience (see sections 3.2.2 Meso Level and 3.3 Related Work)
3. **Adaptability:** to cope with multiple people and their needs, adaptability can be a good tool (see sections 3.2.1 Micro Level and 3.2.2 Meso Level).
4. **Tailored to use:** with the user not having to drive anymore, an entirely new realm opens up with regards to what the activities the user can do while using an AV. To optimally assist in these activities, the AV should be perfectly tailored to each specific activity (see sections 3.2.1 Micro Level and 3.3.4 NDRA).
5. **Facilitator or helper role:** there is a shift in the field of robotics from utilitarian to a more social, or helper role. This should be mirrored in the analogy as well (see sections 1.3 Functional Utilitarianism to Social Utilitarianism and 3.3.6 Alternative Robotics).

User Needs and Wishes (UNaW)

1. **Social aspect:** use of the AV should have a social aspect or drive. It is something that people consciously use together (see section 4.1 Co-Creation Workshop).
2. **Connecting people:** in line with the social aspect, the AV should connect people where there was previously no connection possible (see section 4.1.6 Key Takeaways).
3. **Problem solving:** the AV should solve a shared problem that the community has (see section 4.1.6 Key Takeaways).
4. **Supporting difficult situations:** the AV could help users cope with difficult situations, or act as a sort of catalyst towards a better life (see section 4.1.5.2 Workshop 2: Interest-Based Community).
5. **Supplementing current life:** the AV should not just take over the role of a regular car, it should add something to the user's life that wasn't there before (see section 4.1.5.1 Workshop 1: Location-Based Community).

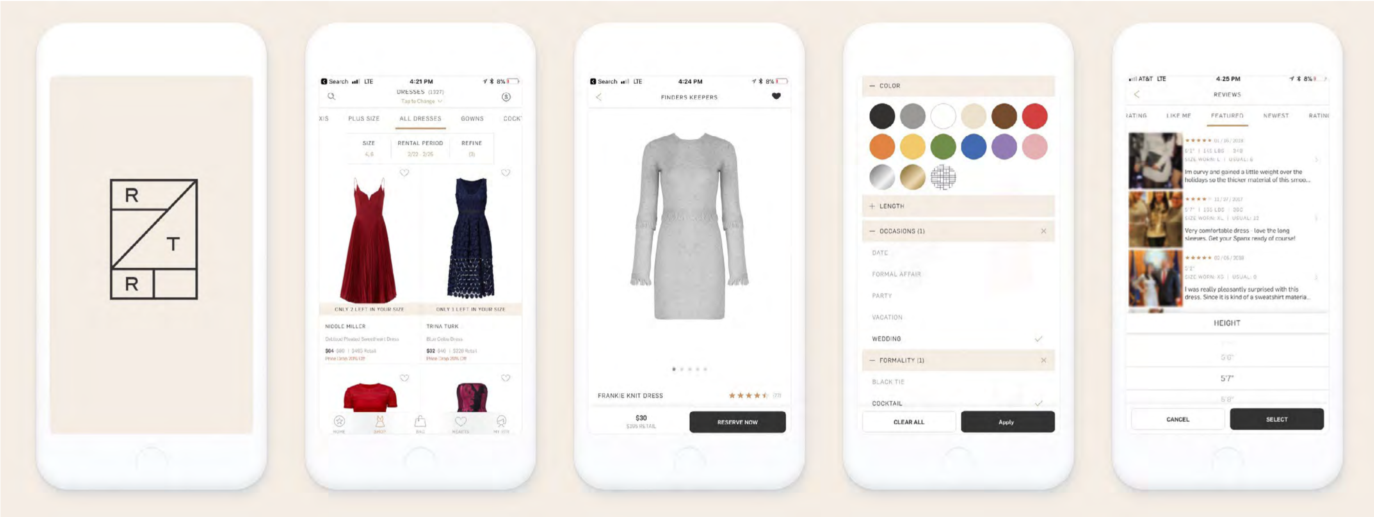


Figure 42: Rent the Runway user interface

The analogy of Rent The Runway stems from the combination of QtE1, QtE3, UNaW4 and UNaW5.

Rent The Runway (RTR) is an e-commerce platform that offers women the opportunity to rent high-end clothing and accessories. The service's primary focus is clothing for special occasions, which is mostly worn only a few times. Rather than having to buy this - often expensive - clothing, women using the service can rent it for the occasion and send it back afterwards as part of a monthly subscription plan that costs only a fraction of the retail price (Rent the Runway, n.d.).

If we look a little closer at the service and its value, there are several aspects that make it an interesting analogy. First, it is aimed towards people that don't want to or can't afford to spend a lot of money on occasion wear. Instead of them being deprived of this luxury, the service offers them an opportunity to still experience it, and to 'feel like a million bucks'. This links to UNaW5, as the service supplements the user's own closet. They still have their own collection of basic or everyday clothes, which they can supplement on-demand with luxury, specialty items. This essentially gives the user luxury-on-demand. This same thought is also what links RTR to UNaW4, as it helps people with a smaller budget still enjoy some luxury. Second, the fact that the user can choose between many different styles connects to QtE3, as they can choose whatever item fits best with the occasion. If the user were to buy occasion wear, they would probably keep in mind that it should be somewhat generic so that they could wear it again. In contrast, with RTR they have the full freedom to choose whatever they want at that specific time, giving them the freedom to express themselves. Third, the fact that every item that RTR offers can be used by all users of the service offers the communal aspect of QtE1. Apart from being directly part of the RTR community, the service can also indirectly provide the user with an opportunity to connect to other communities by providing them with appropriate wear to fit in. For example, if one is invited to a high-class gala and wears a "cheap" dress they might get looked down upon, whereas wearing a designer dress would make them be accepted more easily by the other attendees.

If we distil these aspects of the analogy to an abstract level, we can see that its core is the creation of 'functionality-on-demand'. This means that it does not serve just one function, rather it can be exchanged or adapted to perfectly fit what is desired at that time.

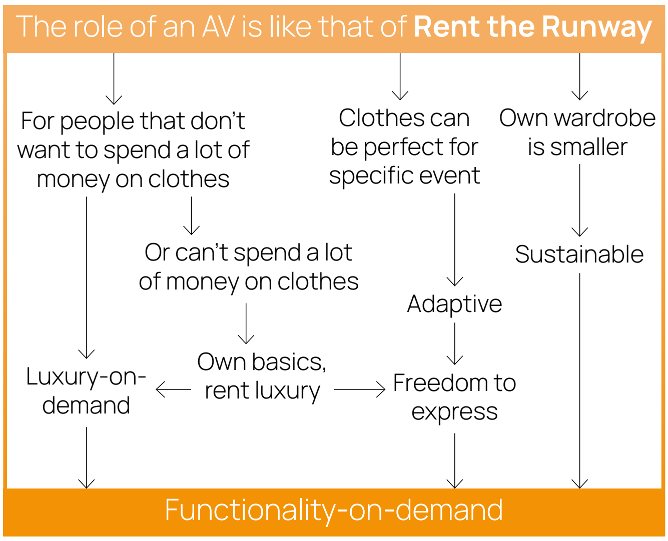


Figure 43: abstraction of Rent the Runway

04.2.2 Taalmaatje

Figure 44: Eritrean Desbele with his son William, and his Dutch 'Taalmaatje' Gerard

The analogy of Taalmaatje was found by the combination of QtE2, QtE5, UNaW1 and UNaW3.

Taalmaatje (translation: language buddy) is a volunteering programme in The Netherlands, that connects a Dutch volunteer to a person who is learning the Dutch language and trying to integrate into the country (often refugees or expats). The user of the programme (the refugee or expat) meets with their Taalmaatje at least once a week. In this time the user improves their language skills by speaking Dutch with their Taalmaatje, but the Taalmaatje also helps the user with their social interaction by taking them to events, introducing them to other people and by engaging in local traditions.

The characteristic QtE5 is very clearly identified in this analogy, as the programme helps the user to learn the new language. It solves their problem of not being able to communicate well in Dutch, therefore also providing a clear link to UNaW3. Both QtE2 and UNaW1 can be identified in the fact that the programme not only offers the users practice of the language, but it also helps them to get in contact with Dutch people. This means that beside its functional aspect, there is also a more social experience focus.

In abstracting this analogy, we can see that it refers to a role as a pre-set catalyst for community inclusion. This means that its goal is to help people be included in communities, perhaps if they are new or if they have some other need for more inclusion. It would do so by providing the first step, which may be scary or uncomfortable to people.

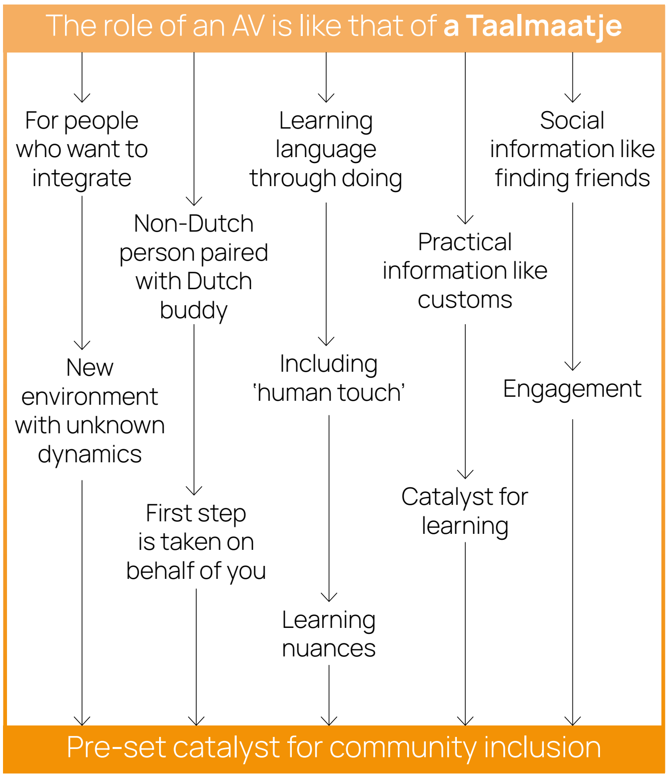


Figure 45: abstraction of Taalmaatje

04.2.3 Community Farming

Figure 46: people enjoying a community farm

The third analogy is community farming, which was identified through the combination of QtE1, QtE4, UNaW1 and UNaW2.

A community farm is a piece of land, often previously fallow and within a residential area, which people of a community around it have transformed into a farm. Here they can come together and plant fruits and vegetables, care for them and eventually harvest them. It's often very collaborative and cooperative, as the users work together in managing it. A community farm provides its members with homegrown produce, which is often more sustainable than what can be bought at a supermarket.

The most obviously apparent characteristic is QtE1, as these farms are by and for the community. The ground principle of a community farm is that it serves the community. They decide what gets planted, they tend to the crops, and they benefit from the harvest. In this thought we can also identify QtE4, as the community itself decides what they want to plant and eventually eat. Their farm can be specifically tailored to their wishes. Additionally, this characteristic can also relate to the fact that some community farms exist on previously fallow land. Rather than it just lying there empty and not being useful to the community, the land is now tailored to what the community wants to use it for. The communal aspect of the farm also relates to UNaW2, as the cooperation that is needed to run it means that the people that are involved have to be connected to each other. This can be through meetings about crop planning, but also simply by providing a place where the community comes together with a shared goal. This last notion additionally links to UNaW1.

On the abstract level, we can summarise this analogy as being a goal but also a tool. On the one hand, there are things to be gained directly from it. It serves a specific function to reach some goal. But, it is also a tool in that it also serves a larger purpose. It is a tool to reach a greater good.

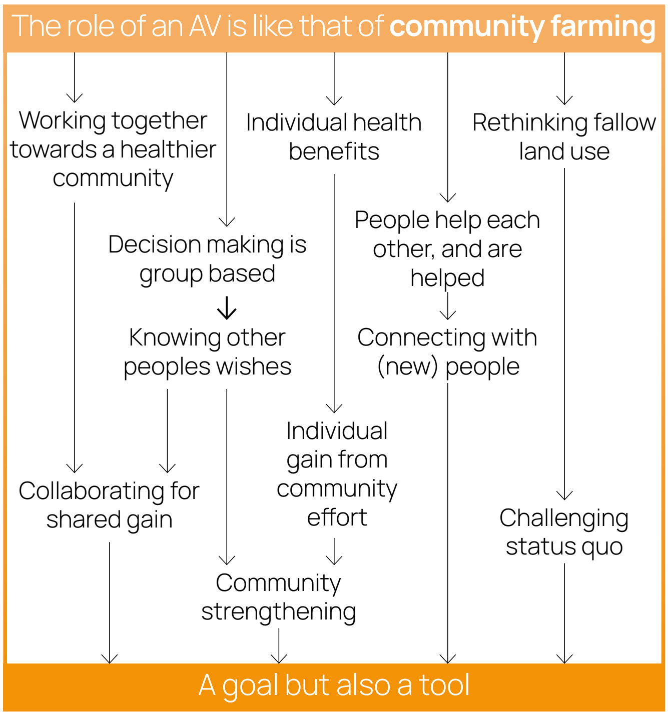
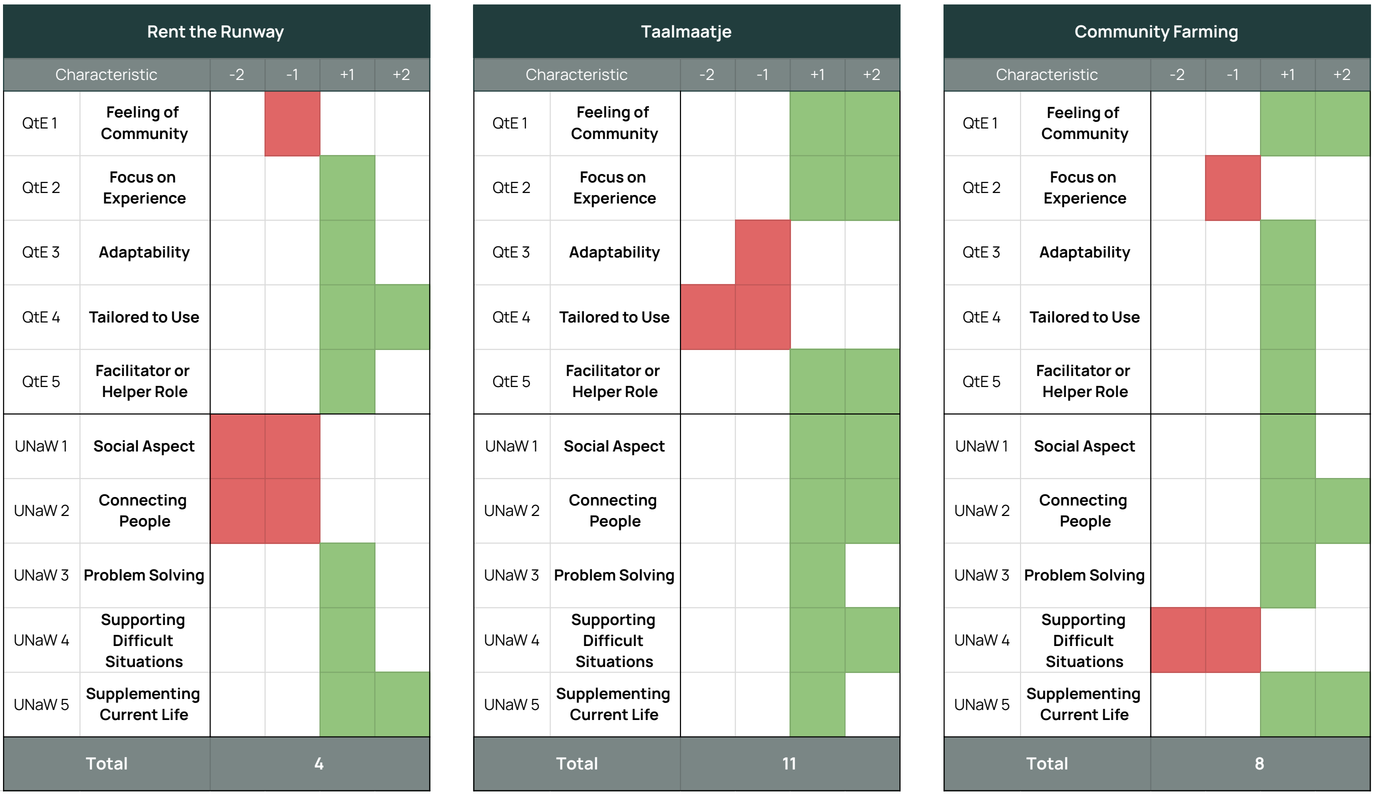


Figure 47: abstraction of community farming

04.2.4 Most Suited Analogy

All three analogies provide quite different perspectives on how we could view the relationship between AVs and humans. Rather than continuing with all three and presenting three possible visions, the decision was made to select one analogy and develop that further. The reason behind this is that the project is performed as part of the Integrated Product Design master programme, a large part of which is concept design. By selecting only one analogy, there is room for deeper development of one direction.

To select the most suited analogy to continue with, Harris Profiles were used. This is a graphic representation of the strengths and weaknesses of design concepts with respect to predefined design requirements (Boeijen et al., 2014), which in this case were the aforementioned characteristics. Figure 48 shows the Harris Profiles for each analogy. On the vertical axis are the ten characteristics (all weighted equally, see section 4.2), which is then given a score on the horizontal axis, ranging from -2 to +2. Scoring is based on to what extent each characteristic can be identified in each analogy, with -2 meaning it cannot be identified at all, and +2 meaning it can be very clearly identified in the analogy. A total score for each analogy was calculated from the sum of the scores from each characteristic. Figure 48 clearly shows that the analogy of Taalmaatje has the highest total score with 11 points, followed by Community Farm with 8 points and Rent The Runway with 4 points. As there is quite a large difference between the scores, we can say with some confidence that Taalmaatje is indeed the most suitable analogy. When continuing with this analogy, we should keep into account that QtE3 and QtE4 received negative scores, so extra attention should be paid to incorporating these characteristics into the final design.



Figures 48 a,b,c: three Harris Profiles

04.3 **Envisioning, Transforming: Design Principles**

In order to convey all of the combined findings and takeaways from the research, this report aims to develop a set of design principles. These design principles (DPs) are aimed at designers and researchers in the field of AV design.

To identify the DPs, all important findings and key takeaways were written down on post-it notes. These notes were then clustered together to find common themes among the findings. When finally five themes were identified, they were combined and summarised to formulate the set of five preliminary DPs that are explained below.

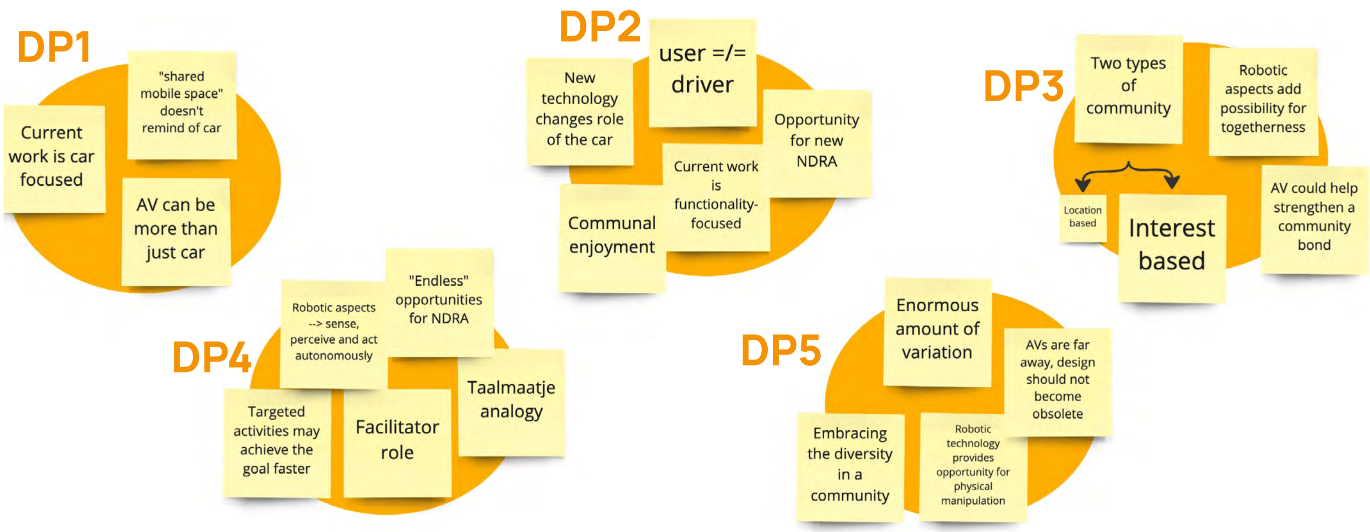


Figure 49: Clustering into preliminary design principles

DP1: AVs should be considered 'shared mobile spaces', rather than 'self-driving cars'

The developing technological field of AVs is one that sparks the interest of many designers and researchers alike. Especially within the fields of HMI/ HVI many scholars provide their input from different perspectives. However, most of these works still take a car-centric perspective. For example, this means that possible NDRAs that are investigated are ones that can currently be performed as a passenger in a non-automated vehicle (see section 3.3.4). When keeping this perspective, the full potential of what an AV could do or mean may not be accessed. After all, so much more is possible in an AV than what a passenger in a non-automated car can do. By shifting our view of AVs from 'self-driving cars' to 'shared mobile spaces' (see section 4.1.6), we also shift away from the conventions and limitations that are set in place by the current state of automotive development and design.

DP2: While Designing AVs, their community value should be considered

Throughout the history of the car, its role in our lives has changed through the advancement and introduction of new technologies (see sections 1.1 and 1.2). Each one of these developments has added a new sense of value to it, in such a way that it is different than it was before. As we are currently going through another new shift which is the automation of the driving tasks (see section 1.2), we know that the role and value of the car is on the brink of changing once again. Currently, the primary perspective that is taken towards the car is from the individual. Most cars are privately owned and used, and car sharing programs have yet to reach high popularity. However, the development towards autonomous vehicles means that there are more possibilities and opportunities for enlarging the community perspective towards AVs, and how they can add value to a community in which they operate (see section 3.4). Although there is some research and concept design that takes on this perspective, it is mostly focused on delivering extra function to a community (see section 3.2.2); additional work that focuses on the experiential value of AVs towards communities is necessary to ensure unlocking the full potential of AVs.

DP3: For communities that don't have a physical shared space, AVs can provide that space

If we take a community perspective, it is important to know what exactly a community is. In section 3.2.2 we see that a community can be location-based or interest-based, the latter of which does not necessarily have a specific physical space connected to it. These communities may have an online space, or a shared space in a more abstract sense. This presents a great opportunity for AVs, as their robotic qualities (see section 1.2, 1.3 and 4.1.5.2) make it possible to (autonomously) move between members of an interest-based community, and thereby connecting them in a physical fashion. This provides an extra level of interaction between community members, which may have a(n) (unconscious) need for a deeper bond (see section 4.1.5.2).

DP4: Targeted Non-Driving Related Activities should be used to catalyse community inclusion

When we adopt the newfound view of the AV (a shared mobile space that is intertwined with a community), we see on the one hand that the list of possible NDRAs is virtually endless (see section 3.2.1), but also that the AV can perceive, think about and interact with its environment (see sections 1.2, 1.3 and 3.3.7). Combining these two we see that NDRAs can be used to bind communities together (as seen in section 4.1.5). On the one hand, the mere existence of a shared mobile space may increase the community bond, however if we target the NDRAs specifically towards the goal of community inclusion the AV may be much more successful in fulfilling its facilitator-role (see section 4.2.2). So, instead of bringing people together in the AV and leaving their activity and connection up to chance, a targeted NDRA should be used to accommodate the users' wishes, needs, shortcomings and strengths.

DP5: Adaptability should be a core characteristic of AVs; robotics can be the enabling technology for this

If we envision the AV to provide very specific and targeted NDRAs, we cannot expect there to be as many vehicles as there are possible NDRAs; the amount of vehicles needed would then be colossal (see section 3.2.1). Rather, a core characteristic of the AV should be adaptability so that it can seamlessly facilitate different NDRAs. This means physically altering the space within the AV so that it can accommodate each NDRA as best as possible. Looking back at the original characteristics of robotics (see section 3.3.5) we see that it can be the enabling technology for the adaptability that is needed. After all, the AV should know or sense what use scenario it should adapt to, and then autonomously perform this physical adaptation.

Beside the physical adaptability that is needed, we can also see that adaptability in the design process of AVs is key. As AVs are predicted to still be decades away from being ubiquitous (see section 3.2.1), our design and research approach should take into account the changing landscape that surrounds AVs. If we keep relying on findings from the past, we may end up designing AVs that are already obsolete.

04.4 **Validating Quality: Expert Critique**

To iterate on the design principles, a number of experts were selected to review the preliminary design principles. These experts are both from academia and the industry, involved in a range of institutions, projects and companies that are related to the (autonomous) mobility fields (see table 8).

Expert	Domain	Expertise
1	Academia	AV HMI UI/UX
2	Academia	Automation systems, meaningful mobility through UI
3	Industry	AV (external) HMI
4	Academia and Industry	AV (external) HMI, AV interaction research
5	Industry	UX design at an OEM, focus on AVs
6	Industry	UX design at an OEM, focus on AVs
7	Academia	Mobility as a Service, seamless personal mobility
8	Academia and Industry	Automotive Design and Strategy

Table 8: expert participants

04.4.1 Procedure

The experts were selected via the personal connections of the researcher and the supervisory team. After a list with possible candidates was compiled, an invitation email was sent out to them with a short explanation of the project, its aimed outcome and the goal for the expert critique sessions. From these invitations, 7 sessions with in total 8 experts were planned. Of these sessions, 6 were one-on-one (researcher and expert), and one session had two experts who were colleagues (experts 5 and 6). Each session started with a brief introduction of the expert and researcher, in which background and fields of interest were discussed. After that followed a presentation containing a short summary of the work and research that was conducted up until that point, eventually leading to the preliminary design principles. These were then explained one-by-one, and discussed with the expert. To guide this discussion, a set of questions was formulated beforehand. Throughout each session, all useful insights were collected through vigorous note-taking. After all sessions had been conducted, these notes were compiled into clusters, which would then be summarised in statement cards (see section 3.2.1).

0: Preparation	1: Introduction	2: Presentation	3: Explanation of design principles & discussion
Goal: invite selected experts for a session, shortly explain the topic and goal.	**Goal:** introduce each other, talk about areas of expertise to identify overlap.	**Goal:** present a summary of the work until now, leading up to the preliminary design principles.	**Goal:** one-by-one explanation of preliminary design principles, discussing them from the expert's perspective.

Figure 50: expert critique procedure

04.4.2 Outcome

An overview of the expert sessions' outcomes can be found in table 9. From these statement cards the following insights can be summarised. First, nearly all experts (n=6) explicitly stated that they found the focus area within the field of AV research interesting, and that there is indeed a gap in research. Some experts even stated that they had pushed for their company/institution to focus more on the community aspects of AVs. The experts found that the general message that the DPs aimed to convey was inspirational and valuable. This is a very positive insight, which underlines that this project does indeed provide value to its research and design environment.

Secondly, the perspective that this project takes towards robotics and its connection to AVs felt novel to the experts, yet also recognizable. Indeed, the AV can be seen as a robot because of its capabilities, but the translation of this link to the more social-utilitarian role of a helper/facilitator was deemed novel and refreshing by several experts (n=5).

Lastly, the way that the preliminary DPs were phrased seemed somewhat inconsistent to several experts (n=4). One aspect of this was that the DPs varied in scope: some were quite abstract where others were very concrete and almost provided a singular solution. For example, DP1 was considered as a very high-level message, as a sort of overarching goal. To deal with this inconsistency, the DPs should either be rearranged to reflect the differing scope (e.g. from abstract to concrete), or they should be reformulated so they are on the same level. Another aspect of inconsistency was found in the phrasing and formulation of the DPs. Though there did not seem to be a consensus among the experts about what phrasing should be used precisely, some experts did point out that not all DPs carried the same weight. For example, DP5 was quite strong in its formulation (using "should") while DP3 used more suggestive language (using "could"). However, multiple experts agreed that all DPs were quite long, and that perhaps each one should be summarised with one or two words.

DP	Statement	N=
G	The phrasing needs some attention: it should be worded in a more convincing, powerful or memorable way.	4
G	The phrasing needs some attention: the strong wording could come off as unbelievable and unfounded.	2
G	It should be clearer who the audience is; it is yet a little unclear who these are aimed at.	4
G	The principles aren't on the same level: there should be hierarchy.	6
G	Some DPs seem to overlap. Each one should have its own specific domain.	3
G	I agree that there is indeed sometimes a lack of focus on community aspects in automotive design.	6
G	The link to robotics is new to me, but it is recognisable.	5
1	What exactly does 'shared' mean? Does it refer to shared mobility?	2
2	'Community value' is a little unclear and broad. What exactly does it mean?	2
2	Perhaps, the AV could be considered part of the community in an anthropomorphic way.	2
3	There seems to be a conflict here, the difference between physical and non-physical space should be clearer.	4
4	The scope of this project is SAE L5, which means there are no DRAs. Then, it may be strange to refer to NDRAs.	2
5	This DP seems more technical than the other ones; it's not on the same level.	3
5	Isn't adaptability important throughout the design process as well? we're talking about a far away future here, we can't set everything in stone yet.	4

Table 9: statement cards. In the first column, G refers to a general comment that does not relate to a specific DP.

04.4.3 Design Principle Revision

After the outcomes and insights were analysed, they were translated into a revised set of DPs. The first revision that was made relates to the difference in scope between the preliminary DPs, and more specifically to DP1. This DP conveys a general message or mindset that emerged from the entire project. In a way, this makes it transcend the other DPs, which all point to a specific (group of) finding(s) in this project. It is a notion that holds value in any situation, separate from the other DPs. To reflect this, DP1 is reformulated not as a DP, rather as an overarching goal that can be reached through implementation of the other DPs.

Following this decision, the uniqueness or novelty of DP2 could be questioned. Similar to DP1, DP2 also takes a more overarching goal. It discusses the importance of taking a community perspective towards mobility design and research (i.e., the meso level), which is a topic that is explicitly mentioned in DP3 and DP4. A second aspect of DP2 is the argumentation for more experience-focus rather than functionality focus, which is something that can be included in the overarching goal as well. Therefore, it was decided to eliminate DP2 as a standalone principle, and to include its aspects in the other DPs and overarching goal.

The 3 remaining DPs are reformulated in accordance with the last main insight as mentioned in the previous section 4.4.2. This firstly means that they are reformulated to one or two words, making them strong and memorable.

AVs should be considered ‘shared mobile spaces’ rather than ‘self-driving cars’.

[DP1] **Nonsimultaneously Connected:** An AV can be the physical space that interest-based communities non simultaneously share.

[DP2] **Tailored:** Targeted Non Driving Related Activities should be used to catalyse community inclusion.

[DP3] **Adaptable:** Adaptability should be a core characteristic of an AV, therefore also to its design process.

04.5 **Ideating, Integrating, Realising: User Scenarios**

The design principles that are presented in the previous section, may seem somewhat abstract. To provide a view of what following these principles could look like, an example storyboard or scenario would accompany each design principle. The process of creating these storyboards is explained in this section.

As there are three design principles, three storyboards needed to be generated. Each one of these scenarios focuses on a different community, to mirror the large variation in community types. As the interest-based communities cover a greater number of possible examples, two scenarios were chosen to cover this type of community, and one that covers a location-based community.

To develop these specific examples, three people that belonged to specific communities were selected through the researcher's own network. In the selection process the researcher looked for possible opportunities between certain communities and design principles, finally deciding on one community for each of the three design principles. Each participant was invited to an informal conversation-style interview in which the researcher explained the specific design principle that was chosen for their community. Then followed a conversation with the participant in which they explained some characteristics of their community and what they felt their community was missing. After creating a shared understanding of the community, the researcher and participant ideated on the possible role of an AV within that community, and how it could fill the previously identified needs or wishes. This last phase included several creative techniques like brainstorming, brainwriting and mindmapping. A summary of the three sessions can be found below.

04.5.1 Session 1: Nonsimultaneously Connected

As this design principle explains that an AV can help interest-based communities to have some sort of physical connection, the example scenario therefore also had to include an interest-based community. In this case, that community was one that plays a fantasy tabletop role-playing game called Dungeons and Dragons (D&D). In this game the players represent different, often mythical, creatures that all work together to complete a set of adventures. These adventures are set in an imaginary world which the players can modify themselves. This makes it possible for each group to have a unique world with unique features, rules and laws. Each group of players has a Dungeon Master (DM) that facilitates the game, fulfilling a sort of narrator-role. The DM talks the other players through the adventure and asks them what they want to do when certain situations arise (for example, a hostile elf is threatening to rob them). By rolling a set of special dice the outcome of the players' actions are determined. This game may be accompanied with a physical board that represents the world, but because the DM is responsible for guiding the players through the game, a physical board is not necessary.

This is also the case for the interviewee's group; the interviewee is the DM for a group of players that always plays online or over the phone. The DM facilitates the game while the players listen and talk their actions through. They have chosen this format because they don't live close together, so the online format allows them to play the game without having to travel for a long time. This group has also chosen to create their own world, rather than playing a premade one. The interviewee states that in creating the game, they have tried to incorporate the wishes of all other players, but that that was sometimes challenging as they could never work on it while being together. As the world was created just by one person, it also resulted in the other players sometimes not knowing certain specifics of the world and therefore being negatively surprised. For example, some geological features of the world may affect the outcome of decisions that need to be made, so if these features are not known to the players then they may not be able to make good decisions. The interviewee saw an opportunity here, as they thought a deep shared understanding of the world could help the players in completing their adventures, thereby omitting possible frustrations.

The main hurdle preventing the collaboration on world-building was the geographical distance between the players, which could be perfectly mitigated by the AV as it is able to autonomously move between players. One idea that was explored involved the users being present in the AV all at once, however the interviewee stated that since the group members lived so far apart, the travel time would be very long (they estimated ±6 hours in total). Additionally this idea does not fully fit into the envisioned design principle, as it does not focus on nonsimultaneous connection. A second idea that was explored was that the AV would still drive past all group members, but they would use it by themselves. In this AV, they could find a physical representation of the world that they will play, which they can alter themselves. This means that they can for instance place geological features, create villages, change laws or rules, etcetera. When a player is finished with their iteration, the AV goes on to the next member who can inspect and alter the world to their liking. The interviewee stated that this scenario could create more understanding among the players about the world, but it could also create a more personal connection to the adventure as they had created the world all together.

04.5.2 Session 2: Tailored

The second DP was found to be suited for a location-based community, as it was closely linked to the Taalmaatje analogy. In this analogy a person that is unfamiliar with the culture of a community that they are (going to be) living in, so for the example scenario for this DP a similar situation was required. This was found in a person that moved from one of the northern provinces of The Netherlands to the southernmost one (Limburg). While they still remained in the same country, the interviewee found the move challenging because the culture differed more than they initially thought. They stated that their neighbourhood was quite a tight and well-connected one, and it was hard for them to become part of it. There were some instances where they were invited to a community event, but the interviewee found those hard to participate in as they were all events having to do with the local culture, which was (at the time) unknown to them. One such instance was the neighbourhood's annual vlaai-baking contest. Vlaai is a type of pie that is traditionally from Limburg, which requires some specific baking instructions. In this contest, the neighbours all make a vlaai according to their tradition, often following recipes that are passed down from generation to generation. As an "outsider", the interviewee felt hesitant to enter the competition without any prior knowledge, relying solely on a recipe they found online.

In discussing the interviewee's struggles, an idea for an AV opportunity came to mind quickly. Though the interviewee was invited to the baking contest, they had no idea about the history or preparation process of a vlaai. They had also heard that the generation to generation recipes often included sourcing ingredients from specific shops or markets. The AV could assist in this by getting the outsider (in this case the interviewee) together with an insider, for instance for a shared commute. During this commute, they could take a detour past some of the specialty shops where the right ingredients for the vlaai are being sold. By giving the ride this secondary purpose, the insider can teach the outsider about the tradition and why certain ingredients are better than others.

This use case does mirror the Taalmaatje analogy, however the connection to specific NDRAs was somewhat lacking. A discussion with the interviewee then followed, exploring the opportunities for more specific and fitting NDRAs in this scenario. The interviewee stated that they now know how to make a vlaai, but that it involved some technique that they were previously unfamiliar with. For example, the yeast-dough needs to proof a certain way and there is a certain technique behind the lattice crust. As the pie is regional, they found it hard to find good resources online. This presents an opportunity for providing NDRAs in the SMS. During the ride, two members of the community could prepare a vlaai together, while the SMS provides the necessary equipment and setup. For example, an outsider and insider could be linked for a recurring commute over the course of a few days. On the first day, they could take the aforementioned detour and gather the necessary ingredients. On the second day, they could mix the ingredients for the dough and place them in a proofer, ready to be rolled out and moulded into shape the next day. By combining these activities with their daily commute, the community members may find it easier to connect with each other, as the threshold to get together is substantially lowered.

04.5.3 Session 3: Adaptable

Arriving at the last session, the selected community should be an interest-based one. In this case that was a group of colleagues that all work on a petrochemical plant. It should be noted that although this community is technically an interest-based one, it could be argued that it is a location-based community as well. The members of this community have a shared interest of some sort - they work for the same company, but they also work in the same geographical location, i.e. the campus. Looking at the Oxford and Cambridge definitions for community (see section 3.2.2), we see that they both clearly state that the community members should live in the same location. Therefore, we will consider this community to be an interest-based one, not a location-based one.

The petrochemical plant that the interviewees and their colleagues work on is housed on a large campus, with many different office buildings. Additionally, there are some buildings that are off campus, about a 20-30 minute drive away. On a regular day, the interviewee stated that they often have to move between buildings for different meetings or inspections. They estimate that in total they have to travel for an hour a day, not including their commute from and to their home. There are some shuttle buses, but those drive rather infrequently and have few stops. This can cause scheduling problems when the travel time is not taken into account. Additionally, people sometimes take their breaks during these work trips to save time, but the interviewee said that those breaks do not feel like breaks. Therefore the interviewee saw great potential in using AVs to provide these trips between office buildings, as they can make seamless trips from beginning to end, and they provide opportunities for making more efficient use of their time. In the past they have tried to have meetings during on-campus trips, but because the environment wasn't very suited for that, those meetings proved to be unsuccessful. Using AVs could solve that problem, as they could provide good chairs, a table and other supplies they may need. While exploring this idea further, the interviewee also thought that it could enhance break time. For example, one of their main hobbies is to paint. They say that it helps them calm down and unwind from a hectic day, and said that it seemed like a perfect activity to do during a break.

The combination of these two examples fits perfectly within this DP. The two activities (painting and having a business meeting) are quite different and both require specific features within the AV. This can be translated into a multi-purpose campus shuttle that employees can reserve. Depending on their needs, the AV would provide the perfect environment for them to have a break or use their trip-time as working time. Because of the vast amount of possible activities, the AV needs to be highly adaptable. This could be solved by using robotics, that transform the AV into the correct configuration in between trips. By incorporating a high degree of adaptability, obsoletion can also be omitted. After all, if certain aspects of the AV are not useful anymore, they can just be taken out.

05 Discussion

After finalising the last main part of the project, this chapter takes a higher look on its surroundings and analyses the limitations and implications that it may have in the broader field of AV design and research.

05.1 **Design Principles**

The DPs and the accompanying example scenarios advocate a novel perspective on AVs. To convey this message more strongly, each scenario can be compared to work that already exists. Through this comparison we can see the missing links in current work, which can help future designers and researchers in finding their focus area.

05.1.1 Nonsimultaneously Connected

To reflect this DP to other work, we take a closer look at the provided example scenario. D&D is a cooperative game, but the process of building the world isn't. In online fora (e.g. Reddit, 2019) some worksheets exist that aim to bring a cooperative aspect into world-building as well. These sheets contain tips and exercises for the players to guide them through the process of creating a world. However, these sheets are not interactive; they are merely notepads that are aimed to guide a conversation. Some examples can be found of people using more interactive platforms to play D&D (e.g. VincentDN (2020) uses Miro), but these examples lack the aspect of collaborative world-building. We can see that in a situation like this, the AV provides added value in two ways. The first and foremost is the aspect of autonomous mobility. This makes it possible for a space to be available to all players without them sacrificing travel time or effort. In this space they can have a dedicated environment to iteratively build a world. The second aspect is the robotic qualities that an AV possesses. This makes it possible to add some physical component to cooperative world building, in contrast to other interactive platforms like Miro. This physical component may enhance the world-building experience by creating a more immersive workspace.

In reviewing the greater aspects of this DP and example, we can see that this view of nonsimultaneous connection through AVs can indeed be considered novel. Apart from a few anecdotal examples that were mentioned by experts, no published work that takes on this view could be identified over the course of this project.

05.1.2 Tailored

A few instances of mobility systems can be found that have the goal of connecting communities through mobility, two of which are RanchRide and Vallecar. RanchRide is a community shuttle service that aims to connect people of the new Rancho Mission Viejo community (near Los Angeles, California, USA) to events nearby, as this community is currently underserved by other forms of public transport (RanchRide, n.d.). This service does indeed connect people from a community to each other and does provide an opportunity for an enhanced connection between people. Where RanchRide is a company-organised service that operates on (semi-)fixed routes, Vallecar is community-organised and more flexible. It was started by a group of people that needed rides between the Tiétar Valley (central Spain) and Madrid, as bus services run infrequently and unreliably. They created an online group where people needing and offering rides could connect. People using the service report that next to providing mobility, it has also brought them good friendships.

We see that these two services have a similar goal as to what is described in this DP, however the DP goes a step further in its way of achieving that goal. RanchRide and Vallecar bring people together inside a vehicle, but the connection between passengers is completely left up to chance. It is almost viewed as a byproduct of mobility. This DP provides an additional and novel way of ensuring human connection by more closely including aspects of robotics. These aspects make it possible for the AV to know exactly who is entering it and what their goals, wishes and preferences are, and is able to make decisions and adaptations to its inner environment based on those. Through robotics it is able to estimate and facilitate a tailored NDRA that will engage all passengers equally.

05.1.3 Adaptable

The third DP is focused around adaptability, both in the physical design and the design process of AVs. Some work can be found that is related to the physical adaptability of vehicles, mainly centred around modularity. Concepts like the Rinspeed Dock+Go (Rinspeed AG, 2012) and the Mercedes-Benz Vision URBANETIC (Mercedes-Benz AG, 2018) incorporate different modules that can adapt the vehicle to what is needed at that specific moment. Both of these concepts have a very functional focus; they offer added functionality instead of added experience. In contrast, the work that is presented in this report aims to take a more experiential focus. Rather than being able to also provide cargo transport (like Mercedes-Benz's concept), this adaptability described in this work aims to facilitate the users' variety of preferred NDRAs.

Some other related concepts can also be identified which focus more on the AVs interior, like the BMW Vision iNext (BMW AG, n.d.) and the MINI Vision Urbanaut (MINI, n.d.). Though their focus is more on the experiential aspects than the previously mentioned examples, they do not specifically facilitate a larger amount of NDRAs. Rather, they use robotics to transform the interior from driving mode (they are automated, not autonomous concepts) to a 'living space'. In this space the user could technically perform a number of different NDRAs, however in contrast to this DP the BMW and MINI concepts are not specifically designed to assist in these activities.

05.2 **Limitations**

As this project is an exploratory one, it inherently has limitations. In the first place this relates to the participant sample size of each test, especially the co-creation workshops. Because of a small sample size, it is more likely that the group will consist of individuals with similar backgrounds, experiences and perspectives. This could lead to a lack of diversity in the ideas that are generated and perspectives that are taken. Additionally, the lack of diversity may limit the ability to generalise the findings to a larger population. Though it was attempted to mitigate this limitation by carefully selecting participants and experts to ensure heterogeneity in background factors, they may still be considered rather homogenous. A large sample

Second, the setup of this project is mainly theoretical and lab-based; it does not include immersive tests such as a field-test or bodystorming. Even though in each step of the process a real-world scenario was tried to be emulated as well as possible, immersive testing provides a more lifelike environment which may help participants to imagine themselves in the aimed situation or use-scenario.

A third limitation regards the timeframe that is taken in this project. From the outset the project is constrained by the level of automation, as it focuses only on autonomous vehicles. Currently the state of technology is mainly in assisted vehicles; and experts estimate that autonomous vehicles are still decades away from being commonplace. This means that this project takes a rather far view into the future. We cannot say with certainty that the findings that are presented here will be completely relevant in the targeted future. That being said, the point of this project is not to set in stone what future AVs must look and feel like. Rather it means to provide inspiration and guidelines for future work.

Finally, a more general limitation is the inherent time constraint that a master thesis has. This study consists of a number of different steps, all of them constrained by time. This constraint means that some steps may not be as elaborate as they could have been without a time constraint. For example, the acquisition of participants for the co-creation workshop was a rather tedious and labour-intensive process, as each group should be a community, which made scheduling a challenging process. Would there have been more time, then perhaps more participants could have been recruited, resulting in a larger and more heterogeneous participant group.

05.3 **Implications for Design**

The results of this study can be beneficial for designers and professionals working in the field of AV design in multiple ways. Firstly, the design principles presented in the study can serve as a source of inspiration for designers to consider not only the individual's perspective towards AVs, but also how AVs fit within and interact with communities. By following these principles, designers can approach their work with a novel perspective which can lead to more meaningful and useful AV designs.

Furthermore, the design principles outlined in the study provide a vision for the potential role of AVs in human society. Although these principles may not be directly applicable to current automotive design, they can be used as a long-term goal to guide designers in the intermediate steps towards autonomous vehicles. By keeping these principles in mind, designers can ensure that their work aligns with a vision of AVs that positively impacts human communities.

Lastly, by understanding the impact of AVs on communities, designers can create solutions that consider the needs of all stakeholders and promote inclusivity. The principles presented in the study can be used as a framework for designing AVs that foster social cohesion, provide added levels of community experience and improve the overall well-being of communities.

05.4 **Implications for Research**

For researchers in fields related to AV interaction, the presented design principles may also be useful as inspiration. This study identifies that there seems to be a dearth of knowledge and perhaps interest in the community aspects of autonomous mobility. This in itself could serve as encouragement for researchers to study the area more carefully.

Additionally, the study can also be seen as a call for researchers to adopt a less car-centric approach to AVs. The outcome of this study suggests that by doing this, a larger potential application and interaction space may be unlocked.

Finally, the overlapping domain between AVs and robotics may need to be explored and researched further. This study does identify that the role that robots have in human lives can be applied to AVs on a somewhat abstract level, yet it doesn't focus on the more tangible and physical qualities of robotics. It lays the groundwork for the connection of these technologies, but it leaves room for researchers to deepen this exploration and to find more concrete applications.

05.5 **Conclusion**

This project has explored the space that exists in the combination of AVs and robotics, and how this combination could add value to humans' lives.

Initial related work review in human vehicle interaction and robotics identified that there is a large amount that takes on many different perspectives, revealing the need for a narrower scope. The adjusted scope comprised a focus on the meso level human vehicle relationship (i.e. the relationship between one vehicle and the community in which it operates) as the autonomous and robotic nature of AVs shows promising opportunities for taking on a less individualistic perspective.

In the synthesising stage that followed the RTDP, user insights gained from co-creation workshops found that communities see AVs as a sort of enabler or facilitator to help them in filling in social or practical needs they may have. This resonates with the view that people have towards robots; they are autonomously acting physical helpers that make our lives better by performing tasks humans can not or don't want to perform. Combining these findings with takeaways from the related work review, a set of design principles was formulated through different steps of analysing, envisioning and ideating. After an expert critique session the design principles were finalised.

These principles are aimed towards practitioners and researchers in the field of autonomous mobility, advocating a less car-centric and more community focused approach to their work. By providing example scenarios for each design principle, this work hopes to inspire practitioners and researchers to adopt these design principles and focus their work towards the creation of an AV future that is beneficial to communities as well as individuals. By taking on this perspective, we hope to offer a more complete and comprehensive understanding of the AV design space and to ensure a positive impact of this potentially disruptive technology.

06 Sources

After finalising the last main part of the project, this chapter takes a higher look on its surroundings and analyses the limitations and implications that it may have in the broader field of AV design and research.

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07 Appendix

Appendix A **Workshop Test Plan**

0: Preparations (asked to be read before the workshop):

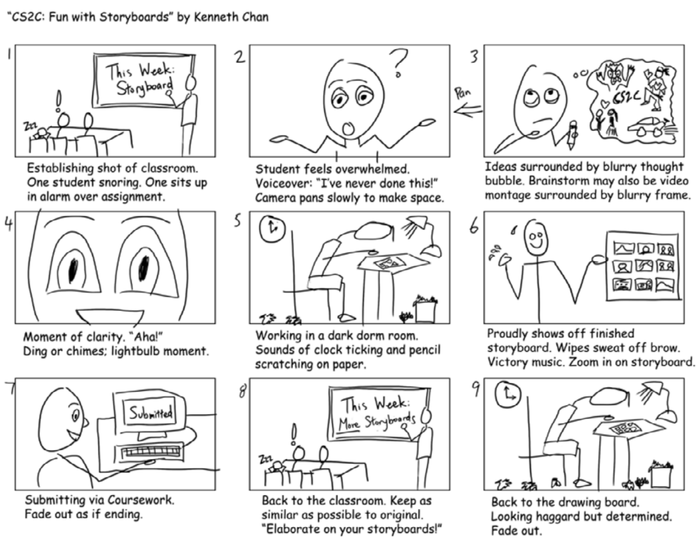
Thank you very much for agreeing to participate in the workshop! It will take about 90 minutes, and to make the most of the time we have during the workshop, below you can find some information about what you are going to do and what methods you will be using. On the second page you'll find the Informed Consent Form which outlines what data will be collected, how it will be handled, and finally you can give your consent to participating in this research. You don't need to sign or print it beforehand; a printed version will be available during the workshop. Please read this before the workshop. If you have any questions, we can discuss them at the start of the workshop.

Your task: find out how a "shared mobile space" (to be defined by you in the workshop) can add value to the life of every person in your group. Examples of this are:

- A local shop owner who instals a parcel locker. This generates extra revenue for them, while giving the people living in the neighbourhood a more hassle-free delivery experience.
- Community farming or cropsharing: a piece of fallow land in a neighbourhood is converted to a farm, where people from the community come and help fertilise the land, pull out weeds, plant new crops, and so on. This system is beneficial to the landowner because they now have use for a piece of land that was previously unusable, from which they can generate income. Simultaneously, it is beneficial to community members because they can harvest locally grown food.

The activities that you are going to do to perform this task are the following:

- How Might We notes: instead of writing down notes or ideas in a normal way, you can rephrase them to start with "how might we …". It may seem a bit strange at first but writing notes like this helps promote thinking positively instead of thinking in obstacles. For example: a medical trial matching company was trying to optimise and streamline their process. Instead of writing a note like "patient acquisition is difficult", it can be rephrased as "how might we redefine patient acquisition?". Or: rephrase "key patient screening information is messy and unclear" as "how might we structure key patient screening information?"
- Crazy 8's: this is a fast-paced way of generating the first ideas. Fold a piece of paper into eight pieces. Take one or two of the most interesting How Might We notes, then use each of the eight rectangles to quickly sketch a solution or idea related to the How Might We note(s). Take one minute for each sketch, so eight minutes in total. They don't have to be beautiful sketches, as long as you can make your idea clear. You can also use text to support your idea.
- Storyboard: a storyboard is a visual representation of a story or narrative about your design in its context of use over time. Start by thinking about what different steps your users will go through. Then, make as many squares on a paper as there are steps, and draw each step of the storyline. Try to incorporate things like: how is the user feeling? Why are they doing what they are doing? Do they interact with other things or other people? A storyboard can look like this:



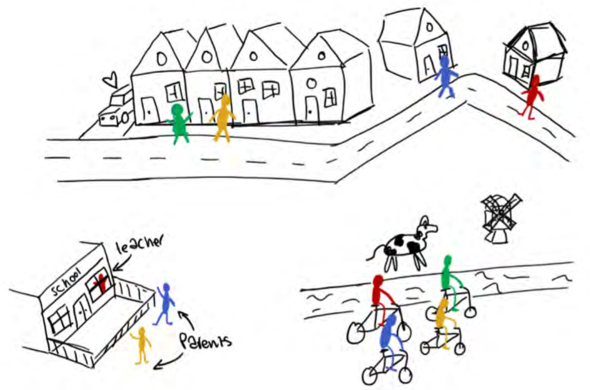
1: Who are we as a group? [10 min]

Goal:

Let the participants think about and sketch what binds them together as a group, as a sensitising and icebreaker exercise. Thinking about what makes them a group creates a group-focuses mentality, while the drawing prepares them for the later creative activities.

Activity:

Using a large paper or a whiteboard, the group will sketch the environment in which the group exists. They are encouraged to think about and incorporate questions like: where do we see each other? How did we meet? What activities do we do together? What is the link between us? What are shared or conflicting interests? The image below can be used as an example. Note that the example is deliberately 'ugly'; this is to show the participants that their sketches do not need to be beautiful, they should merely convey their message.



Aimed Outcome:

A group environment sketch, including the group's essence.

2: What is a mobile shared space? [10 min]

Goal:

Finding out what people think a shared mobile space is; what are their mental boundaries in this? By providing the example definition for robotics, they are already introduced to the concept of robotics, so that the last step may come easier.

Activity:

Brainstorming about the definition, the definition of robotics (from the report) is given as an example. During this stage the group is asked to think about questions like: what should the space be able to do? Are there any restrictions to it? Does it have a specific function? Are there any other requirements? Simultaneously they are asked to write down How Might We notes to use in the next stage.

Aimed Outcome:

A definition for a shared mobile space, including a few defining characteristics.

3: How can the space add value to the meso level experience? [50 min + 10 min break]

Goal:

How do end-users with a non-design background ascribe meso-level value (for examples of this see section 0) to a shared mobile space, and how do they deal with every person's wants and needs?

Activity:

When this stage is started, it is made clear to the participants that we are not asking them to come up with a design; we are just interested in the use of the space.

3.1 [10min]: First start with crazy 8's using HMW notes (individual exercise), with as a goal: how can a shared mobile space add experience for us all or individually?

3.2 [10min]: Discuss all the Crazy 8's and find interesting ones. Perhaps, there are some that can be combined or used together. Use them to find 2 or 3 interesting use cases for a shared mobile space, in which everyone in the group benefits from it. The group is encouraged to think about the combined use, but also individual use. Once again, the focus here is not to design a vehicle, rather to think about how it is used.

3.3 [10min]: Break.
3.4 [30min]: Once a few use cases are found and formulated, they are worked out more deeply in scenarios. In these scenarios each group member should be represented using the shared mobile space.

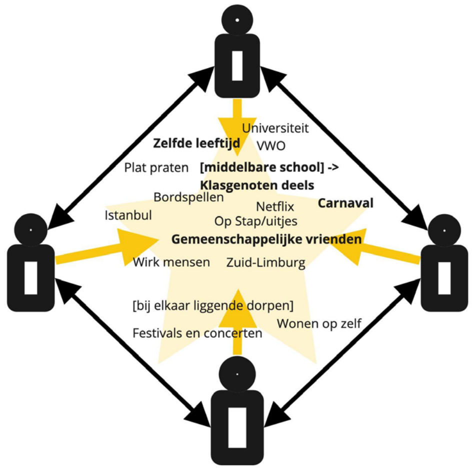
Aimed Outcome:
Scenarios of the shared mobile space.

4: How can robotics assist in the scenario? [10 min]

Goal:
Gain insights from end-users with a non-design background on the possible application of robotics.
Activity:
The group is reminded of the definition of robotics, and is asked to look back at the scenarios they created. They are asked to perform a quick iteration on these scenarios, using sticky notes to envision the areas where and how robots can help to add meso-level experience.
Aimed Outcome:
Possible application areas for robotics.

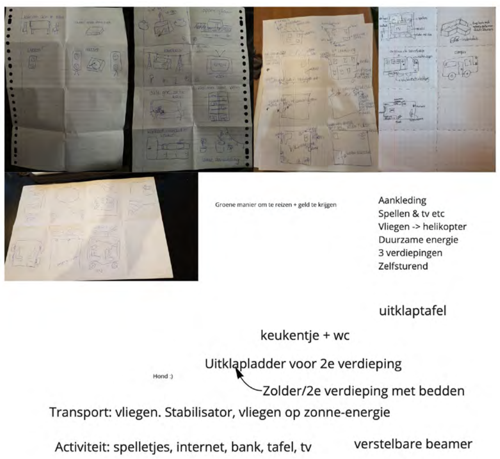
Appendix B **Outcome of Pilot Test**

The participants of the pilot test were a group of friends that lived very close to each other before, but they currently all live in different cities and therefore don't see each other very often. They defined their group as going to parties together, and celebrating carnaval (a local holiday) every year. The participants then designed their scenario to mirror this, resulting in something that is reminiscent of a 'partybus' – a thought which they also noticed themselves. Interpreting this result according to the Iceberg Model, it can be interpreted that this is the manifestation of their desire to see each other more often, and to go back to the good times they had in the past.

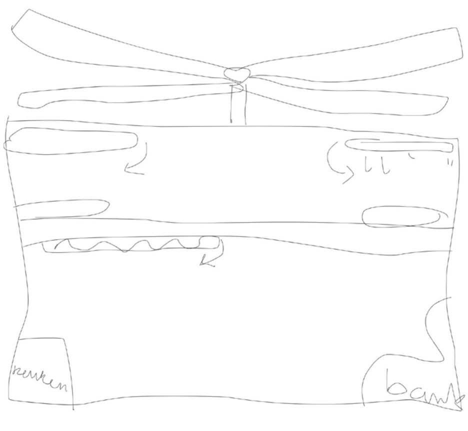


1: Introduction

2: Define



3: Discuss



4: Present (design)

We gaan samen op stap. Hij staat op een vaste plek geparkeerd.
De shared space is ons vervoer. Haalt ons een voor een op, shared space vliegt op zonne-energie. Haalt eerst [P2] op in [stad], dan [P1] in [stad], [P4] in [dorp] en [P3] in [stad]. Vliegt ons samen naar Berlijn. Tijdens het vliegen gaan we indrinken in de shared space. Drinken staat in de koelkast + snacks kunnen we maken in keukentje. Muziek staat aan.
In Berlijn parkeren we de shared space ergens. Gaan op stap en dan komen we terug. Gaan dan op de bovenverdieping film kijken en slapen. Daarna dezelfde route terug om iedereen weer thuis te brengen en de shared space gaat terug naar de opslagplek/parkeerplek. Hier kan hij met de zonnepanelen energie verzamelen.

4: Present (scenario)

Personal Project Brief - IDE Master Graduation

The Dynamic Human-Vehicle Interaction through Robotic Interaction Systems

project title

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

start date 11 - 07 - 2022

09 - 12 - 2022 end date

INTRODUCTION **

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

In recent years, the relationship between car and human is changing. On one hand, technological innovations make it possible for cars to be increasingly digital and automated. This radically changes the way we interact with the car, as autonomous vehicles (AV's) do not require the driver to engage fully with driving tasks for the entirety of the trip. This makes it possible for them to spend time on tasks that they were previously unable to do in the car. Additionally, the digitalization of the car's controls can support the driver's non-driving related tasks. However, this also means that the way we physically interact is becoming more meaningless. Where a car's features were previously controled through tactile buttons, switches and sliders, we now access everything through touchscreens.

On the other hand, we also see a more societal aspect to our the changing relationship. Increasing awareness about the environmental impact of mobility has made us rethink how we move around. Where two-car households were previously commonplace, we currently see a shift towards more shared mobility. This use-when-you-need-it form of car use is much more resource efficient because multiple people share one car, but it also means that cars aren't owned by individuals anymore.

Taking these changes as a high-level domain, this graduation project will more specifically focus on (sub-) robotics, and how the technology can have an impact on the human-vehicle interaction. The perspective that is taken will be from varying levels of human interaction (individual-group-society-humanity).

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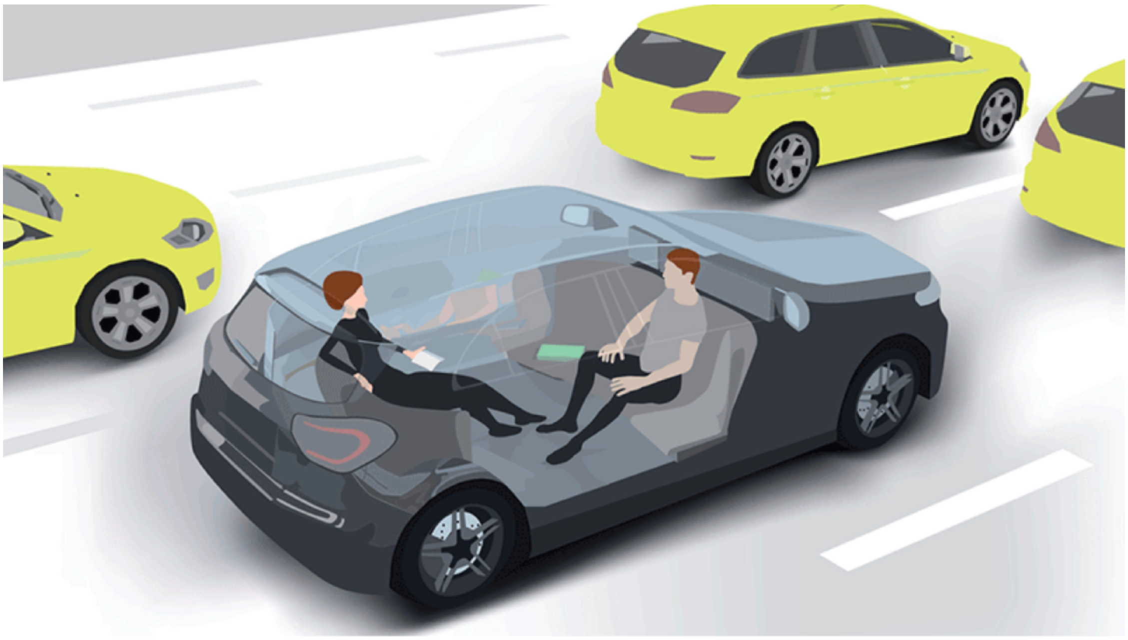

image / figure 1: AV's can change how people view a car, both from a passenger and fellow road-user view.

TO PLACE YOUR IMAGE IN THIS AREA:

- **SAVE THIS DOCUMENT TO YOUR COMPUTER AND OPEN IT IN ADOBE READER**
- **CLICK AREA TO PLACE IMAGE / FIGURE**

PLEASE NOTE:

- **IMAGE WILL SCALE TO FIT AUTOMATICALLY**
- **NATIVE IMAGE RATIO IS 16:10**
- **IF YOU EXPERIENCE PROBLEMS IN UPLOADING, COVERT IMAGE TO PDF AND TRY AGAIN**

image / figure 2:

PROBLEM DEFINITION **

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

The goal of this project is to conduct exploratory research and ideation on the relationship between human and (autonomous) vehicle, using (sub-)robotics as a means of interaction. This will include contextual research from technological, societal and environmental perspectives, as well as research into the smaller scale interactions between user and vehicle. Additionally, exploratory research into (sub-)robotics will be conducted. This will not include deep technological research into increasing performance or safety of the vehicle, as well as driver distrust and information support systems.

The solution space that stems from this research will follow the same limitations and scope. Small scale experiments will be conducted to support and validate the decisions and solutions.

ASSIGNMENT **

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

Research on the macro, meso and micro levels will be conducted to analyse the relationship between cars and humans, and how a (robotic) Human Machine Interface influences that relationship. The research outcome will be used to ideate a concept that adds value to the human experience.

To elaborate, macro/meso/micro here refers to the level at which humans interact with vehicles. For instance, on one hand there is one human interacting with a car by driving it. On the other hand humanity at large interacts with vehicles too, but in a more abstract way. What exactly macro/meso/micro entails will be part of the research.

The aimed outcome is a proof-of-concept model of (part of) a vehicular HMI system, complemented with a context map or video that elaborates on the more holistic parts of the concept. This could for example mean the vision behind the concept and interaction. As the intention behind the project is about exploring interaction, the concept will not go into technical or strategic detail.

Initials & Name S.J. Moonen Student number 4970578

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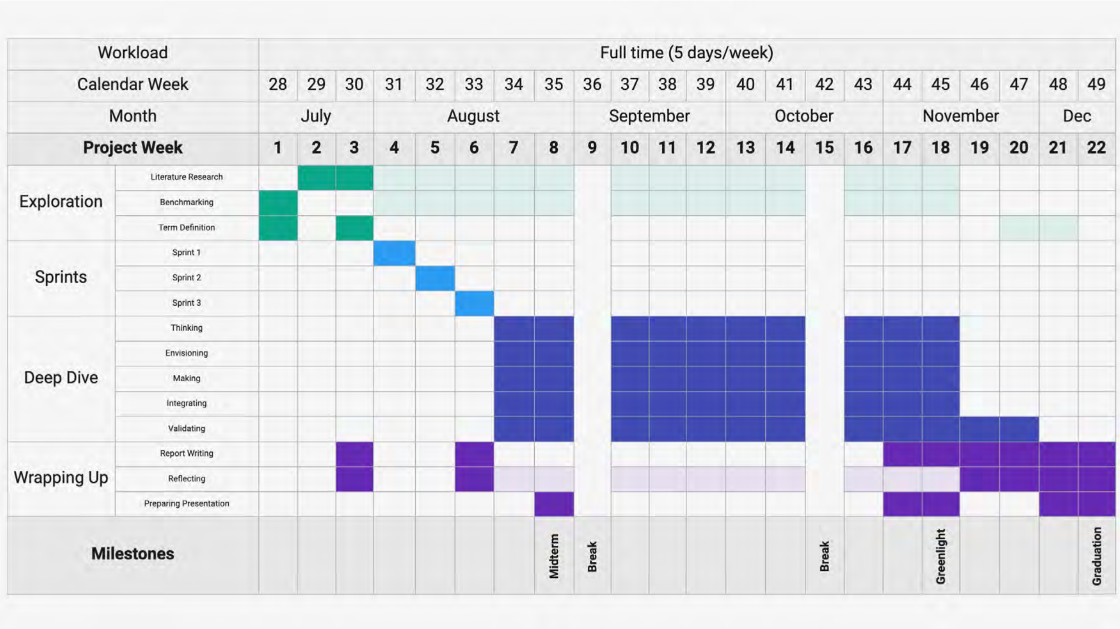
PLANNING AND APPROACH **

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

start date 11 - 7 - 2022 9 - 12 - 2022 end date



The project will start with an exploration phase which will consist of literature research, benchmarking and term definition. The former two activities will be present during the entirety of the process, as inevitably more new subjects will present themselves. After the initial exploration, three consecutive sprints will be conducted in order to narrow down a direction. These will be the base for the deep dive stage, which will follow the Reflective Transformative Design Process. This means that there will be constant switching between the five activities, through reflecting on the previous steps. After completion of each phase there will be room for reflection and report writing. The final four to six weeks will be dedicated to wrapping up the project.

MOTIVATION AND PERSONAL AMBITIONS

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

Throughout my bachelor and especially my master I've been focusing on the user interaction in mobility. Both my ACD and AED projects were done in this field too, which will be complemented quite well with the graduation project described in this document. In order to add to my skillset as a designer, I've set the following goals:

- To conclude my IPD master, I'd like to deliver a design demonstrator at the end of this project. The format of this can be physical, digital, or mixed; whichever applies best to the outcome.
- In previous projects I already gained some basic knowledge on robotics and complex systems, and I think this project is a great opportunity for me to deepen my knowledge on these topics and the combination of them.
- In the past, I've had a tendency to work in a somewhat unstructured way. Although I've already improved quite a lot during my last two years of studying, I would like to take this even further and experiment with the Sprint methodology. I think this project lends itself perfectly for this, as there is a strict time-deadline. Additionally, it is a popular methodology in the working field so I think it will help me greatly in my future endeavours.
- As an academic designer, I think it is important to have the skill of conducting your process in a proper and scientific manner. To support this skill, I would like to challenge myself to write a scientific article. However, this goal is contingent on the fact that it fits within the project.

FINAL COMMENTS

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

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