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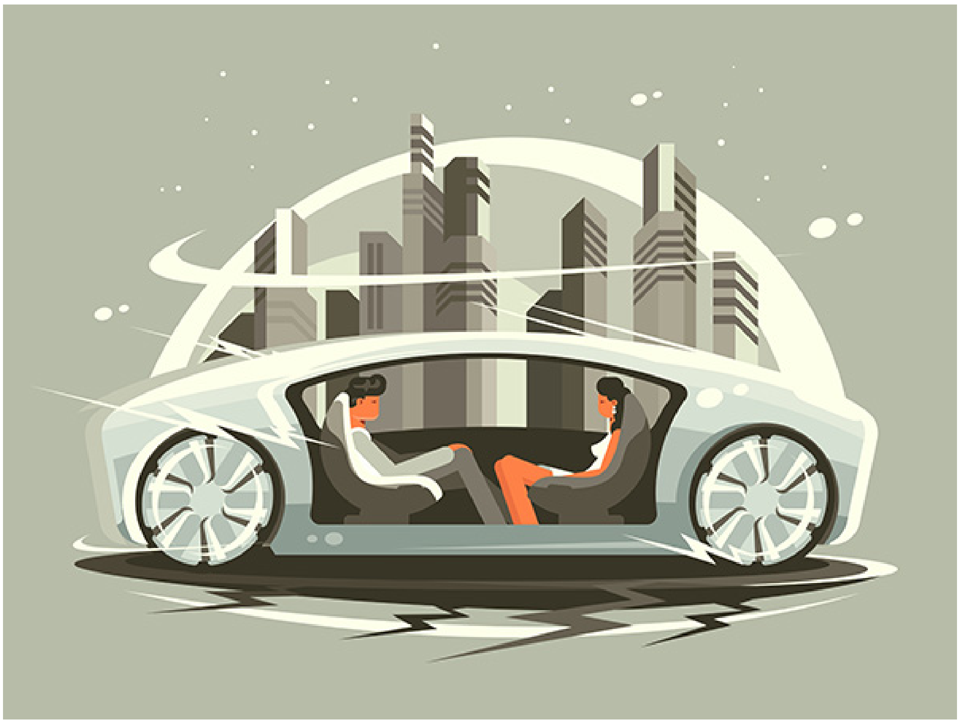

A Sustainable Future with Autonomous Vehicles for Passenger Transport

The Means to Reach a Sustainable Future with Autonomous Vehicles through a Backcasting Approach

Master's thesis in Quality and Operations Management & Management and Economics of Innovation

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Gothenburg, Sweden 2019
Master's thesis E2019:077

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Cover: A possible look for the future robot taxis (Tejeiro, 2017).

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Abstract

Today's transportation system is associated with a number of negative impacts when it comes to environmental, social, and economic sustainability. A prominent negative impact is the emissions of greenhouse gases from vehicles, contributing to climate change. With new technology like autonomous vehicles (AVs), a potential to transform the way transportation is done today into something more sustainable arises. Car manufacturers are paying more and more attention to AVs and it is likely that this new technology will be diffused into society in the future. The aim of this thesis is to lead the way and show how AVs can be used for passenger transportation in a sustainable manner. The thesis scope is delimited to passenger transport only and the geographical scope is limited to the city of Gothenburg.

The contribution of this thesis is to provide an alternative for how to get to a sustainable transportation system in the city of Gothenburg in the future, with the market introduction of AVs. This is done by using a backcasting approach, where a sustainable future scenario, called *our desired future*, is identified in the first step. Our desired future is based on a robot taxi service, where nobody owns a car. The aim is to reduce resource consumption and to increase the utilization of the existing capacity, by minimizing the number of vehicles and even out the demand for transport. To provide a strategy for how to get to our desired future, gaps between today and the desired future are identified and leverage points for how to bridge the gaps are suggested. This is the first part of the thesis project.

In the second part of the project, the gap *incentives to not own a car* is chosen to focus on. The chosen gap is seen as an important difference between the current situation and our desired future, it is possible to start working with already today, and it is crucial from a sustainability point of view, regardless of how long it will take until fully autonomous vehicles are available on the market. Part 2 aims to find a strategy for how to reduce the need for car ownership, to bridge the chosen gap, which would get us one step closer to our desired future. By using the design thinking methodology, a solution with the aim of decreasing the need for car ownership, called the taxi platform, is developed. The taxi platform gathers the existing taxi companies in an app and enables ride-sharing when beneficial. Hence, the taxi platform is like our desired future, but with drivers instead of AVs. A strategy for how to implement the suggested solution is provided in the form of a business model canvas.

Keywords: Autonomous vehicles; Backcasting; Design thinking; Robot taxi; Sustainability; The city of Gothenburg; Passenger transport.

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For the writing of the report, Simon Pedersen has been a recurrent support in big as well as in small matters, and we could not thank him enough. We would also like to thank our thesis supervisor, Maude Hasbi, for making sure our plans looked good and for helping us on the way, whenever we needed her.

Anna Karlsson & Emelie Fredriksson, Gothenburg, June 2019

Contents

List of Figures

List of Tables

One Day in Our Future

The alarm rings and you have an hour to get ready before the robot taxi picks you up outside your house. It is Wednesday and you have planned the week in advance, which means you don't have to interact with the app unless something unexpected happens. The plan is to get your son Max ready for school first, as the robot taxi is ordered to pick him up at half past. You partly make yourself ready at the same time as you help Max and start to prepare breakfast and clothes for Nelly. Max says bye to Nelly before you see him off to the robot taxi, in which he goes to school. There are already other pupils in the taxi and one of them is Max's classmate.

Nelly woke up when Max said goodbye and you get her up to get her ready for kindergarten. The two of you wait outside of your home for the robot taxi as you don't want to make the rest of the people in the taxi wait for you. As the system knows that you are dropping off Nelly, the robot taxi has prepared a child seat for her. It drops you off outside of the kindergarten and drives on. This might be the last week you have to go with Nelly to the kindergarten, as they are installing a system to notify when a child is to arrive. This will let the staff be able to go out and get the child from the robot taxi, allowing the kindergarten children to go by themselves.

It normally doesn't take more than a quarter of an hour to leave Nelly and you have therefore preset the pick-up time for the next taxi according to that. It didn't take very long to drop Nelly off today and you are a bit early and start to walk. After a few minutes, a robot taxi drives up to you and picks you up. When you step into the vehicle your favorite music is playing and the temperature is changing to your preinstalled preference. The robot taxi drives you home.

As a receptionist, the work tasks have been radically changed and nowadays most things can be done from home. Therefore, you work from home four out of five days a week normally. Before starting to work, you go to the shared delivery fridge, where food is delivered during the night. Goods are delivered during the night as not so many people travel at that time, to fully utilize the robot taxis. There's also a package by the food, containing cooking equipment, which you completely forgot you had ordered.

After a days work, Max comes home from school and needs to eat before soccer practice. He comes home with the robot taxi and runs to the kitchen where the food is ready for him. You get a notification that the robot taxi comes to pick Max up again in an hour, which is later than usual. You ask Max if someone from his soccer team was sick from school today and he affirms that two classmates were home from school today. As the soccer training is in the same direction as the kindergarten, you go with Max to pick Nelly up on the way home. From the soccer practice, the robot taxi takes a small detour to fetch another person and then drops you off outside the kindergarten. The robot taxi that brings you home only have two spots left and one of them is prepared for Nelly as usual. The people in the taxi is a talkative group and you get some pleasant conversation on the way home.

At home again you give Nelly a snack and soon after starts with dinner. Your partner has been away on a business trip for a couple of days and is coming home today. You use the new cooking equipment you got this morning. Finally, the whole family has gathered once again and you all have dinner together.

1
Introduction

Cars, and transportation in general, is an important part of many people's lives. The fact that cars enable people to move from point A to point B in a more convenient way than before has generated flexibility and contributed to a higher standard of living. However, there are several drawbacks with cars that have appeared after the standardization of cars, a problem which is further intensified with the constantly growing population.

1.1 Background

A significant part of the world's greenhouse gas (GHG) emissions are caused by transportation. In Sweden, a third of all GHG emissions come from different forms of transportation, out of which road traffic is the cause of 93 % (Morfeldt et al., 2018). Out of this, 67 % is caused by private cars. Although the emissions from transportation have decreased a bit during recent years, the reality of zero emissions is still quite far away. Additionally, the emissions from driving a car are only one part of all emissions associated with the life cycle of the car. Minx et al. (2008) describe how all the different steps, from raw material production, parts fabrication and car manufacturing to the use and disposal, consume resources and contribute to GHG emissions.

Traffic accidents are an additional negative side effect of cars. According to statistics from Transportstyrelsen (2019), 325 people in Sweden died in 2018 due to some kind of road accident, and as many as 2 174 were seriously injured. Studies have shown that the human factor is involved in 90-95 % of all road accidents, while 67 % of all accidents can be considered as a direct result of human error (Rumar, 1985). Due to technological development, possibilities to change how cars are used today have arisen. Autonomous vehicles (AVs) have the potential of disrupting the personal transportation system with effects including increased safety, decreased congestion, and changed travel behaviors (Fagnant and Kockelman, 2015). AVs are already in development and it is possible that these vehicles will become increasingly common in our society. However, exactly how our society will look like with AVs is not known and there are several possible scenarios for the future. This brings the opportunity to steer the disruption of today's transportation into something better and more sustainable.

1.2 Aim & Research Questions

The concept of AVs is something that car manufacturers are paying attention to and the development of the technology is progressing. Hence, it is possible that AVs will be introduced to the market to a continuously increasing extent, potentially disrupting the way transportation is performed today. The intention with this project is not to hurry up the diffusion of these vehicles into the market, but rather to lead the way and show how AVs could be used for passenger transportation in a sustainable manner. Hence, our vision is that AVs are used for passenger transport in an ecologically, economically, and socially sustainable way in the future. Ergo:

Our aim is to lead the way and demonstrate how AVs can be used for passenger transportation in a sustainable manner.

The goal of this thesis is to define a sustainable future and a strategy to get to this future. This by finding gaps between the present and the defined future and then leverage points to bridge the gaps. Hence, our research questions are:

- How does a sustainable future with autonomous passenger transport look like?
- What gaps are there between our sustainable future and today?
- What leverage points are there to bridge the gaps?
- What is a good strategy to implement one of the leverage points?

The results could contribute to sustainable implementation and diffusion of AVs into a sustainable society, as it can be used as a guide for stakeholders on how to lead the way.

1.3 Delimitations

To be able to benefit from local knowledge and to limit the project scope, the thesis investigates the future of autonomous vehicles for passenger transport within the city of Gothenburg. Ergo:

- Only passenger transport with AVs is considered, not the transport of goods or craftsman's transport in work.
- The geographical scope is limited to the city of Gothenburg, see figure 1.1,

excluding the archipelago where it is not possible or allowed to drive cars.

Figure 1.1: A map showing the geographical delimitation of this master thesis. The area within the outer red lines, which is the city of Gothenburg, is the area that is considered.

1.4 Cooperation

This thesis has been executed in collaboration with Coboom, which is a cooperation between Volvo Cars, Stena AB, and CGI. Volvo is one of several car manufacturers that are investing in the development of AVs. The campaign "Drive Me", a project where people get to try autonomous cars on certain roads around Gothenburg, is one example of Volvo's efforts in the area (Drive Me, 2019). A sustainable future with AVs could include changes in infrastructure, which Stena could benefit from. Increased interconnectedness within the cities could concern CGI as they are involved in creating smart cities.

2

Theory

In this chapter, the theory used for the thesis project is presented. This includes sustainability and sustainable transportation, achieving societal change, disruptive innovations, adoption and acceptance of innovations, and, finally, theory about autonomous vehicles.

2.1 Sustainability

In 1987, the Brundtland Commission created a definition of sustainable development, published in the report called *Our Common Future*, which today is a commonly cited definition (Gudmundsson et al., 2016). The definition is as follows (Environment and Development, 2008, p. 43):

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. It contains within it two key concepts:

- the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and
- the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs."

A well-established approach for sustainability is the three pillar model, consisting of economic, environmental, and social sustainability (Gudmundsson et al., 2016). Even though different interpretations exist regarding the implications of this view of sustainable development, it is generally accepted that all three pillars need to be considered to achieve sustainable development.

2.2 Sustainable Transportation

Possibilities for mobility have improved over time which has contributed to social and economic benefits. However, the extended mobility system, including an increased use and density of vehicles per km^2, has also given rise to a number of challenges. Today's transportation system is associated with a number of negative impacts in each of the three pillars of sustainability (OECD, 1996; Steg and Gifford, 2005). A collection of these negative impacts is shown in table 2.1, which is a table from (Gudmundsson et al., 2016, p. 67).

Table 2.1: A table showing a collection of negative impacts, environmental, social and economic, associated with today's transportation system. The table is a compilation from Black (2005), Button (1993), Maddison et al. (1996), Rothengatter (2003), Spellerberg (2002), TRB (1997), Wachs (2005), Whitelegg (1993, 1997), Whitelegg and Haq (2003), VTPI (2005), and Zietsman and Rilett (2002) (as cited in Gudmundsson et al., 2016, p. 67).

Environmental	**Social**	**Economic**
Air pollution	Accidents	Costs of transportation to customers/consumers
Consumption of land/urban sprawl	Declining community livability/community partitioning	Costs relating to accidents
Depletion of the ozone layer	Human (psychological and physiological) health impacts	Depletion of nonrenewable resources and energy supplies *(also an environmental and intergenerational equity concern)*
Disruption of ecosystems and habitats	Inequalities associated with negative environmental and health impacts	Traffic congestion
Global climate change	Mobility barriers/inequalities for the disadvantaged	Transportation facility costs
Hydrologic impacts	Time wastage	Transportation-related health costs
Introduction of exotic species	Visual pollution	
Light pollution		
Noise pollution		
Release of toxic/hazardous substances		
Solid wastes		
Vibration pollution		
Visual intrusion and aesthetics		
Water pollution		

One of the most prominent negative environmental impacts that are associated with today's transportation system is global climate change. In developed countries, the transportation sector, including all kinds of transport means, contributes to 20-30 % of all GHG emissions, contributing to climate change (Hayashi et al., 2015). Greenhouse gases are important for maintaining the current planetary surface temperature. However, for the planetary temperature to remain constant, there has to be a balance between the radiant energy from the Sun to the Earth and the energy sent out from the Earth to space (Mathez and Smerdon, 2018). Too much GHG emissions contribute to an uneven energy balance, leading to an increased temperature as the Earth's attempt to reestablish the energy balance. In figure 2.1, you can see how the change in temperature follows the carbon dioxide increase.

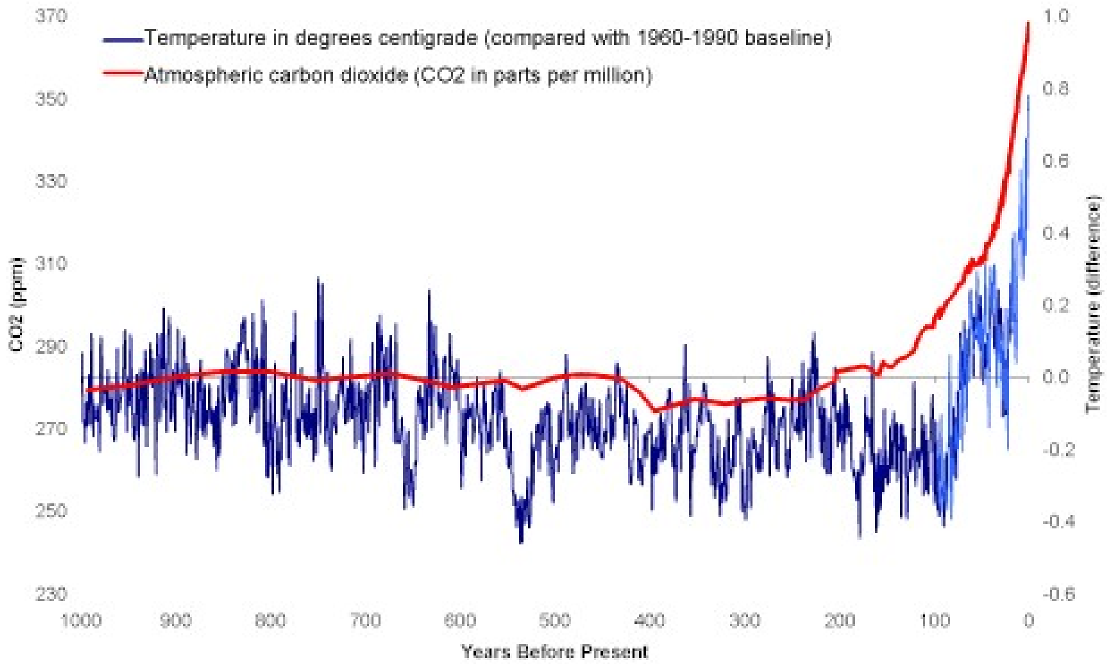

Figure 2.1: A visualization of how the temperature is following the carbon dioxide increase in the atmosphere. Figure from DriverLayer (2015).

For the transportation system to be sustainable, all the negative impacts, listed in figure 2.1, need to be removed or reduced to a level that does not compromise today's and future generation's ability to meet their needs. A proper balance between environmental, economic, and social qualities, today and in the future, need to be achieved (OECD, 1996; Steg and Gifford, 2005; Holden, Linnerud, and Banister, 2013). To achieve a more sustainable transportation system, Steg and Gifford (2005) state that both behavioral and technological changes need to be made. Overall, the aim of behavioral changes is to decrease the level of car use, for instance by traveling less or by sharing rides to an increased extent. Technological changes include, for instance, increasing the energy efficiency of cars and reducing the level of traffic noise by changing the road surfaces. Behavioral and technological changes are both associated with a change in societal culture (Inglehart, 2018).

2.3 Achieving Societal Change

Hargreaves (2011) states that large-scale changes in the everyday life of people, throughout the entire society, are needed to change the unsustainable patterns of human activity that exist today. Several different approaches are available when it comes to achieving societal change. In broad terms, the different approaches can be divided into behavior change models on one hand, and social practice theories on the other (Hargreaves, 2011). The main distinction between these two categories is that behavior change models emphasize the importance of changing the individual's mindset and behavior, while social practice theories offer a broader conceptualization, focusing on the importance of habitual patterns in human behavior.

2.3.1 Behavior Change Models

The basic assumption underpinning the behavior change models is the importance of individuals' beliefs, attitudes, and values as predictors of human behavior (Hargreaves, 2011). This has a close connection to people's cultures, since having different cultures can be defined as having different basic values, attitudes, and skills (Inglehart, 2018). In general, the most common way for policymakers to try to achieve societal change is by attempting to change the individual's values, beliefs, and attitudes through the use of behavior change models (Hargreaves, 2011; Darnton, 2008). Darnton (2008) states that it, as a rule, is not enough to consider why people behave in certain ways when the aim is to achieve change and makes, therefore, a distinction between models of behavior and theories of change. However, the two distinctions are closely related and Darnton (2008) argues that both are needed to achieve effective interventions.

2.3.1.1 Models of Behavior

Models of behavior can both be at an individual and at a higher level. The foundation of the individual level behavior models is the assumption that people behave rationally; they always act to maximize their personal value (Darnton, 2008). As a consequence, these models are linear or multi-linear, where the most basic model assumes that an individual's decision making is based on benefit calculations. Darnton (2008) describe how attitudes, norms, and agency are common factors in individual-level behavior models, while habit and emotion appear in some.

Models of behavior that are at a higher level have a broader perspective. These are also considering the individual behavior but takes external factors into consideration as well. These external factors are macro-level societal factors such as the economy, institutions, and technology. Darnton (2008) argue that it is crucial to consider contextual, external factors, with the aim of limiting the behavioral options that exist, when trying to achieve change.

2.3.1.2 Theories of Change

Theories of change, with strong connections to models of behavior, are approaches derived from the social sciences. One example of a theory of change is Lewin's change model, developed by the social-psychologist Kurt Lewin (Darnton, 2008). In his change model, Lewin describes the process of change as consisting of three different steps: unfreezing, changing, and refreezing, as can be seen in figure 2.2. To unfreeze, awareness needs to be created and an understanding of why change is needed (Levasseur, 2001). To achieve this, communication is crucial. It is important for people to understand why the change will benefit them on a personal level, which is in line with the basic assumption that people, in general, behave rationally. The second step of Lewin's change model, the changing step, is where the actual transition happens. The old habits are discontinued and new are put in place. The third and final step, refreezing, is crucial to ensure people do not fall back into their old habits. They need to freeze the changed behavior as the new norm. Levasseur (2001) describes that requirements for successful refreezing are commitment and active involvement from those who have an interest in the change.

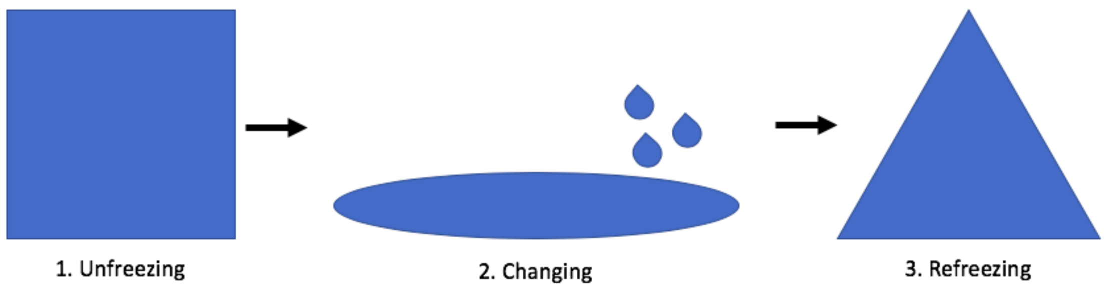

Figure 2.2: A visualization of the three steps included in Lewin's change model.

Another example of how change can be theorized is through diffusion models since these models describe how a certain behavior can be spread in a society or a network (Darnton, 2008). One of the most well-known diffusion models is Rogers' diffusion of innovation theory, even though it is not as commonly applied for social behaviors as for how technologies are adopted. More about Rogers' diffusion of innovation theory is presented in section 2.5.

2.3.2 Social Practice Theories

Understanding social practices is sufficient to achieve change (Hargreaves, 2011). Several different views exist regarding the exact definition of a practice. One way is to see practices as assemblages of three components: images, skills, and things (Shove and Pantzar, 2005). Images are meanings and symbols, skills could be procedures and forms of competence, and things could be technology and materials. These three components are dynamically integrated with links between each other, forming practices such as how we drive, cook, or play football, for instance.

Hargreaves (2011) argue that social practices have to be taken into account to achieve pro-environmental behavior change. When applying social practice theory to achieve societal change, it is the practice itself that is the main element of analysis, instead of individuals or existing social structures. Warde (2005) also states that it is the patterns of behavior, the practices, that decide how individuals behave in certain situations and it is, therefore, the practices that lead to anti- or pro-environmental actions. Hence, it is the practices that should be changed, not the individual decision per se. During a person's lifetime, one get in contact with a wide variety of different practices, which the individual can choose to recruit or defect (Hargreaves, 2011).

By making new links between different components (images, skills, and things) new practices can emerge and, eventually, stabilize. By breaking the existing links, a practice can die out (Shove and Pantzar, 2005). This means that the links and elements of existing unsustainable practices should be challenged and broken, to then be replaced by more sustainable practices (Hargreaves, 2011). Changes in practices take time and can occur from the inside and the outside (Warde, 2005). When a change in a practice occurs from the inside, this means that a new practice is created by people who have improvised new behaviors in new situations. When a practice instead is changed from the outside, active involvement from external parties is required, leading to the intertwining of different practices.

2.4 Disruptive Innovations

Already in 1942, Joseph Schumpeter coined the expression 'creative destruction', where existing structures of the society are destroyed through degradation by a new innovation (Schumpeter, 1942). Schumpeter distinguished between radical and incremental innovations, where radical innovations are the ones leading to creative destruction. A closely related term to creative destruction is disruptive innovations. Christensen, Raynor, and McDonald (2015) describe a disruptive innovation as an innovation which disrupts existing markets and value networks by establishing new markets and new ways of creating value. They describe how the disruption of an innovation is the process in which an existing, incumbent company is challenged by a start-up company in a successful way. According to Christensen, Raynor, and McDonald (2015), disruptive innovations are low performing and introduced to the low-end market by a new company.

Innovation can concern an existing product as well, which means that the innovation is an improvement of a product. This is called a sustaining innovation and will not create new markets but rather satisfy customers' predicted and explicit needs in the existing markets. To deal with the distinction between a disruptive and a sustaining innovation, one can look at how much a product has and is expected to improve over time through a concept called performance trajectories (Christensen and Bower, 1995), as can be seen in figure 2.3. As shown, the sustaining innovation aims for the high end of the market while the disruptive innovation aims for the mainstream.

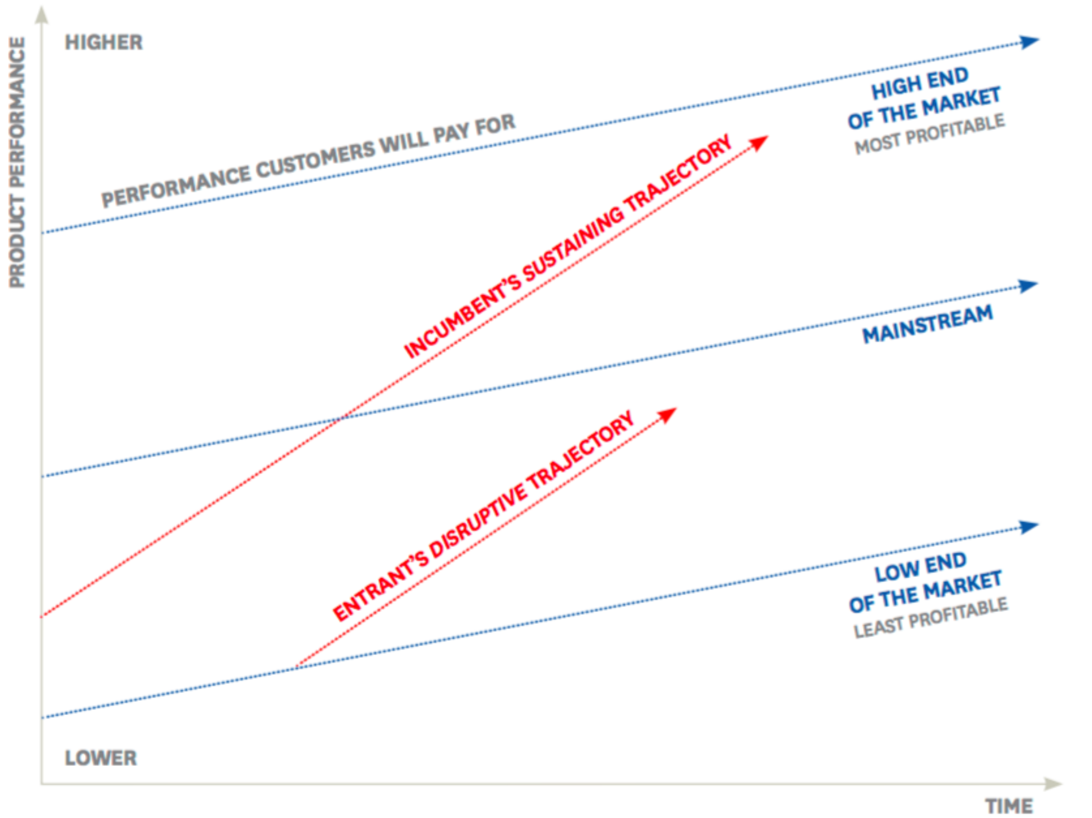

Figure 2.3: The distinction between a sustaining and a disruptive innovation due to the development of the product performance over time. Figure from Christensen, Raynor, and McDonald (2015, p. 39).

2.5 Adoption and Acceptance of Innovations

People adopt differently to new products and some adopt innovations faster than others. The theory explaining this phenomenon is called 'the diffusion of innovations theory', coined by the professor Everett Rogers, and it started to get popularized in 1962 (Rogers, 1995). Diffusion is, by Rogers, defined as "the process by which an innovation is communicated through certain channels over time among the members of a social system" (Rogers, 1995, p. 5). Hence, diffusion is the process where innovations permeate through society and groups. Adoption, on the other hand, is more on an individual level, examining the individual process that people undergo leading up to the adoption of a new product (Rogers, 1995). Important parts of the diffusion of innovations theory are adopter categories and the innovation-decision process.

2.5.1 Adopter Categories

Different types of adopters can be distinguished by their willingness to adopt innovations. One model is to separate the following five adopter categories: innovators, early adopters, early majority, late majority, and laggards (Rogers, 1982). The different adopter categories include specific personal characteristics. Innovators, for instance, are people that are very eager to try new ideas, while laggards are skeptical of new products and are difficult to influence. The five adopter categories, and their respective share of the population, is shown in the diffusion curve in figure 2.4.

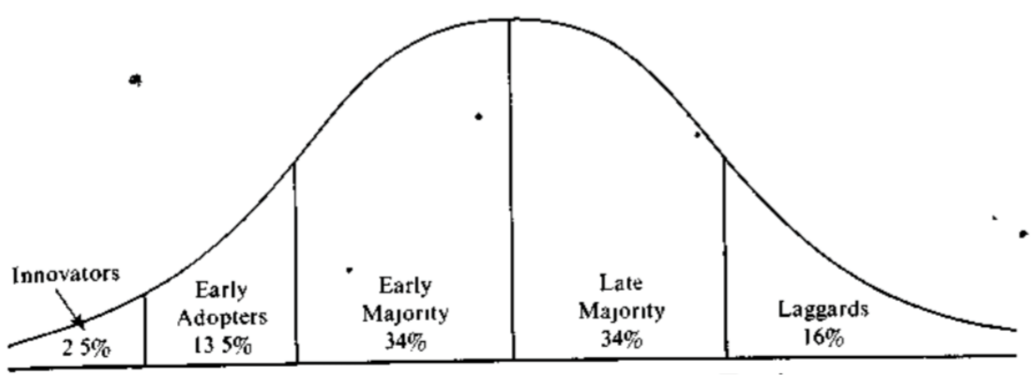

Figure 2.4: The five different adopter categories: innovators, early adopters, early majority, late majority, and laggards, and their respective share of the population in percent. Figure from Rogers (1982, p. 247).

Related to the adopter categories is the notion of change agents. These are people who influence others decisions in a direction that is desired by themselves (Rogers, 1982). A change agent can both hurry up and slow down the diffusion of an innovation, depending on the change agent's intention. This means that change agents can help to influence and affect the development in a specific direction, as well as slow it down.

2.5.2 The Innovation-Decision Process

The process in which an individual adopts an innovation, or takes the active decision not to adopt, is called 'the innovation-decision process' (Rogers, 1982). This decision process starts with the knowledge of a new innovation, followed by the creation of an opinion about it, which then affects the final decision whether to adopt the innovation or not. Rogers (1982) divides this process into five steps, which an individual needs to go through to adopt an innovation. These five steps are:

1. Knowledge - An individual becomes aware of the existence of an innovation and gains some basic understanding of its functions.

2. Persuasion - An advantageous or a disadvantageous attitude regarding the innovation is formed by the individual.

3. Decision - The individual makes the decision whether to adopt to the innovation or not, by engaging in different activities.

4. Implementation - The innovation is put into use by the individual.

5. Confirmation - The individual seeks reasons to strengthen the decision that has already been made. The individual can also change the decision, if conflicting messages about the innovation has occurred.

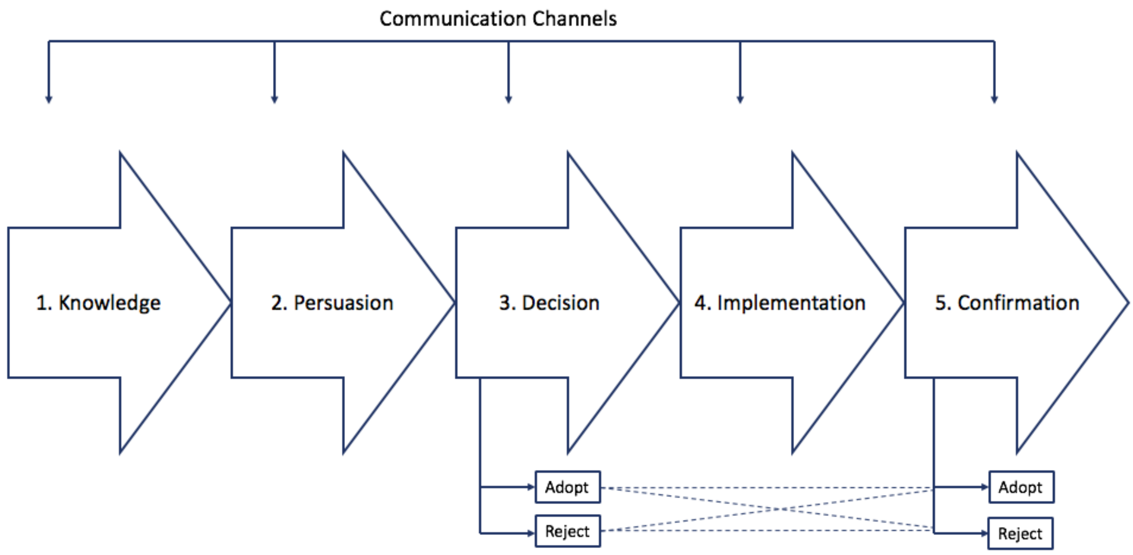

Figure 2.5: The five steps of the innovation-decision process, in line with Rogers (2003).

There are ways to affect the outcome of an individual's innovation-decision process in a specific direction. Rogers (2003) means that communication channels are central throughout the whole decision-making process. To create knowledge about an innovation, different types of communication channels are crucial, since it is through these means or through the creation of a need that generates knowledge about a new product. The communication channels and messages could, for instance, be through salespersons and advertising.

In the second step, *persuasion*, Rogers (2003) points out the importance of the opinions of the individual's peers. This is mainly due to the fact that innovations are associated with uncertainty, and it is more reliable for people to get to hear about a new solution through people they know. To deal with the existing uncertainty, it is important for individuals to first be able to try out the innovation on a probationary basis. This, to be able to determine if they find the innovation useful in their own situation (Rogers, 2003). If the third step, *decision*, leads to adoption, the implementation needs to live up to or exceed the expectations. So that it does not lead to a changed decision in the fifth step, *confirmation*.

2.6 Autonomous Vehicles

AVs future is impossible to foresee. Some do not believe in us ever being able to not sit in front of the steering wheel, while others believe in us doing anything but driving in the future, with no responsibility for the driving. Which would let us sleep in the car during the ride if we would like to.

One of the explanations to 'automation' in the Merriam-Webster dictionary is: "automatically controlled operation of an apparatus, process, or system by mechanical or electronic devices that take the place of human labor". The Automated vehicle is, as the dictionary implies, maneuvering without human involvement. This can be done to different extents and has been categorized by the Society of Automotive Engineers Internationals (Shuttleworth, 2019) in six steps:

Level 0	The system only provides warnings and possibly momentary assistance
Level 1	Lane centering *or* adaptive cruise control
Level 2	Lane centering *and* adaptive cruise control
Level 3	Traffic jam chauffeur
Level 4	*Local* driverless taxi, drives autonomously in known areas
Level 5	driverless taxi able to drive everywhere in all conditions

From level 0 to level 2, the driving is performed by humans and supervision over the autonomy features is needed. Level 3 to 5 does not require constant supervision over the driving. Ergo, a driverless mode may be used, in level 3 at least momentarily and in level 5 completely.

How the autonomy works is complex. Sensors on the car need to read the surroundings, which computers need to convert into information that other algorithms can use to make decisions. Through "eyes" on the car in the form of cameras, an algorithm interprets what is going on around the car. This is called computer vision and is just one part of the sensory perception. The computer vision is supposed to substitute the human vision and the advantage the computer has over the human is the constant level of attention which a human cannot possess over a longer period of time. The computer vision is divided into *generic* and *specific* visual tasks. The generic visual task includes measuring brightness, calculating distance or motion, and detecting corners, while specific visual tasks are understanding ego-motion and how the vehicle can move in the space around it, including detection of pedestrians, for instance. These two are intertwined and sometimes hard to separate (López et al., 2017). Other types of sensors are thermal imaging, laser scanner, radar, GPS (Global Positioning System), and ultrasound.

2.6.1 Passenger Comfort Side Effects With AVs

When it comes to passenger comfort in AVs, a number of aspects need to be considered. Elbanhawi, Simic, and Jazar (2015) have identified four aspects, which all can be tracked down into two main factors, which occur due to the fact that the vehicles are self-driving: the lack of controllability and the robotic control. These factors and considerable aspects, and the relationship between them are shown in figure 2.6. The aim of addressing these aspects is to emphasize the importance of considering these when planning and developing AVs.

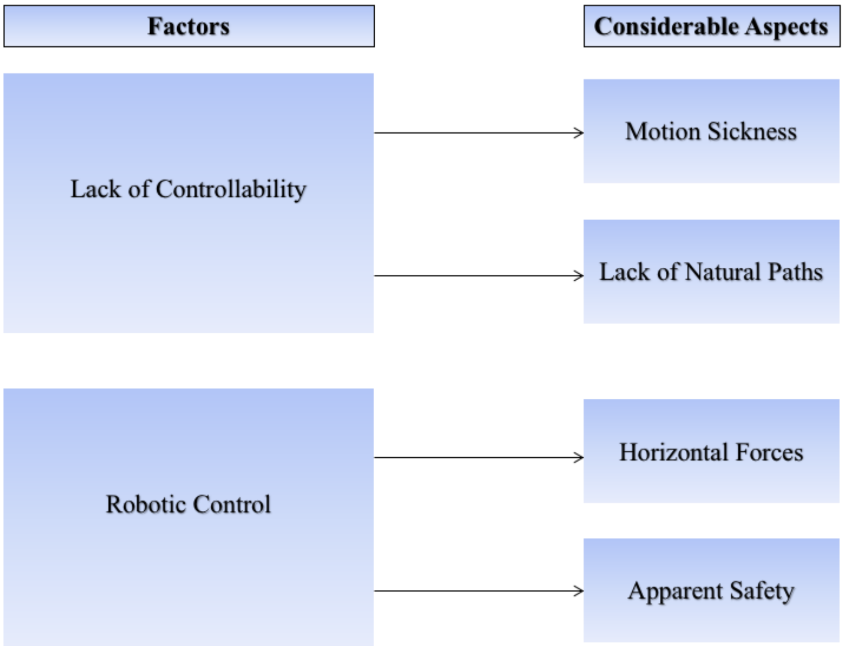

Figure 2.6: Aspects which need to be considered, and the main factors behind these, to achieve passenger comfort in AVs.

2.6.1.1 Motion Sickness

The most common way that motion sickness occurs is due to a conflict that arises between an individual's visual and vestibular inputs (Elbanhawi, Simic, and Jazar, 2015; M Bronstein, Golding, and A Gresty, 2013). In regular cases, a motion of the head in one direction means that the external visual scene moves in the opposite direction. When this is not the case, a conflict between the human body's vestibular and visual sensory systems can arise, leading to motion sickness (M Bronstein, Golding, and A Gresty, 2013). Passengers are more prone to get car sick since they do not have to focus on visual references on the road, which would prevent conflicting impressions from occurring (Rolnick and Lubow, 1991).

Elbanhawi, Simic, and Jazar (2015) explain that the loss of controllability that exists for passengers in AVs would increase the sensitiveness and the risk of getting car sick. This could be avoided by providing sensory feedback for passengers, by the use of driver-vehicle-interfaces (DVIs), see figure 2.7 (Elbanhawi, Simic, and Jazar, 2015; M Bronstein, Golding, and A Gresty, 2013). By using DVIs which visualize the planned route of the AV, the passenger can be prepared for the movements and decrease the risk for conflicts between visual and vestibular inputs. Hence, the risk of car sickness could be decreased. An additional way to decrease the risk of getting car sick in AVs is to develop well-functioning planning algorithms, avoiding abrupt changes in steering, oscillations, and resulting forces (Pérez, Milanes, and Onieva, 2011).

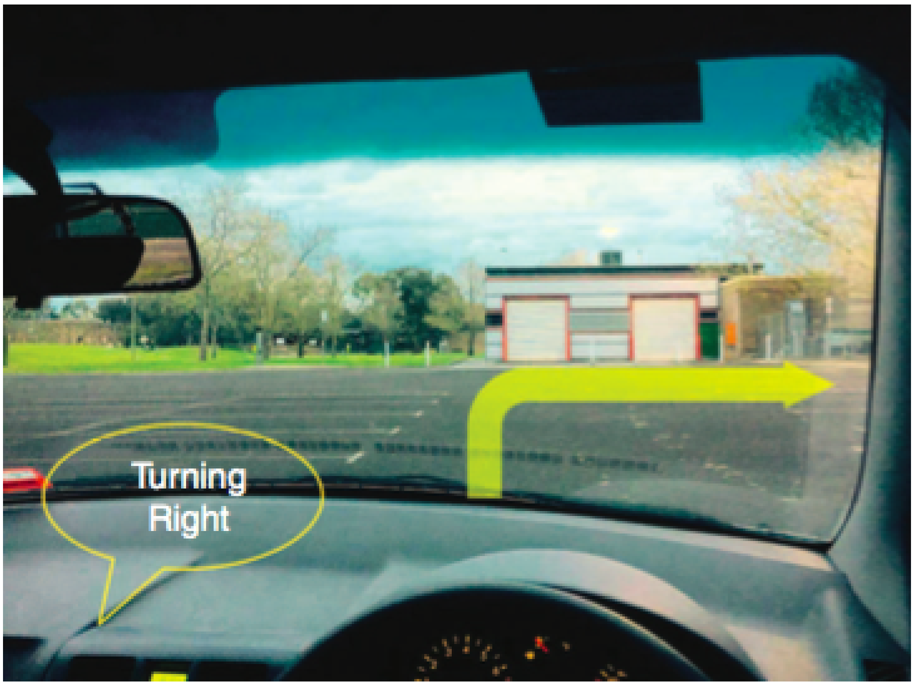

Figure 2.7: How DVI can look like, which could be used to prevent motion sickness. Figure from Elbanhawi, Simic, and Jazar (2015, p. 12).

2.6.1.2 Natural Paths

To make it comfortable for the passenger, it is important that the AVs are driving similarly to how people drive cars (Elbanhawi, Simic, and Jazar, 2015). Natural paths are those that are similar to paths generated by humans. Hence, there is a need to address natural path synthesis for AVs. This need arises due to the lack of controllability, that is a result of self-driving vehicles. To mimic human control, and to achieve natural paths, Elbanhawi, Simic, and Jazar (2015) suggest a combination of behavioral research and the usage of machine learning.

2.6.1.3 Horizontal Forces

Several different forces are acting on a passenger in a vehicle, affecting the passenger comfort. It is important to minimize the jerk and resulting forces acting on the passenger. Elbanhawi, Simic, and Jazar (2015) explain how vertical forces are the result of road disturbances and can be reduced by the design and comfort of the seats and the vehicle in general. The horizontal forces, on the other hand, are affected by acceleration, braking, and veering while steering. These resulting forces can be seen in figure 2.8.

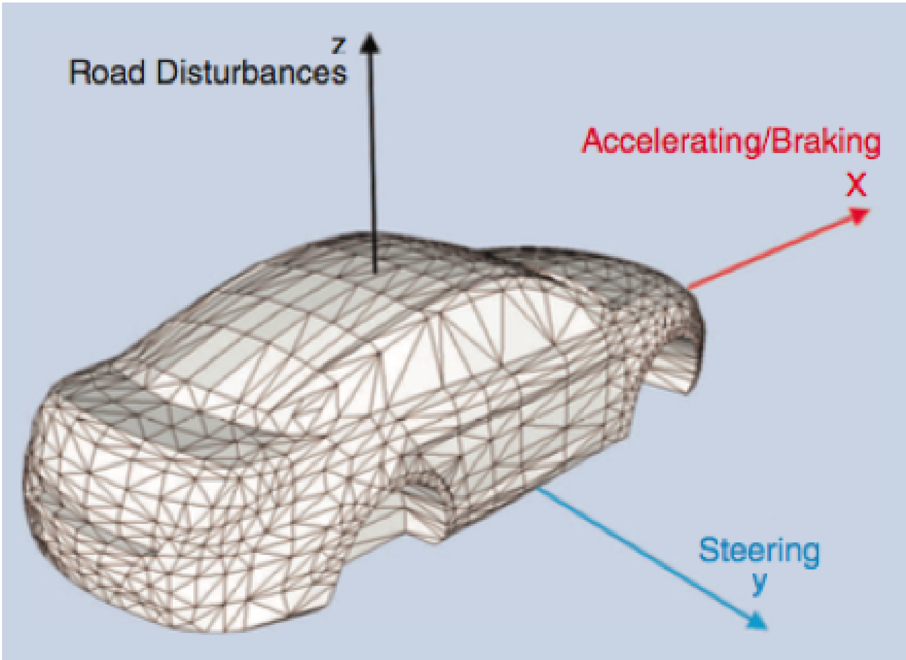

Figure 2.8: The resulting forces that are acting on a passenger in a vehicle, and their root cause. Figure from Elbanhawi, Simic, and Jazar (2015, p. 11).

In vehicles with a human driver, the horizontal forces depend on the driver. However, in AVs, the horizontal forces can be controlled to a greater extent. In a study done by Guarino Lo Bianco (2013), the optimal velocity for robotic vehicles on different types of paths, to achieve minimal jerk, has been evaluated. The author suggests that optimization algorithms in the vehicles can help to minimize the maximum horizontal jerk. Path planning and generation and tracking of trajectories could help to reduce the resulting horizontal forces (Elbanhawi, Simic, and Jazar, 2015).

2.6.1.4 Apparent Safety

To ensure the actual and perceived safety, the way in how the vehicles are driving needs to be considered. Even if the vehicles are safe and behave in a secure way, this does not guarantee that the passengers feel safe. Elbanhawi, Simic, and Jazar (2015) argue that apparent safety occurs when maneuvers are smoothly executed and when the AVs keep a reasonable distance from other vehicles and obstacles on the road. However, they also state that the ideal gap and reaction time for passengers to feel safe in AVs is not fully investigated yet. In relation to safety, some philosophical questions arise as well. More about this can be read in 4.1.2.

2.6.2 Other Opportunities and Challenges with AVs

Additional opportunities and challenges with the introduction and market penetration of AVs, besides the side effects presented above, have been identified by Fagnant and Kockelman (2015) and MarketLine (2018). These are presented in table 2.2.

Table 2.2: A summary of existing challenges and opportunities with AVs, collected from Fagnant and Kockelman (2015) and MarketLine (2018).

Challenges	**Description**
Privacy	The use of AVs generates possibilities of collecting data. In relation to this, a number of questions arise, for instance: *What type of data can be collected?* *Who should own and control the data?* *Who will have access to the data?* *For what purposes could the data be used?*
Initial AV costs	If sold to private persons, the initial costs for the technology will be unaffordable for many people.
Government policies	Rules and regulations take time to change and are lagging behind.
Changed infrastructure	To fully realize AVs' potential, the existing infrastructure might need to change to, for instance, enable vehicle-to-infrastructure (V2I) communication.
Attitudes towards AVs	Depending on the cultural environment, people are susceptible to varying degrees.
Opportunities	
Less accidents	By removing the human factor, less accidents will occur.
Reduced congestion	Depending on how AVs penetrate the market, possibilities for reduced congestion occur. Vehicle-to-vehicle (V2V) communication and less accidents are two factors that could help to reduce congestion.
Less fuel consumption	The development of new technologies generates possibilities to improve the energy consumption, by making the technology more efficient.
Reduced parking needs	There are different ways to achieve this. One is that the cars drive out of the city to park.
Increased mobility	Those who, by different reasons, are not able to drive by themselves, will have increased mobility possibilities.
Changed ways of travel	AVs generate possibilities of a disrupted transport system.
Societal cost savings	Reduced accidents and decreased congestion means cost savings for the society.

3

Methodology

The methods used during this project are backcasting and design thinking, which both have included interviews and literature reviews. The project has been divided into two different parts, separated due to their different focus areas. The first part has a wide focus on the future with AVs for passenger transport in the city of Gothenburg, while the second part is focused on only one aspect. The backcasting process is consistent throughout the whole project, in both the wider and the more focused perspective, while design thinking is used only in the second part of the research. In this chapter, the two methods will first be explained individually, followed by a presentation of how the work has been done in this thesis project, divided between part 1 and part 2.

3.1 Backcasting

The four steps of backcasting, according to Holmberg (1998, figure 1), are as follows:

1. Define a framework for sustainability.
2. Describe the current situation in relation to the criteria for sustainability.
3. Envisage a future situation.
4. Find strategies for sustainability.

They are later on developed to look like this:

1. Identify the conditions that need to be met in a sustainable future.
2. Identify the gap between the current system and the conditions in step 1.
3. Identify leverage points that can bridge the gap.
4. Identify strategies for those leverage points.

This later version of the steps is what is used in this thesis project. An overview of the backcasting process can be seen in figure 3.1.

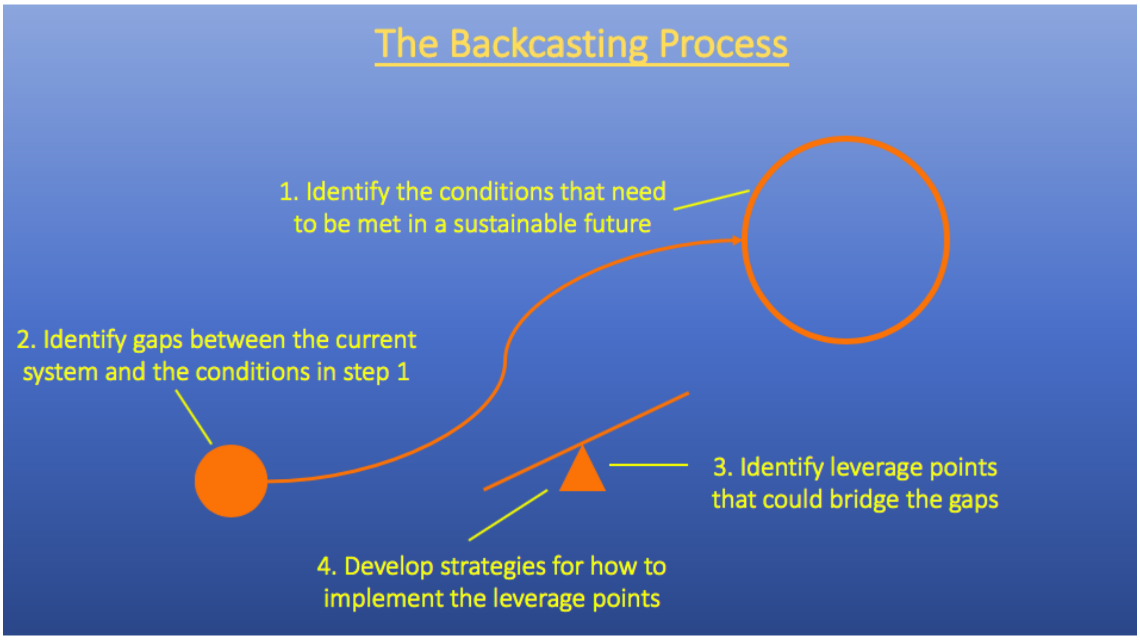

Figure 3.1: A visualization of the backcasting process, which includes four different steps. The figure is based on Holmberg and Larsson (2018).

3.1.1 Step 1

The first step of the backcasting methodology includes defining a sustainable future based on some characteristics that could be defined through, for instance, brainstorming. These characteristics are important, as a future extracted without them easily ends up being extracted from today's trends, which might cause a dangerous course, according to Holmberg (1998). Further, he also mentions four principles that are to be considered when working for a sustainable future: unnecessarily wastage of resources; the use of fossil fuels and scarce metals; the use of artificial resources; and reduced biodiversity and excessive usage of farmland. These four principles can be used for guidance in finding sustainable future characteristics.

Another way to define a sustainable future, which can be used as a complement to the four principles, is to use the so-called 'lighthouse model' by Holmberg and Larsson (2018), shown in figure 3.2. In this model, four dimensions of sustainability are included: social, ecological, economic, and human needs. The human needs dimension and how these needs are met influences the other dimensions. For each dimension, The lighthouse model provides a number of aspects that should be considered to achieve sustainability. Through the lighthouse model, sustainability criteria can be identified which in turn can be used as a base to define a sustainable, desired future.

Figure 3.2: An illustration of the lighthouse model, which can be used as a guidance for identifying sustainability criteria. Figure from Holmberg and Larsson (2018, p. 15).

3.1.2 Step 2

In the second step of the backcasting methodology, the current situation is charted and possible gaps that may exist between the current situation and the desired future should be identified. Even though *gaps* can be defined in several different ways, it is often said to be the differences between the desired and the current situation. To be able to do this second step, a profound understanding of the current situation is needed (Holmberg, 1998).

3.1.3 Step 3

The third step of the backcasting methodology is to identify leverage points. As the name implies, this is possible actions that should have greater impacts than required input. Also comparable with rings on the water. These leverage points are meant to bridge the gaps identified in step 2. Preferably, one leverage point can bridge several gaps, but the amount of leverage points is not specified. Though, it should be enough leverage points to bridge all the gaps for the completion of this step. Step 3 can be seen as delivering the question of *what* should be done.

3.1.4 Step 4

Step 4 can be seen as answering the question of *how* it should be done. The end result of this step is a strategy on how to implement the leverage points developed in step 3. This will link the current situation with the desired future. Holmberg (1998) suggests four points that should be considered in the fourth backcasting step:

- Will the deed lead to an approach to a sustainable scenario? The deed could, for instance, be an investment or a product design.
- Will the deed make it possible to make the next move towards the sustainable future, or does it lead to a dead end?
- Will the return on investment from the deed be soon enough?
- Taking all deeds into consideration, will they help society to change in a sufficient way? By sufficient, speed and scale should be weighted together with collective losses during the transition period.

These four points should all be fulfilled and it is crucial that they work together. If one of the four points are not in line with the others, there is a risk that the strategy will be suboptimal (Holmberg, 1998).

3.2 Design Thinking and Nextapp

Design thinking is a human-centered process of creating products and services (Brown and Wyatt, 2010). A human-centered process focuses on understanding people's needs, which means that the solution is created with the aim of solving a problem for people. There are different tools available to facilitate the use of design thinking, and an example of these is the internet-based tool called Nextapp. Nextapp is the tool that was used during this thesis project since this tool was provided through the Coboom-collaboration. The steps included in this tool are:

1. briefing,
2. sensing,
3. visioning,
4. prototyping, and
5. scaling.

All information presented in this section is from the Nextapp tool.

3.2.1 Briefing

The briefing stage helps to frame and plan the project. Within this stage, a challenge should be stated, followed by a number of questions to answer. Which helps to understand the identified challenge further. Example of questions to answer are *Who are you solving this challenge for? How would success look like?* and *Who are the stakeholders?*. Answering the questions helps to visualize and put words to different aspects of the project.

3.2.2 Sensing

The main goal of the sensing phase is to create personas. A persona is an integration of users who have been interviewed and grouped after some common factor. The persona has goals and pains that are identified from the interviews. Insights and behaviors are also identified and given to the persona. Goals are what the interviewees attempt to succeed with and desire and pains are things that the persona struggles with, in the everyday life. Insights are new conclusions that have been discovered by the interviewer, while behaviors are different notable characteristics in how the interviewees, grouped into one specific persona, behaved during the interviews. All of these can be filled out in the different tasks that are to be done in the creation of a persona. The tasks are interviews, observations, experiencing from the users' point of view, empathy map, user journey, expert interview, scanning the landscape, and collecting facts. After all of these, the last task is to bring the persona to life to truly feel for this person and to define a creative question.

3.2.3 Visioning

The creative question that was identified in the sensing stage is brought into visioning. In this stage, solutions are to be made. The steps toward a solution are to brainstorm, look at existing solutions to see if they can be combined into new solutions and try irrational combinations as well as rational. To try different setups of the creative question to see if new ideas are generated, consider what, for instance, your mother would do. To see opportunities from the future, challenge core beliefs, gather inspiration from competitors or other organizations. To see if an analog question has been answered, see how nature designs things, scan technology trends, make sure it is scalable, and create the value proposition

3.2.4 Prototyping

Prototyping in Nextapp is about testing the attractiveness of the value proposition suggested in the visioning stage. The solution could be tested on users and experts through a number of different missions. These include sketching the user experience; building a physical representation of the solution; developing a paper-based or clickable version of the solution; or using Microsoft PowerApps to build a custom app. The missions should generate observations and learnings that can be transformed into actions which should be used to iteratively update the suggested value proposition. The prototyping stage ends with the decision of whether to go or not go further with the solution.

3.2.5 Scaling

Scaling is the last stage in Nextapp, which implies finalizing the solution's business case. The financial viability, organization legitimacy, and operational or technical feasibility are validated. This is done by identifying competitive advantages and delivery channels, defining a cost and revenue model, outlining an action plan, and identifying which internal and external resources that would be needed. The end result of the scaling stage is a finalized business model canvas, which could be used as a basis to start a new business.

3.3 Our Project, Part 1

The first part of our research was focused on the desired future: on how a sustainable future with AVs for passenger transportation in the city of Gothenburg could look like; what differences that exist between the desired future and the current situation; and defining some leverage points for how to bridge the existing differences. Hence, part 1 includes the first three steps of the backcasting methodology.

To validate our desired future as sustainable, identify existing gaps between our desired future and the current situation, and to be able to identify some possible leverage points, semi-structured interviews with professionals in the field of AVs was conducted. The interviews were held with different stakeholders who have a claim on a future with AVs in Gothenburg. Only one person from each company or authority has been interviewed, to get the width rather than the depth of the scenario. A list of the persons interviewed can be found in Appendix A.

3.3.1 Defining Our Desired Future

The first step of the backcasting process, which is to identify conditions that need to be met in a sustainable future, the lighthouse model by Holmberg and Larsson (2018) was used. By using this model, sustainability criteria could be identified. Our desired future was then defined through brainstorming, with the aim of meeting these sustainability criteria. The desired future was verified during the interviews held in this first part of the project and iteratively updated thereafter.

3.3.2 Identifying Gaps and Leverage Points

The second step of the backcasting process, to identify the current situation and possible gaps that may exist between the current situation and the desired future, was mainly done through the interviews but also through a literature review. The interviewees were also asked if they knew any leverage points that could be used to bridge the identified gaps, to get a deeper understanding and to start a bit on the third step of the backcasting process.

The interviews were conducted and iterated in the following manner:

1. The first characteristic from our desired future is explained and the interviewee is asked if (s)he agrees that this is a part of a sustainable future.
    - If the interviewee does not agree, (s)he will be asked how this characteristic could be more sustainable.
2. Questions regarding the current situation and possible gaps to the desired future are asked. Some gaps might be suggested if they have been identified earlier and needs to be verified.
3. Also, as preparation for step four of the backcasting process, the interviewee are asked if knowing or realizing any possible leverage points to the identified gaps.
4. Start over with step 1, with the next characteristic.

The aim with the interviews was to brainstorm together with experts in the field of autonomous vehicles. The information collected from the interviews is used as motivation for what gaps that does exist between the current situation and our desired future, and also a number of leverage point that could be used to bridge these gaps. The interviews were recorded to be able to go back and listen to it again if something was unclear. Notes were also taken during the interviews. After the interviews, the information gathered were discussed and new information, in the form of gaps and leverage point, were added to our result. The result from the interviews is shown in section 5.2. After identifying gaps between our desired future and the current situation, and some leverage points to bridge the gaps, the further investigation was focused around one specific gap. From this point in the project, the second part started.

3.4 Our Project, Part 2

The aim of the second part of our research was to suggest a strategy for how to move towards our desired future. To be able to develop a focused solution, that is feasible today, the investigation during this second part was focused on one of the gaps identified in the first part of our research.

Part 2 includes the second and the third step of the backcasting methodology, which is to suggest a suitable leverage point and to develop a strategy for how to implement this leverage point. Design thinking was used in combination with backcasting during part 2, as a tool to develop an idea of a solution and a strategy that could be used to implement the solution. This as a way to move towards our desired future. As a beginning of step 2, an understanding of the phenomena of the gap was acquired. This was followed by a suggested solution and then the testing of this solution. Finally, a strategy was developed for how to implement the solution, in the form of a business model canvas.

3.4.1 Understanding the Gap

With the aim of understanding the reasons for the chosen gap, 32 semi-structured quick interviews were conducted. The questions and interviewees age group and gender can be found in Appendix B. This was done as a first part of the sensing stage, to collect data that could be used in Nextapp. The interviews were held outside of the grocery store ICA maxi in Mölndal and in the mall Frölunda Torg, with random people passing by. The interviewees were chosen with the aim of getting a wide diversity in regard to age and gender.

The data generated from the interviews were used in the sensing stage in Nextapp, the tool for design thinking. The generated data indicated some existing patterns in people's behavior. People with similar reasoning were grouped together in Nextapp as different personas. One persona was chosen as our target user, and for this persona, a number of different missions were executed in Nextapp. These missions included: the making of an empathy map; doing a user journey; and to "walk in the shoes" of the persona, which means that we had to imagine ourselves in the situation of this persona. The aim of these missions was to understand the persona and her problems to a greater extent. The end result of the sensing stage was a creative question, which should be answered to solve the identified problem for the specific persona.

3.4.2 Suggesting Solutions

The visioning stage had the aim of creating different solutions to the creative question. As the backcasting methodology's third step includes finding leverage points and the visioning stage includes solving the persona's problem, the suggested solutions are, in this case, synonymous with leverage points. This is the reason why we chose to merge the third step of the backcasting methodology with the visioning stage of the design thinking method.

To identify solutions for our creative question, we used the missions provided in Nextapp. These missions involved different brainstorming exercises, which helped us to think in new ways. However, the visioning stage also includes developing features of the suggested solutions, which was done in Nextapp. For one specific solution we created a value proposition as the last step of the visioning stage.

3.4.3 Testing the Solution

During the prototyping stage in Nextapp, the desirability of the chosen solution was tested. We did this with potential users of the solution to confirm that our value proposition answered the creative question. The mission that was used was 'story boarding', which is a mission that includes sketching the user experience to test, get feedback, and improve the solution. During the test sessions, the potential users were first asked to describe their traveling habits. Then, based on their existing traveling behaviours, we described how this could be done, step by step, with our solution. The potential users gave feedback on each step regarding how the solution could be improved to make it work better for them, in their specific life situation. This generated observations, learnings, and actions that were added into Nextapp. Based on this feedback, the solution was updated iteratively during the prototyping stage.

3.4.4 Suggesting a Strategy

The last stage of design thinking, scaling, was combined with the fourth and last step of the backcasting methodology, which is to identify a strategy for the leverage points. A strategy for how to implement the chosen leverage point was provided by developing a business model canvas in Nextapp. Delivery channels, competitive advantages, needed internal and external resources, an economic model, and a plan for the continued development of the solution were identified and developed through brainstorming. The final business model canvas includes all these parameters, together with a description of the chosen persona, the identified problem, the suggested solution, and the solution's value proposition.

3.5 An Overview of the Process

Throughout the thesis project, the width of the focus has changed. This has followed the so-called double diamond process, which is a design process. The double diamond process visualizes the design process as consisting of four main steps: discover, define, develop, and deliver. What distinguishes the different steps is if the focus is divergent or convergent (Tschimmel, 2012), which generates the form of a double diamond. The first quarter of the double diamond illustrates an initial divergent part of the project, where the focus is wide. In our case, this was when different gaps and leverage points were identified through the first round of interviews. The second quarter of the double diamond is convergent, meaning that the initial findings are reviewed and either selected or discarded. This meant, in our case, that the research was narrowed down into focusing on one specific gap. Together, the first and the second quarter of the double diamond form part 1 of our thesis project.

During the third quarter, the perspective was widened again, with the aim of finding several possible solutions, leverage points, to bridge the chosen gap. This was done by first understanding the gap in more detail, by the second round of interviews, and then finding possible solutions by using the missions in Nextapp. After identifying possible solutions, the project reached the fourth and last quarter of the design process. At this point, the focus was narrowed again by choosing one specific solution and developing a strategy for the chosen solution. Hence, the second diamond in the double diamond symbolizes part 2 of our project. This means that a double diamond figure can be used to provide an overview of our thesis project. However, it is important to emphasize the fact that the double diamond illustrates the change in focus during our project, and not how much time spent on each individual part. An illustration of our double diamond is shown in figure 3.3.

3.6 Literature review

The literature review was done throughout the whole thesis project, including searches at the Chalmers library website and Google Scholar. Examples of search strings used are 'autonomous vehicles', 'diffusion of innovations', 'sustainable transportation', and 'behavioral change'. The result of the literature review is shown in Chapter 2 and in Chapter 4.

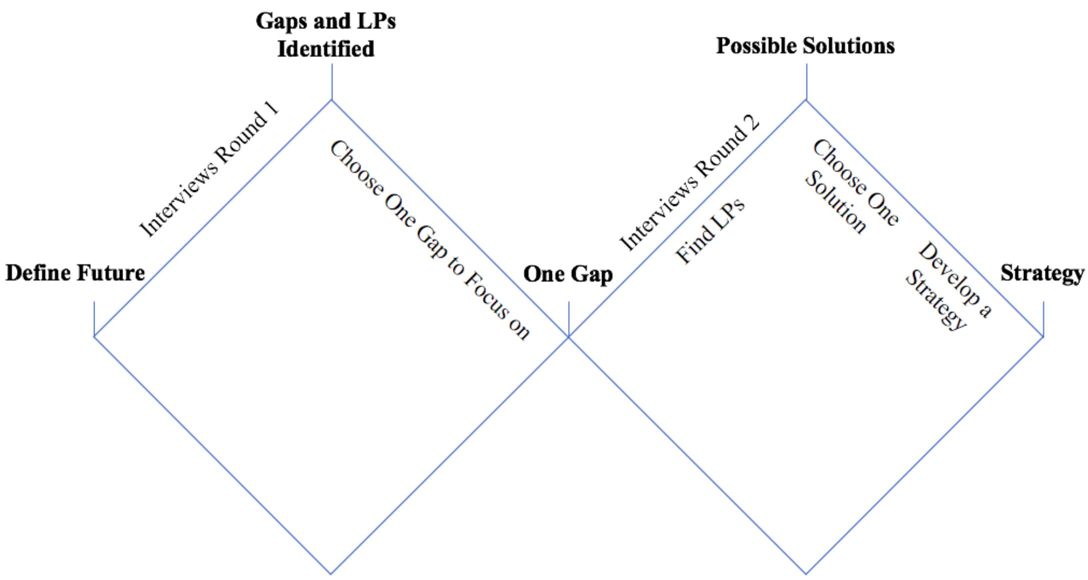

Figure 3.3: A double diamond figure, illustrating the change in focus throughout this thesis project. The figure should be viewed at from left to right, and where the diamond is widened, the focus is wide as well, meaning that it is a divergent part. Where the diamond narrows, the focus is narrowed as well. Hence, these parts are where the focus is convergent.

4

Market Description

In this chapter the market, as it looks like today, will be described. What is happening in the area of AVs and specific facts about Gothenburg will be briefed, to provide a better understanding of the background and our results. This includes car density, population, and transportation means. The part about subsidies is stated as it is a part of car ownership. Lastly, predictions and trends will be presented.

4.1 Autonomous Vehicles

Within safe boundaries, automated guided vehicle (AGV) has been driverless for decades. How automated vehicles will work outside the safe boundaries is what is being investigated by many parties these days.

Einride has a truck called the T-pod with a level 4 autonomy which drives cargo within the warehouse grounds. It is about 7 times 2.5 meters and has a 360-degree awareness (Einride, 2019). Google started the development of Waymo in 2009. In 2017 their cars were tested on public roads in the United States (Waymo, 2019). Uber is today, again, testing their AV on public roads (Meyhofer, 2018), after their fatal incident in 2018, which occurred the last time they tested their AV on public roads (Johnson and Fitzsimmons, 2018). In Gothenburg, there is Zenuity who provides software for the autonomous drive to Volvo Cars, established as a joint venture between Volvo Cars and Autoliv (Volvo Car Group, 2017).

4.1.1 Technology

The main problem today, which is holding the diffusion of autonomous cars back, is that the technology is not fully there yet. This is mainly regarding the safety aspect (E. Coelingh, personal communication, January 23, 2019). A challenge at the moment is the radar most AVs use to detect objects in its surroundings (Palermo, 2018). It could be a problem with it when several AVs are close by, as the vehicles radio waves could interfere with each other and provide false information. A GPS could be used to locate the AVs, but the question is if they can locate vehicles precisely enough, as the vehicles can be placed within inches of each other. The AVs also often use cameras and LiDAR (Light Detection and Ranging) which can have a hard time functioning in rain, snow, or fog if it blurs the view.

As of today, Waymo has taken the lead in the AV war with more experience than any other competitor (Walker, 2018). Before letting their vehicles drive by themselves, they drive the AV and scan the area for a 3D map of the scenery (Waymo, 2019), as is custom. With all driving, the Waymo cars learn and get experience. They have already driven 10 million miles on public roads and billions of miles in simulations.

As A. Walker puts it: "Amidst stunning breakthroughs and tragic failures, for self-driving vehicles, 2018 was the year of yes, but.. Yes, self-driving cars can save lives—but only if they're programmed with all users of the street in mind. Yes, self-driving cars can reduce emissions—but only if they're also electric. Yes, self-driving cars can fix congestion—but only if they're shared." (Walker, 2018, paragraph 1).

4.1.2 Rules and Regulations

Looking at the current situation, regulations which hinder the use of AVs do exist. An example of this is the Vienna Convention, which is a ratified convention in Sweden with the aim of facilitating international road traffic and increasing the overall road safety (Utrikesdepartementet, 1989). Article 8 in the Vienna Convention includes directions regarding the drivers of vehicles, for instance article 8.1 stating that "Every moving vehicle or combination of vehicles shall have a driver" (Utrikesdepartementet, 1989, p. 18), and article 8.5 stating that "Every driver shall at times be able to control his vehicle or to guide its animals" (Utrikesdepartementet, 1989). These directions are not cooperative with the introduction of AVs. However, a new paragraph has been added which allow some degree of automation, and effort is put on developing the convention further, enabling the use of vehicles with higher automation levels (level 3-5) (Statens Offentliga Utredningar, 2018).

The regulations do not only need to accept fully autonomous vehicles, but they also need to address philosophical questions regarding safety and prioritization (Fagnant and Kockelman, 2015). For instance, a pedestrian on the road and no time to brake. Then the AV needs to decide on who to prioritize in regard to maximum and minimum injuries. Either, the AV could prioritize to minimize the injuries of its passengers, or it could prioritize the safety of the other party involved in the accident. If the decision is different depending on what is in front of the car, if it is an animal, a bicyclist, or a pedestrian for instance, is also debatable.

In an investigation made by KPMG (2019), assessing countries' autonomous readiness, Sweden is lagging behind in the policy and legislation aspect. Taking all parameters into consideration, Sweden is put on 5th place at the same time as Sweden is number 10 when it comes to policy and legislation.

4.2 Car Density and Population in Gothenburg

The 31st of December, 2018, the car density in Gothenburg was 332 cars per 1,000 inhabitants, compared to the nations 477 (M. Mattsson, personal communication, April 5, 2019). At this time the number of inhabitants in Gothenburg was 571,868 (SCB, 2019).

The amount of private cars in Sweden has increased from 252,503 in 1950 to 4,870,783 in 2018. The car density in the same period has increased from 36 to 477 cars per 1,000 inhabitants (Trafikanalys & SCB, 2019). However, it seems like there was a peak in 2017, with 480 cars per inhabitant. Another peak was in 1989, with 420 cars, decreasing to 408 in 1994 only to continue to rise again. This indicates that there is not a constant increase and that this new peak does not mean that the density will decrease from now on. Sweden also has the second heaviest car fleet in the EU and larger emissions per km from new cars than the EU average (Friström, 2018).

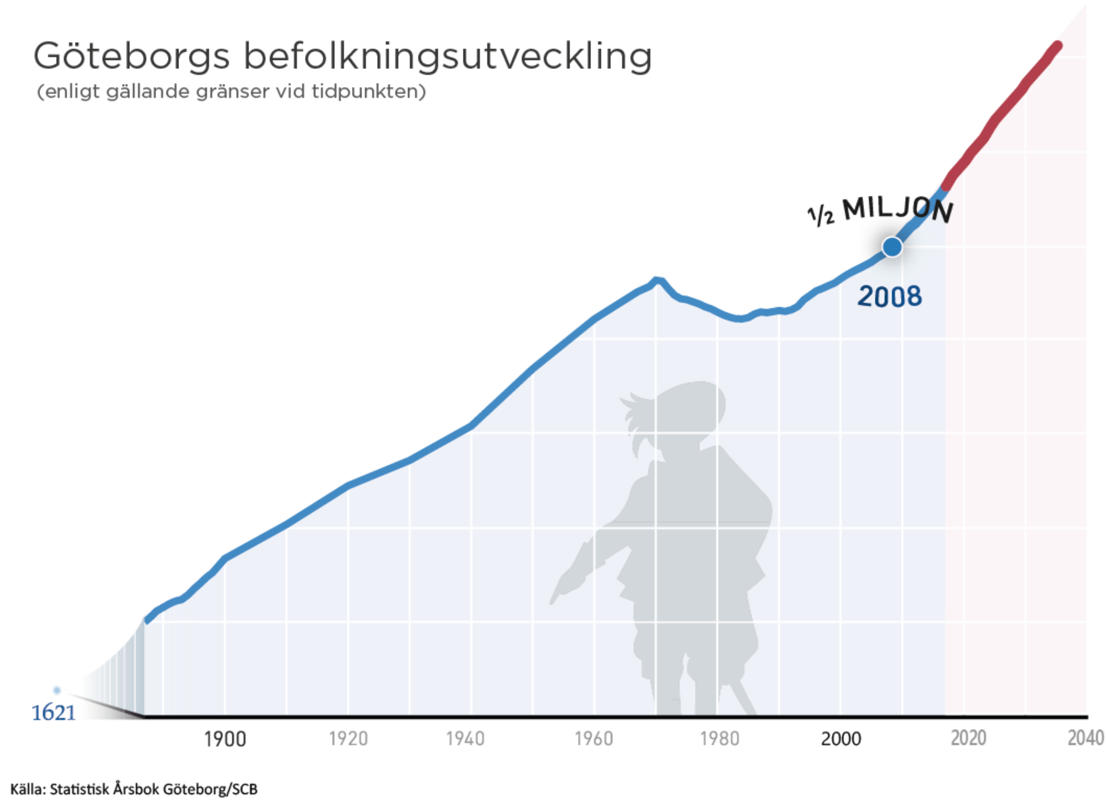

Figure 4.1: The population growth in Gothenburg. In 2008 the population reached half a million.

The population growth can be seen in figure 4.1 estimated population growth in

Gothenburg between 2016 and 2030 is 20 %, which means that there would be 665,300 people in Gothenburg by 2030 (Västra Götanadsregionen, 2016). The city plans for 80,000 new work opportunities and homes to be built by 2035, which will generate the possibility for 150,000 people to live there (Göteborgs Stad, 2019a).

Possible plans for Gothenburg 100 years into the future exist, enabling the city to grow and increase its population density (L. Memborn, personal communication, April 26, 2019). It is possible that the city will grow rapidly in the far future as well as the immediate.

4.3 Subsidies

In Sweden, a number of subsidies exist that are said to be climate contradicting. These are: energy taxes on diesel, which are lower than for gasoline; the traveling relief; and the car privilege for employees. Together, these three subsidies cost around 15.5 billion SEK in loss of tax income each year (Friström, 2018).

The energy tax on diesel has been lower than the energy tax on gasoline from the start. This was motivated by the commercial use of buses and trucks, mostly fueled by diesel. From the start, the tax was compensated with a higher tax on diesel cars, but this tax was removed in 2007 for cars with a particle filter which reached the new environmental standards (Friström, 2018). Even with these new standards, diesel pollution contains more particles and nitrogen oxides, diesel cars even create more noise pollution.

The traveling relief is a decreased tax for people who drive to and from work. To get the tax relief, the distance has to be at least 5 km per trip and the time won, in comparison with taking the bus, has to be approximately two hours (Friström, 2018). The time won is hard for the tax authority to control and therefore people tend to exaggerate the time they have won. This deception is evaluated to cost the taxpayers at least 1.7 billion SEK each year. The relief only covers the traveling costs, but as the ten most sold cars in 2017 are evaluated to cost less than the relief, they are overcompensated with 25 %. This relief was introduced to ease life in the countryside, but today it is mostly used by people in urban areas. The relief has made it cheaper to go by car than public transport.

The car privilege is when a company owns or leases a car that an employee uses for private leisure. The cost is supposed to be compensated with taxes on the pay which are on the same level of what it would cost for the employee to buy the car privately (Friström, 2018). This was quite accurate from the start in 1997 but is not anymore. The difference is about 20 %, and on top of that is free parking nowadays included in the car privilege instead of another taxation point. This privilege is also unfair socioeconomically with 0.3 % of the people in the lowest income category exploiting the car privilege, meanwhile, it is 44 % of the people in the highest income category. Also, 82 % of these privileges go to men.

4.4 Transportation Means in Gothenburg

Common transportation means in Gothenburg are driving one's car, public transportation, walking, and biking, in this order (Göteborgs Stad, 2019b). An alternative to owning your own car is to lease it. When leasing a car, you get a new car to use as your own for a few years, but things like tire change and standard services are included in the leasing subscription. Another possibility is to go with a taxi, where you pay for traveling from point A to point B without having to drive or park by yourself. There are also cars to rent when in need of a car for a short period of time. Additionally, the possibilities for renting bikes exist. Styr & Ställ is a bike pool in Gothenburg where you can have a yearly subscription or pay for three days. While biking, the first half hour is free of charge, and you only have to wait for two minutes if you want to have another half hour directly. Otherwise, it costs extra for every half hour (Styr och ställ, 2019). The newest addition to the transportation family is electrical scooters. With VOI for example, the app can locate the nearest scooter and then you scan the QR code on the scooter and pay for the lock up and per minute (VOI, 2019). There are also the scooters from Lime and Tier, which makes Gothenburg a market for three different electrical scooter brands (Wilhelmsson, 2019).

4.4.1 Shared Vehicles

In Gothenburg, three different commercial carpools exist: Sunfleet, Move about, and Bilpolen.nu. Carpools have cars available for people with an account in the specific carpool, and anyone with a driving license can create an account. The cars have specific parking slots and, normally, there are a few cars available at the same location. Several different carpool-locations exist in Gothenburg. The cars all need to be returned to their specific parking slot, in order to end the usage of the car. Meaning, if you drive the car to and from work, you have to rent it from the time you take the car until the time you return it, when getting back from work.

Sunfleet is the oldest and biggest one of these three companies. They have the largest number of locations and has the most covered area of Gothenburg. They offer four different subscription possibilities with different prices for a monthly fee, the price per hour according to the hour of the day (daytime or nighttime), the price per km, and special price offers for an entire day or weekend. Sunfleet is originally a sister company to Volvo and therefore the majority of the cars are Volvo cars. Since Volvo has not had any electrical vehicles (EV) or vans themselves, they provide some EVs and vans from Renault (and one EV from Hyundai). Their cars are normally not more than one and a half years old. Sunfleet also has an offer for companies (Sunfleet, 2019).

Move about only has EVs and only one price per month for the subscription and an hourly price and special prices for either five hours at a time or a weekend. They also have electrical bicycles to rent and if you only want to use the bicycles there is a specific prescription for that which is cheaper. Move about also has special deals for companies which have to be negotiated. (Move About, 2019)

Bilpoolen.nu has nine spots in Gothenburg with carpools and three different subscriptions, from 0 to 475 SEK/month. Bilpoolen.nu offers the possibility to start their own carpool and also has an offer for companies. (Bilpoolen.nu, 2019)

4.4.2 Lima

Lima stands for Lindholmen Integrated Mobility Arena and is a mobility as a service (MaaS) pilot project for a selected group of employees on and around Lindholmen (Lindholmen Science Park, 2018). It can be used both privately and in the job, where the travels get sent to the company directly instead of the employees needing to save the recipes for their journeys (Lindholmen Science Park, 2019). The mobility options included in the service are public transportation, rental bike, electrical scooters, taxis, a carpool, company cars, and parking. It also allows you to share your own car. All of these possibilities are included in the application. The commercial launch of this concept is potentially supposed to be in December 2020 (Lindholmen Science Park, 2018).

4.5 Predictions & Trends

The e-commerce has been growing steadily since at least 2005, partly cannibalizing on retail and grocery stores (PostNord in cooperation with Svensk Digital Handel and HUI Research, 2019). This trend reduces the need for transports to and from shopping. The change in transports because of this is harder to map, as it could mean that people use the time to travel somewhere else instead, and use the car more, or they stay in the area where they do not have to use a car, which would be a reduction of transportation. The study e-barometer also shows that 82 % of the customers are willing to wait 1-2 days extra for their goods to be transported in a more sustainable way (PostNord in cooperation with Svensk Digital Handel and HUI Research, 2019).

Automation brought a disruptive change. It has decreased the need for human labor as the machines can do the same thing cheaper and more accurate than humans. The consequence of this has been the loss of jobs for many people. On the other hand, the cheaper workforce in other countries has also decreased the job opportunities in countries like Sweden. The automation takes jobs, but it also brings the production back to Sweden and it also creates other jobs as the machines need to be installed and taken cared of (Svedberg, 2017). With more automation the need to get to work decreases, more jobs can be carried out from a distance, for example from home, which might reduce the traveling need.

5

Results and Discussion, Part 1

In this chapter, the results of the first part of our research are presented and discussed. The presented and discussed results include a definition of our desired future, identified gaps between our desired future and the current situation, and leverage points for how to bridge some of these gaps. Finally, potential challenges with our desired future are presented, followed by an argumentation and an explanation for how we focused the further investigation. Hence, part 1 includes the first, second, and third step of the backcasting methodology.

5.1 Our Desired Future

Our desired future is based on our aim and a number of sustainability criteria based on the Lighthouse model by Holmberg and Larsson (2018). This leads up to a description of our desired future, which is the first step of the backcasting process. The time frame is when AVs have reached, and maybe surpassed, level 5 (fully autonomous vehicles in certain areas) are diffused in society and could operate in Gothenburg.

5.1.1 Sustainability Criteria

The sustainability criteria for a sustainable transportation system were defined in order to be able to identify a sustainable future with AVs within the city of Gothenburg. The criteria are divided between the three dimensions of sustainability: ecological, economic, and social sustainability. The aspects that are included in the wellbeing dimension of sustainability, which is a part of the Lighthouse model by Holmberg and Larsson (2018), have been included under the dimension of social sustainability. An overview of the sustainability criteria is shown in figure 5.1, followed by a description of each criterion.

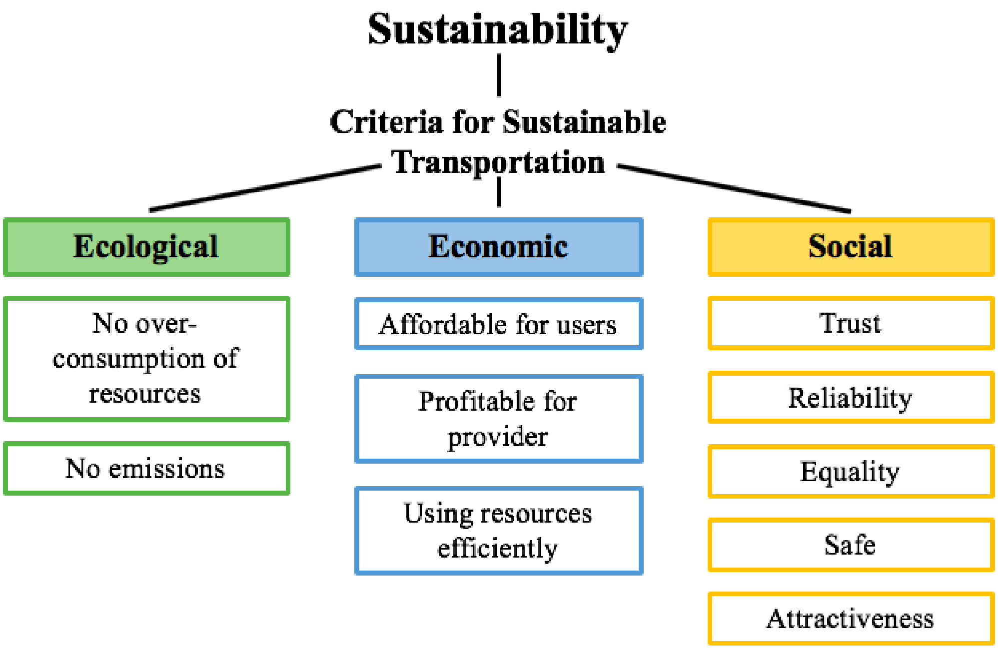

Figure 5.1: Sustainability criteria for a sustainable transportation system, divided between the three dimensions of sustainability: ecological, economic, and social sustainability.

5.1.1.1 Ecological Sustainability Criteria

No over-consumption of resources: Resources are scarce and, hence, it is ecologically sustainable to use a limited amount of materials and substances.

No emissions: No GHG emissions into the ecosphere, since this has a negative impact on the environment.

5.1.1.2 Economic Sustainability Criteria

Affordable for users: The offering should be economically affordable for users in order for AVs to diffuse in society.

Profitable for provider: The offer needs to generate profit, or at least break even, for the solution to be attractive for the provider and generate a constant development of the solution.

Using resources efficiently: Resources should be used efficiently, optimized usage with high utilization, to be economically justifiable.

5.1.1.3 Social Sustainability Criteria

Trust: An overall trust among users, providers, policy-makers, and all other parties involved must exist to facilitate the development and diffusion of AVs.

Reliability: The offer has to be reliable, both technically and functionally, in the sense that it should deliver the promised service.

Equality: The offer should be characterized by equality on all levels, for instance equal access.

Safe: It is crucial that the AVs are safe, both between traveling companions and causing no accidents.

Attractiveness: The offer has to be attractive in order to get customers.

5.1.2 Description of Our Desired Future

Based on the sustainability criteria, a sustainable future with AVs for passenger transport in Gothenburg has been defined. This means that the desired future should be ecologically, economically, and socially sustainable. Ecologically through zero emissions while driving and low natural resource usage in the production. Economically through profits for the investors, affordability for the customers, and efficient use of resources. Socially by equal, reliable, and trustworthy access. Additionally, the future transportation system should be safe and attractive, in line with the sustainability criteria.

Note that the described future is only one alternative to achieve a sustainable future, and it is possible that several other scenarios exist which would meet the sustainability criteria and, hence, be sustainable. It is also important to note that the desired future is not defined with the aim of being the most likely development and diffusion of AVs. The aim is that our desired future should be more sustainable compared with the transportation system that exists today. Therefore, some aspects of the desired future can seem a bit extreme and not likely to be achieved in a near future. The desired future will be described by stating one characteristic at a time, followed by argumentation on why this characteristic meets one or several of the sustainability criteria.

- ***A robot taxi service is provided and no one owns a car***
  Providing a robot taxi service generates possibilities of utilizing each car to a higher degree. This service would allow the end of personal ownership of

cars. Hence, in our desired future no one owns a car since this means that it is easier to make sure that each existing car is utilized to the fullest. Ergo, the only party owning vehicles for passenger transport is the service provider. Additionally, if the existing cars have a higher degree of utilization, fewer cars are needed in total, which in turn means that, ceteris paribus, the consumption of natural resources decreases. AVs and a decreased car fleet also generate possibilities of more green spaces within the cities as well as allowing a higher population density, by reducing the need for spacious roads and parking (KPMG, 2019). This also diminishes the fact that some cars break only because of age when not used.

- ***The robot taxis can be shared simultaneously***
In the same way as providing a service instead of private car ownership means that the utilization of each vehicle can increase, sharing vehicles simultaneously, ride-sharing, contributes to increased utilization of the existing capacity. In that way, the needed number of vehicles decreases which means a decreased consumption of natural resources.

- ***The number of robot taxis is optimized***
In the desired situation, the number of existing vehicles should be optimized with respect to several perspectives. The number of vehicles on the roads should not cause congestion, the use of material and resources should be minimized, and the utilization should be maximized. It should be optimal for the number of people that need to travel and not cause waiting time, which also generates a reliable and attractive service. In our desired future, the number of vehicles for passenger transport is optimized to meet all these aspects.

- ***An even and constant demand for the robot taxi service***
In an optimal situation, the demand is even and constant during all hours of the day, which is the case in our desired future. A fluctuating need and demand for transportation are not sustainable in the sense that it generates a reality where a significantly larger amount of vehicles is needed during certain hours of the day, while almost no vehicles are needed during other. Hence, the consumption of resources can decrease if the demand is dispersed evenly throughout the day.

- ***The robot taxis are smart and connected to a traffic planner***
The robot taxis are connected to the cloud and a traffic planner should optimize the routes according to all available information. This information includes the position, speed, and destination of the AVs; the pick-up position, desired arrival time, and destination of the customers; and the traffic situation. It should constantly update the routs as new and real-time information is available. The optimization should include minimum distance, minimum time, and a maximum number of passengers to eliminate unnecessary driving and maximize the utilization of each vehicle.

- ***The robot taxis emit zero emissions***

To minimize the negative environmental effects caused by transportation, the robot taxis should emit zero emissions while driving. What is used to power the vehicle should also emit zero emissions, it could for instance come from renewable sources.

- ***Equal access to the robot taxi service***
  For the robot taxi service to be socially sustainable, all geographical areas and groups in society should have equal access to the service. This also includes people with special needs, people with different disabilities for instance, or other aspects that might affect what is needed by the vehicle. For instance, a family using the robot taxi service might need both special car seats for the children as well as room for strollers.

- ***The vehicles are produced to last as long as possible***
  In order to produce vehicles, a certain amount of materials and resources are needed. However, to reach the sustainability criteria of having no over-consumption of resources, it is important that as little resources as possible are used. By producing the vehicles with the aim of lasting as long as possible, without any sort of programmed obsolescence, no unnecessary resources are used.

- ***The service should be safe and reliable***
  The service should not cause any injuries of any kind. It should be safe to use the service, both regarding traffic situations (no accidents) and among the people sharing the vehicles.

- ***The transport system is economically sustainable***
  The cost of using the robot taxi service should be balanced between two main parameters. The service should be affordable for everyone in society, at the same time as it should be profitable, or at least break even, for the provider.

- ***Noise free***
  City noise has a negative impact on human health. Therefore, the robot taxi service should be quiet, and not cause any discordant sound.

5.2 Gaps and Leverage Points

The results of the second step of the backcasting method and a part of the third step are presented here. Those parts include identified gaps between the desired future and the present, and leverage points to bridge these gaps in our society. The gaps and leverage points presented in this chapter mainly originates from the first round of interviews. Gaps are defined as *something that is missing in the current situation in order to achieve our desired future.* A leverage point is defined as *a thing or an* *action that has a bullwhip effect*[1] *with the potential to bridge one or several gaps.* In table 5.1, the identified gaps and leverage points are presented. However, a more detailed description of these will be provided in the following sections.

5.2.1 Technology

From our interview with E. Coelingh at Zenuity (personal communication, January 23, 2019) we learned that the technology is not quite there yet to allow AVs level 5 to be sold. The cars do not talk to each other - they are not connected and the technology does not work within the infrastructure today.

The vehicles that are driving on public roads around the world are only test driving and some accidents have occurred where the AV has not done what it was supposed to do (State of California - Department of Motor Vehicles, 2019; Favaro et al., 2017). In other cases where the AV has done exactly what it was supposed to do, the driver in the conventional vehicle has been in error and accidents with AVs have occurred.

A challenge, as explained by Palermo (2018), is the radar most AVs use for detecting objects that exist in their surroundings. Cameras and LiDAR (Light Detection and Ranging) are also common features of AVs today and these can have a hard time functioning in bad weather conditions such as rain or snow. This could be a problem for AVs to function in the city of Gothenburg since the weather is very varied. Therefore, camera, LiDAR, and radar technology might need to be improved before AVs can drive in Gothenburg.

5.2.2 Facilitating Infrastructure

At Zenuity, they believe that the technology should be developed to an extent where it works within the existing infrastructure. Even though the AVs should work within the existing infrastructure, in line with E. Coelingh (personal communication, January 23, 2019), there are ways to improve the infrastructure to facilitate the diffusion of AVs. In a study done by MarketLine (2018), it is stated that smart roads and infrastructure are needed in order for AVs to reach their full potential. Roads that are able to collect and analyze data in real-time could help to increase the connectivity between the vehicles on the roads. This could, in turn, help to prevent accidents by passing important information, for instance about unexpected events, between vehicles.

[1] Describes how small actions at one end, can cause continuously increased effects into the other. The term is often used in supply chain management, explaining how small fluctuations in demand can cause progressively larger fluctuations throughout the supply chain.

Table 5.1: A compilation of the identified gaps and leverage points, where the leverage points are connected to their specific gap.

Gap	Leverage Point
Technology	Research and development
Facilitating infrastructure	Continue the work on developing smart cities *or* develop the AVs to cope with the existing infrastructure
Storage options	Belongings needs to be brought with you
Noise free traffic	Change road surfaces
	Change tires
	Lower traffic speed
Rules and regulations	Adjust legislation to enable AVs on the roads
Even and constant flow of traffic	Congestion taxes
	Parking fees
	Distance or road wear taxes
	Taxes based on streets
	Regulation: No cars allowed within the city center
	More flexible work and school hours
	Deliver goods during night
	Digitalization, reduce need for mobility
	Citizen's income
	Adjusted city planning
Incentives to not own a car	Taxes, make car ownership more expensive
	Remove car subsidies
	Separated road lanes
	Create better solutions
	Enable people to try other transport alternatives
Business model	Force car manufacturers to change
	Find innovative ways to create value
Acceptance	Enable people to try
	Change the vehicle design gradually
	Modular vehicle design
	Transparency
No status in car ownership	Cultural change
Means to avoid car sickness	DVIs
	Smooth driving
Willingness for ride-sharing	Create the feeling of traveling alone
	Make car ownership more expensive
	Travel with several strangers
Changed practices	Encourage and benefit new practices

5.2.3 Storage Options

Today, many of us use the car for storage, we bring our sports gear and leave them in the car as we work, for instance, to have them easily at hand directly after work.

Some keep things in their car to have close by in case they are needed and so on. This way to store things will not be possible, or at least work differently, in our future when the cars do not belong to people.

5.2.4 Rules and Regulations

The legal aspect needs to be addressed when it comes to the automation of vehicles. Looking at the current situation, regulations which hinder the use of AVs do exist. The need to modify existing rules and regulations has been a recurring theme during our interviews. It has been mentioned that the legal aspect regarding automation has not been taken into consideration to a sufficient extent as it is today, and that it will take time until regulations accepting fully autonomous vehicles will exist, especially when it comes to passenger transportation (H. Clasen, personal communication, February 21, 2019). The fact that Sweden is put on the 5th place in total regarding the readiness for AVs, and the 10th place for policy and legislation, in the investigation made by KPMG (2019), indicates that Sweden has some work to do in this aspect. Hence, an existing gap between the current situation and our desired future is the lack of rules and regulations allowing the use of fully autonomous vehicles.

5.2.5 Noise Free Traffic

In today's society, noise from traffic is a phenomenon with adverse health effects. Hence, the desired future includes no traffic noise to increase the health in Gothenburg. This means that the gap between today and our desired future is noise free traffic (S. Bolminger, personal communication, March 8, 2019).

5.2.5.1 Leverage Points to Noise Free Traffic

To reduce the noise from traffic, the cause of the noise, the interacting surfaces, could be developed and invested in, to not cause as much friction. This means the roads and the tires of the vehicles. There is also the possibility to lower traffic speeds to reduce the noise.

5.2.6 Even and Constant Flow of Traffic

Today most of us have similar lives, where we sleep during the night and work for eight hours during the first part of the day. This creates rush hours, among other things. Our lifestyle is a barrier to an even flow of traffic, indicating that the gap is a variation in our everyday life (J. Hellåker, personal communication, February

7, 2019). The rush hours and our similar routines have been mentioned by several interviewees as a gap towards a number of characteristics of our desired future.

5.2.6.1 Leverage Points for an Even and Constant Flow of Traffic

There are many instruments to even out the flow of traffic during the day. The most obvious instrument is to let the costs follow the congestion curve, to make it more expensive when the congestion is high. This is a price setting to limit the congestion peaks. In Gothenburg, we already have congestion taxes and parking fees rated after the time of the day.

Other, more indirect methods, are distance (km) or road wear taxes, or taxes based on which or how many streets one drives. Simply put, put taxes on what causes negative effects (E. Almlöf, personal communication, February 14, 2019). A direct method is to instate a regulation where no cars are allowed in the city of Gothenburg. Another way to shrink the peaks is to have more flexible hours at work and school, and flexibility in where to work, so that people can spread out their traveling during the day. Also, deliver goods during the night, to remove all goods transport which adds to the congestion during the day (A. Svensson, personal communication, February 13, 2019).

Other secondary methods to reduce the congestion is to remove the need for mobility through digitization and another idea to reduce the congestion is to establish a citizen's income. There is also the matter of the city planning, with a good mix of homes, kindergartens, schools, and work opportunities, the need for mobility is reduced (L. Memborn, personal communication, February 26, 2019).

5.2.7 Incentives to Not Own a Car

Today, it can be quite cheap to own a car, especially if it is old. Some places have free parking and others are cheap, the gas consumption can be low and the smaller the car is the less it consumes. As it is today, society subsidizes the ownership of cars, as can be read about in section 4.3. For someone already owning a car, the gas consumption is the only cost usually considered in comparison to traveling with other means, e.g. taxi, bike or public transport. In the same way as for one who has a monthly card for public transport, another journey does not cost anything until one has to buy the next month card.

In many cases, it can be cheaper to take the car and more convenient as well, with the freedom to go as you please. So, when it is cheaper and more convenient, there is an incentive to own a car. Therefore, a gap is an incentive to **not** own a car, as A. Svensson points out (personal communication, February 13, 2019).

Some people will probably have a hard time with letting go of the car. It is likely that cars will go the same way as horses did; after being used for transportation people still have them as hobbies and entertainment (E. Almlöf, personal communication, February 14, 2019).

5.2.7.1 Leverage Points for Incentives to Not Own a Car

Many of the leverage points to not own a car is the same as for the variation in travel behavior, prohibit personal cars in Gothenburg, city planning, citizen's income, work from home through digital means, and making it more expansive to drive through taxes and fees. On this subject, it should not only be more expensive to drive at the congestion peaks but in general (A. Svensson and E. Almlöf, personal communication, February, 13 and 14, 2019). To start off, the car subsidies mentioned in section 4.3, energy tax on diesel, traveling relief, and the car privilege, should be removed.

The cost could be looked upon as the whip and there could also be some kind of carrot if it was advantageous to not own a car. One way would be to have separate road lanes for different vehicle purposes. Gothenburg has this on some roads already, with bus-lanes, if this would be expanded to all roads, the public transportation could be more advantageous to use than taking the car (L. Memborn, personal communication, February 26, 2019). There is also a plan for a lane for AVs in the interest of the nation, which as a start probably will be for transportation of goods, but could in the future be an AV service, in the same way as stated in our desired future.

Since people feel that they need cars for their leisure journeys, they have one, and just owning a car is a fair part of the costs. Therefore, some feel inclined to use it, and it is cheaper with fuel than tickets for the public transport, not to talk about the convenience advantages and the time efficiency of taking the car instead of the bus. This indicated that a leverage point would be to have better options than owning a car when going on a leisure trip.

Leverage points to not own a car is more attractive solutions, something you cannot resist that is cheaper and more efficient (H. Strömberg, personal communication, February 11, 2019). This brings along the problem of people biking and walking also using this more attractive solution, if it is not biking and walking that is the solution. Therefore, these ways of transportation should always have the upper hand on being the most advantageous through different means, as they are sustainable and a healthy way to transport oneself.

An important step in any transition is the allowance to try things out (H. Strömberg and M. Hesselgren, personal communication, February 11 and 13, 2019). For people who own a car, this should be a possibility as it could be crucial before choosing to get rid of the car.

5.2.8 Business Model

The business model mostly used today is where producing companies sell their products. Another newer approach has been to servitize the products, where the company still owns their products but, in a manner, rent them out, to different degrees of product or service orientation (Mastrogiacomo, Barravecchia, and Franceschini, 2018). For the automotive industry, leasing is a step in this direction which has already been taken, but the need is to go all the way to become completely service oriented, to offer a ride instead of a car.

5.2.8.1 Leverage Points to a Business Model

Prohibiting personal cars in Gothenburg would force the car manufacturers to change their business model. Making it more expensive to own a car, as discussed above, would make people more unwilling to do so and probably lead to a new business model for the companies to try new ways of making money when the old way is decreasing. If the road lanes would be divided into different purposes, where car-sharing is favored, it could increase the incentive to have a business model where the company owns the cars.

The business model that we want to see is where the companies own the cars and offer rides as a service. If the cars could have other functions as well, such as delivering goods, it would be another way for the car owner to make money and an incentive for the car companies to keep the ownership of the cars. When this business model is to be installed it is of crucial importance to let people try it out at first, this cannot be mentioned too many times, and show that the technique works.

There are two kinds of leverage points, push or pull. Pull would be when people desire and ask for, in this case, a new way of transportation, indicating a new business model. If the company instead goes ahead and invents a new business model and offers it to the public, it would be a push.

5.2.9 Acceptance

To reach our desired future, the behavior of society needs to change. People need to accept the change, the new ways of doing things, and the new things in themselves. Customer acceptance is one of four parameters that are assessed when evaluating a country's AV readiness index (KPMG, 2019). In this investigation, Sweden has the 4th highest score in the customer acceptance aspect, while Sweden is in 5th place in total. Hence, even though this is a gap that needs to be overcome in order to reach the desired future, Sweden, and the city of Gothenburg, has a good starting point.

In the evaluation made by KPMG (2019), five factors are used to decide the customer acceptance for AVs. These factors are consumer opinions of AVs, the population living in test areas, civil society technology use, consumer adoption of technology, and online ride-hailing market penetration. Regarding the willingness to adopt new technology and civil society technology use, Sweden is one of the countries with the highest score. Looking at the factor regarding population living in test areas, Sweden's score is quite moderate. However, our scope is limited to the city of Gothenburg, where projects such as Lima (see section 4.4.2 for more information about Lima) are implemented. Hence, it is reasonable to assume that this factor would get a higher score when only looking at Gothenburg instead of the entire country. This means that the factors that need to be improved in order to increase customer acceptance are, mainly, consumer opinions of AVs and online ride-hailing market penetration, if using the same factors as KPMG (2019).

5.2.9.1 Leverage Points for Acceptance

To increase the acceptance of the technology, trying out is essential. People need to see and experience that it all works, the technology, the business model, the service and the application, in order to improve consumer opinions of AVs. To ease the acceptance of a new look for the car, it would be advisable to change the look gradually, to not make it too unfamiliar at once. For people with special needs, to accept shared mobility, the car should be modular to fit all needs (H. Strömberg, personal communication, February 11, 2019). There is also a need for transparency between the company and the customer. When people see how and why things work as they do, they have an easier time accepting it. Leverage points, which has been stated earlier, that could have a secondary effect on acceptance are increased costs to own a car and purpose given road lanes. This, because when the car is not the best or cheapest alternative anymore, it is easier to accept another alternative. People who like to own cars hopefully accept the new system and can be satisfied with keeping them as a hobby.

5.2.10 No Status in Car Ownership

The ownership of a car does not only provide the owner with the possibility of traveling from point A to point B. Today, one incentive to own a car is that it is seen as a status symbol for some people (H. Strömberg, personal communication, February 11, 2019). This applies not least for luxury car brands, which could send out signals of wealth and a luxurious lifestyle. The fact that car ownership today is seen as a status symbol is a barrier to achieve our desired future, and what is missing, the gap, is that no status in owning a car exists.

5.2.10.1 Leverage Point for No Status in Car Ownership

To remove the status in car ownership, a cultural change is needed. The status should be in not owning a car (M. Hesselgren, personal communication, February 13, 2019). However, it could be that a cultural change already has started since some people claim that cars in the future will have the same reputation as smoking has today.

As stated in section 2.3, cultural changes are closely related to behavioural changes (Hargreaves, 2011). Several different methods and theories for how to achieve behavioral changes exist, Lewin's change model is one example. This change model suggests that unfreeze, change, and refreeze are the three steps needed to achieve change (Darnton, 2008). When it comes to car ownership, what needs to be "unfreezed" is status in car ownership, and what needs to be "refreezed" is a scenario where there is status to not own a car. To unfreeze the existing situation, it is important that awareness about the negative aspects with car ownership, for instance in relation to sustainability, is spread in society. Car ownership should not be glorified. Instead, negative impacts with car ownership should be visualized. This could potentially start a cultural change and remove the status in car ownership. To refreeze the new situation, active involvement and commitment from those who have an interest in the change is needed (Darnton, 2008). Therefore, the parties interested in a more environmentally sustainable society, for instance politicians, need to be involved.

5.2.11 Means to Avoid Car Sickness

Problems with motion sickness exist for AVs (H. Strömberg, personal communication, February 11, 2019). People get much easier car sick when you are not driving yourself and the brain can prepare for certain movements. Additionally, one main benefit of AVs is the fact that no driver is needed, which means that time to do other things, such as working or watching movies, is released. But to be able to do this, it is important to not get motion sick. Hence, an existing gap is means to avoid motion sickness in the AVs.

It is difficult to change the fact that there is a risk of getting car sick when, for instance, reading while traveling. This is due to the fact that a conflict between the individual's visual and vestibular inputs can arise when the head is moving in one direction and the external environment is not moving in the opposite direction (Elbanhawi, Simic, and Jazar, 2015; M Bronstein, Golding, and A Gresty, 2013). When reading a book, the external environment is perceived to be the book, which is not moving in the opposite direction, generating a risk for getting motion sick.

5.2.11.1 Leverage Points to Means to Avoid Car Sickness

Elbanhawi, Simic, and Jazar (2015) explain that one means to reduce the risk of car sickness in AVs is to have DVIs in the vehicles. These DVIs should provide sensory feedback to the passengers about the coming movements. Additionally, the risk for motion sickness decreases when abrupt changes in steering, oscillations, and resulting forces are avoided (Pérez, Milanes, and Onieva, 2011). This means that it is beneficial if the AVs are developed with the aim of driving smoothly.

5.2.12 Willingness for Ride-sharing

Our desired future includes ride-sharing, when beneficial, in order to increase the degree of utilization of the existing capacity. However, during our interviews, this characteristic has been related to a potential gap, namely the fact that many people do not want to socialize during transportation and prefer to travel by themselves. For some people, the traveling time in their cars is a sacred moment of the day where they get some alone time, before going to work or going home to their families, for instance. For these people, the transition into ride-sharing might be difficult. Other people use public transportation today and are used to traveling with other people. For these, the transition into ride-sharing might be both positive or negative. However, it is likely to assume that resistance against ride-sharing does exist.

One example which could be used to indicate the unwillingness of people to share transportation is a project which was done at Scania in Södertälje in the year of 2017 (M. Hesselgren, personal communication, February 13, 2019). In this project, there were approximately 500 people working in the same building and living in the same area, which were offered a ride-sharing service through an app. The result was that 0.3 % searched for and tried the service, while 1.5 % searched for the service, but never used it (Schillander, 2006). However, the reasons for this nearly non-existent interest for the ride-sharing solution could be multiple and not just due to the unwillingness to share their rides. For instance, it could also be due to existing habits and convenience.

It has also been mentioned during several interviews that one reason for the resistance for ride-sharing is the safety aspect, that people feel unsafe traveling with strangers (S. Bolminger, personal communication, March 8, 2019). This insecurity constitutes a barrier for ride-sharing.

5.2.12.1 Leverage Points to Willingness for Ride-sharing

A leverage point towards car-sharing is to have cars that create the feeling that you are traveling alone, or only with people you want to travel together with (H. Strömberg, personal communication, February 11, 2019). Prohibiting cars in the city of Gothenburg would be a leverage point to this as well, as it would force people to ride share. Making it more expensive to own a car would have a similar, yet not so direct, effect. To reduce the resistance to ride-sharing that is caused by the fact that people feel unsafe traveling with strangers, it could be beneficial to make sure to never have a robot taxi with only two people that do not know each other. In general, people feel safer traveling with several strangers, than with just one (S. Bolminger, personal communication, March 8, 2019). Another solution would be for the robot taxi to have cubicles for each passenger to sit in, to get the feeling of riding alone.

5.2.13 Changed Practices

Comparing today's transportation system with the transportation system in our desired future, different practices are needed. As stated in section 2.3.2, a practice is the normative way of performing everyday tasks and can be seen as assemblages between images, skills, and things (Shove and Pantzar, 2005). As stated by M. Hesselgren, our values and lifestyles of today are not the same as in the described desired future (personal communication, February 13, 2019). People owning cars have to change their habitual behavior patterns, their practices, when it comes to transportation and the way they move from point A to point B. Hence, it is mainly practices for transportation in relation to car ownership that need to change, people not owning cars and travel with, for instance, bikes or by walking do not need changed practices.

5.2.13.1 Leverage Points to Changed Practices

To change the existing practices for how people transport themselves today, the links between the images, skills, and things of the unsustainable practices need to be broken. This should be followed by the creation and stabilization of new practices, that are in line with our desired future. An example of a practice today, for people owning or having access to cars, is driving to work. The thing that is included here is the car, the skill is driving the car, and an image could, for instance, be the status in owning a car. The links between these components, which form the practice, could be challenged and then replaced by the new practice of using the robot taxi service to work. However, it takes time to change practices and it is important that the practitioners of the practices that need to change are encouraged to intercept with the new practices.

5.2.14 Other Leverage Points and Considerations

To achieve a sustainable transportation system, it is important that the vehicles are produced with the aim of being used as long as possible, to decrease resource consumption. To make it easier to fix the vehicles if something is broken, instead of scraping the whole car, it is beneficial if the AVs have modular designs. In that way, it is easier to change parts if something is not working, or if a part needs to be updated.

In our desired future, the AVs that exist should have as high utilization as possible. The number of vehicles should be optimized, meaning that the number of vehicles is adjusted to fit with the demand for the robot taxi service. Additionally, the vehicles should be driven by fuel that does not cause any negative effects for the environment. Looking at what alternatives that exist today, electrical driven vehicles could be an option. However, electric vehicles need to be charged. If the vehicles stand still while charging, this means that the possibility of maximizing the utilization disappears. A way to solve this problem is to have electric paths, where the vehicle gets charged through the road (H. Strömberg, personal communication, February 11, 2019), which is a phenomenon that already is in development.

The vehicles in our desired future do not need to look the same as cars do today. The size of the vehicles could be adjusted after the existing demand for certain road lanes. For instance, road lanes were the demand always is high, there could be shuttle buses that always goes back and forth, and then smaller AVs takes over where the demand is lower. Additionally, to reduce the waiting time for travelers and to decrease the miles driven, people can write intervals for where and when they want to be picked up.

5.3 Identified Challenges

During the process of identifying gaps for our desired future, a number of challenges have been identified as well, which are presented in this section. A challenge is defined as *eventual risks associated with our desired future.*

5.3.1 Difficult to Optimize the Number of Vehicles

One sustainability aspect of our desired future is the fact that the number of vehicles is optimized. We want to avoid unnecessary resource consumption and unused capacity, as well as congestion. However, the possibility of achieving this presumes that nobody has their own cars. Even if strong incentives to not own a car was created, it could still be people that want to have their own cars. Hence, it could be difficult to optimize the number of cars if car ownership is not completely prohibited.

If a mixture of public transportation, privately owned cars, and the robot taxi service exists, this could endanger the possibility of optimizing the number of vehicles on the roads, creating more congestion than necessary. Additionally, optimization is a challenge to achieve in other aspects as well. People's traveling behaviors change in line with several parameters: if it is a weekday or weekend, which season it is, and what weather we have, for instance. Hence, the number of vehicles needed is dynamic during the day, but also during the week and during the year. Achieving a number of vehicles that is optimal in each specific situation is difficult, and some kind of compromise will be needed.

5.3.2 Costly Transition

The transition into our desired future includes the development of advanced technology as well as eventual changes in infrastructure, which could be associated with high expenses. Our desired future does also open up for many new possibilities: narrower roads, more green areas within the city, and a reduced need for parking, for instance. However, to take advantage of these benefits, infrastructural changes are needed, which could be costly.

5.3.3 Violating Integrity

The digital solution needs to collect data from people using the robot taxi service to be personalized. This means that the solution provider knows where the users of their service are and what traveling behaviors they have. The information that could be gathered by the solution provider could, by some people, be seen as violating people's integrity.

5.3.4 The Göta Älv Creates a Bottleneck

The Göta Älv is a river that runs through the city of Gothenburg. A problem in Gothenburg is congestion, and Göta Älv is creating bottlenecks already as it is (A. Svensson, personal communication, February 13, 2019). It is likely to believe that the Göta Älv could create a bottleneck in our desired future as well. One way to decrease the effect of Göta Älv as a bottleneck is to increase the number of bridges over the river. In a city plan for the future of Gothenburg, made by the city architect Lucas Memborn, the number of bridges over Göta Älv is increased (L. Memborn, personal communication, February 26, 2019), which could be a proper solution.

5.3.5 Cannibalization of Other Sustainable Transport Means

Our desired future, of course, includes more ways to travel than the use of the robot taxi service. In a sustainability point of view, walking and biking will always be good means for transportation. However, the robot taxi service will probably replace all public transportation of today as well as passenger transportation by car. Hence, one prerequisite for our desired future to work is that all people traveling with cars and public transportation today will change to either using the robot taxi service, travel by bike, or walk.

A scenario where all passenger transportation, which today includes both public transportation, biking, walking, cars, taxis and so on, is done through the robot taxi service, is not sustainable. This could risk the population health due to too much sedentary when everyday exercise in the form of biking and walking disappears. An age group that, most likely, will walk and bike to a decreased extent with the introduction of a robot taxi service is children (E. Almlöf, personal communication, February 14, 2019).

5.3.6 The Robot Taxi Service Needs to be Attractive

It is important that the robot taxi service is attractive in order to achieve a change and to revolutionize the way personal transportation is done today (M. Hesselgren, personal communication, February 13, 2019). However, the desired future builds upon the assumption that people still use other sustainable means of transportation, such as walking and biking. The robot taxi service should also be more convenient than car ownership is today, if it is supposed to happen without the force of law and regulations.

5.3.7 Rebound Effects

Our desired future has been developed with the aim of being sustainable. Hence, the transition from where we are today into the desired future would mean sustainability benefits in efficiency. However, efficiency, ceteris paribus, leads to lower costs, resulting in cheaper usage. This is called the 'rebound effect', which means that improvements in efficiency could lead to an increased demand, which, in turn, leads to an overall increased environmental impact (Peterson, 2014). The reason for the rebound effect is that people tend to change their behaviors when something is cheaper, for instance if a vehicle is more energy efficient. This often leads to longer driving distances in total. Hence, the robot taxi service needs to take this into account, to counteract this side effect. So that the robot taxi does not lead to an increased number of kilometers driven, which it otherwise could (E. Almlöf, personal communication, February 14, 2019).

5.3.8 A Mixture of Autonomous and Conventional Vehicles During the Transition

Our desired future does not include any conventional vehicles since the only vehicles on the roads are autonomous. The current situation is the other way around. Today there are no level 5 AVs, which are fully autonomous, on the roads of Gothenburg. Even though the number of connected, autonomous vehicles will increase gradually, there will be a mixture of autonomous and conventional vehicles during quite some time (Statens Offentliga Utredningar, 2018). This transitional phase could include additional challenges in a technological aspect (E. Coelingh, personal communication, January 23, 2019). The first fully autonomous vehicles have to be able to handle both other autonomous and connected vehicles, and also conventional cars that are not connected.

5.3.9 A Need for Large Amounts of Fuel

Our desired future includes AVs with zero emissions during driving. Looking at the current situation, one opportunity would be electric vehicles, driven on green electricity. Whatever fuel type that will be used, needs to replace today's gasoline-powered vehicles and, even though the distances driven should be smaller in the desired future, a large amount of this fuel type will be needed. If the AVs will be electrically driven, this would require large amounts of electricity which could lead to power shortages (E. Almlöf, personal communication, February 14, 2019).

5.3.10 Network Effect

If our future is to work out, it needs to be possible to travel to and in other places in an as convenient way as it is to travel in Gothenburg (E. Almlöf, personal communication, February 14, 2019). This fact that traveling needs to work in the same way outside of Gothenburg for it to become big in Gothenburg is called the network effect.

With the project Ubigo, which is a mobility as a service project, the biggest challenge was the leisure activities, where people traveled somewhere they could not return the car until they got back, e.g. going to the summer cottage for a couple of days, since it became expensive (H. Strömberg, personal communication, February 2, 2019).

5.3.11 Collectivism

People are different in how they treat and take care of things and it differs between their belongings and things they borrow. Therefore, there is a preference among some to own the products one uses, to know no one else uses them and brakes them. As it might be unreassuring to not know in what condition one might get the vehicle in when it works as a service, it might be a big step for some to have to use the same car as an unknown number of other people.

5.4 Focusing the Further Investigation

One of the main characteristics of our desired future is the robot taxi service, which presumes that nobody owns a car. Since people do own cars as it is today, this is an important difference between the current situation and our desired future. Also, regardless of how long time the development of fully autonomous vehicles will take, reducing the overall car ownership is of interest in a sustainability point of view since a decreased car ownership offers possibilities to reduce the use of natural resources and reduce GHG emissions. Hence, the further investigation is focused on the aspect of car ownership and the gap that we aim to bridge is *incentives to not own a car*. This means that the further investigation aims to find leverage points which could be used to create incentives to not own a car. As owning a car today provides additional value than just being able to travel from point A to point B, creating incentives to not own a car could bridge a number of other gaps as well.

In order to develop a suitable strategy for the needed transition, which is the fourth step of the backcasting methodology, it is important to understand the underlying reasons why the gaps exist. This, to make sure that appropriate leverage points are suggested and applied. To be able to dig deeper into the underlying reasons for the chosen gap, the further investigation was focused.

6

Results and Discussion, Part 2

In this chapter, the results of the second part of our research are presented and discussed. The gap we aim to bridge is *incentives to not own a car*, but by bridging this gap, there might be other gaps that could be bridged as well. The methods used are a combination of the third and fourth step of the backcasting methodology and the design thinking process. To present comprehensive leverage points, a more detailed knowledge about why people own cars today were needed, which was provided by additional interviews. The proposed actions that could help to reduce the need for people to own cars, the leverage points, are presented as solutions. This is followed by a suggested strategy for how to implement one of the solutions, hence, how car ownership in the city of Gothenburg could be reduced. Nextapp, the tool for design thinking, was used in all steps of part 2. The chapter ends up with a concluding section, discussing a number of challenges and problems with the suggested solution.

6.1 Incentives for Car Ownership

To be able to find suitable leverage points for how to reduce car ownership in general, it was first important to truly understand why people own cars as of today. The aspect of car ownership is complex and there could be several different reasons for why people own cars. The second round of interviews aimed to find out what "job" the car does for people today, to then identify people with similar characteristics and group them together to create different personas in Nextapp.

The data collected from the second round of interviews generated some important insights regarding the aspect of car ownership. For instance, a number of advantages and disadvantages with owning a car were noticed, which are presented below.

Advantages with car ownership:

- They are available and you can drive whenever you want, where ever (with certain restrictions)
- Many times the fastest way to travel
- More comfortable in many cases

- Normally spacious
- You can transport more stuff more easily
- Generates a feeling of freedom

Disadvantages with car ownership:

- Costly: driving license, price, insurance, service, fuel, etc.
- Traffic jams
- Worse accidents in cars than public transport
- Has to be fueled
- Pollutes
- Many rules to follow
- Many demands on the ownership of cars
- The driver has to focus on the driving, cannot do anything else while traveling

When it comes to the reason why people do own cars, it depends to a great extent on what their life situation is and, related to this, what age they are. One pattern that was identified during the interviews was a strong connection between the individuals' life situations and the acquisition of the driving license. People get their driving licenses due to norms in society, it is considered a basic knowledge to have a driving license. However, they do not buy a car until they find it valuable in a concrete way. This could, for instance, be due to a new job situation, where it is difficult to get there by public transportation, or that your family is growing. At this stage in life, there really are no other comparable options than owning a car, in their point of view. When getting older, they have created a habit of owning a car, because of its convenience. It is difficult to get rid of this habit, even though the car is not needed to the same extent as when they were younger. This was identified as a problem and to avoid people getting stuck in the habit of owning a car, it is important to reduce the need for people to buy a car in the first place. A persona was created with the aim of truly understanding people following the presented pattern, with the aim of contributing to a solution for the identified problem.

6.1.1 Our Persona and Creative Question

The identified pattern includes several different possible personas, meaning that the different stages throughout the pattern include people with different characteristics. Since it could be difficult to go from owning a car to not owning a car, we wanted to avoid that people buy a car in the first place.

In the identified pattern, people buy cars at a point in life where they find it valuable in a concrete way, that is when they feel like the only option is to buy a car. Therefore, by creating a better solution than owning a car, that makes the everyday life puzzle easier for people, we could reduce the overall need for car ownership and avoid that people get stuck in the habit of owning a car. To understand the life situation for these people and why they buy a car, our persona is a person in a point of life where the car is a prerequisite for getting everyday life to work. This means that we are not looking into solutions for people who buy a car due to status or just for fun, for instance. The problem we are trying to solve is for those who need a car for convenience, to manage the everyday life puzzle.

Based on the reasoning mentioned above and the data collected through the second round of interviews, a persona, named Charlotte, was created in Nextapp. Charlotte is a woman in her middle age, living in a terrace house in Åkered, in the west part of Gothenburg. She lives with her husband Claes, and their two kids, Nelly and Max, who are 3 and 8 years old. The kindergarten and the school are in two different geographical locations. The family has two cars and her husband uses one of these in his work. Charlotte works in Mölndal as a receptionist. She works out at a gym twice a week and she likes to cook and bake. As a person, she is efficient, active, and social and always has a lot of things going on. In order for her to manage her everyday life puzzle, she needs to have a car. A screenshot of how it looks in Nextapp is shown in figure 6.1.

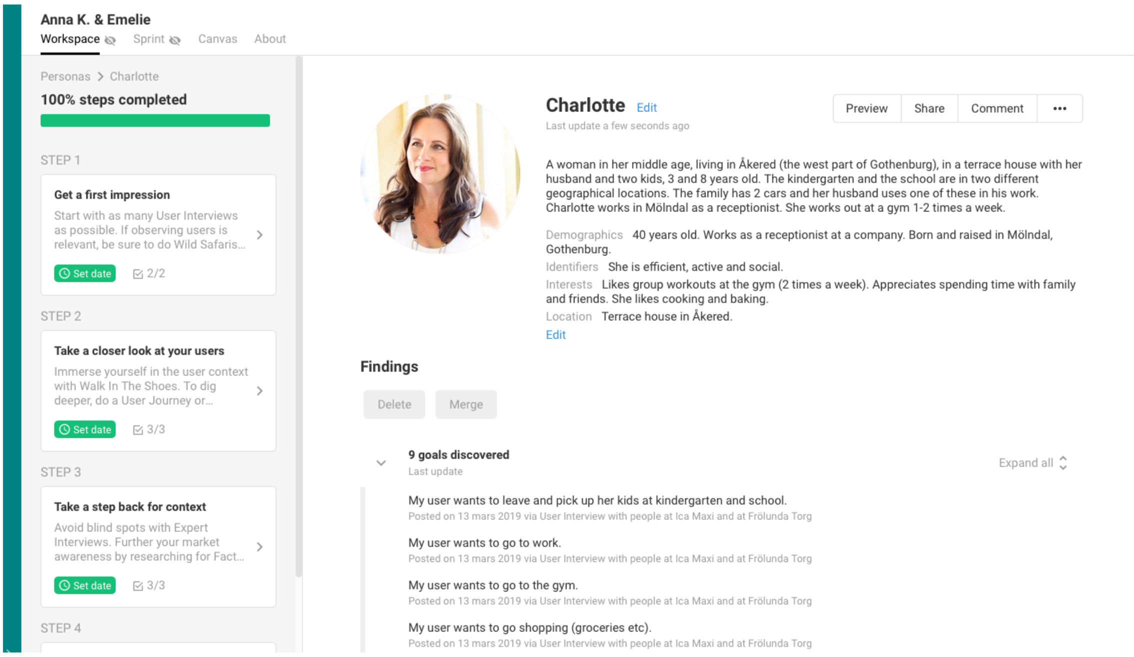

Figure 6.1: A screenshot from the tool Nextapp.

Based on the created persona, Charlotte, a creative question was formulated. It was done by first defining Charlotte's most urgent problem and then defining the biggest challenge in solving this problem. Answering the identified creative question could contribute to the reduction of car ownership, and therefore help to bridge the chosen gap. The final creative question was as follows:

How might we help Charlotte to manage the everyday life puzzle without owning a car, given that cars are the most convenient and time efficient way of traveling for her?

6.2 Solutions to Reduction of Car Ownership

To suggest solutions to reduce car ownership, our chosen gap, the visioning stage in Nextapp was used. The identified possible solutions are presented in table 6.1.

Table 6.1: The solutions, and a description of the solutions, that were suggested from doing the different missions during the visioning stage in Nextapp.

Solution	**Description**
Car pool	Sharing cars with your neighbours
Better public transportation	Faster, more frequent, more destinations
No subsidy of car ownership	No free parking, for instance
Other transport means	Encourage other transport means
Taxi platform	A platform connecting the existing taxi companies
Work from home	Enable people to work more from home
Home delivery	Get everything home delivered
Luxurious public transport	Comfortable seats, air condition
Children's taxi	Collective transport for children
Sharing solution	Platform for borrowing or renting out your car
Boarding schools	A reduced need to transport kids
Home teaching	Home teaching over the Internet
Connect travelers	Travelers with similar travel behaviors share ride
Small communities	Have everything nearby
Robot assistant	Taking care of the home and kids
Hologram	Enables more people to work from home
Flying taxi vehicles	Gives more space for walking and biking
Stay home once a week	Study and work from home once a week
Robot taxi service	Autonomous vehicles for taxi service
Multifunction vehicle	Flying, driving on roads and water

Only one solution can be chosen to continue with in the next stage in Nextapp. The solution that we chose was the taxi platform, and we chose this for several reasons:

- It is a solution that is feasible and possible to implement today.
- The solution could be formed in the same way as our desired future, with the difference that there are drivers in these taxis.

Hence, finding ways to implement the taxi platform solution would be a good leverage point towards our desired future, since today's taxi cars could be replaced by AVs, when available on the market.

6.2.1 Description of the Taxi Platform

The same missions in Nextapp that were used to identify different solutions, in the visioning stage, were also used to describe the chosen solution in more detail. This was done by adding features to the solution, which were then sorted as killer features, support features, or feature to be removed.

6.2.1.1 Killer Features

The features that are classified as killer features are considered as the most important features, needed for the solution to work.

- ***App***
  The platform is based on an app, where all the taxi companies are gathered and the features that the solution offers are accessible.

- ***Travel planner***
  The program plans the traveling route and ride-sharing, with the aim of optimization, decreasing the person kilometer as much as possible, weighted with the waiting time and the individual traveling time.

- ***Notification***
  The user of the app can get notified when someone else orders a taxi nearby. Notifications are only generated when someone with similar traveling behaviors, regarding time and destinations, have ordered a taxi. It is possible to set the times for these notifications, so the traveler does not get notifications when not necessary.

- ***Traveler's time requirements***
  If the traveler needs to arrive or leave at an exact time, the price will be higher. If the traveler is fine with being picked up or left off within a time frame, the price will be lower. The bigger time frame that is accepted by the traveler, the lower the price. This with the reasoning that the travel planner can optimize ride sharing.

- ***Flexible drop off spot***
  If it is not that important exactly where the traveler wants to be dropped off, the traveler can choose to have a flexible drop off spot. This means that the traveler will be dropped off where ever suitable within a chosen radius of the destination since it is possible for the travel planner to optimize the route to a greater extent. The price will also be lower when choosing to have a flexible drop off spot.

- ***Gamification for ride-sharing***
  To increase the incentives for ride-sharing, gamification could be used. The game could be a competition between how many people you have traveled

with, during as few travels as possible. A traveler that often share rides gets rewarded, with for instance discounts.

- ***Profile settings***
  The app should make it possible to have preinstalled profile settings. This could, for instance, be standard pickup times during certain days, or how long time you, as a standard, are willing to wait for your taxi. It should of course also be possible to decline the preinstalled taxi times if something unexpected happens. In the profile, it should also be possible to decide some specific settings of the car, e.g. the indoor climate and music.

  To create a profile, and to be able to use the app, the traveler needs to log in with hers or his bank id. This is to avoid the risk of people creating fake accounts.

6.2.1.2 Support Features

Support features are those features that are considered as extra-functions. The support features are important, but they are not vital for the solution to work.

- ***Transparency***
  To increase the trust among travelers and in relation to the solution, it is important that the solution is transparent. For instance, it should be visualized where the taxis are geographically and who you are traveling with. This feature could reduce parents' concerns regarding how safe the solution is for their children since they can see where the taxi is driving their children.

- ***Visualize the estimated pick-up time***
  The estimated pick-up time should be available in the app. Even though it is updated iteratively, as it can change with new information about travelers to the system - the aim is to optimize the whole system. The changing pick-up time concerns the people who choose a time frame for the pick-up and the pick-up time is always within this time frame.

- ***Possible to travel alone if desired***
  Travelers that do not want to travel with others can choose this feature, to a higher price. It is possible to have this as a setting and everything between all the time and specific hours or travels can be chosen.

- ***Silent traveling companions***
  If a traveler does not want to talk to others, but still is fine with ride-sharing, it should be possible to choose a "silent rid", where you travel with others who, as well as you, do not want to talk to others.

- ***Lower kilometer price when traveling longer***
  With the aim of encouraging people to walk or bike short distances, the price

per kilometer will be adjusted after how long the traveler needs to go. For longer distances, the price per kilometer will be lower than for shorter distances, as it is less convenient to walk or bike.

- ***Icebreaker function***
  To make it easier to start a conversation with your traveling companions, when desired, the app should include an icebreaker function. This function includes questions that can easily spin off to interesting conversations. The questions could be individually adjusted, based on everyone's profiles, in order to suit all travel companions.

- ***Provide other services***
  The app could have a function where it is possible to buy other services than just transportation of a person. For instance, it could be possible to order a service where the taxi picks up packages that the traveler has ordered.

- ***Blocking***
  If there is a travel companion that the traveler does not want to share ride with again, it should be possible to block this specific person to ever share a ride with from that point in time. Therefore, the app should include a blocking function.

- ***Background check of drivers***
  To avoid that people feel unsafe using the taxi platform and that parents feel unsafe with letting their children go with the taxis alone, a background check of the drivers might be needed. This background check could include looking into criminal records.

- ***Add luggage***
  If the traveler needs to bring extra luggage, there should be a possibility to order a luggage spot in the taxi. Also, bikes should be possible to bring.

6.2.2 Value Proposition

The value proposition of the taxi platform is formulated with the aim of solving the creative question. This means that the taxi platform is believed to create value for the chosen persona, Charlotte. Therefore, the value proposition is formulated as follows:

Charlotte will love the solution because she can manage the life puzzle in a convenient and time efficient way without the complications of owning a car. The time spent traveling can be used for other things than driving.

6.3 A Proposed Strategy

A way to move closer to our desired future is to develop the suggested solution, the taxi platform. However, it is valuable to provide a more detailed strategy for how this could be done. This is generated through a business model canvas, which was created in the last step in Nextapp, the scaling stage. The business model includes the chosen persona, Charlotte, a description of the problem, a presentation of the suggested solution and a description of its value proposition, which all have been presented in previous sections. Additional information included in the business model canvas, generated through the scaling stage, are delivery channels, competitive advantages, internal and external resources, an economic model, and a plan for how to move forward with the creation of the solution. These parts will be presented individually in the coming sections. An overview of the business model canvas is presented in Appendix C.

6.3.1 Delivery Channels

The taxi platform will have the form of an app. Therefore, the delivery channels of the solution will be through digital distribution platforms such as App Store and Google Play.

6.3.2 Competitive Advantages

The identified competitive advantages have been divided into main advantages and support advantages. The main advantages are those that are seen as the most important advantages in comparison to existing transportation alternatives, while the support advantages are advantages that help to increase the attractiveness to the business.

6.3.2.1 Main Advantages

The identified main advantages with the taxi platform are the following:

- ***Existing customer base***
  The solution is based on an already existing service and therefore there is already an existing customer base. What is needed is to make them start using the app instead of contacting each specific taxi company.

- ***The solution is easy to use***
  The customer benefits from using the solution since it is easy to use. When all taxi companies are included in the app, it is certain to get a taxi and the

closest one available. Therefore, it is the most convenient and fastest way to get a taxi. There is no need to get in contact with several different taxi companies when ordering a taxi, as it might be on peak hours. Additionally, the payment will be carried out through the app, which releases time, as it can be done during the ride, and normally goes faster.

- ***Personalized***
  The users of the app are not limited to specific stops, as with public transport. Instead, the traveler can decide where to get off. Additionally, other personalized settings can be added in the profile, as mentioned earlier, such as music preferences, standard pick-up times, and if the traveler wants to have silent traveling companions or not.

- ***High accessibility***
  With the taxi platform, there is no need for the traveler to adjust to a timetable or to feel stressed about missing the last ride home, the taxis are available around the clock.

6.3.2.2 Support Advantages

The identified support advantages with the taxi platform are the following:

- ***Risk-free business***
  Starting the taxi platform could be considered to be risk-free since the only thing needed is the app. The taxi cars are already existing, and the suggested solution does not need any more initial investments than creating the app and connecting the taxi companies in the app. It is rather a matter of time that needs to be invested.

- ***Fast and convenient way to travel***
  With the taxi platform, the user can travel without the need to stop at many stops, in comparison to public transportation. At the same time, users do not need to drive by themselves.

6.3.3 Internal and External Resources

The resources needed for the taxi platform are the following:

- Knowledge in app development (internal resource)
- Access to credit (internal resource)
- Networking/selling skills (internal resource)
- Marketing (internal resource)
- Taxi companies (external resource)

6.3.4 Economic Model

The economic model for the taxi platform includes implementation costs, recurring costs, and revenue streams. Implementation costs will be for the development of the app and upfront marketing costs. Recurring costs will arise through maintenance and improvements of the app, that should occur iteratively throughout its lifetime. Revenue streams will come from those using the app, by taking a percentage of the payment, as it is done through the app.

6.3.5 Plan

The suggested plan for the continued development of the app is presented through different activities that are suggested to be performed after the scaling stage in Nextapp. The time schedule is approximate and starts from July 1st. The suggested activities are the following:

- ***[July 1, 2019] - Prototype visualization***
  Develop a prototype to show to the taxi companies when pitching the idea for them.
- ***[July 8, 2019] - Create the network***
  Pitch the idea for taxi companies, to get their approval of adding them in the taxi platform.
- ***[July 22, 2019] - Develop a beta version***
  Develop a beta version of the app to be able to try the feasibility of the solution.
- ***[August 5, 2019] - Launch the beta version***
  Launch the beta version of the app and test the feasibility. See what works and what does not work, to be able to update the app.
- ***[August 19, 2019] - Update the app***
  Update the app based on the trial time on the market.
- ***[August 26, 2019] - Launch the new version***
  Launch the new, updated version of the app.
- ***[August 26, 2019] - Marketing***
  Start a marketing campaign reaching out to target customers, tentatively through social media.
- ***[August 27, 2019 and onward] - Update iteratively***
  Continue to improve the app iteratively.

6.4 Concluding Discussion

The suggested solution, the taxi platform, is only one mean that could help reduce car ownership. However, to achieve a scenario where nobody owns a car, more intervention is most likely needed. This accounts especially for people who already own a car since they are used to the practices associated with car ownership. As explained by Shove and Pantzar (2005), a practice dies out by breaking the links between the images, skills, and things that are intertwined in the existing practice. This can be done both from the inside, by changed behaviors of practitioners, and from the outside, which requires active involvement from the surroundings (Warde, 2005). Additionally, traveling by car and the ownership of cars is deeply embedded in our culture, which means that a cultural shift and changes in an individual's behaviors are required. Lewin's change model describes how change can occur by the three steps unfreezing, changing, and refreezing (Levasseur, 2001). To achieve the first step, unfreezing, communication is needed. To not fall back into the old habits, refreezing the new behavior is important. Successful refreezing requires active involvement from those who have an interest in the change. Hence, both by applying practice and behavior change theory, communication and active involvement from external parties is crucial. Hence, to change into a scenario where cars are not used to the same extent as today, parties with an interest in a more sustainable society need to be actively engaged in the transformation.

Due to the difficulties of changing already existing practices, it is likely that people not owning cars are the ones to become the early adopters of the taxi platform. In due time, the taxi platform's diffusion curve will include the people that are not able to drive by themselves and in the long run, reach the car owners as well.

The taxi platform has possibilities of reducing the need for people to own cars. However, there are a number of problems, or challenges, associated with the solution as well. One main benefit of owning a car that was identified during the second round of interviews was the freedom that is associated with car ownership. It is considered as valuable accessibility, increasing the standard of living, to be able to go anywhere any time you want. You just go out to your car and drive away. For the taxi platform to achieve the same sense of freedom, the waiting time for the taxi needs to be as short as possible. This requires taxi cars to not be too far away from the users, which could be facilitated by more people using the solution. The more people that use the platform, the higher the probability that there is a taxi nearby.

The waiting time for the taxis could vary depending on where you want to travel from. If the user wants to travel from an area where not so many people are using the service, the waiting time could be longer. If the user instead wants to travel from an area where many people are using the taxi platform, the waiting time would most likely be shorter. This could lead to the fact that in areas where it is common to use the taxi platform, the solution has higher quality, which leads to the fact that more people want to use it. In areas where only a few people use it, the waiting time will most likely be longer and, as a result, the quality will be lower and fewer people want to use it. This means that the solution benefits from more people using it and therefore, network effects exist.

What is desired with the taxi platform is that it will enable our chosen persona, Charlotte, to manage the everyday life puzzle without owning a car. This means that we want car ownership to be replaceable with our solution, even for people who are more or less dependent on using a car in their everyday life. For instance, we want people to use the solution instead of driving their children to kindergarten, school, and other activities. What would be most beneficial for the parents is to let their children go by themselves with the taxis, to release more time to do other things. However, a number of difficulties are associated with this aspect. During the second round of interviews, we realized that letting children go by themselves in a taxi is far from being given for some parents. Parents could be protective of their children, and sometimes the parents need to help their children into the kindergarten or school. Additionally, driving children to school or different activities could both be seen as a status symbol, for some it is a sign that you value your children highly, and an opportunity of spending time with your family. These problems could be reduced by normalizing that parents go with their children in the taxis. This could also make the parents realize the safety of the service and let the children go by themselves earlier than otherwise.

7

Conclusions

The answers to the research questions presented in section 1.2 are here summarized. The first and last will be presented by themselves, while the second and third will be presented together. The chapter also includes some final notes, conclusions regarding the validity of the results, and recommendations for future studies.

7.1 Answers to the Research Questions

How does a sustainable future with autonomous passenger transport look like?

A sustainable future with autonomous vehicles (AVs) for passenger transport in the city of Gothenburg includes a transportation system based on a service, a robot taxi service. This means that nobody owns a car, which generates a possibility to limit the number of AVs on the roads, with the aim of decreasing the resource consumption and increasing the utilization of each vehicle. In line with this, the demand needs to meet the supply and, therefore, needs to be even and constant throughout the day. No emissions should be emitted while driving, and the vehicles should be produced to minimize the total sum of emissions from the entire life cycle.

The robot taxis should be shared simultaneously by several passengers when possible, to maximize the degree of utilization. To be able to optimize the service, a computer plans all trips with distance, time, and number of passengers in consideration. Everybody in the city of Gothenburg should have equal access to the service. To add, the service should be noise free, safe and reliable for everybody, and economically sustainable for both travelers and for the party providing the service.

In this project, the scenario described above is called “our desired future”, since it is a sustainable alternative to today’s transportation system, in ecologic, social, and economic terms.

What gaps are there between our sustainable future and today? *and* **What leverage points are there to bridge the gaps?**

A gap is defined as *something that is missing in the current situation in order to achieve our desired future.* A leverage point is defined as *a thing or an action that has a bullwhip effect*[1] *with the potential to bridge one or several gaps.* This means that implementing the suggested leverage points could help to come closer to our desired future. Between our desired future and the current situation, 13 gaps were identified. Examples of these are *rules and regulations*, *acceptance*, and *even and constant flow of traffic.* To bridge the identified gaps, 27 possible leverage points were suggested. Among these, *congestion taxes*, *more flexible work and school hours*, and *enable people to try AVs* were proposed.

The gap *incentives to not own a car* was chosen as the gap to focus on. The suggested solution, the chosen leverage point, is called the taxi platform. The taxi platform is like our desired future but with drivers and is based on an app where all the existing taxi companies are available and enables ride-sharing when suitable. In this way, the accessibility and the resource utilization increases and it will ease the market penetration of our desired future. The users of the app will have a fast and convenient way of traveling without the complications that are associated with car ownership.

What is a good strategy to implement one of the leverage points?

The strategy to implement the leverage point, the taxi platform, is presented in the form of a business model canvas. Delivery channels are suggested to be digital distribution platforms such as App Store and Google Play. Competitive advantages are said to be the already existing customer base and the risk-free business. Also, the solution is easy to use, it is personalized, and it is a fast and convenient way to travel.

Internal resources that are needed for the taxi platform are knowledge in app development, access to credit, networking and selling skills, and knowledge in marketing. The external resource needed is taxi companies for the collaboration. The revenue model for the taxi platform is suggested to be a percentage of the payment from the traveler, which is made through the app. Costs would arise through developing, maintaining, and improving the app, and for upfront marketing costs.

A part of the business model canvas is to develop a plan for how to move forward with the development of the solution. The first suggested action in this plan is to provide a prototype that could illustrate how the solution would work, which should be used to create a network of taxi companies. After creating a network, a beta version of the prototype should be developed and launched. Based on feedback generated from introducing the beta version to the market, the app could be updated.

[1]Describes how small actions at one end, can cause continuously increased effects into the other. The term is often used in supply chain management, explaining how small fluctuations in demand can cause progressively larger fluctuations throughout the supply chain.

After launching the updated version, a marketing effort to spread the awareness of the solution's existence should be made. The continued work with the app should include iterative updates.

However, it is important to emphasize the fact that the taxi platform is only one way to reduce car ownership. To achieve a scenario where nobody owns a car, more effort might be needed to achieve the necessary changes.

7.2 Final Notes

During this thesis project, it has become obvious that it is rather a question of *when* than *if* AVs will drive on our roads. Beyond the fact that it is a topic of many people's interest, numerous companies are working on the development of AVs in different ways, and existing rules and regulations have been adjusted with the aim of enabling vehicles with some level of automation to drive on the roads. However, to achieve a scenario with a transportation system based on only fully autonomous vehicles, time is required. Rules and regulations need to be developed further, including overcoming and solving philosophical issues, and behavioral changes need to be achieved. Regulatory and behavioral changes are often associated with the requirement of time.

To achieve a more sustainable transportation system, the vehicles that are developed need to have an as little environmental impact as possible. Hence, car manufacturers of today need to develop AVs driven on fuel with no negative impact on the environment. Today, a good alternative is electricity driven vehicles, but other fuels and sources could beneficially be developed and used as well. Additionally, the traditional business model for car manufacturers, to sell as many cars as possible, is not sustainable. We need to move away from the ”wear and tear society” we have created. Car manufacturers need to take their responsibility and use their opportunity to influence, to change their business models, and to develop more sustainable vehicles. To force the development into a more sustainable direction, and to change people's behaviors, regulatory efforts are most likely needed. The results of this thesis project could be used as guidance for how to get one step closer to a more sustainable transportation system.

7.3 Validity of the Results

The backcasting methodology has been used throughout the whole thesis project, while design thinking was used in the second part. The backcasting methodology was performed in line with recommendations provided by Holmberg (1998). However, the limited time for this thesis project, of approximately 20 weeks, meant that a limited number of interviews could be conducted. Hence, it is likely that additional gaps and leverage points, not identified during this project, do exist. By interviewing people from different companies and instances, a width of different approaches and views could be collected, rather than generating a depth in a specific, niche field. To add, even though this study is limited to the city of Gothenburg, a majority of the results are general and are most likely transferable to other geographical areas as well.

Semi-structured interviews were conducted both in the first and the second round of interviews. Notes were taken during both rounds of interviews, and the first round was recorded. However, the second round of interviews was done "on the run", with people passing by. The fact that some of the persons interviewed were in a hurry could have contributed to not as fully thought through answers as provided if the interviews were held in a more relaxed environment instead. This was counteracted by creating the persona in Nextapp, developing a deeper understanding of a certain group of people.

7.4 Recommendations for Future Studies

This thesis project has had its base in the backcasting methodology, and in the desired future that was identified during the first step. However, several other possibilities for a more sustainable transportation system than today exist as well. Hence, studies investigating other possibilities of changing the transportation system into something more sustainable, with the market introduction of AVs, could beneficially be made. This with the aim of deciding what would be the best and most likely development of today's transportation system.

The second part of this project aims to find a leverage point and a strategy to bridge one of the identified gaps. To get a more comprehensive view, strategies to implement other leverage points, bridging other gaps, could advantageously be developed as well. To be able to provide such strategies, a deeper understanding of the identified gaps is needed as a start. By doing this, suitable leverage points can be suggested, either new ones or the ones identified during this project. Depending on the nature of the leverage point, different methods such as, in our case, design thinking can be used.

To reach a scenario where nobody owns a car, it might not be enough to develop the taxi platform and to introduce the solution to the market. Due to this, the next step to complement this research would be to find out what is needed for this solution to be diffused into society and be embraced as a lifestyle.

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A

Interviews, Round 1

Table A.1: Persons interviewed, what company or instance they work for, and which date the interview was conducted, during part 1 of the project.

Person	**Company/Instance**	**Date**
Erik Coelingh	Zenuity	January 23, 2019
Jan Hellåker	Drive Sweden	February 7, 2019
Helena Strömberg	Chalmers University of Technology	February 11, 2019
Mia Hesselgren	Kungliga Tekniska Högskolan	February 13, 2019
Anna Svensson	Göteborgs Stad	February 13, 2019
Erik Almlöf	Kungliga Tekniska Högskolan	February 14, 2019
Hamid Zarghampour	Trafikverket	February 19, 2019
Henrik Clasen	Aptiv	February 21, 2019
Lukas Memborn	Göteborgs Stad	February 26, 2019
Staffan Bolminger	Friends of Gothenburg Innovation	March 8, 2019

B

Interviews, Round 2

The following questions were asked during the interviews:

- Do you have access to a car today?
  - If no:
    * Are you interested in buying a car?
    * Have you considered other alternatives, and if so, why do you prefer the car?
  - If yes:
    * How often do you use the car?
    * For what purposes do you use the car?
    * What do you see as the advantages of owning a car?
    * Are there any disadvantages with owning a car?
    * Do you use other transportation means, and if so, which ones?
    * Why did you acquire your car in the first place?
    * What would be required for you to stop using a car?

Table B.1: The number of persons interviewed during the second round of interviews, separated between age group and gender.

Age Group and Gender	Number of Interviewees
Young women	3
Young men	8
Middle age women	7
Middle age men	5
Older women	6
Older men	4

C

Business Model Canvas

The business model canvas includes:

Our persona Charlotte:
A woman in her middle age, living in Åkered (the west part of Gothenburg), in a terrace house with her husband and two kids, 3 and 8 years old. The kindergarten and the school are in two different geographical locations. The family has 2 cars and her husband uses one of these in his work. Charlotte works in Mölndal as a receptionist. She works out at a gym 1-2 times a week.
Problem:
How might we help Charlotte to manage the everyday life puzzle without owning a car given that cars are the most convenient and time efficient way of traveling for her.
Taxi platform:
Our desired future but with drivers, until AVs are available on the market. Hence, it is a service where you order a ride and the system optimizes if it is beneficial to share rides with others or not.
Value proposition:
Charlotte will love the solution because she can manage the life puzzle in a convenient and time efficient way without the complications of owning a car. The time spent traveling can be used for other things than driving.

Additionally, the business model canvas includes delivery channels, an economic model, competitive advantages, organization (internal and external resources needed), and a suggested plan for the continued work with the solution. An overview of the business model canvas is shown in figure C.1.

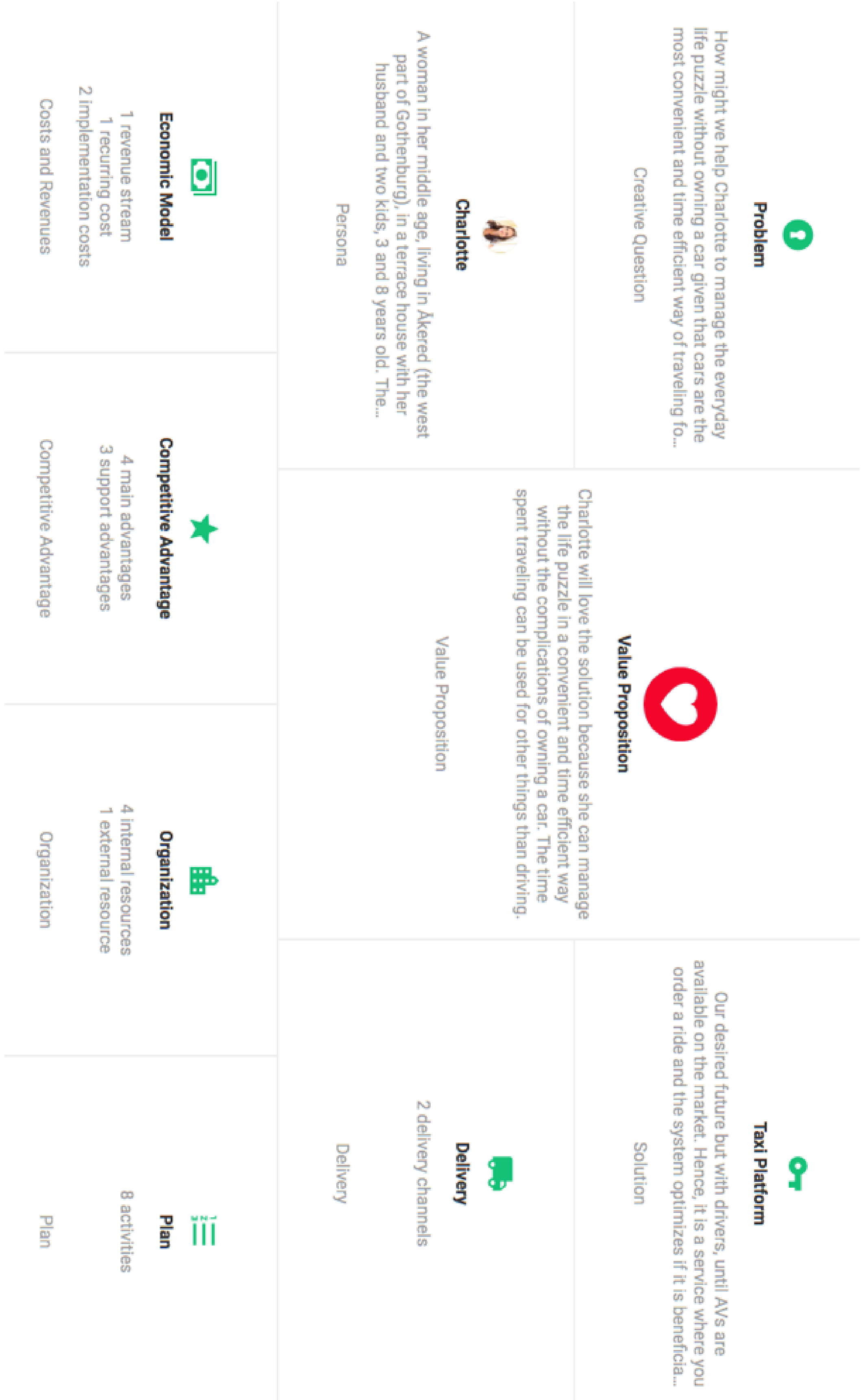

Figure C.1: An overview of the business model canvas for the taxi platform. The figure is a screenshot from Nextapp.